Wireless World

ELECTRONICS, RADIO, TELEVISION

JULY 1964

CONTENTS

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NEW MULLARD PACKAGE FOR PORTABLE RADIOS

PFL200 TEN-PIN VALVE

UNIQUE DOUBLE PENTODE FOR DUAL-STANDARD RECEIVERS

DEVELOPED by Mullard to meet the needs of the latest dual-standard television receivers, the PFL200 is a video valve of unique construction. A novel feature in its design is the use of a 10-pin B10B valve base. This new base—the decal base—makes possible the inclusion of two completely separate pentode systems in one envelope.

What's new in the new sets

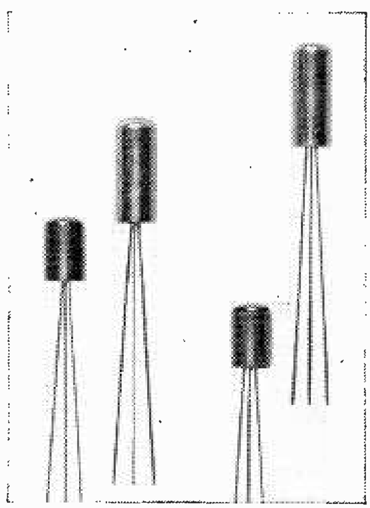
The pentodes in the PFL200 are dissimilar, and have been given complementary electrical characteristics which make possible the design of exceptionally economical full-performance television receivers. Particular care has been taken in the pinning and in the screening between the two sections of the valve to provide independence of operation.

The PFL200 'L' section is designed to operate as a high-gain video output pentode capable of producing a large output voltage across a low-value anode load resistor. The 'F' section is a voltage-amplifying medium-slope pentode designed principally for application as a synchronising pulse separator.

Mullard LFK4 forms basis of economical audio stages

COMPACTNESS, good performance and economy of operation are prerequisites of present-day portable radio receivers, and all three are achieved in the latest models using the new Mullard LFK4 transistor audio package.

Two n.p.n. and two p.n.p. transistors comprise the LFK4. A complementary matched pair of an AC127 n.p.n. transistor and an OC81 p.n.p. transistor form a transformerless output stage. Preceding this stage is an OC81D driver stage, and the package is completed by another AC127 used as a pre-amplifier. (When ordering replacements for the LFK4, the particular transistor required should be specified.)



Because the package can be d.c. coupled throughout, the number of interstage coupling components is reduced. This, together with the elimination of the comparatively bulky transformers, results in notable savings in space and cost.

D.C. coupling also offers improvements in terms of performance. An extended frequency response is obtainable, and the amplifier has a better response to rapidly changing audio signals.

The sensitivity of the LFK4 is such that an output of 700mW can be obtained using a 9V battery, or approximately 1W using a 12V supply.

An attractive feature of the LFK4 package is that the OC81D driver transistor can be run at low quiescent current. Battery drain is therefore reduced even with the large outputs obtainable with the LFK4. Extended battery life—an obvious benefit—is therefore a significant "extra" of the new Mullard audio package.

AC107 LOW-NOISE TRANSISTOR FOR TAPE RECORDERS

THE Mullard AC107 low-noise junction transistor is now frequently used as a voltage amplifier in inexpensive hybrid tape recorders. In this application, it offers the required amplification while introducing the minimum of hum and microphony. In addition to hybrid recorders, the AC107 is particularly suitable for battery-operated all-transistor tape recorders.

Use of the AC107 is not limited to inexpensive equipment, however. Manufacturers of high-quality audio equipment who wish to employ transistor pre-amplifiers because of their inherently good microphony properties are making increasing use of the device. The Mullard AC107 is thus contributing greatly to the high standards attainable with the wide present-day range of audio equipment.

MVM 3286

10WW—098 FOR FURTHER DETAILS.

Wireless World

VOL 70 NO 7 JULY 1964

Societies for Technicians

IT is now more than two years since an article in our sister journal *Wireless and Electrical Trader* drew attention to the need for an association of servicing technicians through which meetings could be arranged to exchange ideas of special interest to those engaged in the construction and maintenance of electronic equipment, as distinct from those responsible for primary research, design and development. Even earlier than this reference was made (in the 1959 Annual Report of the Council of Management of the Radio Trades Examination Board) to the possibility of forming such an association. More recently the Association of Supervising Electrical Engineers have proposed a society for "technician engineers" in the electrical and electronics industries.

We are wholeheartedly in favour of any and all of such moves as will gain recognition for the skill, and augment the knowledge of what may be regarded as the non-commissioned ranks of the industry and, let us not forget, the colleges, universities and Government research establishments. These men—who hold their jobs because of an innate common sense and practical turn of mind which is often exercised, consciously or unconsciously, to influence the decisions and to stiffen the morale of their "betters"—are the salt of the earth. It is high time that they had their own "mess" as a basis for technical discussion and for an exchange of hospitality with the commissioned ranks. We were pleased to note quick approval in principle of the I.E.E. for the A.S.E.E. moves, and it is no secret that the I.E.R.E. through its associations with the R.T.E.B. is behind the move to form the Society of Electronic and Radio Technicians (S.E.R.T.).

That is not to say that the professional bodies have any wish to control the activities of the new societies, which will presumably be autonomous after some initial clerical help in the early stages, but we hope that close contact will be maintained, if only to facilitate transfer from the technician to the engineer grades. We would like to think that this flow could take place both ways and that an engineer whose talents and inclination for work at the bench exceeded at any time those at the drawing board could, without loss of face, transfer to and be as proud of the title of technician as those who can legitimately call themselves engineers. In parenthesis, it seems odd that the I.E.E., which has fought so long to prevent abuse of the title of engineer, should condone the curious mixture of "technician engineer." Will this society, when it is formed, be a sort of transit camp?

Questions have been asked about the desirability or otherwise of forming two societies of electronic technicians, and why after so much talk and procrastination agreement on the aims of a single society could not have been reached. Here we are faced once again with the problems of optimum size and of reconciliation between common aims and the needs of specialization. As in the case of the larger learned societies and professional qualifying bodies we must live with the natural process of association and dissociation, of growth and decay. When these stop there is no longer any vitality.

Meanwhile, we congratulate S.E.R.T. on having at last done something effective and we wish the newly elected chairman E. A. W. Spreadbury, his future colleagues and all members of the Society every success. This will be assured if they keep constantly in mind the spirit of the opening meeting in London and the chairman's opening remarks in which he reminded us that no man should evade the obligation to contribute to the advancement of his group. His skill is a personal possession for the exercise of which he justly expects a reward, but his knowledge is part of a common heritage to which he should contribute with the same freedom as he draws. If he cannot make primary contributions then he should pay his debt by supporting an organization which makes it possible to preserve, disseminate and increase the common fund of knowledge.

Wireless World

CRYSTAL-CONTROLLED TRANSISTOR

SINCE the beginning of broadcasting as a means of entertainment, methods have been sought of improving the quality of reproduction. The standard of receiver design eventually reached such a level that interference and noise became limiting factors in the search for quality, and the system had to be changed. The old method—amplitude modulation—was abandoned by serious seekers after high quality, and frequency modulation now reigns

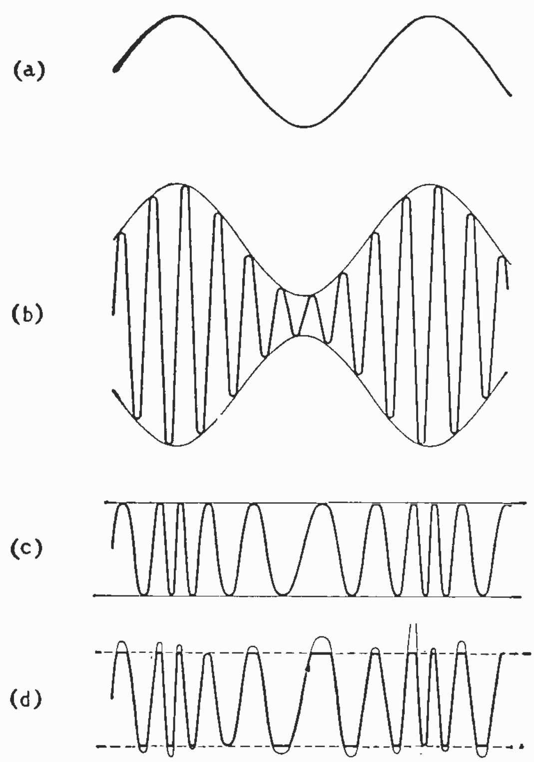


Fig. 1. Amplitude and frequency modulation. Modulating signal at (a) gives a.m. wave as at (b). F.m. signal at (c) is unaffected by random amplitude modulation, as a receiver limiter removes variations.

supreme. Fig. 1 shows the differences. Amplitude-modulated carriers convey information by the varying *amplitude* of the carrier as at Fig. 1(b), (a) being the modulating signal. The frequency is constant. At (c) is a frequency-modulated carrier, and it is seen that the *frequency* varies with the modulating signal, the amplitude being constant. As a matter of fact, if the amplitude were not constant, it wouldn't matter, because the variations can be chopped off at the receiver, as at (d), and the information—the variations in frequency—left intact. If these random variations in amplitude, which are the result of noise and interference, were present on an a.m. carrier, they would become part of the information and would be reproduced by the receiver. This is the basic advantage in f.m. systems.

The medium-wave band already being fully committed to a.m. broadcasting, f.m. transmissions are in Band II—about 80-100 Mc/s—which is less restrictive. This would be necessary in any case, as the frequency must be swept over a range of 150 kc/s to provide 100% modulation, which is far too wide a band to be accommodated in the medium-wave band.

Detectors

F.m. detectors, or discriminators as they are called, usually employ some form of limiter, to exclude amplitude variations, and a pair of tuned circuits followed by diode detectors, as in Fig. 2(a). The primary and secondary windings of the transformer are tuned to the i.f. and, as they are loosely coupled, produce voltages 90° out of phase. At the centre frequency, with no frequency modulation applied, the voltages on the diodes will be equal—the vector sums of the primary and secondary voltages. Off resonance, the secondary voltage will be either more or less than 90° out of phase and the vector sums will be larger or smaller on each diode as shown in Fig. 2(b). Frequency variations have thus been transformed into voltage variations at the modulation frequency. Although it is possible to obtain a frequency/voltage linearity of a high order from this type of circuit, it is not easy for the home constructor to align it accurately, and home-built tuners using this circuit do not usually take full advantage of its potential.

The type of tuner to be described needs no alignment of either i.f. or discriminator, and its full linearity is obtained automatically.

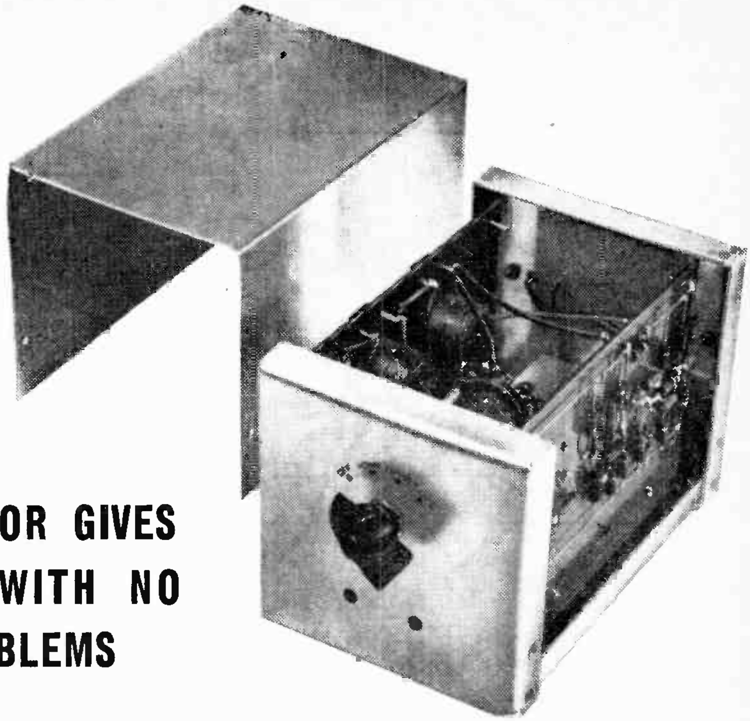
Principle of Operation

We claim no originality for the discriminator—it was used in a valve f.m. tuner by M. G. Scroggie in 1956 and for many years before that in industrial and military applications such as f.m. telemetry. One version was used in the *Wireless World* Audio Signal Generator, described in November and December 1963.

The prime requirement is a train of constant-energy pulses, shown in Fig. 3. In (a) the pulses are identical in width to the spaces between them; in other words, the mark/space ratio is unity. The mean level of the voltage is half the peak amplitude.

F.M. TUNER

PULSE DISCRIMINATOR GIVES LOW DISTORTION WITH NO ALIGNMENT PROBLEMS



The mark/space ratios of the pulse trains shown at (b) and (c) are 1 : 2 and 2 : 1 respectively, and the average levels are one-third and two-thirds of peak value. If the mark/space ratio is varied continuously, as in (d) (where the pulses are shown narrower to get more on the diagram) the average level varies and, when filtered to remove the pulses, becomes a reproduction of the modulating signal (e). The pulses are derived rather deviously from the carrier, and most of the tuner circuitry is concerned with their production.

One of the benefits of the discriminator is that it has no tuned circuits; to extend this advantage to the i.f. stages, and to enable the pulse stages to work efficiently, the i.f. is set at 130 kc/s, and a wide-band, RC-coupled i.f. amplifier used.

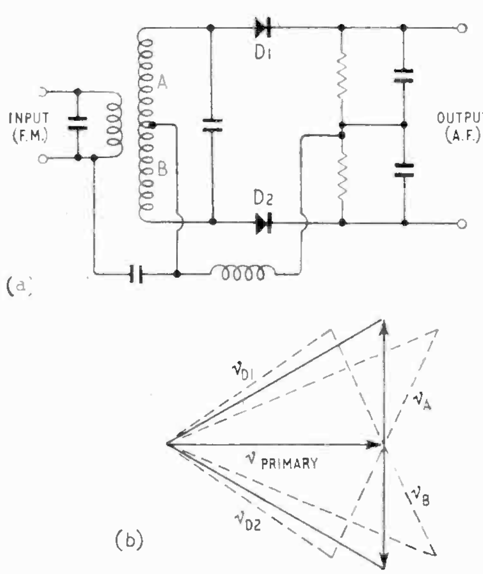
The other significant feature of the tuner is that it is switch-tuned. Continuous tuning for the three British programmes only seems nothing less than primitive but, in any case, with an i.f. of 130 kc/s, tuning would be very critical, and one can envisage difficulty being experienced. Accordingly, we have used a crystal oscillator with three switched crystals.

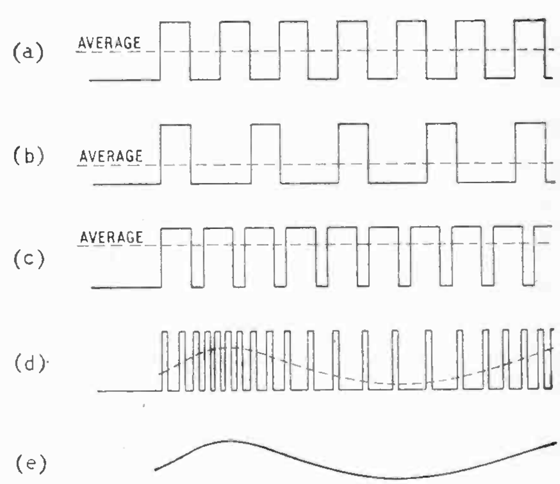
Pulse Stages

Schmitt: It is convenient to start at what appears to be the wrong "end" of the tuner, for the charac-

Left: Fig. 2. Common type of tuned discriminator shown at (a). Varying voltages on diodes shown in (b).

Below: Fig. 3. Principle of pulse discriminator.





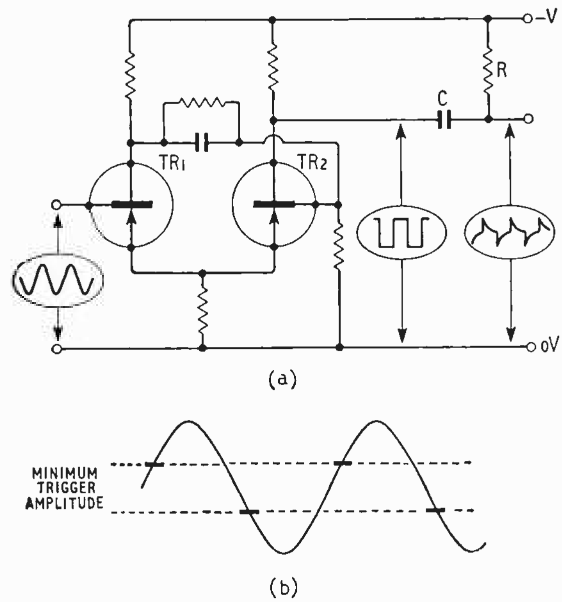


Fig. 4. Schmitt trigger circuit. At (b) is shown the reason for the minimum amplitude of input required.

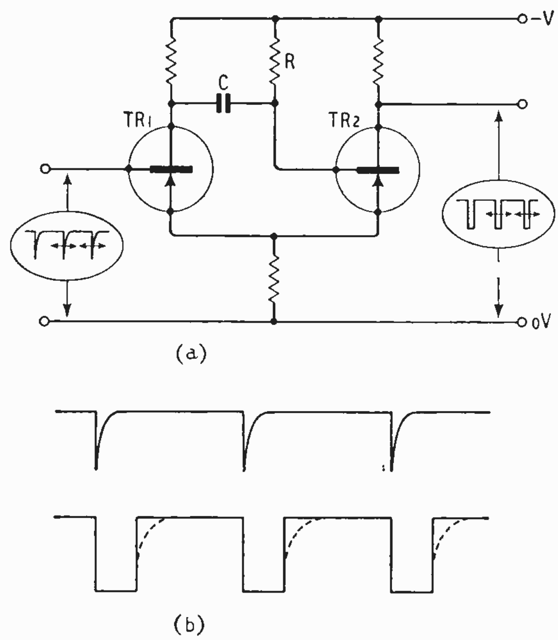


Fig. 5. Monostable flip-flop.

teristics of the trigger and pulse forming stages determine the type of i.f. and front end to be used.

The first bit of shaping the signal encounters is a Schmitt trigger which, for those who have not met the circuit before, is shown in Fig. 4(a). The Schmitt is a means of obtaining rectangular waves from sine waves, and is a two-stage amplifier with the output fed back to the input to provide positive feedback. A positive-going disturbance, for instance, on the base of Tr1 is amplified by Tr1 and fed back to the emitter via the emitter-follower—Tr2. The fed-back signal is of the correct polarity to augment the original disturbance, and the result is a steep positive-going transient on the collector of Tr2. This condition remains until the base of Tr1 is driven in a negative direction, when the opposite process takes place. The output amplitude is only governed by the supply voltage and transistor characteristics, so that a constant-amplitude rectangular wave is produced for even an irregular input. This

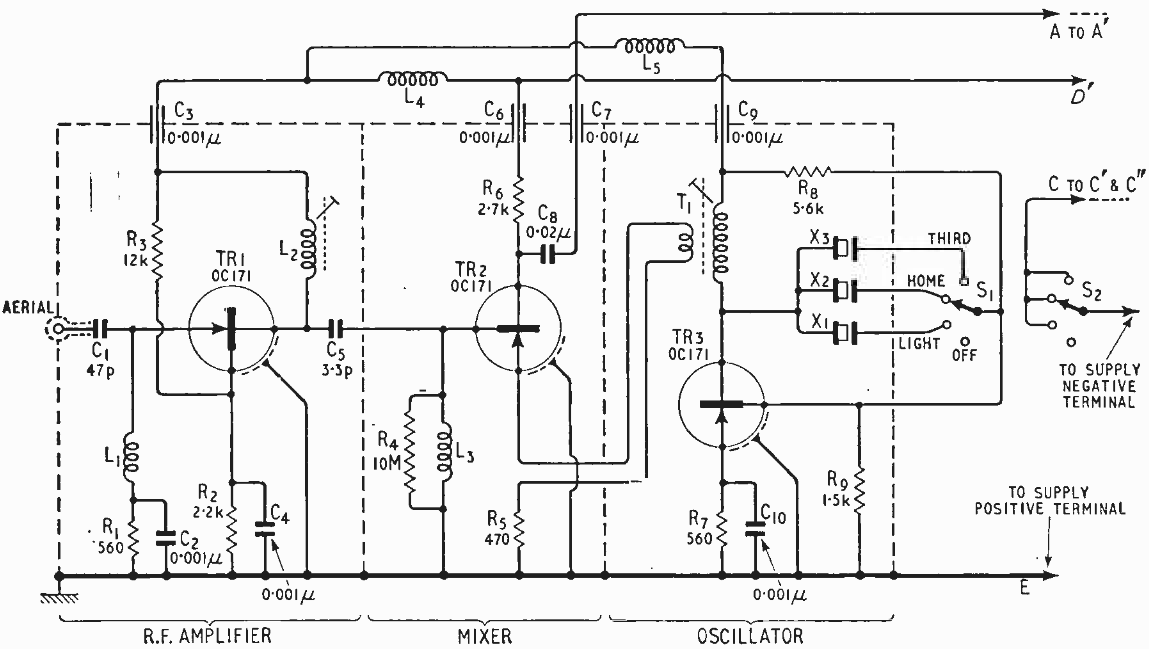


Fig. 6. Circuit diagram of r.f. chassis

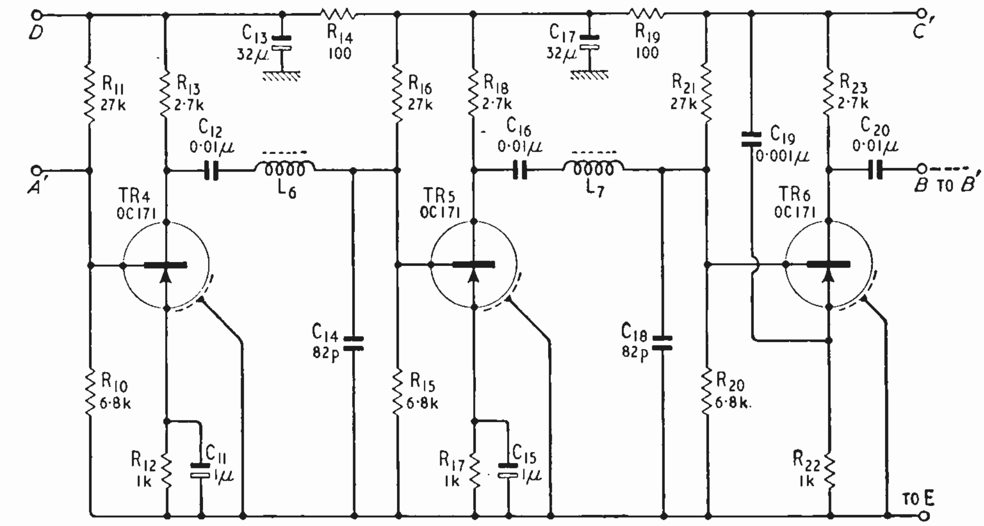


Fig. 7. I.F. amplifier.

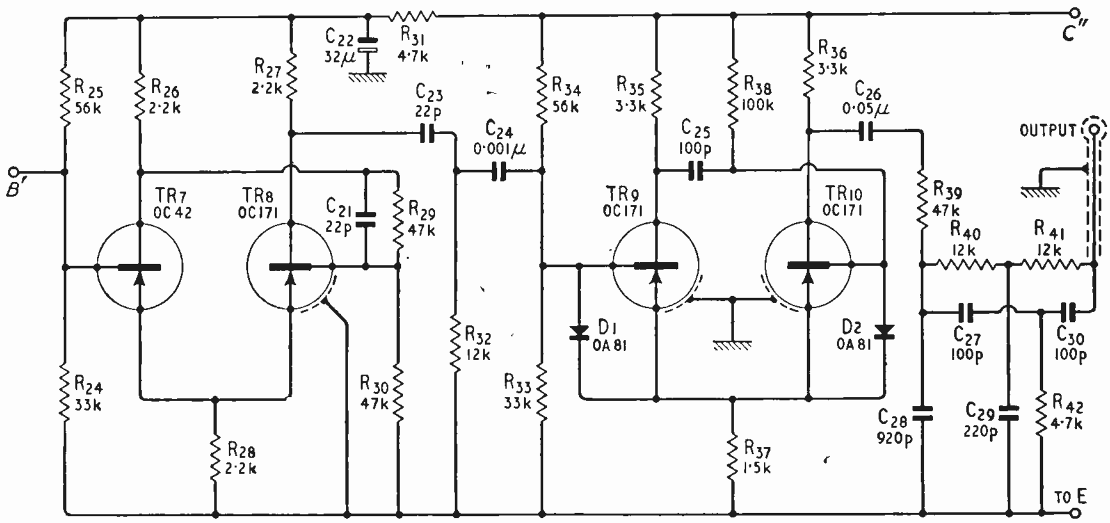


Fig. 8. Discriminator.

square wave is now passed into a differentiating circuit, CR, from which the series of spikes, suitable for triggering, emerges. The circuit does not trigger at exactly the same level in both positive and negative-going directions of the input signal, so that there is a minimum signal amplitude, below which the square waves are not obtained. Fig. 4(b) shows this. In our circuit, this minimum is 300mV for reliable operation, this level fixing the gain of the i.f. amplifier.

Multivibrator: The constant-width pulses are obtained from an emitter-coupled, monostable multivibrator, the basic circuit of which is shown in Fig. 5(a). The operation is roughly similar to that of the Schmitt, except that after the initial step, the a.c. coupling to the base of Tr2 returns the circuit to its initial condition after a time determined by the CR product. An input pulse from the Schmitt serves only to initiate the step, the reverse process being controlled by CR. The output is a series of rectangular pulses, as in Fig. 5(b), at the frequency of the carrier and of constant width and amplitude.

In Fig. 5(b), the dotted line shows the actual, as opposed to the idealized, shape of the output pulse. The curved trailing edge is caused by transistor limitations, and to avoid this curve running into the next pulse and causing audio distortion, the frequency of the i.f. is low. Transistors are available which could work at a much higher pulse repetition frequency, but they are expensive. 130 kc/s was found to be the best frequency to work at, avoiding distortion at the +75 kc/s deviation limit and still being easy to filter out at the lower 75 kc/s deviation limit, which is 55 kc/s.

Filter

To improve the high-frequency signal-to-noise ratio at the receiver input, the higher audio frequencies are boosted at the transmitter, so that at the receiver they can be attenuated, together with the noise.

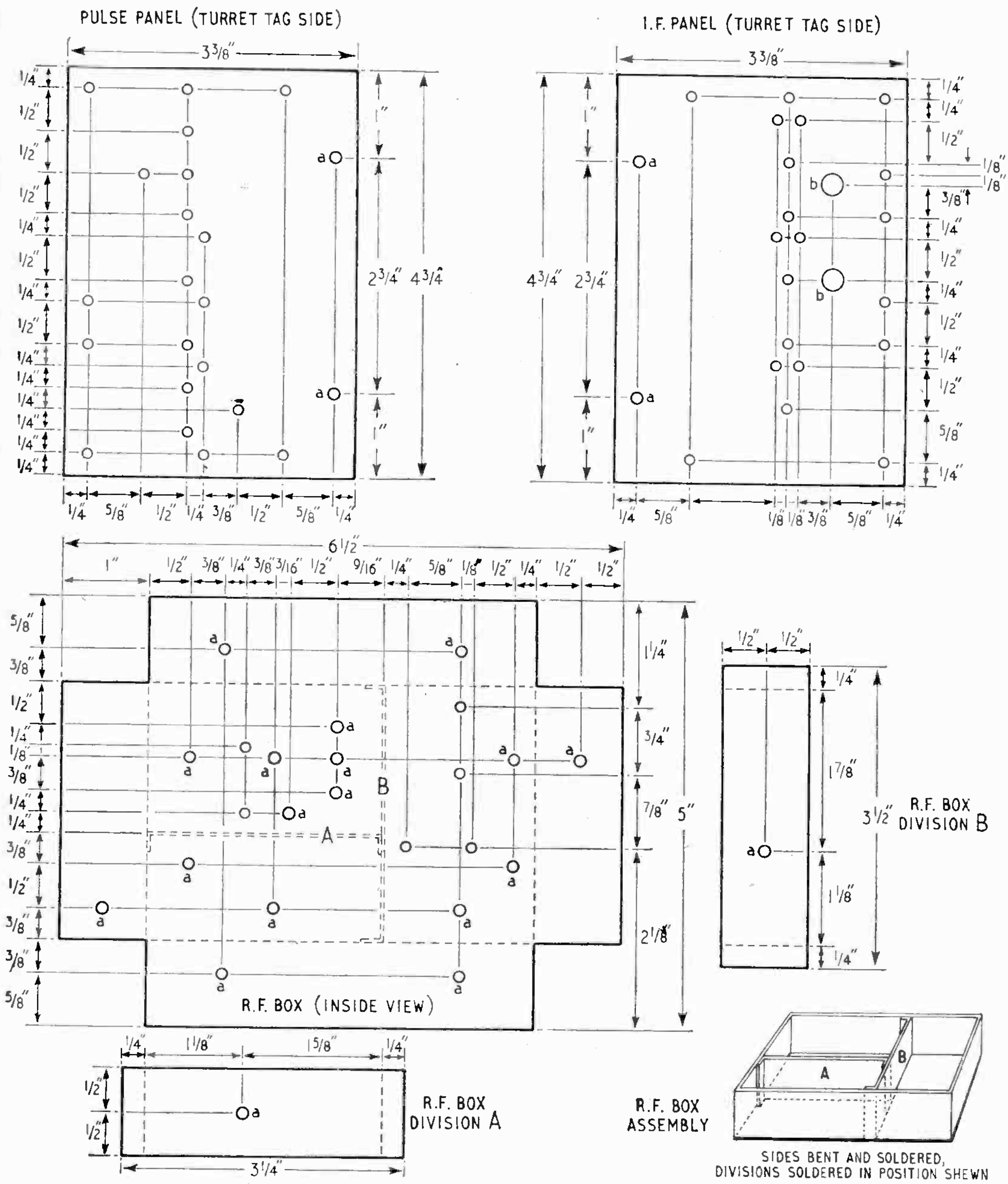
The amount of boost is such that the attenuation required is provided by a low-pass RC filter, seen in the main circuit diagram, Fig. 8, with a time constant of 50 μsec. The audio characteristic is then -3 dB at about 3 kc/s. In addition to this "de-emphasis" filter, there is the problem of removing the pulse frequency, centred at 130 kc/s.

To remove the pulses, we use a "twin-T" RC filter, with its infinite attenuation point at 130 kc/s. This has a very steep trough near 130 kc/s, but with a very broad skirt. The lack of sharpness is normally a nuisance, but in this case, with a bit of help from a half-section filter, it is just right to provide de-emphasis. The loading of the output terminals by the following pre-amplifier or amplifier affects the shape of the curve, and we have specified two capacitors in C28 position, for amplifier input impedances of 1 MΩ and 100 kΩ. The output for ± 75 kc/s deviation is 150 mV when loaded by 100 kΩ.

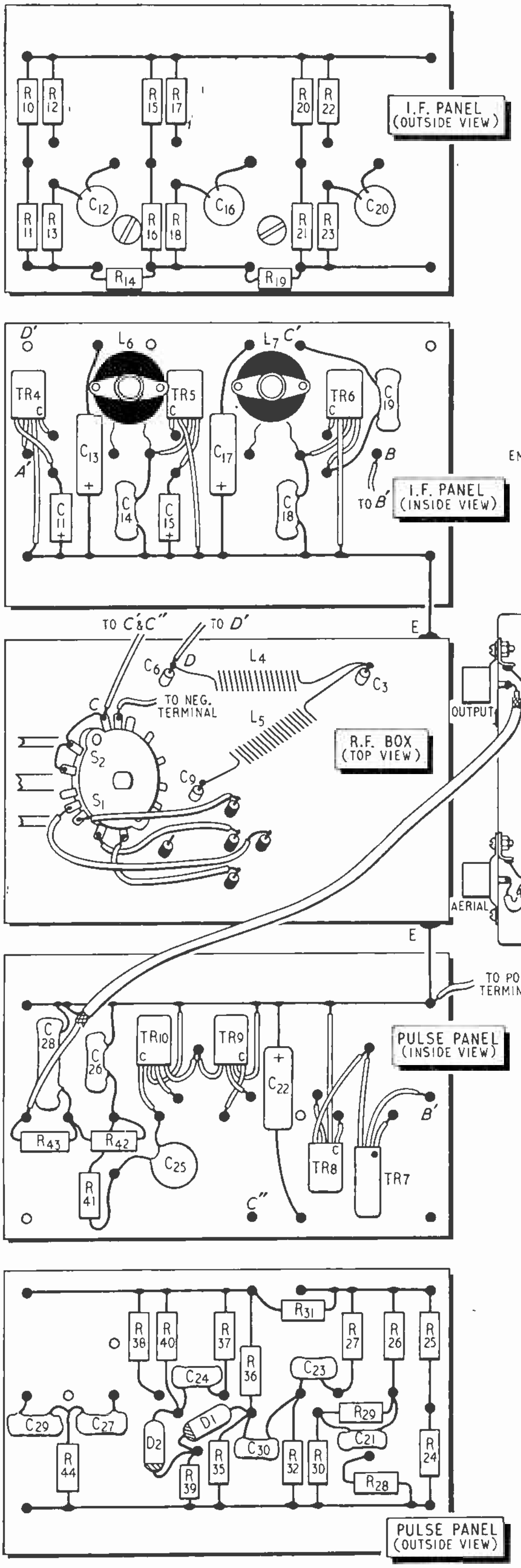
R.F. Stages

The "front end" is fairly conventional. A common-base r.f. amplifier is used, presenting an input im-

Fig. 9. Drilling diagram of tag-boards and r.f. chassis.



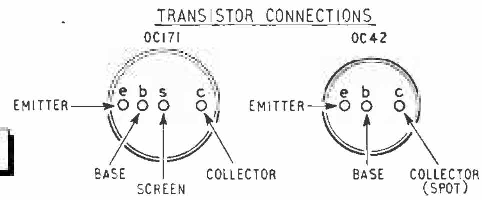
PULSE AND I.F. PANELS MADE FROM 1/16 in PAXOLIN   R.F. BOX AND DIVISIONS MADE FROM THIN TINPLATE
HOLES MARKED **a**, DRILLED 1/8 in DIA.   HOLES MARKED **b**, DRILLED 1/4 in DIA.   REMAINDER DRILLED 3/32 in DIA.



pedance of around 60-80 Ω, and feeding the base of a common-emitter mixer stage. The crystal oscillator uses third-overtone crystals which work at one third of the required local oscillator frequency. There are no tuned circuits in the f.m. band, which, together with the use of an r.f. amplifier reduces possible interference with other receivers. The output is applied to the emitter of the mixer, which seems to be happiest when working with no bias, harmonics of the oscillator frequency being, presumably, most prolific in this condition.

I.F. Amplifier

The sensitivity of the tuner is not high, but is adequate for use in areas of about 25 μV/m with a proper



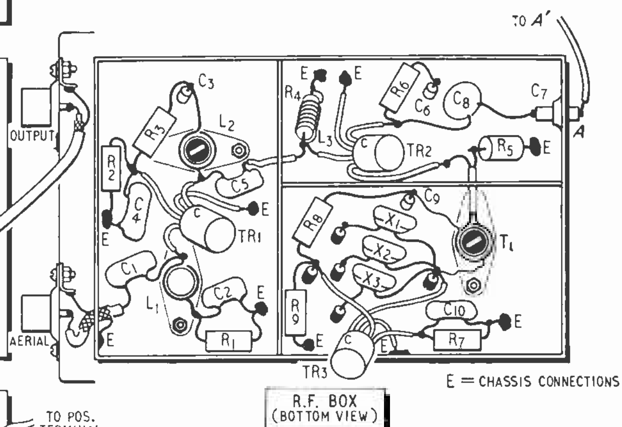


Fig. 10. Layout of components and wiring diagram.

dipole aerial. (It compared favourably with an established design in an unfavourable position at Harpenden, where it performed well with no audible noise on a bit of wire two feet long.) From the minimum triggering level of the Schmitt, it is evident that the gain from aerial to i.f. output must be at least 40,000. The r.f. stage and mixer give a gain of about 4.5, so that the i.f. amplifier must supply 9,000 times amplification. The output from the mixer contains a certain amount of signal at the channel separation frequencies (approximately 2.2 and 4.4 Mc/s). If allowed to pass to the Schmitt, this would cause phase modulation in addition to the signal and a.f. noise would occur. We have, therefore, included LC filters in two stages to attenuate the breakthrough.

Construction

All components are easily available, and the total cost is somewhere in the region of £14-£15. The crystals are available at £4 per set of three from

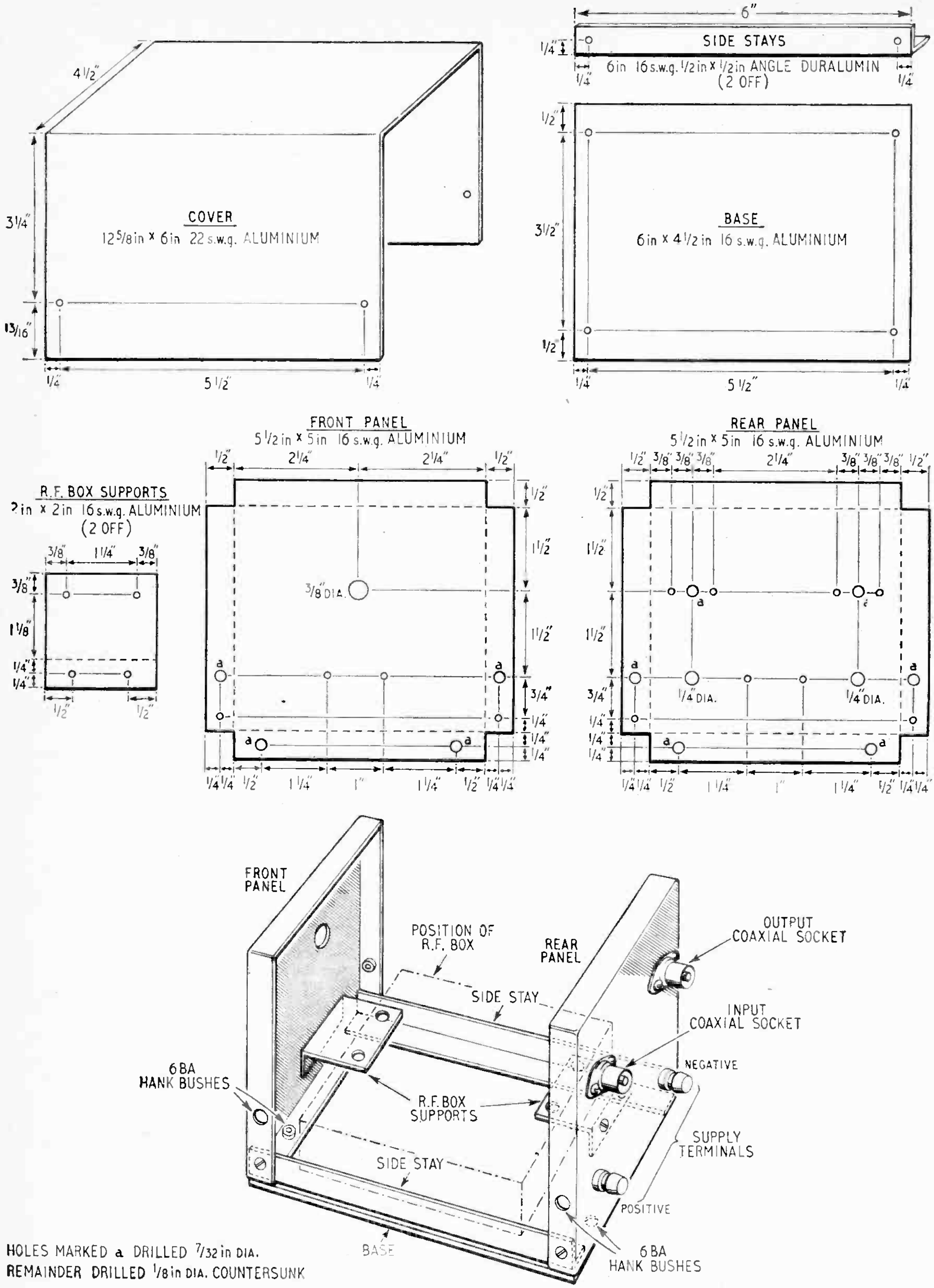


Fig. 11. Construction and assembly of case.

LIST OF COMPONENTS

Capacitors

C_1 47pF ceramic ± 10%
C_2 1,000pF ceramic ± 10%
C_3 1,000pF lead-through ceramic
C_4 1,000pF ceramic ± 10%
C_5 3.3pF ceramic ± 10%
C_6 1,000pF lead-through ceramic
C_7 1,000pF lead-through ceramic
C_8 0.02μF 30V disc ceramic (Radiospares)
C_9 1,000pF lead-through ceramic
C_{10} 1,000pF ± 10% ceramic
C_{11} 1μF 15V sub-miniature electrolytic
C_{12} 0.01μF 30V disc ceramic
C_{13} 32μF 15V sub-miniature electrolytic
C_{14} 82pF ± 10% ceramic
C_{15} 1μF 15V sub-miniature electrolytic
C_{16} 0.01μF 30V disc ceramic
C_{17} 32μF 15V sub-miniature electrolytic
C_{18} 82pF ± 10% ceramic
C_{19} 1,000pF ± 10% ceramic
C_{20} 0.01μF 30V disc ceramic
C_{21} 22pF ± 10% ceramic
C_{22} 32μF 15V sub-miniature electrolytic
C_{23} 22pF ± 10% ceramic
C_{24} 1,000pF ± 10% ceramic
C_{25} 100pF ± 10% ceramic
C_{26} 0.05μF 30V disc ceramic
C_{27} 100pF ± 1% silver mica
C_{28} 920pF* ± 1% silver mica (800 + 120 in parallel)
C_{29} 220pF ± 1% silver mica
C_{30} 100pF ± 1% silver mica
*for 100kΩ load. For 1MΩ load, use 500pF.

Semiconductors

9 × OC171 transistors
1 × OC42 transistor
2 × OA81 diodes

Resistors

R_1	560Ω	±10%	½W
R_2	2.2kΩ	,,	,,
R_3	12kΩ	,,	,,
R_4	10MΩ	,,	,,
R_5	470Ω	,,	,,
R_6	2.7kΩ	,,	,,
R_7	560Ω	,,	,,
R_8	5.6kΩ	,,	,,
R_9	1.5kΩ	,,	,,
R_{10}	6.8kΩ	,,	,,
R_{11}	27kΩ	,,	,,
R_{12}	1kΩ	,,	,,
R_{13}	2.7kΩ	,,	,,
R_{14}	100Ω	,,	,,
R_{15}	6.8kΩ	,,	,,
R_{16}	27kΩ	,,	,,
R_{17}	1kΩ	,,	,,
R_{18}	2.7kΩ	,,	,,
R_{19}	100Ω	,,	,,
R_{20}	6.8kΩ	,,	,,
R_{21}	27kΩ	,,	,,
R_{22}	1kΩ	,,	,,
R_{23}	2.7k	,,	,,
R_{24}	33kΩ	,,	,,
R_{25}	56kΩ	,,	,,
R_{26}	2.2kΩ	,,	,,
R_{27}	2.2kΩ	,,	,,
R_{28}	2.2kΩ	,,	,,
R_{29}	47kΩ	± 5%	,,
R_{30}	47kΩ	± 5%	,,
R_{31}	4.7kΩ	±10%	,,
R_{32}	12kΩ	,,	,,
R_{33}	33kΩ	,,	,,
R_{34}	56kΩ	,,	,,
R_{35}	3.3kΩ	,,	,,
R_{36}	3.3kΩ	,,	,,
R_{37}	1.5kΩ	,,	,,
R_{38}	100kΩ	,,	,,
R_{39}	47kΩ	± 5%	,,
R_{40}	12kΩ	,,	,,
R_{41}	12kΩ	,,	,,
R_{42}	4.7kΩ	,,	,,

Coil Data

L_1 5 turns, close-wound 24 s.w.g. enamelled copper wire on Neosid former Type 3500/8B.A. polystyrene, no core.
L_2 7 turns, close-wound 24 s.w.g. enamelled copper wire on Neosid former Type 3500/8B.A. polystyrene, core grade 900.
L_3 12 turns, close-wound 24 s.w.g. enamelled copper wire wound on 10MΩ resistor.
L_4 and L_5 15 turns, 24 s.w.g. enamelled copper wire self-supporting 3/16in. diameter.
L_6 and L_7 250 turns, 42 s.w.g. enamelled copper wire on Neosid pot core assembly Type 10 D/WR.
T_1 Primary—33 turns, close-wound 32 s.w.g. enamelled copper wire on Neosid former Type 3500/8B.A. polystyrene, core grade 900. Secondary is 3 turns, close-wound over the middle of the primary winding.
Neosid components are available from Denco (Clacton) Ltd.

Miscellaneous

½in. aluminium angle
16 s.w.g. aluminium
Thin tinplate
$\frac{1}{16}$in Paxolin sheet
Turret tags
5 × feed-through bushes
2 × coaxial sockets
1 × insulated terminal, red
1 × insulated terminal, black
1 × standard "Maka-Switch" assembly (Radiospares)
2 × long "Maka-Switch" spacers (Radiospares)
1 × 3-pole 4-way switch
1 × pointer knob
3 × crystals, 3rd-overtone, ±0.02% series resonance, (Cathodeon Crystals Ltd., Linton, Cambridge).

The sub-miniature electrolytic and disc ceramic capacitors shown in the photographs of the tuner can be obtained through local dealers from Radiospares Ltd.

Cathodeon Crystals Ltd., Linton, Cambridge, the frequencies required being obtained by subtracting 130 kc/s from the transmitter frequency and dividing by three. For instance, Wrotham transmits the Light Programme on 89.1 Mc/s. The crystal required is (89.−10.12)/13=29.657 Mc/s.

The construction of the unit is fully explained by the drawings. Tags have again been used, although printed circuits can be used if readers should so wish. It is intended to power the tuner by a common power supply in the rest of the builder's sound installation, but there is room inside for a battery if required; the battery terminals should then be omitted. The battery drain is 7 mA.

I.E.A. 1964

TRENDS AND SOME HIGHLIGHTS AS SEEN BY THE STAFF OF "WIRELESS WORLD"

THIS year's exhibition, the fifth of the series, demonstrated the wisdom of arranging a two-year interval between shows. Although the R.E.C.M.F. alternates with the I.E.A., the accent is on different types of product, and a more interesting exhibition is provided by the greater development that occurs between shows.

Transistors are finding greatly increased application in measuring instrumentation, especially in oscilloscopes and digital methods of frequency and voltage measurement. Most of the traditional objections to their use—high noise levels, low frequency characteristics, low impedance and low power—have been overcome, and they are now the designer's first choice for many applications.

Computers, many of which were second and third generation designs, and data-processing systems were very much in evidence, the trend being towards size reduction for a given application.

More so than in previous years the international flavour of the I.E.A. was noticeable in the increased number of "agency" stands and manufacturing companies who also showed products of overseas manufacturers.

MEASURING INSTRUMENTS

Voltage Measurement: One of the most clearly-defined trends at the whole exhibition was the large increase in the numbers of digital voltmeters. It would seem that no laboratory is now complete without its d.v.m., and one begins to wonder whether they are used because of their accuracy, reading convenience, or status "image."

The Solartron LM1420 is, however, quite definitely a good enough reason for using this type of instrument, having a measurement range of 2.5 μV to 1000 V, an accuracy of 0.05% and an input impedance of over 5 k$\text{M}\Omega$. Common-mode rejection is 150 dB, both input terminals being completely isolated from earth and the power supplies. Power to the voltage-to-frequency converter, and signals from this unit to the counter, are transmitted by toroidal transformers, a "guard" terminal being provided for applications where a high common-mode signal is present, guard being taken to the source of c.-m. voltage. The principle of the v.-to-f. converter is a variable-rate ramp generator. The applied signal varies the rate at which the output of an integrating amplifier rises towards a preset trigger level, at which point it is reset by a standard charge. As the rate of rise, and therefore the number of cycles, is determined by the input voltage, the frequency is a direct indication of voltage, and can be counted. The counters can be used separately for frequency measurement. A further feature is the cancellation of 50 c/s by making the gate time 20, 40 or 80 msec, up to 30 dB series-mode rejection being obtained in this way.

An accuracy of 0.001% is claimed for the Digital Measurements DM2010, which has a sensitivity of 10 μV and a 6-figure display. The usual method of obtaining the standard—two close-tolerance resistors—has been replaced by an inductive ratio arm, which is inherently more accurate, the ratio effectively being fixed by the number of turns on a coil.

The International Electronics DSV.1 instrument is noteworthy for its low cost—less than £100. It employs a 3-staircase successive-approximation type of circuit, in which the input to a summing amplifier is reduced in steps. The staircases are produced by the transistor equivalent of a unijunction "cup-and-bucket" circuit.

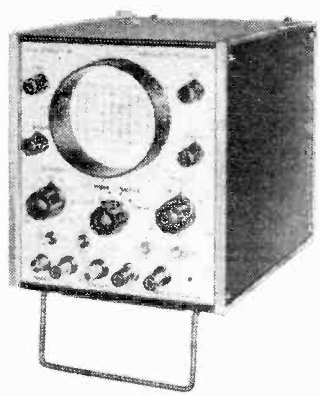
A different type of circuit is used in the Hughes 5100. A voltage-controlled oscillator is used, the transfer characteristic being linearized by means of a frequency-to-voltage comparator, giving an accuracy of 0.005%. A counter measures the frequency of the v.c.o., and transfers the counter states to a buffer store which operates the Nixie readout.

The more conventional type of "moving-finger" voltmeter continuous to develop, and a sudden increase in the number of true r.m.s. meters has been noted. A typical example is the Hewlett-Packard 3400A, which measures r.m.s. values from 100 μV to 300 V, at frequencies from 10 c/s to 10 Mc/s, of waveforms with crest factors up to 10 : 1 (100 : 1 at 10% of f.s.d.). A sensing thermocouple and reference thermocouple are arranged in a self-balancing bridge, giving freedom from drift. A d.c. output is provided for recording.

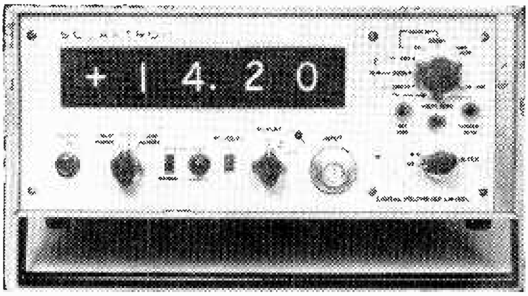
A direct voltmeter by the Ministry of Aviation shows the use of transistors in high impedance and low drift circuitry. Silicon planar types are used in a long-tailed-pair circuit, current drift being balanced by an auxiliary transistor. The input transistors are worked at a base current of 10^{-9}A, which, when the balancing current is subtracted, gives an input current of less than 3×10^{-10}A. Input resistance is 50 k$\text{M}\Omega$.

Oscilloscopes: Several transistor oscilloscopes have made their appearance recently, one of the more sophisti-

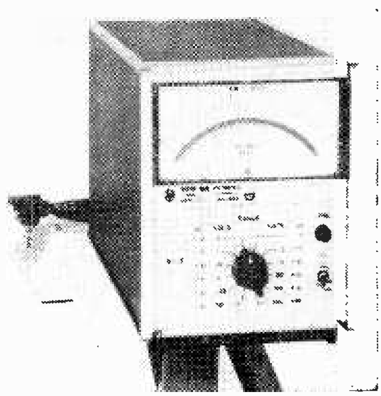
Levell TM51C universal counter. Operation is simplified.



Bradley transistor oscilloscope. Tube is 3in diameter.



Solartron digital voltmeter LM1420. Exceptional common- and series-mode rejection is achieved.



Right: Hewlett-Packard true r.m.s. voltmeter 3400A. Crest factors up to 100:1 can be tolerated.

cated being the Tektronix 647. The basic instrument uses a new 14 kV Tektronix ceramic tube with flat face and internal graticule. A tracefinder (attenuator type) and directly coupled bright-up are used, and a frequency-stable voltage calibration square wave is provided. The dual-trace plug-in amplifier has a bandwidth of 0-50 Mc/s (−3 dB) and 10 mV/cm sensitivity. Common-mode rejection, when the two identical channels are algebraically added, is 20:1, and cross-talk when operated separately is −80 dB. Input impedance is 1 MΩ and 20 pF. The timebase plug-in is a two-sweep unit, one being used to delay or strobe the other. Maximum writing speed with the 10× expansion in use is 10 nsec/cm.

The C.R.C. OCT 343 instrument shown by Claude Lyons is a small instrument with a 3-in, 1.6 kV tube. Vertical bandwidth is 500 kc/s and sensitivity 80 mV/cm. The chassis is isolated so that differential and high-voltage measurements may be carried out.

An even smaller instrument is the Bradley 148, using a 3-in tube and a front panel of 7×6 in. The sensitivity of the y amplifier is 20 mV/¼ in over 0-1.5 Mc/s, at an input impedance of 1 MΩ and 50 pF.

More conventional valve instruments seem to be following the trend towards diversity of application, in that the basic instrument consists only of power supplies, cathode-ray tube and tube controls. Amplifiers and timebases of the type required are then plugged into holes in the front panel.

The usual two compartments for x and y deflection units have merged into one in the Hewlett-Packard 140A oscilloscope. This compartment can thus be used for x and y, x and x, y and y or a special unit for transmission-line testing, which takes up the whole accessory compartment.

A scanning technique is used in the SGM43 large-screen instrument by Knott Elektronik, shown by A.E.P. International. This method has been described in *Wireless World* (Feb., 1956) and has been called the "voltage-coincidence" method. A scanning waveform, or raster, is applied to the tube and to one input of a coincidence detector. The input signal is applied to others when the two are equal, a pulse is produced which is used to brighten the tube. In this way, effective writing speed has no effect on brightness, and as many channels can be displayed as there are amplifiers available. The amplitude of the display is largely a function of the scanning waveform, so sensitivities up to 50 μV/cm can be obtained. A graticule is applied electronically.

Counters: Digital frequency meters using counting techniques seem to have reached a plateau in the development of faster counting speeds. 50 Mc/s is about the limit that is now reached in indicating decades, although heterodyne techniques and, in one case, a digital divider, push the limit to much higher frequencies.

The Venner TSA 3338 is a 50 Mc/s counter, using established techniques to measure frequency, time and random events. The crystal is a 5 Mc/s type in a 1-in-10^9 oscillator.

A lower-frequency basic counter, the Racal SA.540 11 Mc/s instrument is transformed into the SA.550 100 Mc/s type by the addition of the SA.545 non-indicating divider. This comprises a shaping amplifier, feeding a current-fed binary toggle, which drives a transistor/tunnel diode ring-of-five divider.

Levell Electronics introduced their TM51C, which is typical of the range of equipment in that it is a simple, general-purpose instrument with a sound specification and no frills. It is capable of counting up to 3 Mc/s, with the rather unusual input conditions of 35 mV and 100 kΩ. Special attention has been paid to reducing the noise level at the trigger stage to avoid errors when measuring periodic time. Display storage is used, so that the display only changes when the result of a new cycle of counting differs from the last. A high sampling rate is thereby usable without the need for display blanking or hold controls. When used as a counter, the capacity can be increased by the suppression of 90% or 99% of the input pulses.

In all the above counters, and in most of those seen at the exhibition, in-line displays of various forms were used and semiconductors are employed exclusively.

Signal Generators: Transistors have been relatively slow to take their place in high-quality signal generators, but the Marconi Instruments TF2002 wide range instrument uses them quite successfully in a very versatile unit. The generator employs eight separate oscillators to cover the range 10 kc/s to 72 Mc/s, with amplitude modulation and, on the top six ranges, incremental frequency shift, obtained by either Varicaps or reactance transistors. The internal modulation oscillator is variable from 6.3 c/s to 20 kc/s and, to eliminate the wearisome trudge from one end of the tuning scale to the other when plotting a response curve, the scales are made to run in opposite directions on each range.

A typical example of several lower-frequency sine/square oscillators is the Venner TSA 625. This is another transistor design covering 10 c/s—1 Mc/s in 5 push-button ranges, and giving a 2.5 V maximum sine wave at better than 2% distortion and a square wave with a rise time of 100 nsec.

SEMICONDUCTORS

Transistors usually tend to make the news in the semiconductor world, but at this exhibition, the diode stole a little thunder. The Hughes Microglass diode is possibly the smallest and shows promise of being one of the most reliable. No whiskers are employed, the junction being an epitaxial diffused type, with large-area silver contacts. The whole package is sealed by a glass-to-metal seal, and the junction itself is again protected by a glass-to-silicon seal.

Among the fastest diodes extant are the SGS-Fairchild FD7 series planar types, with a carrier lifetime

50 psec. The capacitance is F.

aimed by Mullard to be the world's fastest is the 54CAY gallium arsenide diode with a reverse recovery time of between 0.25 nsec and 0.5 nsec. The exact time is indeterminate, because the measuring instruments are not sufficiently precise.

Turning to transistors, two new planar field-effect devices were introduced by SGS-Fairchild—the 2N3277 and 2N3278—which exhibit a 0.5B noise figure, 0.1 nA collector leakage and an input impedance of 50 MΩ.

The planar technique is also used by Brush Clevite in their CZD Zener diodes, which offer low temperature coefficients and low noise. The forward voltage is roughly equal to the Zener voltage and the devices are rated at 400 mW. Again with low noise figures, the Mullard 2N929 and 2N930 silicon planar devices offer 4 dB and 3 dB respectively at 10 μA. They are intended as input stages for measurement and control amplifiers. Mullard also exhibited a range of devices which can be used for a wide range of applications. The BFY50 series have an f_T of 50 Mc/s and a very low saturation of 200 mV at 150 mA collector current. Current gain is well maintained between 1 mA and 1 A.

High-power, high-frequency transistors are always of interest, one such being the RCA TA2307 silicon device, giving 3 W at 400 Mc/s. This transistor is suitable for driving varactors to give considerable power at microwave frequencies.

Mullard RPY28 cadmium sulphide cell for car light control.

SGS-Fairchild also offered this kind of device in the form of the 2N2892 and 2N2893 silicon planar types. With 80 V collector/emitter ratings, they are rated at 30 W at 40 Mc/s. The same firm introduced the 2N3137, intended as an output stage for mobile radio telephones, and giving ½ W at 250 Mc/s or ¼ W at 500 Mc/s.

Intended for automatic control of car headlamps and parking lights, the Mullard RPY28 photocell is particularly suitable for use in transistor circuits. When illuminated with 50 lux, the cell resistance is about 450 Ω, the power dissipation being 200 mW.

COMPONENTS

Considering the intrusion of instrumentation into principal component exhibitions held in the U.K. over the past few years, it was not surprising that component manufacturers entered wholeheartedly into the 1964 I.E.A. fray. Many component manufacturers announced extensions to existing ranges only, while others introduced yet smaller articles to already miniature lines.

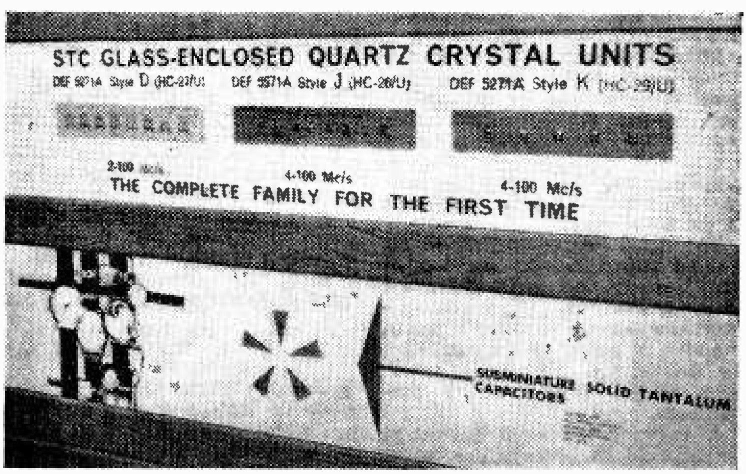
A notable feature in the resistor field was the conforming of new components to military specifications. Welwyn Electric introduced a new range of vitreous-enamelled, wire-wound resistors. These components meet the requirements of the DEF5115 specification, a feature of which is the long-term, cyclic-load test at full power and at 70°C. Designated "W" resistors, there are no protrusions along the resistor body and identification markings are "fired-in."

Turning from the fixed to the variable resistor field, the Colvern "Dialpot" though looking like a small clock, is a ten-turn helical potentiometer with an integral clock-type dial. A hundred divisions on the dial enable 1,000 settings over the ten turns of the potentiometer. The maximum resistance range is from 100Ω to 100kΩ. The dissipation is 3 W at 20°C. A new wire-wound trimmer potentiometer range was introduced by Painton. Components from this series measured ¾in long and approximately $\frac{5}{16}$in square. The temperature range over which these trimmers can be operated is −55 to 110°C.

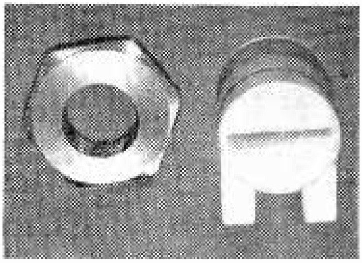
A number of new capacitor types were introduced and it was in this class of component that outstanding examples of miniaturization could be found. The term "monolithic construction" rightly or wrongly, has, for some time, been applied to integrated circuitry. Two classes of capacitors were shown, both of which were described as monolithic types. T.C.C. monolithic ceramic capacitors (shown for the first time in the U.K.) were designed to obtain the maximum capacitance per unit volume obtainable with ceramic capacitors. The high capacitance is obtained by the use of multi-layer construction of thin ceramic dielectric films which are sintered with palladium electrodes into a solid block. At present 15 values ranging from 0.01 to 2.2 μF may be obtained. The temperature range over which these components may be operated is −40 to 100°C. The other monolithic range was exhibited by Electrosil. Their "Lo-Cap" components consist of two flat ribbons of metal serving as plates (and also as leads), a layer of glass (dielectric) and two pieces of cover glass all fused into a solid unit. Available from 0.1 to 10 pF with tolerances of ±5, 10 and 20%.

Tantalum capacitors were prolific at this year's exhibition, of these, the sub-miniature types shown by S.T.C. and T.M.C. required a second glance to assure oneself that they were indeed electronic components and not pin heads. The "Hi Voltan" types on the T.M.C. stand weighed 0.1 gm and are available from 400 pF to 10,000 pF, values up to 3000 pF being available for 125 V working. The volume occupied by these capacitors is approximately 0.0006 cubic inches. Etched tantalum foil capacitors demonstrated by S.T.C. and sub-miniature solid tantalum capacitors attracted much attention.

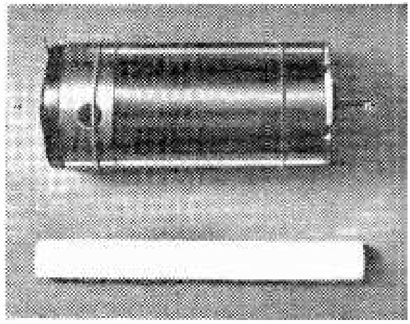
(Continued on page 337)



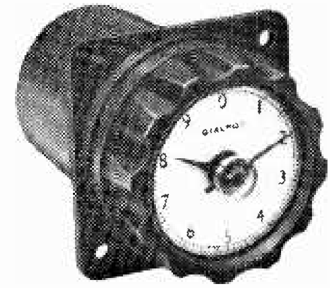
The "stop press" board of S.T.C. displayed the recently-announced, glass-enclosed crystals and sub-miniature tantalum capacitors.



Steatite trimmer capacitors with 4 B.A. nut for size comparison.



GK26 Dunker motor (compared with cigarette).



Colvern "Dialpot" 10-turn potentiometer.

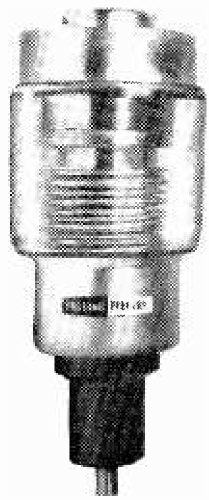
Occupying a volume of twice the size of an average pin head, these were developed mainly for use in electronic watches, hearing aids, etc. The ratings of these were given as 9 μF-volts. Thus a 3 μF type could be used as a 3 V capacitor and similarly a 1 μF could be used in a 9 V application.

Steatite Insulators showed what they believed to be the smallest available ceramic trimmer capacitor. Four types are available having values of 1.4 to 6.5 pF (Type N750) 1.2 to 2 pF (N470), 0.9 to 2 pF (NO33) and 0.4 to 1 pF (P100). A new series of vacuum variable capacitors was shown by the English Electric Valve Company. Components from this series are available for 75 A (r.m.s.) operation and ten types may be obtained covering capacitance ranges up to 2000 pF with peak r.f. voltages up to 30 kV.

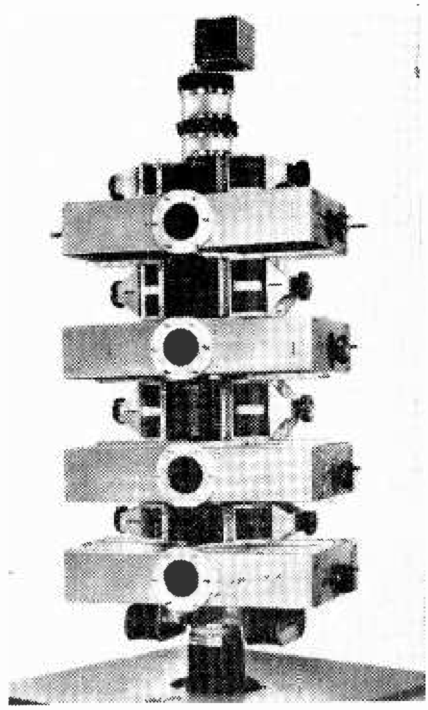
A high-power klystron, Type YK1001 shown by Mullard measured over 5ft high and is intended for use in the output stages of medium-power television-translator equipment. This valve will be particularly suitable for use in remote installations. Other features include permanent-magnet focusing, depressed-collector operation and air cooling.

The Brimar (Thorn-A.E.I.) SE4/2B and SE5/2A double-beam oscilloscope tubes have been added to the existing range of single-beam cathode ray tubes. The former tube is a 4 in version, the latter being a 5 in tube gives a raster area of 6 × 10 cm. Both types are helical post-deflection acceleration tubes in which the raster-distortion limits are better than 2%. Two methods are provided for brightness control, an anode modulator or the conventional grid method. An electrode is also provided for the final alignment of the two beams.

Despite their size, miniature motors and fans were prominent. The Dunker GK26 series of motors (Dunkermotoren) were worthy of mention. The series included motors with gears and governors. A typical example with governor measured less than 3 in long and about 1 in in diameter. The average efficiency of these motors was claimed to be well over 60%.



Above: 75A vacuum variable capacitor (English Electric).



Right: Mullard klystron Type YK 1001 stands over 5 ft high.

A visit to the Belling-Lee stand resulted in a demonstration of the improved Pattern 15 B.N.C. connector range. Principally, the improvements were concerned with the bugbear of cable clamping. In the new version, the braid is clamped between two metallic ferrules. The cable is gripped by a compression gland of silicone rubber, which is controlled by an internally threaded ring (this also makes an effective moisture seal). Finally, the cable is gripped by a split-tapered collet. The strength of the termination thus made is claimed to approach the breaking strain of a normal coaxial cable.

MATERIALS

Materials for the electronics industry, as in all other industries, must be considered the life blood. With these may be included such commodities as wires and cables, laminated boards and insulating materials. Formica showed their new grade of copper-clad industrial laminate for applications where a moving contact will be required to pass over the surface of the conductor. The material is supplied in a "semi-cured" state and after etching is pressed under heat so that a flush circuit results. The new laminate is made from sheets of bleached Kraft paper impregnated with a phenolic resin. When fully cured, the base material with the copper foil removed exhibits mechanical and electrical properties which meet all the requirements of British Standard Specification 1137 Type 1.

Many an electrical draughtsman took heart from a new Ilford material. This was a polyester drawing film designated Draflex. The surface is said to be suitable for all standard makes of quality pencil (graphite and waterproof), all drawing inks and typewriting. Because of the coating, multiple erasing is possible. The Asmac Division of R. H. Symonds showed a low-cost lacing tape made from nylon filaments bound with a wax which gives a flat lace with good knot tying and handling qualities. The tape is available natural or black in colour and usable over a temperature range of −67° to +200°F.

Brush Clevite gave an impressive demonstration of the piezo-electric properties of their ceramic material based on lead zirconate-lead titanate (PZT). A hand-operated "spark pump" using two elements mechanically in series but electrically in parallel was used. The output was estimated to be some 18 kV.

DATA PROCESSING AND COMPUTERS

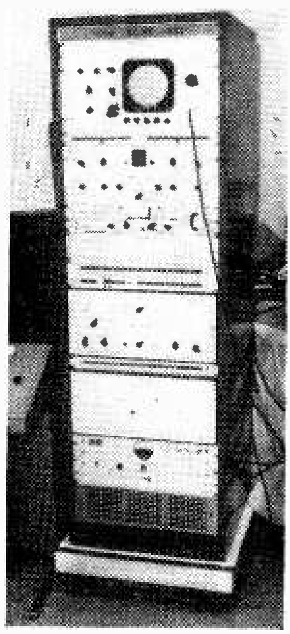
A visitor making a quick tour of the exhibition halls could be excused if he thought that he had visited a data processing and computer show. For, indeed, it was probably in this field that the greatest developments had been made since the 1962 I.E.A. Elliott-Automation on their vast stand in the Grand Hall showed, besides many other equipments, a relatively inexpensive digital computer ideal for educational purposes, and available in kit form. The basic computer comprised a set of Minilog logic elements and the necessary hardware which can be extended to include core storage, tape input and tape output facilities.

Model railways systems, used to demonstrate the application of computers to control systems, again attracted large crowds, though one was suspicious that the interest shown was not always academic.

A.E.P. International, in what may be described as "in the nick of time," received and showed the latest computer in the Scipp Series of instruments manufactured by the Victoreen Company. Using silicon semiconductors throughout, features of this Type 1600 computing instrument include variable bias for marginal testing, 32-position function programmer, 8-position memory programmer and serial decimal readout with digital data differentiating and integrating capabilities.

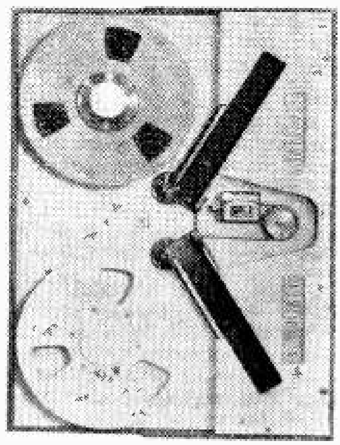
The Marconi Company gave an insight into the shape of computing equipment to come by a demonstration of an experimental ultra-high-speed computer which will be the basis of the next generation of Marconi Computers. The equipment demonstrated performed over 30×10^6 orders per minute with applications in air traffic control. As well as data-handling operations, the apparatus was simultaneously used as an on-line automatic teleprinter exchange with message-storage facilities. The circuitry utilizes microminiature silicon diode logic modules with stage delay times of the order of 5nsec. The ferrite core store has a capacity of 4,096 words. The computer uses a 24-bit word length and has a store access time of $0.4\frac{1}{2}$ μsec and store cycle time of 1.2 μsec. The whole equipment occupies a console approximately the size of an office desk.

The Type TM7 tape-transport equipment used in a number of Ampex systems showed some unusual features. Pinch wheels were not required and the passage of tape through the guide system was such that the oxide coating only contacted the tape heads. A single servo-controlled capstan is employed and two vacuum columns with photoelectric cells maintain a uniform tension of the tape.



The ever-increasing operating speeds of computers means that the output must be displayed in more convenient and faster form. Rank Cintel have introduced a new character display tube which produces the whole character simultaneously, which means that a 1 μsec display at 50 c/s affords adequate brightness. The electron gun produces 35 separate beams, each being provided with an aperture and controlling electrode. 35 leads are taken out, and depending on the signal voltages applied, the required character appears on the tube face.

Ericsson Telephones' system employs a 13×9 matrix of ferrite cores switched by coincident drive. Character readout wires are threaded through the cores in a pattern dictated by the required character. As each core switches, a pulse is induced in all wires threading it; the pulses are processed and connected to individual lines for each character, which are connected to the grid of the tube. Staircase generators deflect the beam to each spot position in turn and move the whole matrix of spots over the tube face.



Above: Ampex Type TM7 tape transport deck.

Left: Scipp 1600 computer (A.E.P. International.)

A small character display tube by Marconi-Osram, the 700E gives a display 45 × 24 mm and is designed to operate at high brightness levels. Large currents can be taken from the cathode, but as little of it is diverted to the focus and deflection electrodes, common supplies can be used to provide large numbers of the tubes with these facilities.

MISCELLANEOUS

An interesting optical telephony demonstration was provided by S.T.C. using a gallium arsenide light-emitting diode and a silicon photovoltaic diode. Both components were mounted on pan and tilt heads (cine cameras) and a mirror enabled a 40ft transmission path to be obtained on the stand. Speech and music were transmitted with visitors' heads occasionally interupting transmission.

Simple Electronic Stroboscope

USE OF TWO FLASH-TUBES FOR MULTIPLE EXPOSURE PHOTOGRAPHY

By J. D. PYE,* B.Sc., Ph.D.

THE unit to be described was originally developed for the study of animal behaviour by multiple exposure photography, but the mode of operation has certain advantages over conventional stroboscope circuits that may also be useful in other fields. It uses cheap components, at low voltage if desired, and may also be constructed in a modified form as an accessory unit for use with an existing electronic flash-gun.

The following outputs can be obtained:—
Either—single flashes of 50J or 100J;
or—two simultaneous flashes, each of 50J, from two heads;
or—short sequences of repeated flashes of 1 to 7J at rates of 1 to 80/sec.

This performance satisfies the initial design requirements but may readily be extended by changing the values and increasing the ratings of the components used. The maximum flashing rate has not been investigated but by modification of the trigger-pulse generator it should be possible to extend it to at least several hundred flashes per second. Even higher rates would be possible with flash-tubes specially designed for stroboscopic use, since the only limitation is the de-ionization time of the gas.

Principle. The main energy store consists of two 400 μF electrolytic capacitors charged to 500 V. Each is connected to an output socket so that either one or two tubes (FT1 and FT2 in Fig. 1) can be used to give 50J each. The double flash is useful for portrait work but a shorting switch allows a single tube (either FT1 or FT2) to be operated at 100J if required. For stroboscopic operation the two tubes are connected in series (FT3 and FT4 in Fig. 1) with a third capacitor, of 10-70 μF, across one of them. Initially, as explained later, this capacitor C may be charged to the full voltage of the main store. Then when FT3 fires, C is discharged and when FT4 fires, C is recharged. This process may be repeated as often as required, within the power rating of the tubes used, to produce a regular train of flashes. The voltage on C then steps up and down as shown in Fig. 2.

The strobe capacitor C cannot be recharged to the full supply voltage since FT4 extinguishes before the potential across it falls to zero. If the extinction voltage is an appreciable proportion of the supply voltage, the output from a given capacitance is less than might be expected. The tubes used here showed extinction voltages of 20 V (FA27) to 35 V (FA15), giving reductions of 8-13%. The value of C must be increased accordingly if the energy output is to be maintained; in the present case 10 μF is taken to represent 1J. Since the energy in a capacitor is proportional to the square of its voltage, the discrepancy due to the extinction voltage of FT3 is negligible.

When flash-tubes are operated from a supply that is less than their breakdown voltage, the discharge is initiated by a high-voltage triggering pulse. This is usually generated by discharging a small capacitor through the primary winding of a step-up transformer whose secondary winding is connected to an external electrode on the flash-tube. This forms a tuned circuit which rings (at about 100 kc/s in the case examined) and the first half-cycle, with a peak amplitude of several kilovolts, causes ionization and breakdown of the gas in the tube. In the double-tube stroboscope a single train of pulses is applied simultaneously to both tubes. The necessary switching is performed automatically since at any given time one tube has only its own extinction voltage (or less) across it while the other has the remainder of the supply voltage.

However, when the first tube fires, the voltage applied to the other increases rapidly and if its own ionization persists it will also break down. The two tubes will then conduct simultaneously to discharge the main energy store. This may be prevented by damping the trigger circuit so that

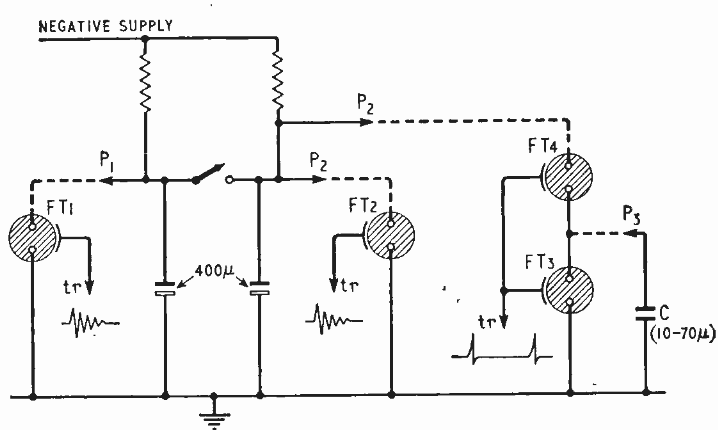


Fig. 1. Basic circuits for single, double or stroboscopic flashes. The points P_1, P_2 and P_3 refer to the corresponding points in Figs. 4 and 5.

*Institute of Laryngology and Otology.

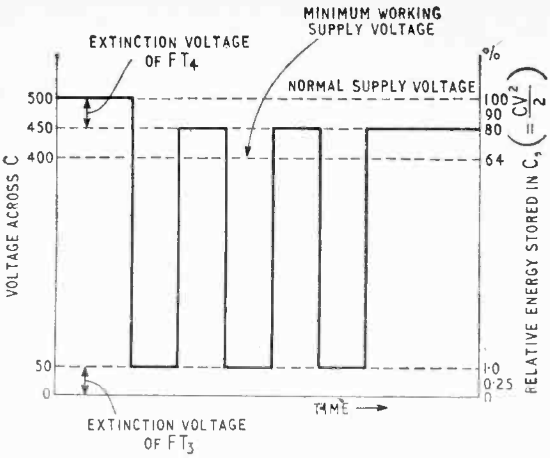


Fig. 2. Voltage and energy changes for the stroboscope capacitor C, initially charged to the full supply voltage and used for a sequence of six flashes. The extinction voltage has been exaggerated to 50 V for clarity.

only the first half-cycle is effective in causing ionization and by arranging that its amplitude is not so great that the ionizing effect is too prolonged. While the requirements of any given pair of tubes must be determined empirically, it is found in practice that these conditions are easily satisfied and the damping is not highly critical. With the particular trigger circuit used here, alternate firing of FA6 and FA15 tubes (working voltage 500-1,100) is achieved by connecting a diode across the primary winding of the trigger transformer. For FA27 tubes (working voltage 400-500) it is necessary to increase the pulse damping by adding a resistor of 1.4 kΩ (8 × 180 Ω, ½ W) across the secondary winding.

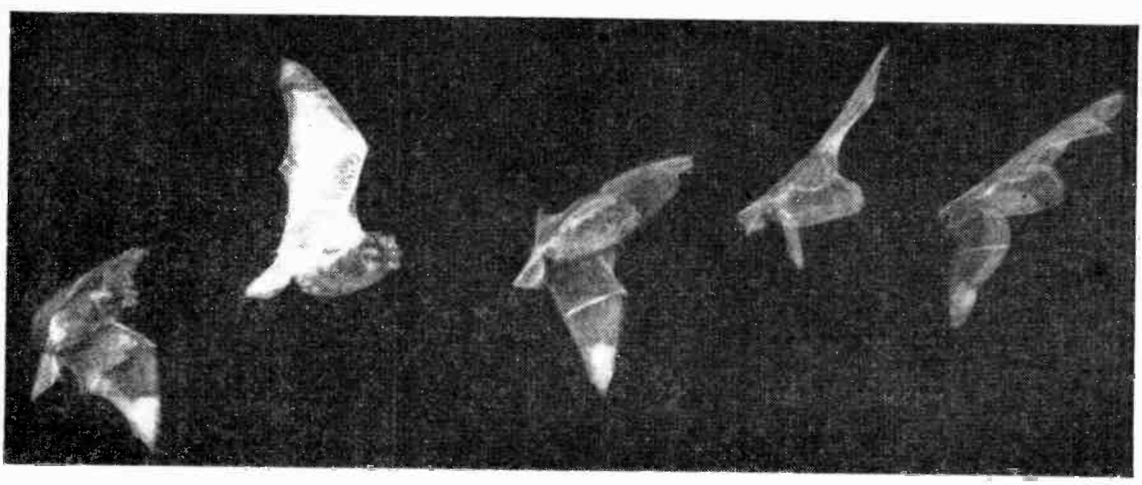
The power rating of two tubes used in this way is obviously double that of a single tube. For example, FA27 tubes have a continuous rating of 10 W and a pulse rating of 100J. Two such tubes are therefore capable of delivering up to 20 flashes, each of 10J, in rapid succession, or 1J at 20 per second continuously. With suitable reflectors this can represent a quite useful output (Fig. 3). The total number of flashes in each burst can be kept within safe limits by the camera shutter contacts, provided that they are of the type that remain closed only for the duration of the exposure.

This simple arrangement appears to have several advantages over conventional circuits. It is wholly electronic, thus eliminating the inconvenience of high-voltage rotary switches which are sometimes used alternately to charge the strobe capacitor and to discharge it through the flash-tube(1). The more common resistive charging of C presents two problems. First, if the charging resistance is too low, the tube will not extinguish; this can limit the maximum flashing rate even if high voltages are used to reduce the capacitance and thus the time constant. Secondly, during the charging phase a resistor dissipates an amount of energy equal to that of the subsequent flash. The double tube circuit overcomes both these difficulties by providing an extremely short charging time and by making use of the charging energy as another flash. Another common circuit uses non-dissipative inductance charging, with a series thyratron for controlling the discharge (1),(2) but this needs special components that are considerably more expensive than an extra flash-tube, and the thyratron dissipates an appreciable proportion of the discharge energy.

Circuit:—The complete circuit used in the instrument is shown in Fig. 4. It is intended primarily to be powered by the mains although the 6 V winding may be used with a battery and vibrator if necessary. The main storage capacitors are charged towards 630 V but are held at 500 V by a semiconductor diode and stabilizer-tube arrangement. This permits wide latitude of battery or mains supply voltage and improves the replenishment rate during stroboscopic operation by eliminating the asymptotic region of the charging curve. About 13 W is immediately available for recharging when the capacitor voltage falls slightly. The circuit also ensures that the full voltage of the storage capacitors is maintained if their leakage current rises. This commonly occurs in such large-value electrolytics after they have been

(*Continued on page* 341)

Fig. 3. A pipistrelle bat in flight photographed on Kodak Tri-X film (ASA 400) at f/11. The flashes were generated at approximately 25/sec by 7J discharges through FA27 tubes in a white plastic reflector 3ft from the subject.



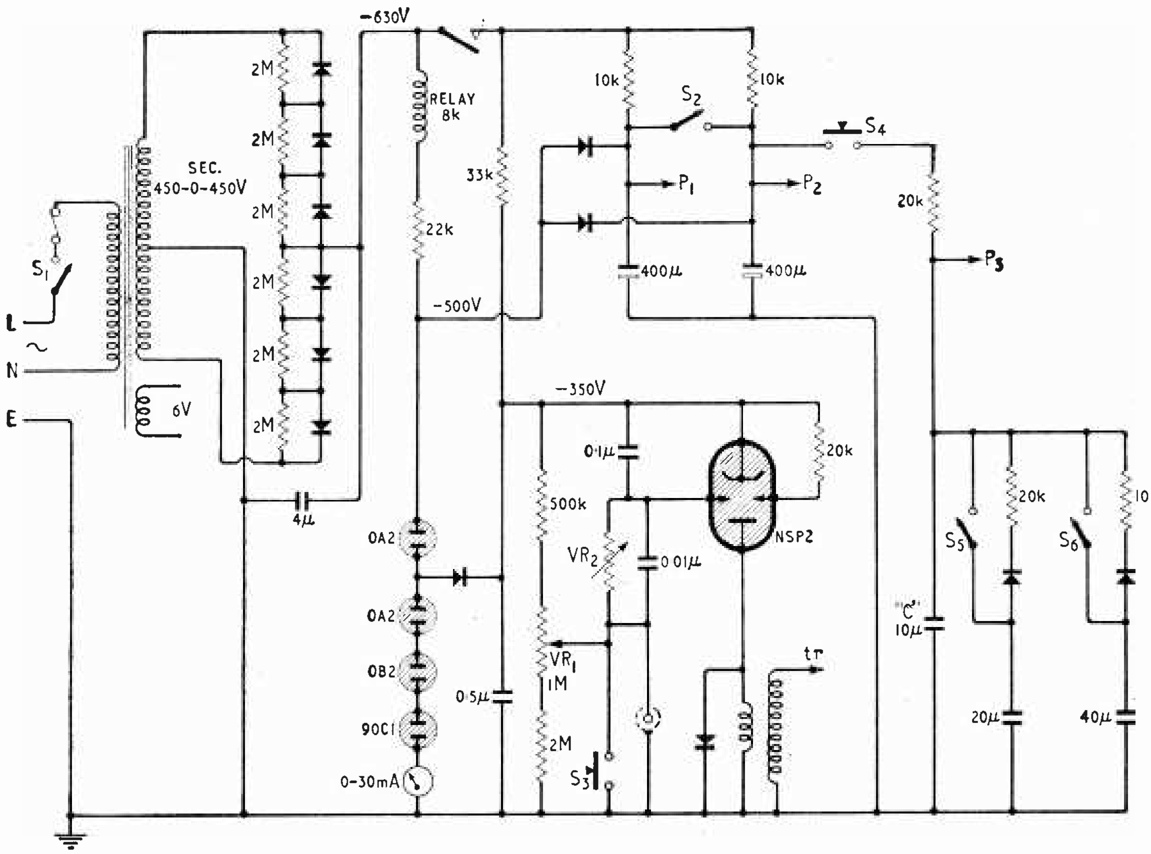


Fig. 4. Complete circuits of the power supply, trigger-pulse generator and stroboscope capacitor. VR_1 is a pre-set control of trigger sensitivity and VR_2 is a switched potential divider (200kΩ to 20MΩ) for control of strobe rate. All semiconductor diodes are OY241.

charged for some time, and would otherwise result in an appreciable reduction of the stored energy.

The relay is included as a safety feature to prevent overcharging of the electrolytic capacitors beyond their voltage rating, should the stabilizers fail to ignite. The milliammeter measures several functions in turn without switching. When the flash unit is switched on, a reading of 4 mA indicates ignition of the stabilizers; when the storage capacitors are charged, the meter current rises to 30 mA, and a later reduction from this reading represents the leakage current in the electrolytics.

While this supply circuit is rather wasteful of power in the stand-by condition, a factor of some importance for battery operation, it is very convenient for its purpose. However, the circuit described so far could be replaced by any standard electronic flash supply, especially if the energy stored in its capacitors is large compared with the total energy which the stroboscope is required to dissipate in any one sequence of flashes.

Complete replenishment of the main store between flashes is in any case unimportant provided that the tubes remain within their working voltage range and that a progressive diminution in flash energy can be tolerated. Even after the mains supply has been switched off in the above circuit, a pair of FA27 tubes will give a series of flashes that would be adequate for most purposes. For example, a reduction in supply voltage over the whole working range of these tubes, from 500 V to 400 V, gives a reduction in flash energy to about two thirds; more than 40 flashes, nominally of 1J each, can be obtained before this point is reached, even without recharging the main store.

The strobe capacitor C must have a low leakage current if its voltage is not to fall during the long intervals at low flash rates. Paper dielectric capacitors are therefore preferable to electrolytic types, despite their greater bulk. The switch S4 (biased off) allows the capacitor to be charged initially so that the energy of the first flash of each sequence does not deplete the main store. This operation also ensures that the capacitor is not charged to an intermediate voltage (say by leakage during an interval of rest) which can result in simultaneous firing with two low-voltage tubes, or render higher-voltage tubes incapable of firing at all. The value of C is conveniently adjusted by the circuit shown provided that the bank is charged by S4 before either S5 or S6 is closed. The charging current used for this purpose is indicated by a reduction in the milliammeter reading, and the condition of the bank can easily be determined when S4 is depressed.

The trigger-pulse generator is a straightforward relaxation oscillator with a Ferranti "Neostron"†

†Formerly Type NSP2, now EN10—Ed.

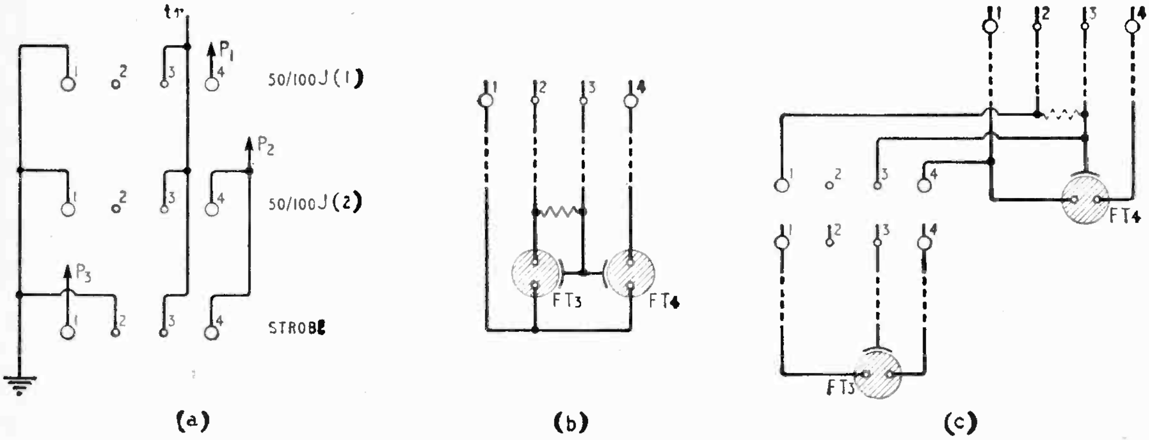


Fig. 5. Diagrams of the output and flash-head wiring. (a) The three UX4 output sockets. (b) A strobe-head consisting of two FA27 tubes on a single base. (c) Two separate heads, one of which bears an accessory UX4 socket for strobe use.

cold cathode trigger tube feeding a high-ratio pulse transformer. This particular arrangement keeps the body of the camera at earth potential. The $0.01\mu F$ capacitor ensures that the first flash of each sequence occurs as soon as possible after closure of the contacts, and a single flash is well within the 1/500 sec timing of a between-lens shutter set to "X synchronization." The $0.5\mu F$ trigger discharge capacitor should be of good quality; capacitors with too high an inductance may cause incomplete breakdown, resulting in damage to the Neostron as well as giving erratic operation.

Operation:—The two strobe tubes may be placed close together within a single reflector. Two FA27 tubes have been mounted on a single base as shown in Fig. 5(b) so that, when connected to one of the 50/100J sockets, one of the tubes can be used to give a single flash of high intensity. Alternatively the two tubes may be mounted in separate heads; FA6 and FA15 tubes have been used in this way. With the connections shown in Fig. 5 (a) and (c), only two tubes are required for all the output configurations permitted by the unit. Thus either or both heads may be used for high-energy single or simultaneous flashes, or they can be connected together and plugged into the strobe output socket for repetitive flashes.

The alternate use of two flash-tubes presents problems for incorporation into an optical system, although of course only the light from one tube need actually be used if the flash rate is doubled and the extra power can be afforded. But the double head arrangement may have some advantages, for instance if two or more moving objects are to be photographed or if a single object moves in an erratic fashion. The heads may be spaced on opposite sides of the camera to give different formations of shadows and highlights (or even of exposure) on alternate flashes, so halving the ambiguity of image pairing or ordering. If colour photography is possible, the two heads may be differently tinted to facilitate subsequent examination or they could be used with two cameras in the Aspden colour-channel system.(1) The application of polarization effects can also be envisaged for special purposes.

Finally, the owner of an electronic flash-gun, who wishes to undertake multiple exposure photography within the limits imposed, need only acquire a second tube and add the trigger oscillator and strobe capacitor as a separate unit. It is felt that the provision of this facility at low cost could find many applications in photographic recording or any other techniques requiring repeated flashes of light.

Acknowledgements:—The work was sponsored by the Office of Scientific Research, OAR, through the European Office, Aerospace Research, United States Air Force. The author is also indebted to Mr. M. Flinn for much helpful advice.

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(1) Aspden, R. "Electronic Flash Photography" (Temple Press, 1959).

(2) Edgerton, H. E. "Close-up Strobe Motion Pictures," *Research Film*, Vol. 4, pp. 310-5, 1962.

July Conferences

6-8 Malvern
Electron-beam Processes for Microelectronics
(Royal Radar Establishment, St. Andrew's Road, Malvern, Worcs.)

6-9 Birmingham University
Signal Processing in Radar & Sonar Directional Systems
(I.E.R.E., 8-9 Bedford Square, London, W.C.1.)

6-10 Savoy Place, London
Magnetic Recording
(I.E.E., Savoy Place, London, W.C.2.)

9-11 Boulder
Aerials and Propagation
(I.E.E.E., Box A, Lennox Hill Station, New York.)

E.M.F.

By "CATHODE RAY"

ANY course on electricity could hardly be so elementary and practical that it didn't bring in e.m.f.—quite likely in Lesson 1. Yet there is perhaps more confusion about it than about anything else.

Most of this confusion is because there is another thing also reckoned in volts—difference of potential, or potential difference (p.d.). The older books I have been looking at draw little, if any, distinction between them. They talk about current flow being due to "what is called electromotive force (e.m.f.) or potential difference." Some of the books in use today even, are far from clear on the subject. Take S. B. Hammond's *Electrical Engineering,* published as recently as 1961. On p. 13 it says quite bluntly: "Electromotive force is a synonym for potential difference."

The British Standard *Glossary of Terms Used in Electrical Engineering* (B.S. 205: Part 1: 1943) might be expected to put matters right. Its Definition 1212 defines e.m.f. as:

"That force which *tends to cause a movement of electricity* in a circuit," and Definition 1213 defines p.d. as:

"A difference between the electrical states existing at two points *tending to cause a movement of electricity* from one point to the other."

True, these definitions are not identical, and perhaps the brighter readers will deduce the essential distinction between e.m.f. and p.d. from the differences, but the operative parts (which I have picked out in italics) will mean much the same to most people. Incidentally, some of the books declare that e.m.f. is *not* a force!

It looks as if the committee of wise men who formulated these definitions were unable to agree among themselves about what an e.m.f. is, for Definition 1212 goes on to include what appear to be alternatives:

"The electrical condition for generating electromagnetic energy by the transfer of electricity in a certain direction."

"The line integral of the electric force around the circuit."

Further confusion can be found if we compare statements of Kirchhoff's Second Law. Many books present it as saying that the algebraical sum of the p.ds. around any circuit is equal to the algebraical sum of the e.m.fs. But others just say that the algebraical sum of the p.ds. is zero.

Or perhaps they say that the sum of the *voltages* is zero. All except the fussiest (or perhaps, to be more polite, I should say "most conscientious") people, and even some of the books, dodge the issue of having to distinguish between e.m.f. and p.d. by using the non-committal word "voltage." One seldom hears the other terms outside academic circles. And it must be admitted that electrical engineering gets along remarkably well without them. One might conclude that the old books had something after all and that it is just hair-splitting to try to distinguish between the two sorts of voltage.

Still, it isn't really satisfactory to be so hazy about any of the basic ideas of electricity, is it? And when we use symbols the problem breaks out again, because p.d. is V and e.m.f. is E.

In trying to clear up the matter we had better review several related fundamental quantities. The first is the "electric force" mentioned in Definition 1212. It is, I think, still rather better known as "electric field strength," denoted by $\mathcal{E}$. An electric field is the peculiar state of the space surrounding an electric charge. This state is revealed by the fact that any other electric charge is acted upon by a force tending to move it in some direction. The strength and direction of this force are, naturally, a measure of the strength and direction of $\mathcal{E}$. But the

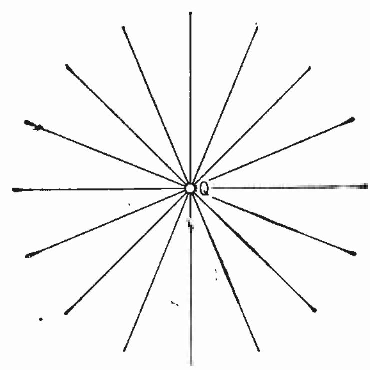

Fig. 1. Conventional representation of an electric field by lines of force takes this form around a concentrated charge in space.

strength is also proportional to the amount of the test charge used to explore the field. So, to bring $\mathcal{E}$ into a consistent set of units, unit $\mathcal{E}$ is defined as equal to the force that would be experienced by unit charge.

I say "would be" deliberately, because unit charge in the practical and m.k.s.a. systems of units is the coulomb, and a charge of 1 coulomb would be enormously too large for the purpose. Besides being difficult to gather together, it would almost certainly swamp the field we were trying to measure. So the test charge must be "very small" compared with that responsible for the field. For example, it could conveniently be an electron, on which the force would be -1.60×10^{-19} times the field strength, because that is the charge in coulombs on an electron.

$\mathcal{E}$ is commonly represented in diagrams by lines; their direction at any point shows the direction of $\mathcal{E}$ there, and their closeness together indicates its relative strength. For example, in Fig. 1 lines of force are drawn around an isolated charge, Q. That the force anywhere in this field varies according to an inverse square law can be seen, because the density of the lines falls off with distance from Q in that way.

Next, the product of force—any force—and distance is potential energy and work. These are both in the same unit (the joule) because energy is capacity for doing work. If you have sufficient energy to lift your 160 lb (shall we say?) up Ben Nevis (4,406 ft) from sea level, that energy, and the amount of work its expenditure does are both equal to $160 \times 4{,}406 = 705{,}000$ ft-lbs (not counting, of course, mechanical losses en route). Because a joule is a newton-metre, and a force of 1 newton is equal to 0.2248 lb weight (strictly, at sea level at 45° latitude) and 1 metre equals 3.28 ft, your expendable energy is 956,000 joules. That is also the work done thereby in moving your mass against the force (weight) it is subjected to in the earth's gravitational field. Unlike the additional energy that has been wasted in wearing away your boots and the rocky path, it is recoverable, at least in theory. Even if you perished in the cold at the top of Ben Nevis, your frozen corpse would have 956,000 joules of potential energy. Unfortunately it would probably do nothing more useful in its descent to sea level than help to keep the stretcher bearers warm.

We are still considering movements of a small charge in an electric field. If Q in Fig. 1 was positive, the force on an electron would be towards Q. So the analogy of your climb would be the carrying of electrons farther from Q. But whereas the strength of the earth's gravitational field varies so little in a 4,406-ft climb that we can without much error assume it to be constant, the field in Fig. 1 varies (as we have already remarked) inversely as the square of the distance. Only when an electric field is between large closely-spaced parallel plates is it reasonably uniform. Elsewhere one has to divide the distance the charge is carried into infinitesimally small stages, multiply each by the field strength there, and add the results all together. This apparently tedious job is done swiftly and easily (if the law of field variation is known) by mathematical integration.

Suppose we had a stone weighing 3.6 oz. The point of choosing that particular size is that the gravitational force on it near the earth's surface is 1 newton. And suppose we took it with us on a mountain climb and marked every point where we had completed one whole joule of work on it against gravity. Because of the way the joule is defined, each of these points would turn out to be 1 metre higher than the last. Difference in height between places could be called differences of gravitational potential. The higher point would have the higher potential, and energy expended in raising the stone there would be recoverable by allowing it to fall back to the starting point. The total work done on it would thus be zero.

Similarly, if we moved a charge of 1 coulomb about in an electric field and again marked the points where each whole joule of work was given or received, any two successive points would be separated not only by distances (in general, non-uniform) but by unit difference of electric potential. We call this unit the volt.

Where the field was strong, the p.d. points would be close together; where weak, far apart. So the field strength in any direction is reckoned in volts per metre along that route.

Because the volt is related to the coulomb and the joule in this way, the energy expended in lifting 3.6 oz 1 metre is exactly equal to the energy expended in moving 1 coulomb 1 volt higher in potential. And because a current of 1 ampere is a movement of electric charges at the rate of 1 coulomb per second, 1 joule is equal to 1 ampere-volt (called 1 watt) operating for 1 second.

The reason why potential is considered as a *difference* is that like height it has no starting point other than that which we care to agree upon. What is called the height of a building is usually understood to be the difference in height between its top and the ground on which it stands. Its height would probably be very different if it was reckoned like a mountain's, above sea level. Electrical potential is usually reckoned for practical purposes with reference to earth, but for theoretical purposes the zero is assumed to be an infinite distance away.

We have noted that the amount of work done on a body by lifting it against gravity through a certain height is the same as that body will do in returning to the start, so that the total work done on it in the whole process is nil. That is so, even if the return is made by a different route. If it were not, from the way we defined height as difference of gravitational potential it would follow that there was a difference in height between the starting point and itself, which is absurd. If the p.d. between the two points in Fig. 2 is $V_2 - V_1$, work equal to $q(V_2 - V_1)$ is done in taking a charge q from V_1 to V_2 *by any route*, and $q(V_1 - V_2)$ on the return journey, also by any route. And so the work done in taking it around any closed path is zero.

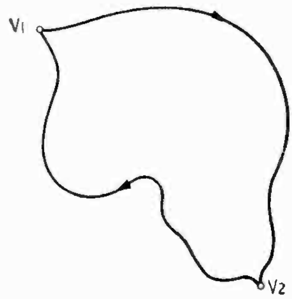

Fig. 2. Derivation of the fact that the net work done in taking any elecric charge around any closed path in any electric field is zero.

The sort of closed path we are most likely to be interested in is a circuit. And circuits normally have resistance, which means that the electrical energy of current flowing in them is converted into heat energy. Some metals—lead, for example—can be made to lose all electrical resistance by cooling them sufficiently. So any current started in a circuit made of such infinitely-conducting metal continues to flow round it indefinitely, and there is no p.d. This state can be likened to a completely frictionless wheel, which would keep on turning once it was started. The work done to raise the mass of any piece of the rim from bottom to top of its circular movement would be supplied by the fall of an equal mass at the opposite point on the wheel. Apart from this quite exceptional state, however, electrical energy departs from a circuit as heat, in proportion to the resistance.

If a charge is losing energy it must be falling in potential, the loss of potential multiplied by the amount of charge being equal to the loss of energy, as we have seen. There would therefore be no electric currents unless there was something which could "lift" charges from one point in a circuit to another of higher potential *against* the electric field between them, or (alternatively) create a p.d. to enable charges to flow from high to low through resistance. These alternatives are just two ways of looking at the same thing, but the difference in viewpoint can cause much futile argument if their equivalence is not recognized. The "something" is what we call an e.m.f.

The amount of e.m.f. is not the amount of energy it has or work it can do or power it can exert. It is not essential for it to be doing any of these things in order to exist. But it is related to them. The e.m.f. is equal to the p.d. it can oppose by raising the potential of electric charges against it. It is therefore equal (as Definition 1212 mentions) to the amount of energy imparted to *unit* charge in the process. So e.m.f. is measured in volts, and E volts of it imparts EQ joules of energy to Q coulombs of charge by transferring it from the lower to the higher potential terminal of the source of e.m.f. A current of I amps is I coulombs per second, so EI is equal to the number of joules per second, or watts. Not all of this energy or power is usually available, because part of it is converted into heat in the source.

When an e.m.f. is driving current it is injecting electrical energy into a circuit, and this energy must come from somewhere. If the source is a dynamo it is converting mechanical energy into electrical. A battery is much more complicated, but without going into details we can in these days readily accept that there is energy in atoms which can in certain circumstances be released. What is commonly called atomic energy converts this into heat and other kinds of radiation; but when certain substances are brought together an e.m.f. is created, and if a circuit is provided for it to make current flow therein, the atoms of those substances rearrange themselves in forms with slightly less total energy. The difference is equal to the electrical energy imparted to the circuit.

We have already noted one way in which electrical energy can be converted into another form, heat, when current flows through resistance; and that the rate of energy conversion is equal to the product of the current and the p.d. The fact that the p.d. is a drop is indicated conventionally by a negative sign. The product is therefore negative, which means that the electrical energy is being lost from the circuit. If the direction of current flow is reversed, the p.d. also reverses, because electrical energy is still being lost, so the potential must be falling in the reverse direction. In Fig. 3, if current from A to B is reckoned as $+I$, the p.d. is $-V$ and the power $-IV$. Reversing the current, we have $-I$ and $+V$ so $-IV$ again.

If instead of a resistor between A and B we had a source of e.m.f. driving the current $+I$ from A to B, then B would be at a higher potential than A, so the p.d. would be (say) $+V$ and the power $+IV$. The positive sign means that energy is coming into the circuit.

Current can also be reversed through a source of e.m.f. by means of a greater e.m.f. But the first e.m.f. is still there, maintaining B at a higher potential than A. So we have $-I \times +V = -IV$, indicating power leaving the cicruit.

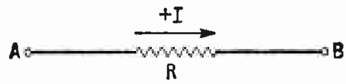

Fig 3. When a positive current is flowing from A to B through a resistance, the potential of B is reckoned as lower than that of A, so that the product of I and the p.d. being negative means that electrical power is being lost.

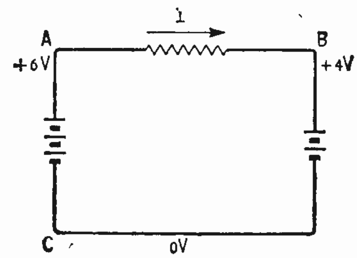

Fig. 4. Unlike the p.d. across a resistance, the p.d. across a source of e.m.f. does not reverse with direction of current.

Here then is an essential difference between resistance and a source of e.m.f. Both can allow electrical energy to leave the circuit by conversion into some other form, but whereas the source is reversible and can bring electrical energy into the circuit the resistance is not.

In Fig. 4, for example, potential is falling from A to B and also from B to C, but if the e.m.f. of the left-hand battery were reduced to 2V so that the current was reversed, potential would rise from C to B and fall from B to A.

Of course, one usually has to take account of resistance in the source, so that the p.d. between its terminals is less than the e.m.f. when it is driving the current and greater when it is receiving it.

When current is driven against an e.m.f., the electrical energy is converted into the form that that e.m.f. relies on when it is supplying electrical energy. In Fig. 4, one battery is "charging" the other (an unfortunate word to use, because the process is entirely different from charging a capacitor). A dynamo, which is a source converting mechanical energy into electrical, runs as a motor when the current is reversed, converting electrical energy into mechanical. Its e.m.f. is still there, and because it tends to oppose the flow of current it is often called a back e.m.f. The same applies to a transformer except that there is a double conversion either way: from electrical to magnetic and back to electrical.

So far everything seems to be quite simple and straightforward. You may be wondering why anybody gets confused or why I have bothered to hand out a lot of elementary textbook stuff. But we shall see.

Look again at Fig. 2, where we noted that the total work you would have to do to take a small electric charge completely round the course would be zero. The potentials V_1 and V_2 are supposed to be different because they are in an electric field, but there is no e.m.f. If you are working against the field from V_1 to V_2, the field is helping you from V_1 to V_2, and the total effort is nil. In Fig. 4, with its e.m.fs, surely the same applies? From C to A (by either route) you rise in potential by 6V and from A to C (again by either route) you fall 6V, so what is the difference in principle?

If that is what you are thinking, then you have so thoroughly received the message of Fig. 2 that you are assuming it applies to Fig. 4. True enough, if you follow any route from C to A except one you will have six joules of work to do for every coulomb you carry with you. But if you follow the circuit, which means going through a battery, things are quite different. Directly you enter the left-hand battery your coulombs will suddenly offer no opposition at all; they will float freely up to A. The work you would have had to do by any other route is done for you by the battery.

So that is one place where confusion is liable to occur. Definition 1213 says that p.d. "is measured by the amount of work done in transforming unit quantity of electricity from one point to the other."

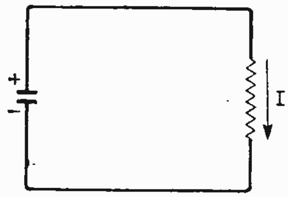

Fig. 5. The British Standard definition of p.d. gets into difficulties here.

You may say you have done no work in transferring electricity from C to A so there is no p.d. between those points. Someone else who has gone by another route says "Rubbish; there is 6V p.d. I know—I've had to do six joules of work per coulomb." A spectator who has been watching these experiments and the resulting dispute produces BS.205 and quotes "work done" from Definition 1213. As he points out, it doesn't say who has to do the work. Even via the battery it is done, so there is 6V p.d. Then we all notice some small print at the foot of Definition 1213:

Note. It is assumed that the work done is independent of the path followed between the two points. When this is not the case, as in the presence of varying magnetic fields, the conception of potential difference is not strictly applicable.

The dispute now breaks out afresh; one school of thought, following the spectator, maintains that this note is superfluous; there must always be work done in transferring charges to a point of higher potential, and BS.205 says nothing about who has to do the work, so presumably the battery and the varying magnetic fields are allowable. The same school of thought (which I notice consists mainly of the more modern, communications-minded types) tends to state Kirchhoff's Second Law in the concise form

$$\Sigma V = 0$$

The classical engineers and physicists, a little set in their ways, no doubt, will defend BS.205 (which, one suspects, was compiled by them or their kind). They will say that of course everyone knows that the work referred to has to be done by the one agency that is exploring the field, who is disqualified if he receives outside assistance. So the definition doesn't apply where there are e.m.fs, as the note says.

Trying to preserve a judicial impartiality, I would agree that the latter is a point of view, but it seems to have grave difficulties. If the "work done" isn't allowed to be done by atomic rearrangements in batteries or by varying magnetic fields, what about the negative work done, that always brings the total to zero around any closed path (with no e.m.fs)? Consider Fig. 5 where a previously charged capacitor is discharging through a resistor. You would undoubtedly have to do some work to carry a positive charge from − to + across the space between the plates. And if you chose any air path you would get it back on returning to −. But if you followed the circuit you would find you got none back; it would all go towards heating the resistor. So the total work you would do in making a round trip would be positive. But Definition 1213 says nothing about that. It disqualifies work done for you, but not (apparently) work taken from you.

Then if the "conception of potential difference is not strictly applicable" where there are e.m.fs, what about Kirchhoff's Second Law, which I suspect the BS.205 types would express in the form

$$\Sigma E = \Sigma V?$$

How can they bring p.ds quite strictly and quantitatively into a situation where they are "not strictly applicable"?

I must confess that the whole spirit of that footnote seems to me wrong. Is the "conception" applicable or isn't it? A Standard Glossary ought to tell us quite plainly instead of sitting on the fence. Even without the word "strictly" it is a pity to have a definition followed by a sort of lame excuse that it doesn't always apply. It smacks too much of that notorious discussion meeting on fundamental electromagnetic principles* when the homopolar generator was declared by some to be an anomaly, to be hushed up lest students find out that it doesn't conform to the textbooks laws.

In a thunderstorm there are strong updraughts which in certain places counteract the gravitational field and carry raindrops upwards against it. Yet I've never heard it suggested that in such regions the concept of height doesn't strictly apply. Or, to change the analogy, surely the upper station of a ski-lift is higher than the lower even if one rides in it instead of foot-slogging? While the ascent may feel less, no scientist is going to include in a Standard Glossary a note to the effect that height (or gravitational p.d., if you like) doesn't strictly apply in the presence of thunderstorms or ski-lifts or escalators.

Having settled that, if we have, we may think that the subject of e.m.f. has now been pretty well aired and we can relax. If so we are very much mistaken. We are only beginning. But the continuation will have to wait until next month. In the meantime you may care to decide whether there is an e.m.f. in Fig. 5, and if not, why not? If you find that too easy, put an inductor in series and say whether the expression "e.m.f. of self-inductance" is justified. If you decide differently between inductive and capacitive impedance, why?

See you next month.

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*Reported unofficially in *Essays in Electronics*, Chapter 4 (Iliffe Books Ltd.).

WORLD OF WIRELESS

Subscription Television

ALTHOUGH the Postmaster General's licences for the pilot schemes for subscription television in various parts of the country have not yet been issued to the five companies promised them, plans are going ahead for the introduction of the service.

British Telemeter Home Viewing, which has the U.K. franchise for the American Telemeter system, has placed a £100,000 contract with Teleng Ltd. to provide the cable system for its south London service which will be made available to residents in the Mitcham, Merton, Morden and Wimbledon areas. Teleng is the manufacturing subsidiary of Telefusion Ltd.—relay specialists —who are among the ten or so companies with an interest in British Telemeter. The coaxial cable system will provide all three broadcast television channels serving the area and f.m. sound programmes to some 8,000 houses and a coin-in-the-slot service to a selection of these. The system can, in fact, accommodate up to nine television channels and as many as 30 f.m. channels as it does in some Teleng installations in Belgium.

The relay system has a frequency coverage of from 8-230 Mc/s and radiated carriers are frequency converted for distribution. The distribution carriers used for a recent demonstration at Teleng's works at Romford, Essex, where a cable distribution system of 7 miles was simulated, were Channel 2 for 10, 4 for 9, 5 for pay-TV, 13 for 1 and G* for 33. On Channel 5 there were actually three pay-TV "programmes" available, selection being at the Telemeter coin box. These boxes, modified for English coinage, are initially being imported from Canada.

British Telemeter is also conducting an experimental scheme at Billingham, Co. Durham, for which E.M.I. is installing teleciné machines and control equipment. In this area British Telemeter is collaborating with Rank who have a television relay service in the area. This is particularly interesting in view of the fact that Rank-Rediffusion have their own subscription television system—Choiceview.

British Telemeter is concerned with a system and not the provision of programmes; these will be the concern of an associated company, Telemeter Programmes.

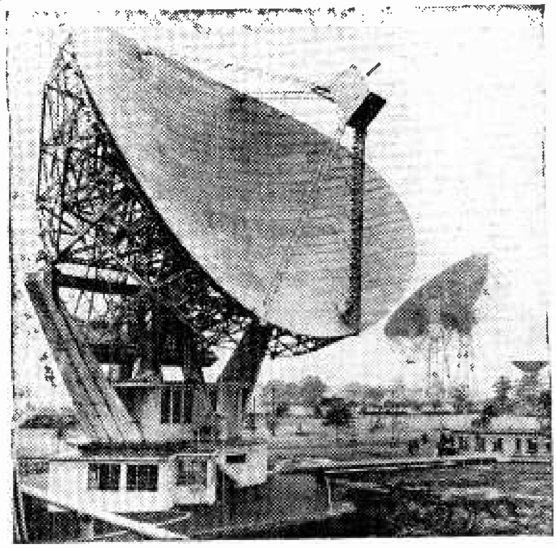
* One of the six 8 Mc/s channels in Band III recommended for the wired distribution of 625-line television.

Industry Forum

THE number of "bodies" speaking for the industry is now reduced by one. The Electronics Industry Council set up in 1960 by the British Radio Valve Manufacturers' Association, the Electronic Engineering Association and the Radio and Electronic Component Manufacturers' Federation has been dissolved. From its inception the Council had limitations in that there were several associations in the radio and electronics industry which were not members. Last year the Conference of the Electronics Industry was formed by nine associations* providing a much wider representation for the discussion of common problems. This consortium, of which O. W. Humphreys (vice-chairman of the G.E.C.) is chairman, has now taken over the functions of the Electronics Industry Council although individual associations will, of course, continue to represent their members' interests in their own particular spheres.

* British Electrical & Allied Manufacturers' Association, British Radio Equipment Manufacturers' Association, British Radio Valve Manufacturers' Association, Electronic Engineering Association, Electronic Valve & Semi-conductor Manufacturers' Association, Radio & Electronic Component Manufacturers' Federation, Scientific Instrument Manufacturers' Association, Society of British Aircraft Constructors, and Telecommunication Engineering and Manufacturing Assocation.

Jodrell Bank



A NEW 125-ft radiotelescope has been brought into use at the Jodrell Bank research centre of the University of Manchester. The 250-ft Mk I telescope, which has been in use continuously since 1957 and can be seen in the background of the above photograph, was designed for frequencies around 300 Mc/s (1 m) whereas the new Mk II is for operation up to 30 Gc/s (1 cm) and investigations on 3, 6 and 10 cm are planned. The elliptical paraboloidal steel bowl, the surface profile of which is accurate to within $\pm\frac{1}{16}$ in, measures 125 ft across the horizontal axis and 83 ft 4 in across the vertical axis. The total weight of the concrete superstructure and dish is over 800 tons and the whole can be revolved at speeds varying from $\frac{1}{8}°$ to 90° per minute and has a "following accuracy" of better than 2 minutes of arc. Similar speeds are also available when tilting the dish.

A feature of the new telescope, designed by Husband & Co., is that it is controlled by an "in-line" computer (Ferranti, Argus 100) connected to a closed-loop servo system. A simple dipole with director is fitted at the focus of the bowl behind the 8 ft cube cabin which houses parametric amplifiers—both cooled and uncooled.

A third telescope, which is transportable and will have a 125-ft dish, is now being built.

Technicians' Society Formed

AT a meeting held in London on 2nd June and attended by more than 100 technicians (most of them holders of R.T.E.B. certificates) a resolution was passed forming the Society of Electronic & Radio Technicians, appointing a chairman and an *ad hoc* committee with powers to draft a Memorandum and Articles of Association. Full membership is to be open to those who have obtained the Radio Trades Examination Board Final Certificate or some exempting qualification such as H.N.C., but it is possible that associate and student membership may be established for those with lower qualifications and less experience. Other meetings in Birmingham, Manchester and Glasgow supported the resolution.

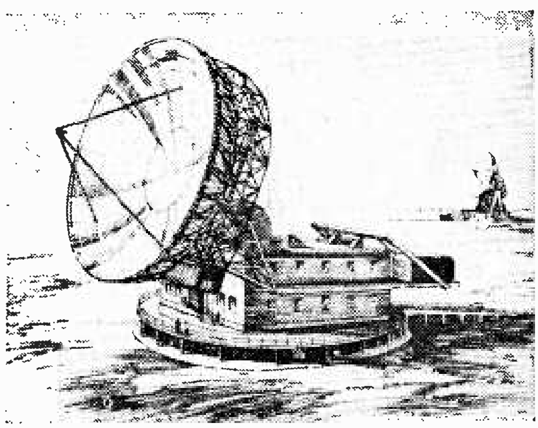
Co-ordination is for the time being in the hands of the Secretary, Radio Trades Examination Board, 9 Bedford Square, London, W.C.1.

Goonhilly Expansion

IN preparation for the launching of the American "Early Bird" synchronous communications satellite for public service, the Post Office satellite ground station at Goonhilly Down, Cornwall, is to be modernized at a cost of over £1.25M.

The first phase of the expansion calls for extensive modifications to the existing large steerable aerial, in which the present 85-ft paraboloid is to be replaced with one of the same size, but comprising a 25-ft solid paraboloid and 24 adjustable segments. Mr. J. H. H. Merriman, assistant engineer-in-chief of the General Post Office, said it would take about six months to complete and work is planned to start this September. It is hoped to complete this task before the launching of "Early Bird," which is scheduled to be put into orbit next spring by the American Communications Satellite Corporation (Comsat).

Under the second phase of the Goonhilly extension, a second aerial, similar to the modified one, is to be erected. This is expected to be completed in 1966.



The artist's impression above shows the two aerials as they will appear in 1966. The one in the foreground will have more room on the turntable for transmitting and receiving equipment than the present aerial, which is shown in the background. Husband & Co. are consulting engineers for the project.

Broadcasting Stations Guide

THE fourteenth edition of the *Wireless World* book "Guide to Broadcasting Stations" has just been published. It lists both geographically and in order of frequency all authorized long- and medium-wave broadcasting stations in Europe but the major part of the 128-page book, which costs 5s, is devoted to details of short-wave stations throughout the world In this section there are nearly 4,000 entries as it includes all frequencies at present in use or notified for use at other seasons of the year.

Local Sound Broadcasting.—Addressing the Radio Industries Club, of which he is the new president, Sir Ian Orr-Ewing, M.P., spoke on a variety of topics ranging from the R.P.M. Bill to the General Election via Radio Caroline! On the latter subject he said that the problem of "pirate radio ships" could be solved and the public demand for the type of service they provide assessed by the introduction of local sound broadcasting stations run independently like local newspapers. "If they served no local need, they would," he said, "quickly close down and only private money and personal reputations would be at stake." Sir Ian said that "there are ample wavelengths available" although he did not say in what part of the spectrum!

Electronica.—An international trade exhibition is to be held in Munich this autumn for electronic components and allied products. The exhibition is to be known as Electronica and will run from 21st to 28th October. Further details may be obtained from the organizers'—Münchener Messe u. Ausstellungsgesellschaft m.b.H.—London Office: Gerald G. Kallman Associates, 16 Soho Square, W.1. A two-day symposium on microelectronics is to be held at the same time.

Radar Awards.—The Radar and Electronics Association has introduced the annual award of not more than two plaques for services to the Association, for papers presented, or for outstanding contributions to the radar and electronics industry. Raymond Caws, who has been chairman of the Council of the Association for 12 years, and Charles W. Knight, secretary since the formation of the original Radar Association nearly 20 years ago, were the first two recipients of plaques "for service to the Association." The annual award of prizes to "the best student members of the year" were presented to Y. C. Hua, of Singapore, and S. G. Chamberlain, of Cyprus, both studying at the Northern Polytechnic, and Cpl. B. Pratt of the R.E.M.E. School of Electronics, Arborfield.

Baird Scholar.—The second John Logie Baird Travelling Scholarship has been awarded by the Television Society to James D. Last, B.Sc.(Eng.), aged 24, of Cubley, Penistone, Yorks. He is a graduate apprentice in the B.B.C. Engineering Division who a year ago was granted a B.B.C. Research Scholarship and is now at Sheffield University. The award is a monetary grant from Baird Television Limited with which the scholar is to undertake a short period of investigation abroad in some aspect of television.

DX Record for V.H.F.?—Georgi Rumyantsev (UA1DZ), of Leningrad, according to Ivan Demyanov, secretary of the Soviet Amateur Radio Federation, set up a new record in long-distance v.h.f. communications of 1,240 miles. Between 10th and 13th December last year Mr. Rumyantsev carried out several two-way c.w. transmissions, via ionized meteor trails, with a Swiss amateur Dr. Lauber (HB9RG) of Zürich. The transmitter used by Mr. Rumyantsev had an e.r.p. of 50 watts and that of Dr. Lauber an e.r.p. of 1 kW.

The **British Amateur Television Club** is holding a convention on 12th September in the Conference Suite of the Independent Television Authority's headquarters, 70 Brompton Road, London, S.W.3. There will be an exhibition of members' equipment and a short symposium of lectures delivered by members on various television topics.

Transistor Circuit Design is the title of a one-week full-time course starting on 13th July at the Twickenham College of Technology, Egerton Road, Twickenham, Middx. Application forms are available from the College. Fee: 7 gn non-residential, 13 gn residential.

PERSONALITIES

O. W. Humphreys, C.B.E., B.Sc., F.Inst.P., vice-chairman of the General Electric Company, has been nominated president of the I.E.E. for 1964/5 in succession to **Sir Albert Mumford,** K.B.E., B.Sc.(Eng.). Mr. Humphreys, who is 61 and a graduate of University College London, joined the scientific staff of the G.E.C. Research Laboratories (now the Hirst Research Centre) in 1925 and became director of the laboratories in 1951. He was appointed to the board of the G.E.C. as technical director in 1959. Mr. Humphreys is chairman of the Conference of the Electronics Industry and was chairman of the Radio Research Board of the D.S.I.R. from 1957-62.

Air Cdre. Lionel H. Greenman, who since 1961 has been senior technical staff officer, Far East Air Force, has been appointed senior air staff officer, R.A.F. Signals Command at Medmenham, Bucks. Air Cdre. Greenman, who is 48, spent several years with the Post Office as a telecommunications engineer before joining the R.A.F.V.R. in 1936 and becoming a sergeant-pilot. He was commissioned early in the war before transferring to the technical branch to serve with the Ministry of Aircraft Production. Included in his more recent appointments is that of officer commanding No. 30 Maintenance Unit, R.A.F., Sealand, Cheshire, in 1959.

Kennyeth Harris

F. C. McLean, C.B.E., B.Sc., M.I.E.E., the B.B.C's director of engineering, has been appointed chairman of the British Standards Institution's Telecommunications Industry Standards Committee. Mr. McLean, who has been with the B.B.C. since 1937, became the Corporation's deputy director of engineering in 1960 and took up his present appointment in May last year.

Sir Ian Orr-Ewing, Bt., O.B.E., M.A., M.I.E.E., M.P., is the new president of the Radio Industries Club in succession to **Basil Z. de Ferranti,** M.A., A.M.I.E.E., M.P. Sir Ian was a member of the engineering staff of the B.B.C. until 1949 when he joined Cossor's of which he became a director in 1951. He entered Parliament in 1950 and on his appointment as Under Secretary of State for Air in 1957 relinquished his industrial associations. He subsequently became Civil Lord of the Admiralty but resigned from the Government last year. Sir Ian, is now chairman of the Carr Fastener Company.

Sir Ian Orr-Ewing

Leslie W. Hayes, O.B.E., M.I.E.E., who was appointed adviser to the director of the International Radio Consultative Committee (C.C.I.R.) in March 1963 and has been acting director of the Committee since the death of Dr. Ernst Metzler a few months later, has been appointed director *ad interim* until the next plenary assembly in 1966. Mr. Hayes was in the B.B.C's engineering division for 25 years until his appointment as vice-director of the C.C.I.R. in 1948. When he left the B.B.C. he was head of the overseas engineering & information department.

D. J. West has been appointed marine service manager of Elliott Marine Automation Ltd. Mr. West was previously with Cossor Electronics Ltd., first in the position of chief marine service engineer to the equipment servicing division and latterly the company's marine sales manager. During the war he was engaged on radar research at various Admiralty establishments.

K. E. Harris, B.Sc., M.I.E.E., M.I.E.R.E., who last year became the manager of the communications division of Redifon Ltd., has been appointed to the board of directors. Mr. Harris joined the Post Office engineering department at Dollis Hill in 1934 and at the outbreak of war he was seconded to the Telecommunications Research Establishment (now the Royal Radar Establishment) at Malvern. After spending seven years engaged on radar research, he left Malvern as principal scientific officer in charge of the ground radar division, to join Sir Robert Watson-Watt in a private consultancy. Two years later, 1947, he joined A. C. Cossor as research manager, became director in 1953, and was appointed technical director of Cossor Radar in 1957.

A. Burke, A.M.I.E.R.E., chief development engineer of British Relay Ltd., has been elected president of the Society of Relay Engineers. Mr. Burke joined British Relay in 1948 and after National Service spent nearly two years with the B.B.C. as a maintenance engineer before rejoining British Relay in 1953. He was equipment liaison engineer from 1959 until his appointment as chief development engineer two years ago. Mr. Burke has been vice-president of the Society for the past two years. The new vice-president is **L. T. Mudd,** **A.M.I.E.E.,** of Rediffusion Research Ltd.

Brian K. Ridley, B.Sc., Ph.D., A.Inst.P., a physicist in the Solid-state physics division of the Mullard Research Laboratories at Salfords, Surrey, has been appointed lecturer in physics in the School of Physical Sciences of the new University of Essex which opens in October. Dr. Ridley, who is 33 and a graduate of the University of Durham, where he also obtained his doctorate, has been working on the fundamental properties of semiconductors at the Mullard Laboratories.

Victor A. Haffner, A.M.I.E.E., assistant engineer-in-chief of the Post and Telegraphs Division of Nigeria's Ministry of Communications, has been appointed a director and general manager of Nigerian External Telecommunications Ltd. in succession to **Hugh Rutter** who is retiring and returning to the U.K. Mr. Haffner, who is 45 and was educated at the C.M.S. Grammar

School, Lagos, came to London in 1943 to study and then joined the Radio Division of Standard Telephones and Cables and later worked with Redifon. He returned to Nigeria in 1954. Mr. Rutter was the Lagos manager of Cable and Wireless and handled arrangements for the formation, last year, of N.E.T. Ltd. which is jointly owned by the Government of Nigeria and Cable & Wireless.

C. Hardy, the founder and deputy chairman of the Data Recording Instrument Company, a subsidiary of I.C.T., has retired. In a reorganization of the board, **R. E. Hutchins,** C.B.E., D.S.C., has been appointed managing director. Mr. Hutchins who was commissioned in the Royal Navy in 1933, was appointed deputy director of the radio equipment department, Admiralty, in 1952, and Captain Superintendent of Admiralty Signals and Radar Establishment (now Admiralty Surface Weapons Establishment), Portsdown, in 1956. He joined I.C.T. in 1961, and for the past year he has been manager of their computer laboratory at Stevenage.

Cdr. H. St. A. Malleson, who has been head of the Government & Industrial Valve Division of Mullard Ltd. for a number of years has recently retired. Cdr. Malleson had been with Mullard's for 28 years.

Dr. Dennis Gabor, F.R.S., professor of applied electron physics at Imperial College, London, has been elected an honorary member of the Hungarian Academy of Sciences. Dr. Gabor came to this country from Hungary in 1934 and worked in the B.T.H. Research Laboratory (now part of A.E.I.) at Rugby until he joined the staff of Imperial College in 1949. Prior to being appointed to the chair of applied electron optics in 1958 he was Mullard Reader in Electronics.

J. W. McPherson, B.Sc. (Eng.), A.M.I.E.E., has been appointed technical manager of Gardners Transformers Ltd. Mr. McPherson, who since 1955 has been a group leader in G.E.C's applied electronics laboratories at Stanmore, will be responsible for all technical aspects of the company's products including the co-ordination of technical development. Before joining G.E.C. he spent seven years with the research branch of the Post Office at Dollis Hill, specializing in the design and development of transformers for all types of electronic equipment.

R. P. Henegan, Assoc.I.E.R.E., is to become the new general manager of Gardners Transformers Ltd. Mr. Henegan relinquishes his directorship and his post of general manager of Technograph Printed Circuits Ltd. to take up this appointment.

Sir Gordon Sutherland, F.R.S., who has been director of the National Physical Laboratory since 1956, is to become master of Emmanuel College, Cambridge. Sir Gordon was Professor of Physics at the University of Michigan prior to his appointment at the N.P.L. He is president-elect of the Institute of Physics & Physical Society.

Alan Wolstencroft, C.B., is the new deputy director general of the Post Office in succession to **Sir Robert Harvey,** K.B.E., C.B., M.A., who is retiring in August. Mr. Wolstencroft, who is 49, joined the Post Office in 1936. He was closely associated with the setting up of the Independent Television Authority in 1954 and was secretary for the first year of its life. He has been director of the Radio Services Department since 1960.

E. K. Cole, C.B.E., M.I.E.R.E., has tendered his resignation from the board of Robinson Rentals (Holdings) Ltd. Mr. Cole was the founder and former chairman and managing director of E. K. Cole Ltd. until its merger in 1960 with Pye. He resigned from the Pye organization in the following year to join Robinson Rentals as advisory chairman. **David Robinson** has been elected chairman of the company in succession to Mr. Cole.

BIRTHDAY HONOURS

AMONG recipients of awards in the Queen's Birthday Honours List are the following:

Viscount

Rt. Hon. Harold Watkinson, Minister of Defence 1959-62 now director, Plessey Co.

Knight Bachelor

Arnold L. G. Lindley, chairman of G.E.C.

C.M.G.

G. D. Clifford, secretary, Institution of Electronic & Radio Engineers (formerly Brit.I.R.E.) since 1937 and secretary National Electronics Research Council.

C.B.E.

H. C. Husband, senior partner in Husband & Co., designers of the Goonhilly Down and Jodrell Bank paraboloids.

R. Kirkwood, regional director, Posts & Telecommunications, Sabah.

E. N. Rowbotham, chairman Ever Ready Co. (G.B.).

O.B.E.

W. S. Cowie, lately, director of telecommunications (planning) Malaysia.

E. C. Drewe, head of B.B.C. Equipment Department.

J. R. H. Hutchison, director, Posts & Telegraphs, N.S.W., Australia.

R. O. Jones, Ph.D., senior principal scientific officer, D.S.I.R.

J. P. Wykes, manager, Maritime Division, Marconi Co.

M.B.E.

D. H. Elliott, senior telecommunications engineer, Cable & Wireless.

J. A. G. Fitzgerald, chief engineer, control gear division, Laurence Scott & Electromotors.

R. R. Harris, engineer (telecommunications), Swaziland.

E. G. Lloyd, executive engineer, G.P.O., N. Ireland.

W. K. Newson, engineering recruitment officer, B.B.C.

B. J. O'Brien, lately director, Posts & Telegraphs, Queensland, Australia.

T. S. Robson, senior engineer, transmitters, I.T.A.

E. S. Russell, chief telecommunications superintendent, External Telecommunications Executive, G.P.O.

I.S.O.

W. Swanson, deputy inspector of wireless telegraphy, G.P.O.

B.E.M.

H. Banfield, charge hand, G.E.C. Ltd., Wembley

R. Clague, progress chaser, Automatic Telephone and Electric Co., Liverpool.

D. Escott, chief radio electrician, R.N.

J. Lewington, chief radio supervisor, R.N.

J. D. Pye, B.Sc., Ph.D., who describes a simple electronic stroboscope on page 339, has, for the past five years, been at the Institute of Laryngology and Otology, University of London, where he is now a lecturer. Dr. Pye obtained his degree in zoology at the University College of Wales in 1955 and later spent two years at Bedford College, University of London.

OBITUARY

Melville Eastman, founder and retired president of the General Radio Company, died on 7th May in Boston. Mr. Eastman, who was 79, began his radio career in 1906 as a co-founder of the Clapp-Eastman Company, which was set up to manufacture radio receiving and transmitting equipment. In 1915 he founded the General Radio Company to manufacture electrical measuring instruments, and he served as president of that company until 1944. From then until his retirement in 1950, he held the title of chief engineer for General Radio. He played a principal rôle in the development of the Loran navigational system. In 1945 he was awarded an honorary degree, of doctor of engineering, at the Oregon State College.

Elements of Transistor Pulse Circuits

6.—WAVEFORM SHAPING

By T. D. TOWERS,* M.B.E.

ELECTRONICS nowadays is much taken up with manipulating strings of pulses. This manipulation often involves shaping or reshaping pulses and the modern circuit engineer is expected to know something of at least the principles of the basic waveform shaping circuits to be described in this article.

The commonest waveforms met with are illustrated in Fig. 56. The basic one (from which all others can be derived by so called "Fourier synthesis") is the sine wave at (a) in the figure. The "step function" at (b) is merely an abrupt change between two d.c. levels. When engineers talk of "pulses" loosely, they generally mean a rectangular pulse, as in (c), made up of two equal steps in opposite directions. If pulses such as these are in a repetitive series or "train" as at (d) they are usually referred to as "square waves." Exponential waveforms are exponential functions of time and may be rising as in (e) or falling as in (f). A "ramp" waveform is usually taken to mean a nearly straight rising waveshape as in (g). The "sawtooth" of (h) is a train of rising and falling ramps. By passing these waveshapes through combinations of passive or active circuit elements, we can modify their shapes substantially. For convenience we will look at such "shaping" circuits in three main categories: (a) linear, (b) non-linear passive, and (c) non-linear active.

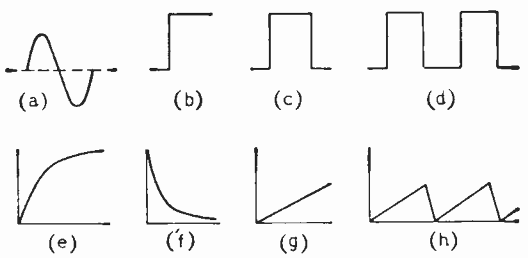


Fig. 56. Waveshapes commonly met with in pulse circuits: (a) sine wave, (b) step, (c) pulse, (d) square wave, (e) exponential, rising, (f) exponential, falling, (g) ramp, (h) sawtooth.

Linear Waveform Shaping

Linear waveshaping circuits are those which preserve the waveform of a sine wave passed through them. On the other hand, any non-sinusoidal waveshape will have its form altered. The two most important of these networks are the high-pass and low-pass RC filters.

High-Pass RC Filter (Differentiator):—The circuit of Fig. 57(a) is a high-pass RC linear filter. It is linear because a sine wave, $E = E \sin 2\pi ft$, passed through it still reappears as a sine wave at the output, but with a reduced amplitude $E/(1+f_1^2/f^2)^{\frac{1}{2}}$ and a phase angle advance of $\theta = \tan^{-1}(f_1/f)$ where $f_1 = 1/(2\pi RC)$. The output amplitude is 0.707 of the input, i.e. an amplitude reduction of 3dB, at $f = f_1$. Because of this, $f_1 = 1/(2\pi RC)$ is known as the *lower 3dB frequency* of the filter.

The response of the high-pass RC filter to an input *step voltage* is illustrated in Fig. 57(b). Assume that C is initially discharged; then when the input changes abruptly by E, the voltage across the capacitor cannot change instantaneously, and the output must also change abruptly by E. Then the capacitor begins to charge up via R, and as it does so the output voltage falls exponentially until ultimately it reaches zero (because the capacitor cannot pass direct current). The output waveform can be shown to be represented mathematically by the equation $e_o = Ee^{-t/RC}$.

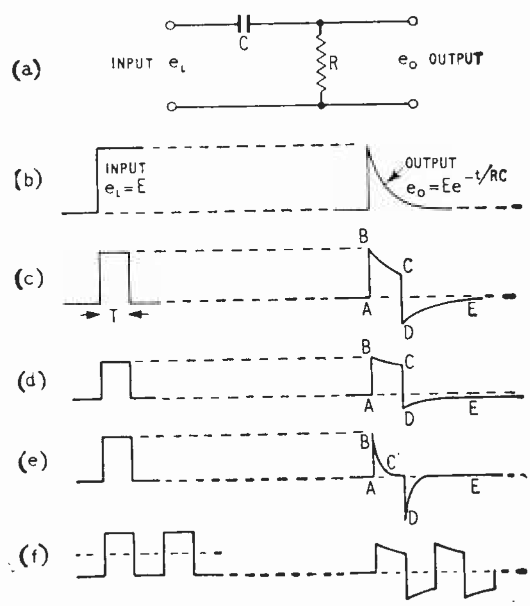


Fig. 57. High-pass RC filter (differentiator): (a) basic circuit, (b) step input, (c) single pulse (RC ≑ T), (d) single pulse (RC ≫ T), (e) single pulse (RC ≪ T), (f) pulse train.

The high-pass RC filter changes the shape of a *rectangular pulse* as shown in Fig. 57(c). The response of the filter to the front edge of the pulse is the same as in Fig. 57(b), but the back edge may arrive before the output has returned to zero and take the output only to the negative voltage point D. After this the output voltage rises exponentially to zero along DE with a time constant RC, until

*Newmarket Transistors Ltd.

both input and output are again at zero voltage and C is completely discharged. As the capacitor cannot conduct d.c. the mean output level must be zero. Thus the area above and below the axis must be equal.

If RC is very long compared with the pulse width T, the output response takes the shape of Fig. 57(d), where there is only a small droop on the top edge of the output pulse, and, on the back edge of the input pulse, the negative-going output step carries the output waveform only a short distance negative. The waveform then takes a long time to recover to zero because the total areas above and below the axis must again be equal.

If RC is short compared with the pulse width T, the output is as shown in Fig. 57(e). Here the capacitor effectively discharges itself well before the end of the input pulse and the negative-going back edge carries the output practically to the full pulse amplitude negatively. Because of the equal positive and negative areas, the recovery curve is virtually a mirror image of the forward curve and the output is symmetrical. This process of passing a square wave through a short-time-constant high-pass RC filter is widely used for converting pulses into "spikes" or "pips."

Rectangular pulses in a train of regular repetition rate or period, are often referred to as "square waves." Purists call them "rectangular" waves if the *on* time of the pulse, T_1, is not equal to the *off* time, T_2, but we will follow common practice and use the term "square wave" even where the *on* and *off* times are not equal. Engineers are interested in the steady-state response of a high-pass RC filter to such a train of square waves. If RC is very much less than both T_1 and T_2, then the output is a train of positive and negative spikes of amplitude each equal to the input pulse amplitude and coinciding with the positive and negative going edges of the input pulses. The peak-to-peak output amplitude is equal to twice the peak-to-peak input amplitude and the mean d.c. level is zero at the output. If RC is much larger than T_1 and T_2, the output pulse is virtually the same shape as the input pulse, but the capacitor gradually charges up until in the steady state the mean output level is zero. If RC is of the same order as T_1 and T_2, a complex situation exists where the output pulse is substantially a square wave but the peak droops or tilts significantly. If $T_1 = T_2 = T$ and we have a "true" square wave, it can be shown that the output waveform becomes symmetrical about zero volts as shown in Fig. 57(f) with a tilt defined as the percentage of the front edge by which the output pulse top drops) given by $P = 100\pi f_1/f$, where $f = 1/2T$ is the repetition frequency of the input train, and $f_1 = 1/2\pi RC$.

In discussing the response of a high-pass RC filter to step functions and square waves, we have cunningly assumed that the input wave is ideal, i.e. that the input has truly vertical sides—an impossibility in a real waveform. In practical circuits, with finite rise times on the input pulses, it can be shown that near the origin of time the output follows the input. Also, if the RC time constant is made smaller and smaller, the output pulse will tend to get narrower and narrower. Down to a certain value of RC the output peak will remain approximately equal to the input peak, i.e. the discontinuity in the input square wave. After that, the smaller RC the smaller the output peak. For example if RC just equals the rise time of the input wave, the peak output will be only about one-third of the peak input, but a very narrow pulse will result. Thus as we reduce RC compared with the rise time of the input pulse, the height and width of the output pulse both ultimately decrease. In practical circuits, a value of RC is chosen to give the best compromise between the conflicting requirements of sharpness and height in the output spike.

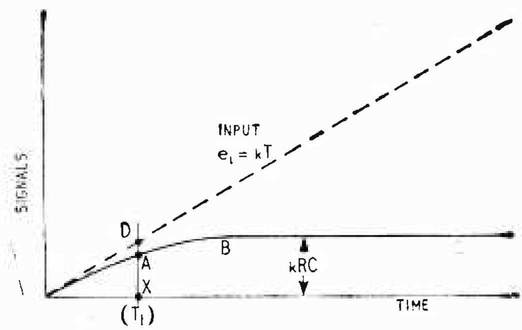


Fig. 58. Response of high-pass RC filter to rising ramp input.

The effect of a high-pass RC filter on a ramp input voltage is illustrated in Fig. 58. Here the dotted straight line represents the ramp or sweep input voltage which increases linearly with time. The output of the RC filter is as shown by the curve OABC. Near the origin, for times short compared with the RC time constant, it can be shown that the output signal falls away only slightly from the input. For example, at time T_1, small compared with RC, the departure from linearity is only AD in the diagram as compared with XD, and is commonly characterized by a so-called "transmission error" which is the difference between the input and the output divided by the input. For times short compared with the RC time constant of the network, the transmission error can be shown to be equal to $T/2RC = \pi f_1 T$, where $f_1 = 1/(2\pi RC)$ is now the "low-frequency 3dB point" of the RC filter. For example, if we want to pass a 5msec sweep through with less than 0.1% deviation from linearity, it can be shown that RC must be greater than 2.5 seconds. Now consider what happens to the output after a time T long compared with RC. This is illustrated along BC in Fig. 58. It will be seen that the output approaches a constant value which can be shown to be kRC, where k is the slope of the input ramp.

In general, where the RC time constant of the high-pass filter is very short compared with the time the input signal takes to make an appreciable change, the circuit is called a "differentiator." In this case, it can be shown that the output voltage $e_o = RC\, de_i/dT$, i.e. the output is the derivative of the input.

In theory the derivative of a step function is a waveform uniformly zero except at the point of discontinuity. Exact differentiation would yield an output of infinite amplitude and zero width. However, in practice the RC time constant cannot be negligible small compared with infinitely short rise time of a true step function, and the RC differentiator provides, in the limit of a very small RC time constant, a waveform which approaches the ideal except that the amplitude of the output peak can never exceed the input step voltage E, and the output spike has a finite width.

The differentiating action of a low-time-constant high-pass RC filter has practical uses such as measuring the rate of rise of a very fast rising pulse. Here we can assume that the leading edge of the input pulse is approximately a ramp and then the output pulse should after a very short time settle down to a constant amplitude proportional to the rate of rise of the input pulse. This output pulse peak divided by RC gives the rate of rise of the input pulse.

Low-pass RC Filter (Integrator):—The other important linear waveshaping circuit is the *low-pass RC filter*. This takes the form shown in Fig. 59(a). As its name suggests, it passes on low frequencies easily, but attenuates high frequencies, because the reactance of the shunt capacitor C falls with increasing frequency. As with the high-pass filter previously described, this is a linear waveshaping network because a sine wave passed through it reappears as a sine wave at the output. This time the amplitude is reduced by a factor $1/(1 + (f/f_1)^2)^{\frac{1}{2}}$ and the phase angle is retarded by $\theta = \tan^{-1}(f/f_1)$, where $f_1 = 1/(2\pi RC)$. It can be shown that the "gain" quoted for the circuit falls to 0.707 of its low frequency value at the frequency f_1, which is therefore called the "upper 3dB frequency" for this low-pass filter. The upper 3dB frequency of a low-pass filter, is the same as the lower 3dB of a high-pass filter when both use the same RC product.

The response of the low-pass RC filter to an input *step voltage* is illustrated in Fig. 59(b). Assume that C is initially discharged. When the input changes abruptly by E, the voltage across the capacitor cannot change instantaneously, and the output starts from zero and rises towards the steady state value E. The output waveform can be shown to be represented mathematically by the equation $e_o = E(1\text{-}e^{-t/RC})$. It can easily be proved that the output voltage reaches 1/10th of its final value in a time equal to 0.1RC and 9/10ths in a time 2.3RC. The difference between these two times (called the "rise time," T_R, of the circuit) is the indication of how fast it can respond to a discontinuity in voltage. This rise time is related to the upper 3dB frequency point approximately as follows: $T_R = 2.2RC = 0.35/f_1$.

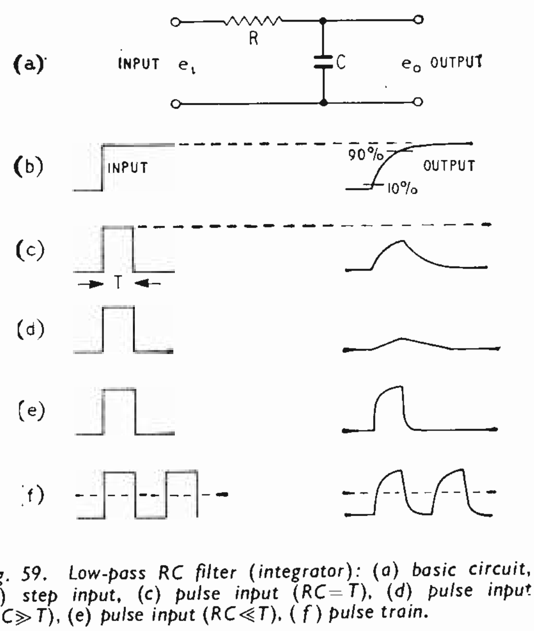


Fig. 59. Low-pass RC filter (integrator): (a) basic circuit, (b) step input, (c) pulse input (RC=T), (d) pulse input (RC≫T), (e) pulse input (RC≪T), (f) pulse train.

A *rectangular pulse* is changed by transmission through the low-pass RC filter as shown in Fig. 59(c). For any time less than the pulse width T, the response is the same as the response to a step input already dealt with. At the end of the input pulse, the output voltage starts to decrease to zero exponentially with a time constant RC. In the low-pass filter, since the output is directly connected to the input, the mean d.c. level of both is the same.

If RC is very long compared with the pulse width T, the output response takes the shape of Fig. 59(d), where there is only a small output rise and fall as compared with the input. The output consists of exponential sections which are nearly linear. Thus with a long RC time constant we can get a good approximation to a sawtooth waveform output.

If RC is short compared with the pulse width T, the output is as shown in Fig. 59(e). Here the capacitor effectively charges itself up well before the end of the pulse and on the cessation of the pulse the output returns to zero on an exponential curve.

Sometimes, when we pass a rectangular pulse through a low-pass RC filter, instead of trying to shape it we may be trying to keep its shape as far as possible. To minimize the distortion, the time constant of the RC network should be made small compared with the pulse width. A common working rule is that the pulse shape will be substantially preserved if the 3dB frequency is not less than the reciprocal of the pulse width. This can be put another way by saying that the RC time constant should be selected not greater than 1/6th of the pulse width. Under these circumstances, the output will rise to 90% of its final value after not more than 1/3rd of the input pulse has passed, and the rectangular pulse is transmitted reasonably undistorted.

Engineers are usually concerned not so much with the response of a low-pass filter to single pulses, but to a recurrent train of them. Where RC is much less than the repetition period of the train, the output becomes a train of pulses similar in shape to the input pulses, but with rounding on the front and back edged as shown in Fig. 59(f). The mean d.c. levels are the same at input and output, as are the peak-to-peak amplitudes. Where RC is much larger than the repetition period of the train, the output is a sawtooth of much smaller amplitude than the square wave input. Finally, if RC is comparable with the repetition period, the output is a very non-linear sawtooth with a marked exponential curvature on the rise and fall. Each case has one point in common—the mean d.c. level of the input and output pulse trains is the same.

Theoretically, the infinitely steep rise and fall times of the input pulses dealt with so far must be replaced in practice with something like a steep exponential ramp. The front-edge response of the low-pass filter to this waveshape is of interest because it shows what happens in actual circuits. It can be shown that if T_R is the rise time of the input waveform to 90% of its peak value, it reaches 50% of its final value in about 0.7 of T_R. If we define the "delay" of the filter as being the time for the output to reach 50% of its peak value, it can be shown that when RC = 0.16 T_R (condition described earlier for limited distortion) the delay is about $1.7T_R$;

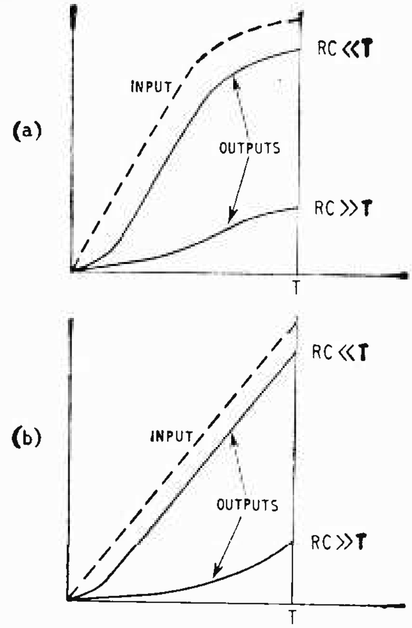


Fig. 60. Low-pass RC filter response to rising ramp: (a) xponential, (b) linear.

thus the output pulse is delayed behind the input pulse by approximately T_R.

The complete response of the low-pass filter to an exponential ramp input is sometimes important. This is illustrated in Fig. 60(a). If the total rise time of the exponential ramp is T and RC is small compared with this, the output (except for the delay distortion at the origin) follows the input very closely. If RC is large compared with T, the origin delay distortion is greater, and the output takes the second form shown.

The response of a low-pass RC filter to a *linear* ramp is given in Fig. 60(b). If the total rise-time of the ramp is T, and RC is small compared with T, the output again follows the input closely except for the short period at the origin. The transmission error, defined as before as the difference between the input and the output divided by the input, works out at D = RC/T and is relatively small. As an example, if we want to pass a 5msec sweep with less than 0.1% error it can be shown that RC must not be more than 5μsec. If RC is large compared with the sweep duration T, the output is very distorted as compared with the input as shown in Fig. 60(b). It can be shown that in this case the output voltage e_o is approximately equal to $kT^2/(2RC)$, where k is the slope of the input ramp.

In general, where the time constant RC in the low-pass filter is large in comparison with the time required for the input signal to make an appreciable change, the circuit is known as an "integrator." Under these conditions it can be shown that the output is given by $e_o = (1/RC) \int e_i dt$. Where RC is large compared with T, the output gives a very good approximation to an integral. But as RC is reduced, the departure from true integration increases, as was shown in Fig. 60(a) where the output is not in fact an integral of the input. This shows that this simple integrating circuit must be used with caution.

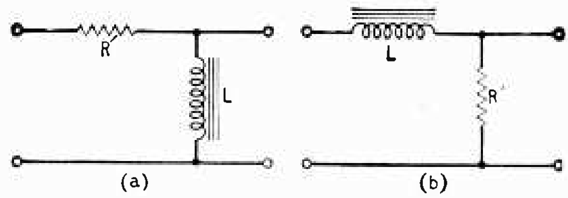


Fig. 61. Linear waveshaping RL filters: (a) high-pass, (b) low-pass.

RL Linear Passive Networks:—If in the high- and low-pass RC filters dealt with so far, we replace the resistance R by an inductance L and the capacitor C by a resistance R′, we get the high-pass RL circuit of Fig. 61(a) and the low-pass RL circuit of Fig. 61(b). It can be shown that if the time constant L/R′ is equal to the time constant RC, all the preceding analysis remains unchanged, and the properties of these low- and high-pass RL filters can be worked out easily. In actual pulse work, RL circuits are much less common than the RC ones. Where a large time constant is called for in particular, an inductance is seldom used because a large value of inductance can be obtained only with an iron-cored inductor which is physically large and expensive. In general, however, because suitable capacitor values are so much more easy to obtain than inductors, the bulk of linear waveshaping is done with RC circuits, except where special features call for RL ones.

Non-linear Passive Waveform Shaping

Many useful waveshaping operations can be performed if non-linear elements are added to the linear circuits already described. Space being limited, we will confine our examination of these to semiconductor ("crystal") diodes and transistors.

Diodes as Non-linear Passive Waveshaping Elements:—The ordinary diode is probably the most important non-linear waveshaping element in common use. The semiconductor diode shown in symbolic form in Fig. 62(a) is a device which in one direction behaves as a short circuit and in the other as an open circuit. When the "anode" A is positive with respect to the "cathode" C, the diode conducts as though it were a closed switch. When the anode is negative with respect to the cathode, the conduction stops and the diode becomes essentially an open switch. A real diode departs from an ideal one in several respects. Firstly, the forward resistance is not zero (with semiconductor diodes it lies in the range of 1 to 500 ohms). Also this forward resistance

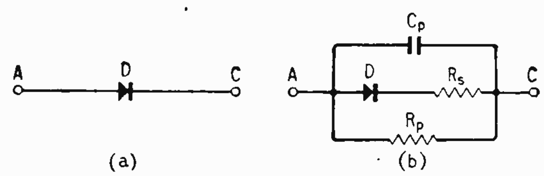


Fig. 62. Ideal and real diodes: (a) ideal diode symbol, (b real diode equivalent circuit.

is not constant, but varies with the applied voltage. Again, the reverse resistance is not infinite. For germanium diodes (which are most commonly used), reverse resistances of the order of 100K to tens of megohms obtain, provided the operating temperature is not above about 60°C. At higher temperatures, the reverse resistance tends to fall rapidly. There is in practice in a real diode a shunt capacitance in parallel with it which will have some effect on its circuit use. Point contact diodes have usually a capacitance of about 1 pF, gold bonded diodes about 3pF, and junction diodes from 10-40pF. When a diode is switched rapidly from conduction to non-conduction or *vice versa* it is found that there is a certain delay in reaching the final resistance value. This delay, called "recovery time," is due to minority carrier storage effects in the device. In practice it ranges from nanoseconds to tens of microseconds depending on the type of diode, and becomes really important only in circuits handling fast pulses. The reverse recovery time, i.e. the time to switch from forward conduction to reverse cut-off, is usually more critical because the reverse resistance builds up gradually. It is in fact more accurate to regard real diodes as variable resistors rather than switches. Fig. 62(b) gives the equivalent circuit of a real diode, where R_p is the shunt reverse resistance across the diode, D is the ideal diode and R_s is the series resistance representing its forward resistance. Finally, C_p is the shunt capacitance. For many switching operations, the departure of the diode from the ideal characteristics are not very important, and in the rest of this article we will treat the diode as an ideal one with zero forward and infinite reverse resistance.

Diode Clippers (or Limiters):—Clipper circuits are used when we want to select for transmission that part of an arbitrary waveform which lies above or below some particular reference voltage level. Such clipper circuits are sometimes referred to as voltage selectors or amplitude selectors.

Series diode clippers operate directly in the path of the pulse or wave that is to be shaped, as shown in Fig. 63(a). When the incoming signal makes the anode positive with respect to the cathode of the diode, the diode conducts, and an output voltage is developed across R_L. However, when the input voltage causes the anode to go negative with respect to the cathode, the diode cuts off and becomes an open circuit. No current then flows through the load resistor and no output voltage is developed. The result of this is shown in the waveform of Fig. 63(a) where the part of the input waveform below +V volts is cut off.

Similar clipping can be obtained when a diode connected to a d.c. supply source is placed in parallel with the load resistance R_L across the signal input as shown in Fig. 63(b). This is a parallel or shunt diode clipper. Here, when the input waveform falls below +V volts, the diode conducts and the output waveform cannot fall below that level and is therefore clipped off.

In either type of clipper of Fig. 63(a) and (b), the battery voltage and the diode polarity could be reversed, and then the output waveform would be clipped at the maximum instead of the minimum. A combination of two diodes connecting the signal line to a positive and negative d.c. supply as shown in Fig. 63(c) is known as a "double clipper" or

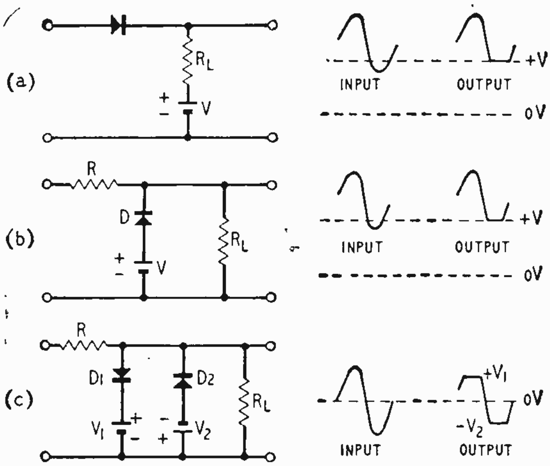


Fig. 63. Diode clippers (or limiters): (a) series, (b) parallel (shunt), (c) double parallel clipper (slicer).

"slicer" and leads to both the upper and lower peaks of the waveform being cut off.

We have used the term "clipper" in the description above but the term "limiter" is frequently used as synonymous with it. Some writers distinguish between clipping (as referring to a voltage waveform) and limiting (to a current waveform). There is no standard practice in this matter. Where the circuit is designed to tie the upper or lower peaks of a waveform to a fixed reference voltage the clipping process is usually known as clamping. Limiters or clippers can be regarded as special clamping devices which also modify the waveshape they clamp. True clamping preserves the signal waveshape but shifts the entire waveform up or down so either the top or bottom peaks are brought to a some predetermined d.c. level.

Unbiased Clamper:—The capacitor-coupled clipper circuit shown in Fig. 64(a) causes an input waveform to be shifted so that its negative peaks rest on zero level at the output. This does not happen on single pulses, but only on a train of

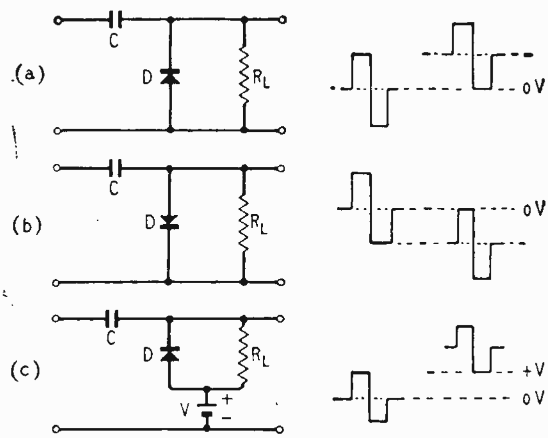


Fig. 64. Diode clampers (unbiased): (a) clamping −ve peak to OV, (b) clamping +ve peak to OV, (c) clamping −ve peak to +V.

pulses where after a settling down time the capacitor C charges up and shifts the mean output d.c. level.

If it is wished to clamp positive peaks of the output waveform to zero, the circuit of Fig. 64(b) is used. Here again the output d.c. mean level shifts until it settles down on a train of pulses with C charged up to a level where the positive peaks of the output signal are clamped to zero volts.

Finally, if it is desired to clamp the output waveform to some voltage other than zero, the circuit of Fig. 64(c) can be used. Here C steadily charges up under a train of input pulses until the output waveform has its negative peaks clamped to +V volts.

Non-linear Active Waveform Shaping

The non-linear waveshaping by means of diodes shown so far is very effective, but has the disadvantage that the networks have no gain and when the tops and bottoms of waveforms are removed by clipping, etc., the resulting output has a lower amplitude than the input signal. The obvious answer is to make up this attenuation by introducing amplification and this can be done by linear amplifiers after the clipper circuits. However, the same result can be achieved economically by using a transistor as a combined clipper and amplifier. When used this way the transistor stage is called an "overdriven amplifier." In this application the transistor is connected as shown in Fig. 65(a). If a voltage waveshape is applied to the input which is of sufficiently large amplitude, the transistor will be cut off on the positive-going half cycle, and the output at the collector will rise virtually to the negative rail voltage along the path AB in Fig. 65(b). Once the transistor is cut off, the input wave carrying the base further positive has no effect on the output and the transistor collector remains clamped to the negative rail voltage as shown by BC. When the input signal moves negative, the transistor is driven hard on and the output at the collector falls virtually to zero volts along DE. As a result, a signal passed through

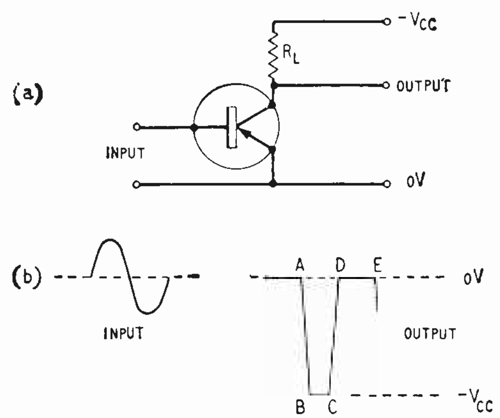


Fig. 65. Overdriven amplifier as amplified clipper.

the overdriven amplifier is clamped in one direction at the negative rail voltage and in the other at zero voltage. If it is desired to clamp the output signal at a voltage level other than zero on one side, a bias voltage can be added in the emitter circuit and the positive-going swing of the output signal cannot then pass beyond this.

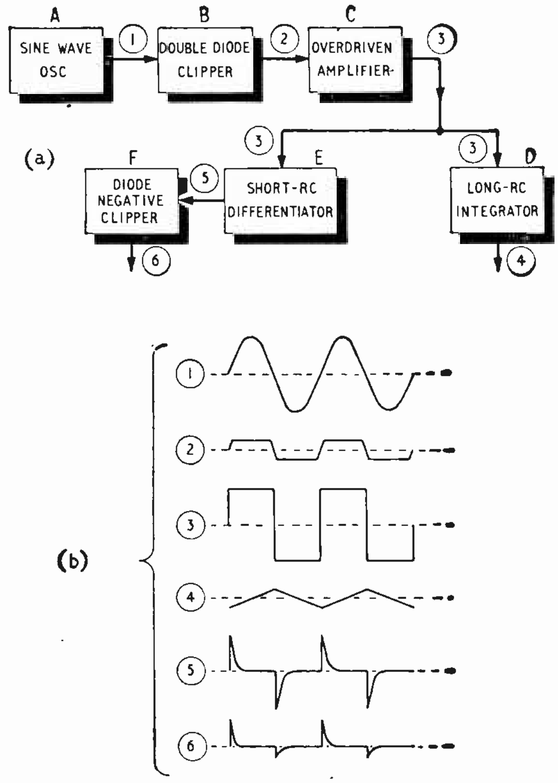


Fig. 66. Typical example of waveshaping of pulse train in computer.

Practical use of Wave shaping Techniques

As an example of the use of some of the circuits described in this article, Fig. 66 sets out an approximate diagrammatic representation of the processes whereby in a digital computer a stable sinusoidal signal from a master clock oscillator is shaped to produce various other waveforms accurately synchronized with the input sine wave. To begin with, a train of sine waves is generated by a conventional oscillator as at (1) in Figs. 66(a) and (b). This sine wave output is then applied to a double-diode clipper which produced the trapezoidal waveform at (2). The sides of the waveforms are rather too sloping for accurate synchronization so the pulse train is fed into an overdriven amplifier C which sharpens up the rise and fall times of the pulses and produces a virtually square wave output as at (3). This output may then be applied to an integrating circuit D with a long RC time constant which gives an output (4) in the shape of a sawtooth which can be used for gating purposes. The output of C can also be applied to a differentiator E with a short RC time constant to produce the output (5) in the form of a series of sharp positive- and negative-going spikes coinciding with the points at which the sine wave input waveform crosses the zero voltage axis. If this output is then applied to a negative diode clipper F it produces the waveform (6) where the negative-going spikes have been virtually removed. As a result, the waveform ends up as a train of sharp positive spikes

(*Continued on page 357*)

closely synchronized with the input sine wave and available therefore as clock pulses to time the various processes in the computer.

Conclusion

We have not had space to cover the complete family of waveshaping circuits. The most important omissions are regenerative amplifier circuits using either transformer coupling from output back to input, i.e. blocking oscillators, or two-stage amplifiers with positive feedback from output to input, i.e. multivibrators and Schmitt triggers. We have already covered multivibrators in earlier articles. Blocking oscillators and Schmitt triggers will be dealt with in a later article. Another widely used shaping circuit is the " diode pump " and its related " transistor pump " which are used to produce continuous or " staircase " ramp waveforms from a train of input pulses. These too will be covered in a later article.

The linear and non-linear waveshaping circuits described above are worthy of more detailed exposition than is possible within the scope of this article. Readers interested in following them up in more detail should consult one of the two " classics " on pulse circuits . . . " Pulse and Digital Circuits " by J. Millman and H. Taub, McGraw Hill, 1956, and " Waveforms " by B. Chance *et al.* M.I.T. Radiation Lab. Series. Vol. 19, McGraw Hill, 1949.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse opinions expressed by his correspondents

Black-level Correction Circuits

EVER since the beginning of television, the d.c. component of the video signal seems to have been alternately shown to be unimportant of even undesirable and then subsequently "discovered," both in technical literature and set makers' publicity. In the past few years, however, with the increasing use of mean level a.g.c. systems, the amplitude of the video signal has become indeterminate along with the d.c. component.

Mr. Mothersole's article in last month's issue shows a circuit to restore the black level to the position that nature intended but hardly makes mention of the highly undesirable effects caused by the peak white signal varying by some 2:1 depending on picture content. As the accompanying Fig. 1 illustrates, if the black level is restored on a mean level a.g.c. system, pictures with a high white content show as grey while predominantly black pictures have defocused peak white areas usually accompanied by black streaking due to the excessive video drive causing grid current in the c.r.t. I submit that these effects are subjectively as disturbing as the shift in black level and if manufacturers were to make television receivers that would do justice to the transmitted picture, then both effects would be eliminated.

Recently I bought a new dual-standard receiver and had little choice but to buy one with mean level a.g.c. After being used to a set with a fixed overall gain and a d.c. coupled video stage, I found viewing became intolerable. Believing that the cobbler should not be worst shod, I designed an add-on black level clamp and gated a.g.c. circuit which could be simply included into the existing receiver.

Fig. 2 shows the added circuitry while Fig. 3 shows the more important circuit waveforms. V1 is a flip-flop to produce a 4 μsec wide rectangular pulse initiated by the back edge of each line sync pulse. Were one designing the sync separator circuit, this valve could probably be left out and the pulse produced by differentiation, but the overall performance might not be quite so good. V2 is the black level clamp which d.c.-restores the negative-going video signal at the c.r.t. cathode to the correct transmitted level and the method of coupling ensures that any clamp pulse content added to the signal in the clamp does not reach the cathode, eliminating the possibility of white streaking during line flyback. V3 is a conventional long-tailed comparator working directly on the high-level signal. A.g.c. signal is produced when the negative-going signal back porch on pin 2 exceeds the setting of the positive-going pulse tips on pin 7 adjustable by the contrast control setting. The 120-V Zener diode is necessary as the h.t. lines on television receivers are not noted for their stability, although other forms of voltage regulator would prove cheaper. All the valves are E88CCs although I've little doubt that ECC81s would give identical results.

The performance of the circuit is such that from peak white to black level video, the back porch level changes <3 V in 70 V of drive while the peak white level changes by $< 20\%$ for aerial signals requiring an a.g.c. voltage varying from -2 V to -7 V. The contrast control and brightness control operate completely independently and the only change in brightness setting required when changing from 405 to 625 lines is due to the change in potential on the c.r.t. anodes. Were these to be stabilized, both these controls could be pre-sets.

I include these details because Mr. Mothersole states that, "It is therefore practicable to incorporate a simple clamp or d.c. restorer circuit only at the grid of the video valve," and "In dual-standard receivers a black level a.g.c. system and the correct display of signal black-level call for several pre-set controls, involving system switching and a critical adjustment of the brightness control whenever the picture contrast is varied," which Fig. 2 shows to be untrue.

Set makers will be horrified at the expense involved in including such a circuit, but when a suitable cheapening process has been applied to the circuit, such as the elimination of V1 and a cheaper voltage regulator fitted, I don't see why this should add more than £5 on to the selling price of the receiver. In fact, it may prove entirely satisfactory just to include V3, the high level a.g.c. valve, as, on a correctly transmitted signal, this valve keeps both

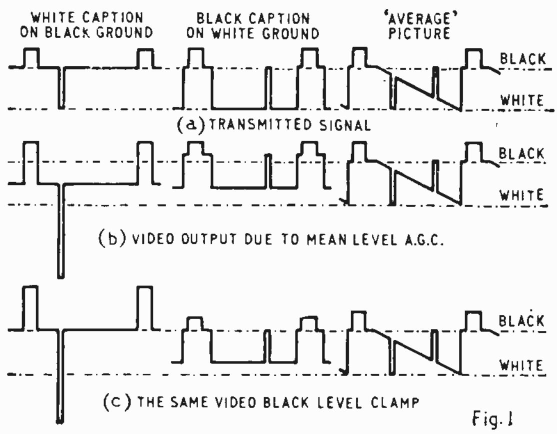


Fig. 1

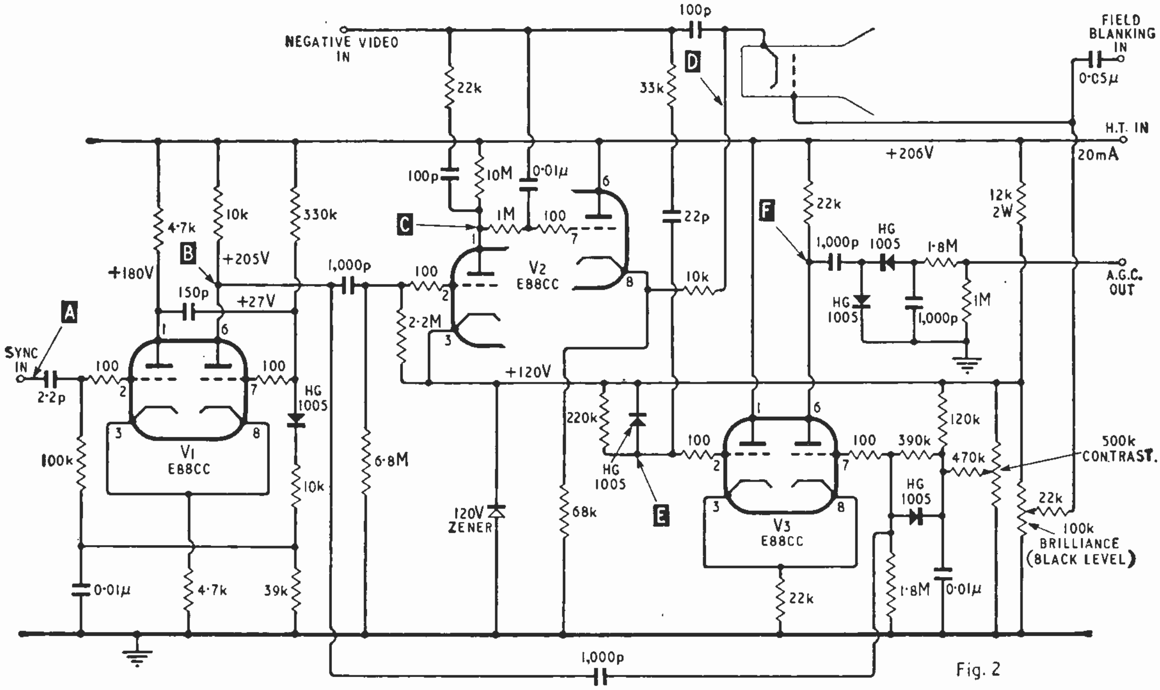


Fig. 2

the black and the white parts of the signal at the correct level. The only facility the user would lose would be the independent operation of the brightness and contrast controls as the brightness level would now depend on the contrast setting, but this should not prove very irritating. Such an addition as this should only add some £2-£3 on the receiver price which I, for one, would have gladly paid had such a set been advertised.

Set makers will probably retort that only cranks would pay the extra for such a subtle improvement, as the "average" picture is satisfactorily displayed. To them I reply: "Try selling a film or a camera that only gives good results on an 'average' picture or run a cinema such that the projector only displays good 'average' pictures." The public should soon react. With television, due to one reason and another, the public has

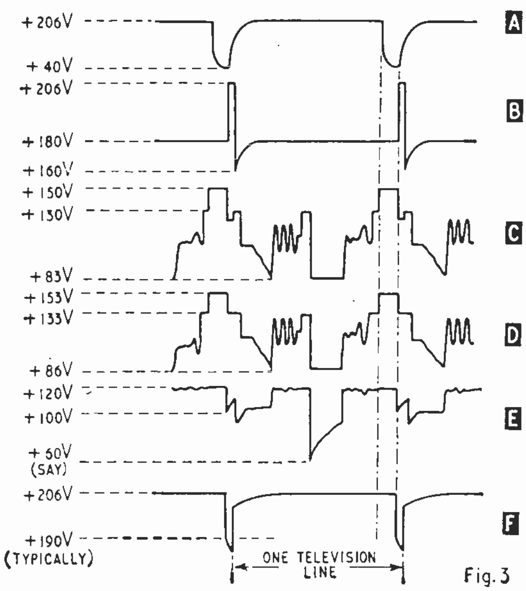


Fig. 3

grown to expect inferior pictures over other visual entertainments so there is no outcry for better pictures as the defects are dismissed by most viewers as being all part of the television magic.

Mean level a.g.c. is probably the worst thing that has ever happened to television receiver designs, so let us hope that Mr. Mothersole's article heralds the universal rediscovery of the significance of gated a.g.c. and the d.c. component, then the set designers can start attenuating it all over again—for the average viewer's benefit, of course!

Cuffley, Herts. J. D. MIDDLETON

The author replies:

I was most interested to read Mr. Middleton's letter and I think his Figure 2 fully justifies my statement regarding the difficulty of retaining the d.c. component in a dual standard receiver. I pointed out in my article that a keyed clamp required to operate into a very high impedance load such as the grid of a valve and I discussed where a simple clamp circuit could be incorporated in a normal receiver. Mr. Middleton's circuit illustrates just this point since he uses a keyed triode clamp, and in addition a cathode follower to provide the required high-impedance load.

While I am sure Mr. Middleton's circuit performs very well in his receiver one must ask whether it is suitable for mass production, can maladjustment of the receiver controls cause damage to any components or valves by excessive beam current, will the additional circuitry impair reliability and is it usable in all the receiving areas?

In strong signal areas, for example, an a.c.-coupled a.g.c. system with a d.c. restoration diode, which Mr. Middleton uses, has been found to be very susceptible to "blocking," particularly with negative modulation. The mechanism is as follows: When the receiver is suddenly switched to a strong signal the final i.f. amplifier is overloaded before the a.g.c. potential can build up. The result is that no a.c. signal is developed at the video detector, the output being simply a high d.c. potential, and an a.c.-coupled a.g.c. system is unconscious of this situation and hence no a.g.c. potential is developed. Experience has shown that a d.c.-coupled a.g.c. system is essential to completely avoid this difficulty. The simple mean-level circuit is of course a.c.-coupled and on negative modulation it is normal practice to obtain part of the a.g.c. potential from the video detector diode to minimize the danger of blocking.

It has also been found that mean level a.g.c. tends to give better results where reflections from aircraft or interference pulses disturb reception. A gated a.g.c. system cannot respond to signals during the time the synchronizing pulse of the reflected signal is coincident with the back porch of the main signal (positive modulation). Hence the a.g.c. system is ineffective (with positive modulation the sync pulse is equal to zero transmitter output). A keyed black-level clamp circuit is often sensitive to interference pulses which give rise to a shift in the black level following interference, and again special precautions are necessary.

Mr. Middleton's claim that the variation in video drive with video information is the main failing of mean level a.g.c. is not so in my experience. Experiments with receivers showed, surprisingly enough, that variations in black level were definitely the worst effect of mean level a.g.c. and this led to the development of the simple circuit to stabilize it.

One of the contributing factors is that many people view television receivers in high ambient illumination and this requires a high level of video drive. In such conditions some variation of video drive with picture information is desirable to minimize e.h.t. potential variations and hence picture breathing due to large changes in beam current with picture content. However, to obtain the maximum contrast on low-key scenes the black level must be stabilized.

The design of a domestic television receiver is a compromise between technical performance in its widest sense, ease of operation for a non-skilled viewer, reliability and final cost. I think most people will agree that the modern television receiver strikes a fairly happy balance between these conflicting requirements and my correction circuit is designed with this philosophy in mind.

P. L. MOTHERSOLE

Loudspeaker Polarity

I WAS most interested in the contribution from A. M. Wooller, A. Thorley and J. T. Boys in the June issue.

Certainly it is to be expected that correct sign in the reproduced pressure waves would be essential in obtaining realistic quality.

The assertion that phase is unimportant in audio systems is at best "not proven." It cannot be proved: evidence that some observers don't notice is never evidence that others can't.

The characteristic in question is probably better regarded as "sign" than "phase." Changing this sign (in terms of phase) corresponds to dispersion of the signal by a time delay of half a cycle, i.e. one inversely proportional to frequency. Such a time delay would clearly not be negligible.

Use of the asymmetry of speech waveforms was proposed (in an American article more than a decade ago, if I remember correctly) for a lightweight a.m. transmitter designed to modulate beyond 100% upward on peaks, thus claiming to obtain greater range.

I have suggested in correspondence with the B.B.C. (March and June 1961) that conservation of sign would be worth while, since (prior to provincial v.h.f.) land lines were brought up to generally a much higher standard and realism of reproduction in other respects was being approached. I also suggested that listeners to the experimental stereo broadcasts who were not able to reverse speaker connections might be advised to turn their loudspeakers round, if necessary, to improve realism. This latter suggestion was rejected on the grounds that the rearward radiation pattern is likely to be inferior; but the importance of absolute (as well as relative for stereo) sign conservation did not seem to be appreciated.

Now that we have experimental support for the proposition, I hope that no time will be lost in adopting a convention. A start has been made in matching in stereo equipment, so that audio components with marked senses are available.

Perhaps lack of regard for this attribute of transmission and recording explains the impression that not more than half the reproduced speech or music programmes sound fully realistic!

Many years ago, when using a capacitance bridge with an audio oscillator (of complex waveform) as source, and an old pair of headphones as detector, my brother (K. C. J.) and I, both remarked how, on passing through balance, the sound seemed to shift from one ear to the other. We did not investigate this useful effect and I can not say whether it would have been present had the headphones been linear.

Another suggestion I make in the interests of quality is that where a high-frequency pre-emphasized channel (such as v.h.f./f.m.) is being handled, de-emphasis should be left until the final stage, where it may be obtained by suitable negative feedback in conjunction with the loudspeaker characteristics. Such pre-emphasis is arranged not to increase the peak signal level which must be handled, so its advantage (in masking detector and amplifier distortion) may be retained throughout the whole reproducer chain.

Malvern, Worcs. G. F. JOHNSON

Commercial Literature

"**Special Products**" is the title of a 72-page brochure describing the range of items manufactured by the special products division of Decca Radar Ltd. The publication is split into five sections to cover microwave instruments and allied equipment, electroforms, metal spray formed components, metallized elements, and electronic equipment (e.g., i.f. and r.f. amplifiers, microwave receivers, electron spin resonance). Copies are available from Decca House, Albert Embankment, London, S.E.1.
10WW 325 for further details

The 1964 edition of the Siemens & Halske 17-page short form **semiconductor catalogue** is available from the U.K. agents, R. H. Cole Electronics Ltd., 26-32 Caxton Street, Westminster, London, S.W.1. A leaflet describing the Siemens & Halske range of **miniature electrolytic capacitors** is also available from the U.K. agents.
10WW 326 for further details

A complete index of **SGS Fairchild reports** is available from the company's offices in Stonefield Way, South Ruislip, Middx. About a hundred application reports are included in the index.
10WW 327 for further details

The American Shure audio catalogue "for sound system specialists" is obtainable from Shure Electronics Ltd., 85 Blackfriars Road, London, S.E.1. A wide selection of **microphones** for all applications are included in this 38-page publication.
10WW 328 for further details

Two technical data leaflets (No. 43 & 46) describing the West German Elac range of magnetic, ceramic and crystal stereo **pickup cartridges** are obtainable from the U.K. agents, The High-Fidelity Centre, 61 West Street, Dorking, Surrey.
10WW 329 for further details

Auto, isolating and low voltage transformers are described in a broadsheet available from Gardners Transformers Ltd., Somerford, Christchurch, Hants.
10WW 330 for further details

A leaflet describing the GV "Thermette" 9-pin miniature **thermal time-delay relay** is available from Coventry Controls Ltd., Godiva House, Allesley Old Road, Coventry, Wars.
10WW 331 for further details

ENERGY BANDS—

Described in Circuit Language

By THOMAS RODDAM

EVERY culture, possibly every sub-culture, has its visible symbols from the gnomes and rabbits of a suburban garden to the Sacred Heart of a peasant's home, from the Jaguar to the jeans. The visible symbol of the current electronic text seems to be a set of energy band diagrams. In Wood Green, and some of my best friends would live there if they knew how to get there, the gnomes and rabbits are not worshipped with strange rites on pay day. In our text-books the pages dealing with energy bands stay singularly clean. Somehow the whole business seems rather remote. It may be that engineers just do not want to know, but my own guess is that the average discussion of energy bands starts off at a point which is too remote from our everyday concerns.

When we wish to deal with a new concept we generally find it convenient to work in terms of analogous familiar events. Later we may come to reverse the analogue. Voltage, e.m.f. and p.d., were explained in my youth in terms of the water pressure from an elevated tank, the current rushing out of the tap under its influence. Now, when the hot water stops flowing into the bath because the kitchen tap has been turned on I brood about the common impedance in the two circuits. Analogues are always dangerous, of course, and should always carry the sign " Do not feed." The contriver of the analogue will extend its use until he sees some false conclusions ahead, and will then stop: the unwary student will extend the analogue and will be in dead trouble.

Nineteenth century physics was the climax of the art of the analogue. It is not too unfair to say that the failure of nineteenth century physicists was a simple logical failure. If a model aids in understanding a phenomenon, the model must be simpler than the phenomenon. One cannot exclude complexity simply because it does not appear in the model.

A reasonable starting point is the electron. The essence of the problem is well known. Model 1 is a small lump of who knows what, always considered to be hard sphere, carrying a unit charge. This model is adequate to describe the simple behaviour of a cathode ray tube. The inadequacy of the model is quickly revealed if a beam of electrons is directed against the face of a crystal of rock salt. The regular network of atoms behaves as a diffracting structure, while the electrons behave as waves. It is difficult not to ask questions which are unanswerable. All that we have at this stage is a wave-equation and a characteristic length. We can determine, however, that this characteristic length the wavelength λ, is inversely proportional to the momentum of the electron p, and that the essential equation is

$$\lambda p = \mathrm{h}$$

where h is Planck's constant.

Any elementary discussion is dangerously loaded with traps: we find it too easy to draw the electron as a billiard ball with curly whiskers. The wavelength is, however, a quality which can be measured and for an electron moving at the sort of speed with which it might escape from a cathode we get values of the order of 0.5×10^{-10}m. A fast-moving electron has a much shorter characteristic wavelength.

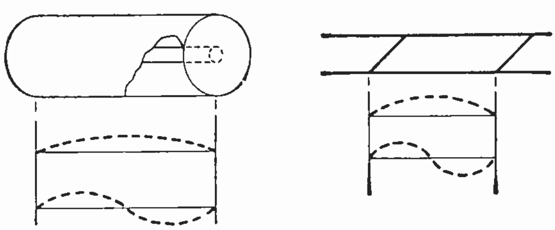
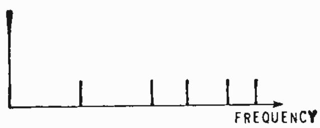


Fig. 1. Coaxial and twin-wire short-circuited resonant structures.

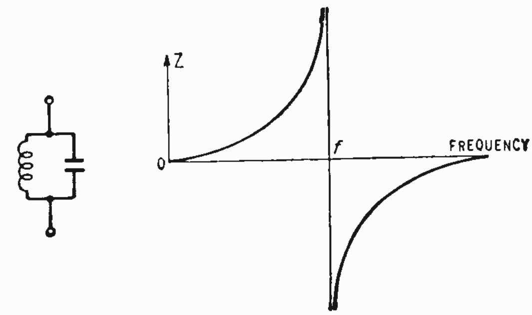
To indicate the sort of false step one can take, one writer in this field states that an electron in an empty container will extend its wave-packet to fill the chamber. You see how he has assumed that the walls are smooth and continuous, not just the electrons of the atoms which make up the walls. The electrons inside the atoms, however, are a little easier to picture, for they can be regarded as " tail-eating," with the wave appearing as some kind of standing wave in the three-dimensional space round the nucleus. The various possible models are associated with the quantum numbers. We can get a rough physical idea of why each electron must have its own mode by the following reasoning. The electron *is* the standing wave, and if we had two standing waves in the same mode they would form just a single wave of anything from zero to double the amplitude, depending on the phase. This just cannot be true, and we know, indeed, that each electron has its own unique set of identifying quantum numbers when it is in an atom.

If we wish to produce a model of this system of discrete values of wave-length at which we can have standing waves we may take a familiar structure, either of those shown in Fig. 1. So long as we stick to simple theory, each of these has a set of characteristic wavelengths, given in fact by $2l/n$. Since we treat this as a one-dimensional problem it is not surprising that there is only one quantum number. When we make the system a little more complicated, first by terminating the ends with reactances and later by using a large section wave-guide, we move from the simple harmonic form through to a system with a multiplicity of modes.

Because of the way we produce our electromagnetic waves we think, first and foremost, of frequency as the determining parameter. We make use of the equation $f\lambda = c'$ to relate the wavelength to the velocity in the medium. There is no connection between energy and wavelength, for energy is associated with the amplitude of the wave. For our electron we have the momentum, $p = \mathrm{h}/\lambda$, and if the



Above:—Fig. 2. The characteristic frequencies corresponding to different orbits.



Right:—Fig. 3. Circuit with characteristic frequency f and its impedance characteristic.

equation $E = \frac{1}{2}p^2/m$ has any meaning we have $E \propto 1/\lambda^2$.

We are only making models, anyway, so let us assume that there is some velocity c' which will enable us to describe the orbits in terms of frequencies given by $f = c'/\lambda$, where λ is the corresponding standing wavelength. Now $E \propto f^2$ and to each orbital energy there corresponds a characteristic frequency. This line of discussion enables us to say that each possible electron state is something like a characteristic frequency, and thus to plot a spectrum of available states in the form shown in Fig. 2.

Most of the electrons in an atom are securely bedded down in the lowest energy states, tucked away out of sight of anything we propose to do. We are concerned with the energy of the outside electron, if we wish to keep matters simple. This will, of course, be safest in the lowest free level, at the lowest free frequency. We can therefore say that for the moment we are concerned with a system having a characteristic frequency f. In order to make a model, let us use the circuit shown in Fig. 3. The oscillation in this infinite-Q circuit represents a single state of a single electron in a single atom.

Now let us bring a second similar atom towards the first. We simulate this by bringing one tuned circuit towards another. If the atoms are to be related to each other the outermost electrons must interact in some way. The tuned circuits will be coupled, either by capacitance or by the magnetic field, and we shall have one of the circuits shown in Fig. 4. The behaviour of the characteristic frequency is most easily examined by using Bartlett's Bisection Theorem, and the operation is shown in Fig. 5. The conversion of the capacitively-coupled circuit to a lattice form leads immediately to a structure which reveals the two characteristic frequencies (the poles). The impedance diagram is then easily drawn as Fig. 6, and shows the way in which a second pole is added at a frequency below f, while the pole at f remains unmoved. It is now extremely easy to see that with inductive coupling the second pole would be added above f.

In the language of atomic physics we speak of energy levels rather than of frequency and we can say that the proximity of the two atoms causes the level we are considering to be split. We see the limitations of the analogy in the fact that we cannot say that our coupling is of one kind or another, and so we cannot expect that the split will leave one energy level unaffected. We do find, however, that the closer the atoms, the tighter the coupling between the circuits, the wider is the split; and this is only common sense, since with no coupling there is obviously no split.

Let us now introduce a third atom, a third circuit, and we get the network of Fig. 7(a), which has the three poles shown in Fig. 7(b). Each element with the standard characteristic frequency contributes one pole, and we may extrapolate and guess that a system with n atoms will have n energy levels, which

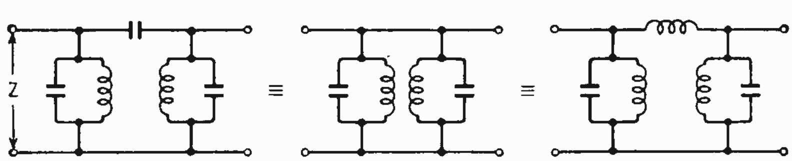
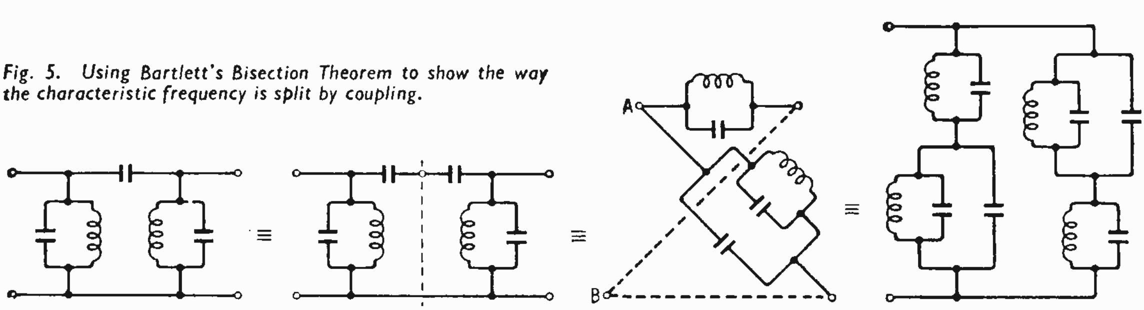


Fig. 4. Coupled circuits, each with characteristic frequencies.

Fig. 5. Using Bartlett's Bisection Theorem to show the way the characteristic frequency is split by coupling.



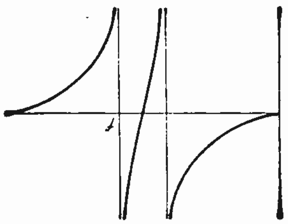


Fig. 6. The impedance diagram for Fig. 5.

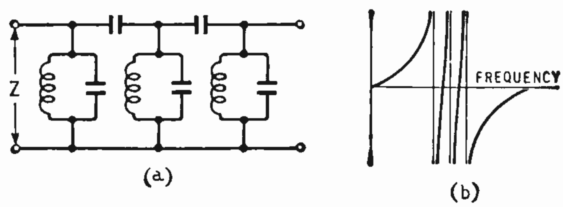


Fig. 7. As additional circuits are coupled, the splitting is repeated.

will, for reasonably loose coupling, be bunched round the initial level of the single atom. The reactance network of Fig. 7(a) has been arranged, however, to encourage a second attitude towards the network. It is familiar structure, a three-element band-pass filter. Classical filter theory has accustomed us to the idea of the infinite ladder, and since we are dealing with systems which may have some 10^{23} atoms per cm^3 we expect to be much nearer this theoretical concept than we ever are with our electrical networks. We can therefore think in terms of the ideal filter pass-band, the limit to which the concentration of poles converges as we increase the number of sections of the filter.

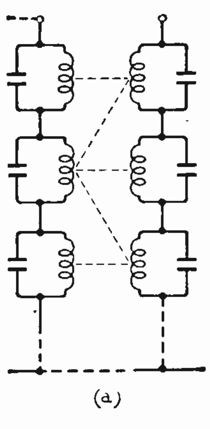
The energy band of a set of interacting atoms is thus the equivalent of the pass-band of the analogue filter. There are two points to notice here. Firstly, the filter terminations, at the edges of the crystal, are very many sections away and there will be little trace of their effects inside the crystal: secondly, the crystal is a three-dimensional structure and the network will, in fact, extend outwards in three dimensions from each anti-resonant circuit.

With this kind of approach we can get some idea of the significance of the conduction band which is discussed in the semiconductor papers. Somewhere in the network we apply an impulse. A single tuned circuit would be set into oscillation at its characteristic frequency, or, as we usually say, the corresponding energy level would be filled. The energy, the electron, does not go into a single element when we have a solid structure, because of the coupling with the neighbouring elements. We get a band-limited signal propagated through the network instead of the single frequency. Usually we are dealing with only a few sections, of finite Q, and we get a damped wave determined by the few characteristic frequencies, but in our atomic structure we have something more like a perfect transmission line which has been excited by noise.

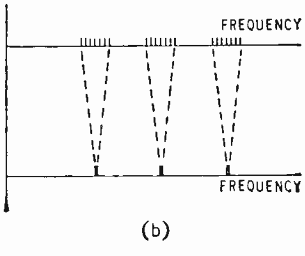
Let us go back to the energy band. So far we have considered the splitting of only a single energy level. In fact, each atom gives us a number of levels, so we must consider a circuit of the form shown in Fig. 8(a). The couplings are indicated rather vaguely as mutual inductance, and, as shown in Fig. 8(b), each frequency, each level, will split up into a number of levels, or, with enough sections, into a number of bands. The usual sort of diagram takes the form shown in Fig. 9, which shows how the bands may be confluent, or may actually overlap. So long as the bands are separated it is pretty obvious that if the excitation of the circuit is limited to frequencies in one pass-band there can be no excitation transferred to the other.

The difficulty with the network analogue is now forced upon us. When we apply a 10.710 Mc/s signal to a band-pass filter, passing say 10.5 to 10.9 Mc/s, we expect to get out 10.710 Mc/s. We have, in addition, the superposition theorem, which allows us to apply two signals to the same resonator. The circuit theorist who wants to push the analogy further must proceed with care. I do not mean to devote too much space to this, but the following reasoning is attractive. In order to know what is happening we must draw some energy from our network. We must not, in doing this, disturb matters too much. We know how to produce an infinite-Q circuit which will stand a certain amount of resistive

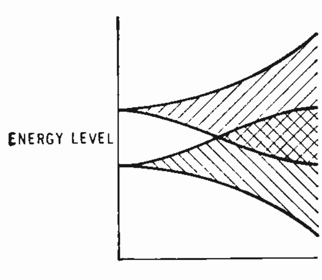
(*Continued on page 363*)



Left:—Fig. 8. Each atom has, in fact, several levels which split when the atoms are coupled.



Below:—Fig. 9. The usual way of showing the level splitting.



loading: it is just an ordinary oscillator circuit, complete with the non-linearity needed to allow the system to re-set as the loading changes. Most line-carrier engineers, at some point in their careers, have designed multi-frequency oscillators, with one valve driving several circuits. If you do not get this kind of circuit right, it operates on one only of the, perhaps three, wanted frequencies. A suitable electrical push will cause a mode change, and normally the circuit will oscillate in the minimum energy state.

The idea of a great network made up of elements of this kind shows us that before we try to use our analogue very fully we shall find it easier to go back to atomic physics. We can stay with our band-pass filter only so long as we realize that the analogue applies not to the electrons, but to the electron rules of behaviour. A rather similar chart could be produced for, say, Park Lane. We could show permitted bands of places where you may sleep, separated by forbidden bands, the streets and the park. In each of these bands (or hotels) there is, indeed, a fine structure, for when a level (or bed) is filled it is not available for another would-be sleeper. The network analogue, because of the enormous number of sections, gives us the very sharp distinction between stop and pass, forbidden and permitted, bands.

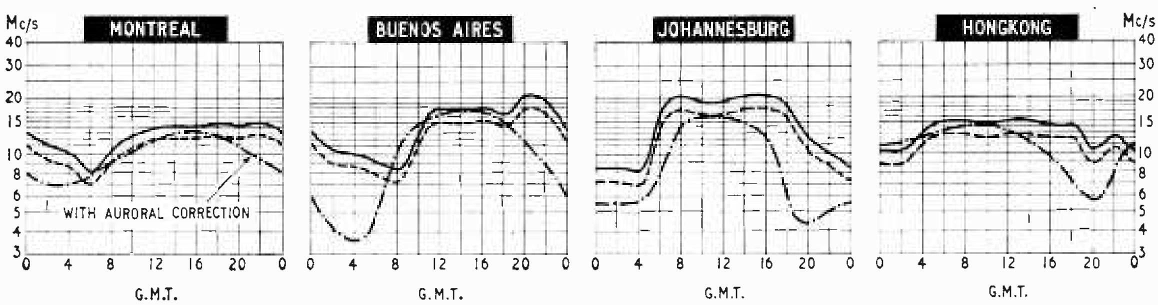
The hotel analogue can help to clarify some aspects of the band structure. In one hotel, anyway, the higher you go, the more it costs. An engineer staying there will seek the lowest level, and if a gap appears at a lower level will move into it. His natural indolence will make it difficult for him to jump the gap if there is a lower-cost vacancy in the next hotel, because the information does not cross the gap. Join the hotels together and engineers will flow to the lowest level which is free. A small win on the football lottery, and he may move to a higher level, only to drop, after a short period to a new low. This is the maser action, the reverse of miser action. Another point dealt with by this analogue is the way in which energy band diagrams are usually shown. Most of the possible states are already filled, most of the rooms in a town are occupied by people who will only move if they get a new job somewhere else. To the mobile elements it is only the transient accommodation which matters. The energy levels for the inner shells of electrons, which do not couple very much with their neighbours in any case, are omitted from the diagram. We show just the valence band and the conduction band.

Analogue fever, as I said at the beginning of this article, is the great danger. Having simplified the system to fit the analogue one then proceeds to make the model more and more complicated to cover the additional properties of the real system. Do not do this. As soon as the model has clarified the idea for which it was planned, move on with the idea, not with the model. If you look back to the basic assumption from which the band-pass model began you will see that it turns on the equations:

$$\lambda = h/p \quad \text{and} \quad \lambda f = c'.$$

The first of these is in order, but since we don't know what the waves are, how can we put a number to c', and how can we know f. Only when the energy is changed to radiated energy do we know that we are dealing with electromagnetic waves. What happens if we dig deeper is another matter, but once we start a more profound study it is just as easy to throw the model away.

H. F. PREDICTIONS — JULY



MEDIAN STANDARD MUF
OPTIMUM TRAFFIC FREQUENCY
LOWEST USABLE HF

The prediction curves show the median standard MUF, optimum traffic frequency and the lowest usable high frequency (LUF) for reception in this country. Unlike the standard MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, local noise level and the type of modulation: it should generally be regarded with more diffidence than the MUF. The LUF curves shown are those drawn by Cable and Wireless, Ltd., for commercial telegraphy and they serve to give some idea of the period of the day during which communication can be expected.

During the summer months in the minimum of the solar cycle past experience has shown that frequencies considerably higher than the predicted standard MUF can at times be received. This effect is mainly confined to daytime on the radio path and has been especially noted on reception in the U.K. from the Far East. The cause is thought to be associated with sporadic-E ionization.

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Digital-circuit Blocks

TWO new series of digital circuit blocks based on "Nand" logic and including flip-flops, gates, pulse shapers and amplifiers are available from M.E.L. Equipment Company, King's Cross Road, London, W.C.1. In addition to encapsulation, the blocks are hermetically sealed in metal cans and the leads are brought out through glass-to-metal seals. The individual components are sandwiched between small printed-circuit boards. The maximum dimensions of a block are 53×25×12.7 mm and 19 leads are standard on all types.

The two series are compatible, both employing n-p-n transistors and requiring 12 V supplies. Units from the Series 10 blocks use germanium transistors and the maximum permissible operating temperature is 55°C. The basic flip-flop switches in 3.5 μsec. The Series 20 units use silicon epitaxial devices and have a maximum temperature rating of 85°C. These units have faster operating speeds.

10WW 301 for further details

Power Supply

A DIRECT voltage, floating output is available over the range 0 to 30 V from the stabilized power supply Model PP7. Intended mainly as a laboratory instrument and manufactured by Advance Electronics, Hainault, Essex, the ripple is less than 1 mV peak-to-peak. Output-voltage adjustment is made in decade steps of 0.1 V, the maximum current available being 3 A.

A constant-voltage transformer is used in conjunction with a temperature-compensated, Zener-diode control circuit to ensure a stable output even with large variations in supply voltage, load and temperature. The line regulation is such that there is less than 5 mV change in output voltage for ±10% change in supply voltage. There is also less than 5 mV change in output voltage for any change in current. The output impedance is less than 0.25 Ω. The instrument can be used over a temperature range of 0 to +40°C.

An electronic cut-out circuit provides overload protection including short circuits and it can be continuously adjusted within the range 33 mA to 3.2 A. An overload indicator is fitted on the front panel, together with a 4-range ammeter that can also be used for voltage-check measurements. The equipment weighs 28 lb and costs £90.

10WW 302 for further details

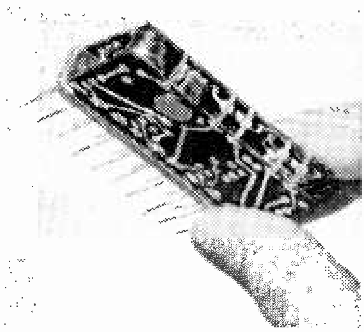
Decade Capacitance Box

THE Model CD133 capacitance decade, manufactured by B.P.L. Radlett, Herts., has a range of 1 pF to 1.11 μF with a direct reading accuracy of 0.2% or 2 pF over the range 100 pF to 1.11 μF and an incremental accuracy of 0.5 pF over the range 1 pF to 100 pF. The instrument is a double-shielded decade capacitor employing silver mica or air capacitors. It is suitable for either two- or three-terminal measurements. The insulation resistance of the instrument is better than 5,000 MΩ at 50 V (d.c.) at maximum capacitance. Weighing only 14½ lb the apparatus is housed in a metal cabinet and is priced at £112.

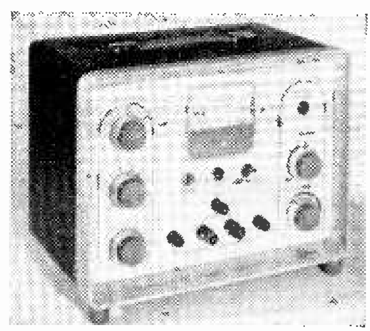
10WW 303 for further details

Multi-way Connectors

DESIGNATED the AMP-LOK connector, the new multi-way plug and socket set introduced by Aircraft-Marine Products Ltd., Saffron Hill, London, E.C.1, utilizes two, mating nylon housings each containing a number of contacts (3, 4, 6, 9 or 12 circuits can be accommodated). The contacts themselves are identical and create a positive wiping action. Wiring can be achieved by automatic-machine or hand crimping. The housings are held together by an integral locking device which allows the connectors to be "free hanging" if required. If the con-

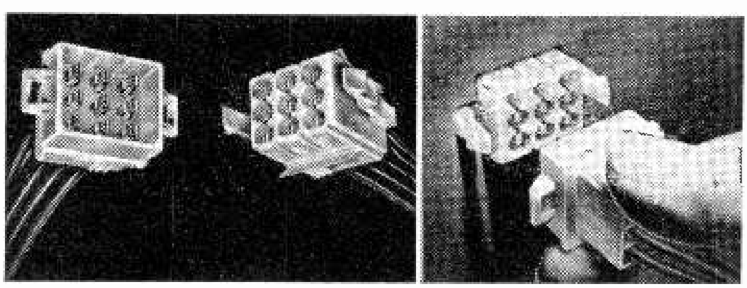


▲ *M.E.L. digital-circuit block prior to encapsulation.*



▲ *Advance Electronics laboratory power supply.*

AMP-LOK connectors (may be used free-hanging or panel mounted). ▼



nectors are required for panel mounting then the locking arrangement also provides a wedge for seating a connector.

10WW 304 for further details

Selenium Rectifier

A MINIATURE selenium rectifier is announced by S.T.C. who disclose that the component is currently being used in a number of television receivers. The rectifier, consisting of 150 discs stacked inside a 3-in tube, is little more than 3 mm in diameter and is designated Type X80/150. Three of these components are normally used in a conventional black-and-white television receiver, but only two are required in small-screen receivers (battery powered).

10WW 305 for further details

Television-signal Amplifiers

A NUMBER of amplifiers, manufactured by Television Installation Services, Mansfield, Notts. have recently been announced. The u.h.f./v.h.f. amplifier is intended for indoor operation and is pre-tuned to any two channels in Bands I and III with gains of 14 and 17 dB respectively. The amplifier also permits amplification over a 30 Mc/s bandwidth on u.h.f. (11 dB). Battery powered, the unit is claimed to give 200 hours' service on one P.P.4 battery or equivalent.

Another unit, the u.h.f. masthead amplifier is a high gain, low noise amplifier housed in a plastic case. The gain is 15 dB. The amplifier can be powered from either a battery power unit or mains power unit.

Both amplifiers cost £4 10s. A battery power unit (15s) or a mains power unit (£3 10s) are available for the masthead amplifier.

10WW 306 for further details

Expitaxial Thyristor

THE International Rectifier Company (Great Britain) has extended its epitaxial thyristor range to include 150 A versions. The new thyristors, 150RE series, are available with peak inverse voltages from 800 to 1,300 V. Bulk avalanche characteristics are a feature of these devices and the 1,300 V component has a minimum reverse avalanche voltage of 1,500 V.

10WW 307 for further details

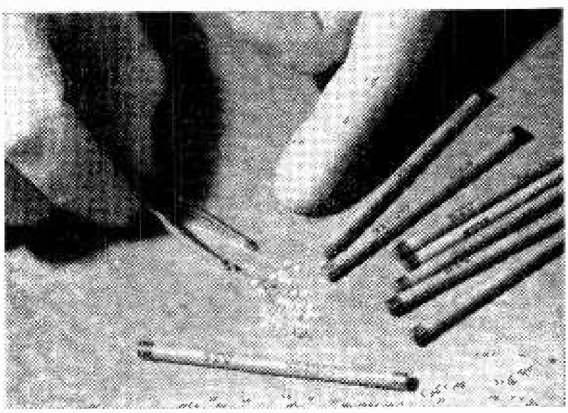
Paint-thickness Meter

THE Belix Company, Victoria Road, Surbiton, has introduced a transistor paint-thickness meter (built under licence to B.A.C.). The apparatus measures only $9\frac{1}{8} \times 5\frac{3}{4} \times 7\frac{1}{8}$ in and contains a probe unit which is applied to the area being measured. The probe contains oscillator coils, the inductance of which varies according to the proximity of the metallic base, and a micrometer which is adjusted until the meter on the face of the instrument reads a minimum value. The coat thickness is then read off the micrometer. An accuracy of up to ±0.0003 in can be achieved for coatings up to 0.02 in thick. Coatings up to 0.01 in can be measured with the aid of a calibration-correction chart. The equipment is powered by batteries and supplied with a 4 ft cable link to the probe.

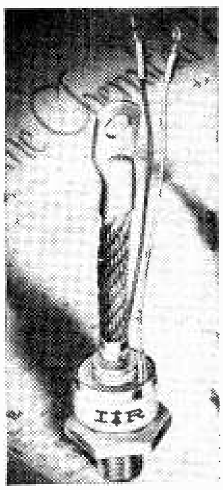
10WW 308 for further details

Television Camera

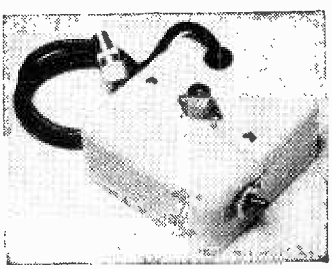
A HIGH-DEFINITION, automatic television camera, for industrial use, introduced by Philips, is now available in the U.K. from M.E.L. Equipment Company. The equipment is fully transistored and is contained, together with time bases and other circuitry, in an alloy housing. Also included is a heater which automatically switches on when the ambient temperature falls below 0°C. Designated the Type



▲ *STC miniature selenium rectifiers showing some of the 150 small discs used in the assembly of the components.*

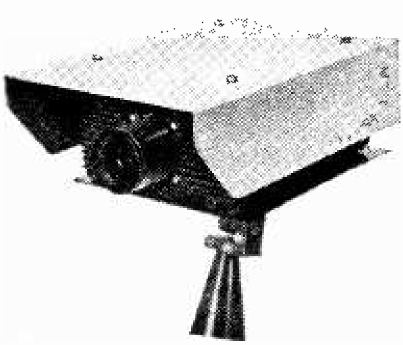


International Rectifier 150A epitaxial thyristor. ◀

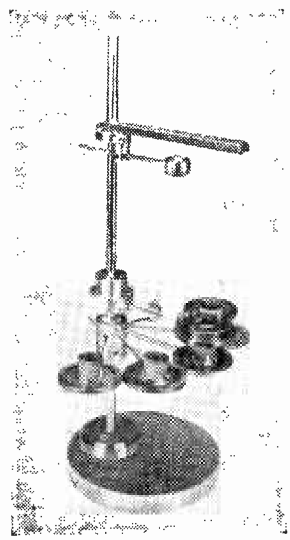


Television Installation Services u.h.f./v.h.f. amplifier. ▶

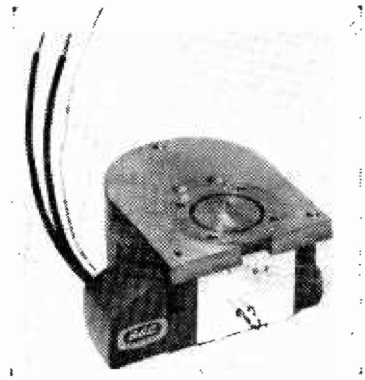
Paint-thickness meter manufactured by Belix. ▶



Automatic television camera Type PM1000 (Philips).



Universal evaporating source Type EBU/1 manufactured by G. V. Planer.



Magnetron Type E3094 (M-O Valve Company).

PM1000, the only connections required are the mains supply and coaxial cable to the monitor. A system of light-level control adjusts the vidicon sensitivity so that the output remains constant to within 3% for light variations of 1:3,000. A 625-line system (C.C.I.R.) is employed, random interlaced, but 2:1 interlacing can be arranged. The video amplifier has a bandwidth of $8\frac{1}{2}$ Mc/s and the resolution is 600 lines. External triggering of line and frame frequency is possible. If the camera is connected to an external source of line and frame pulses and they should fail, then it will switch automatically to its own oscillator.

10WW 309 for further details

Electron-beam Evaporation

THE new Universal model of the G.V. Planer (Sunbury-on-Thames) range of electron beam evaporation equipments is designed for the vacuum deposition of thin films. It is suitable for either direct electron-beam heating or, by simple adjustment, for indirect heating by bombardment of the evaporant container. The system is particularly suitable for the vacuum deposition of an extensive range of metals and non-metals but can also be used in conjunction with conventional vacuum-coating plants.

The equipment comprises the new evaporation source EBU/1 powered by the S7/1 power unit. This latter unit provides an h.t. supply of up to 7 kV, 200 mA d.c. and a variable l.t. supply for heating the emitter filament. In operation, the power unit is connected to the evaporating source via vacuum-sealed, high-voltage electrodes. Among the advantages claimed for this equipment are high purity of the deposit obtained, reliability and simplicity in operation and high evaporation temperatures for refractory materials.

10WW 310 for further details

INFORMATION SERVICE FOR PROFESSIONAL READERS

To expedite requests for further information on products appearing in the editorial and advertisement pages of *Wireless World* each month, a sheet of reader service cards is included in this issue. The cards will be found between advertisement pages 16 and 19.

We invite readers to make use of these cards for all inquiries dealing with specific products. Many editorial items and all advertisements are coded with a number, prefixed by 10WW, and it is then necessary only to enter the number(s) on the card.

Readers will appreciate the advantage of being able to fold out the sheet of cards, enabling them to make entries while studying the editorial and advertisement pages.

Postage is free in the U.K., but cards must be stamped if posted overseas. This service will enable professional readers to obtain the additional information they require quickly and easily.

Magnetron

THE latest addition to the M-O Valve Company, Brook Green Works, London, W.6, range of rugged magnetrons is an X-band valve with a peak output power of 7 kW and a warm-up time of less than 10 sec. This component, Type E3094, is capable of withstanding a swept vibration of from 20 c/s to 10 kc/s with g levels commencing at 3 g and rising to 50 g. Under these conditions the output frequency will not change by more than ±3 Mc/s. Depending on the type of modulator used, both heater and high voltage can be switched on simultaneously. The valve, which features integral thermocouples for anode temperature measurement, can operate over a temperature range of −65°C to +90°C. The magnetron measures approximately $4\frac{3}{4} \times 4\frac{1}{2} \times 2$ in and weighs 4 lb.

10WW 311 for further details

Data-plotting Keyboard

USERS of the Model XY-IP Autoplotter can speed up graph plotting of tabulated digital data with the low-cost, Model K1 digital keyboard available from the Electronics Division of Scientific Furnishings, Poynton, Cheshire. The x and y co-ordinate values are entered on the twin 3-digit keyboard and are converted to points on a curve by pressing the PLOT bar. The keyboard supplies voltages to x and y axes of the recorder, the magnitudes of which are proportional to the co-

(*Continued on page* 367)

ordinates set up on the x and y key decades with an accuracy of $\pm 0.25\%$. Suppressed zero and scale expansion permits optimum scaling of the graph and both positive and negative values can be plotted. The price of the new keyboard is £93.

10WW 312 for further details

Printed Boards

SMALL-SCALE production of printed circuit panels is being undertaken by J.E.S. Printed Circuits, Llangefni, Anglesey. At present, printed boards available include those suitable for the construction of recent *Wireless World* designs.

10WW 313 for further details

Oscilloscope Camera

HIGH-SPEED transients or repetitive waveforms are equally easy to record with the A.B.C. oscilloscope camera produced jointly by Avo and Beattie-Coleman. The camera is available with the Polaroid "flat-pack" back or with roll-film back. The standard lens is an $f1.9$ 75mm Oscillo Raptar but $f1.2$ or $f4.5$ types can be supplied. Accessories available enable written information to be photographed on to each oscillogram and enable the camera to be used for "off-scope" photography.

10WW 314 for further details

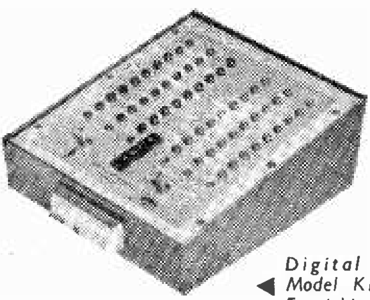
Capacitor Blocks

BLOCKS of capacitors, intended mainly for delay-line construction, are announced by Johnson, Matthey and Company. The capacitors used in the blocks are of identical construction to those in the Silver Star range of precision silvered-mica capacitors. Each block consists of an encapsulated epoxy moulding containing a number of capacitors. The capacitors are earthed on one side to a common lead. A typical block measuring $3 \times 0.45 \times 0.2$in contains 23 capacitors each 22 pF in value. In this particular size the individual components can have capacitance values of up to 200 pF and are rated at 150 V. Other block sizes with different numbers of capacitors (and values) can be produced.

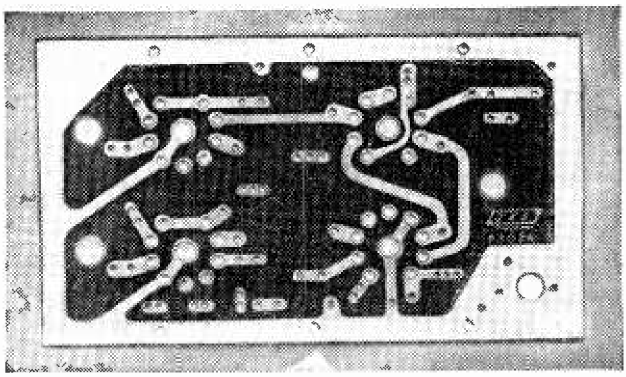
10WW 315 for further details

Stabilized Power Units

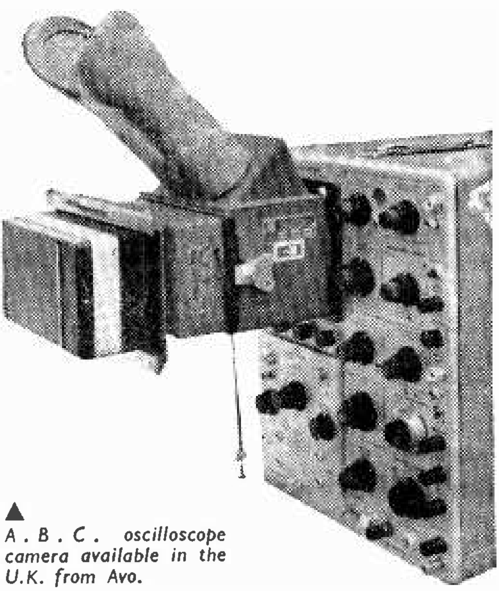
THE Type KB series of stabilized power units produced by Newton Brothers, Derby, provide supplies from 15 V (200 mA) to 40 V (1 A). Six types are available and all models have current-limit control and short-circuit protection facilities. The output voltage is continuously adjustable by means of a high-resolution potentiometer, but some instruments in the series are provided with 3- or 10-turn Helipots. The ripple present is quoted as 0.3 mV for the cheapest power supply Type KB1502 and 0.1 mV for the Type



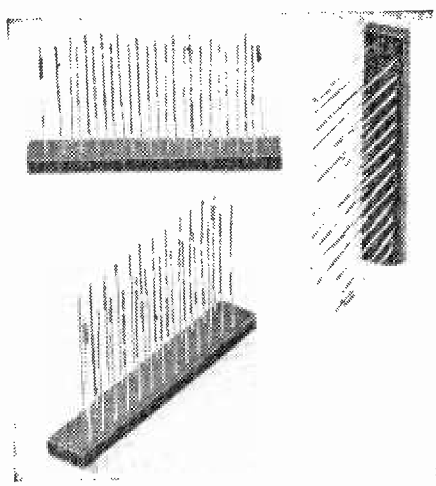
◀ *Digital keyboard Model KI (Scientific Furnishings).*



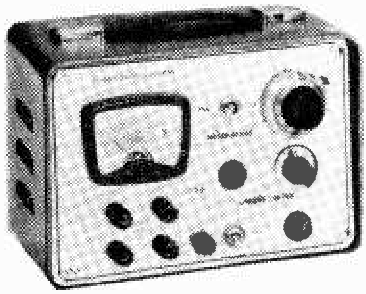
▲ *JES printed circuit. The circuit is that of the Wireless World wide-band oscilloscope amplifier*



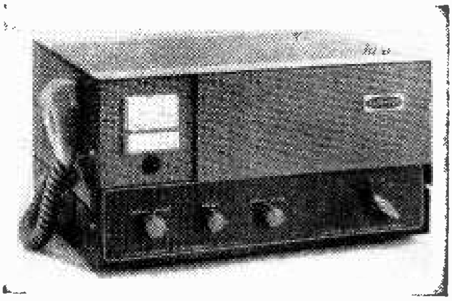
▲ *A.B.C. oscilloscope camera available in the U.K. from Avo.*



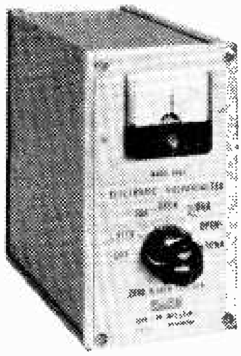
Capacitor blocks produced by Johnson Matthey for delay-line applications. ▶



Power supply Type KB1510 manufactured by Newton Derby.

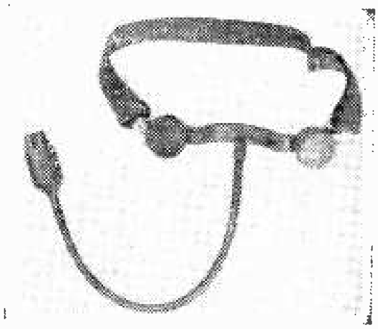


Raytheon Model Ray-1128 single side-band receiver.



John Fluke Model 840A electronic galvanometer.

Model G34 sine and square wave generator (Paco Electronics).



Amplivox throat microphone Type X.13761.

KB4010SD. The voltage regulation is better than 0.01% in the case of the KB1510SD, 3103SD and 4010SD power supplies and 0.1% for Types KB1502, 3003 and 2002-2.

10WW 316 for further details

S.S.B. Transceiver

THE Model Ray-1128 single side-band transceiver manufactured by Raytheon and available from Cossor Communications Co., Harlow, Essex, offers a choice of four crystal-controlled channels in the 1.6 to 16 Mc/s range. The equipment, which weighs 34 lb, can be powered from a mains supply or, with a converter, from a 12 V car battery. The front panel carries an S-meter as well as s.s.b./a.m. switch, volume control, upper/lower sideband selector and channel selector switch. Other features include automatic level control in the transmitter and automatic gain control in the receiver.

10WW 317 for further details

Electronic Galvanometer

A SOLID-STATE instrument, the Model 840A electronic galvanometer, manufactured by John Fluke, is available in the U.K. from Livingston Laboratories. Suitable for null-detector applications, the instrument has a current sensitivity of 2×10^{-9} A per scale division and a power sensitivity of 8×10^{-16} W per division. The full-scale ranges of this centre-zero equipment are 30—0—30, 300—0—300 and 3,000—0—3,000 nA (10^{-9} A). The input impedance on all ranges is 180 Ω, and the input isolation from the chassis is greater than 10^9 Ω. The equipment is battery powered and protected against overloads up to 10 mA. The cost is £78.

10WW 318 for further details

Wide-range Generator

THE Paco Type G.34 generator produces sine waves over the range 7c/s to 750kc/s and square waves from 7c/s to 300kc/s. Distortion is less than 0.3% from 20c/s to 20kc/s and the output remains flat (within ½dB) from 120c/s to 120kc/s and within 1dB to 750kc/s. Sine waves from 0 to 10V (600Ω) can be produced and square wave amplitudes, at no load, can be adjusted to 20V peak-to-peak. The rise time is quoted as less than 1μsec. The output level is controlled by an attenuator with three 20dB steps and a fine adjustment. The instrument may be obtained from KLB Electric, Whitehorse Road, Croydon, Surrey, at a cost of £40 7s assembled or £38 5s in kit form.

10WW 319 for further details

Throat Microphone

AMPLIVOX (Wembley, Middx), have completed the design of a miniature throat microphone in collaboration with R.A.E. Farnborough. The microphone is intended primarily for military use in high noise level aircraft, ground servicing applications and wherever external noise levels affect communications. Two small magnetic capsules are contained in a moulded Neoprene connector assembly with two press studs for easy attachment of the elastic neckband. The assembly is tropicalized and connectors are available to provide series or parallel wiring with 300 or 75Ω impedance.

10WW 320 for further details

Magnetizing Equipment

FIVE new magnetizers are announced by Hirst Electronic, Crawley, Sussex. Designated Types

MC2-6, the range caters for nearly all magnetizing applications. Type MC2 is a medium-power instrument with two outputs, 215 W/sec at 900 V and 54 W/sec at 450 V. This unit is intended for energizing medium-sized magnets as used in meters and loudspeakers, etc. Type MC3, a low-voltage magnetizer, is intended for use in laboratories and repair shops where precise output control is required. Types MC4, 5 and 6 are floor-standing, high-capacity units for large magnets. Magnets of barium ferrite, Magnadur and Triconal can be energized with these instruments. A large number of jigs for specialized applications are available.

10WW 321 for further details

Carbon-film Potentiometer

THE Ferranti (Holinwood, Lancs.) range of precision potentiometers has been increased by the introduction of carbon-film potentiometers. The resistance range of the new components is from 1 kΩ to 300 kΩ and the power rating is 2 W at 70°C. The temperature range within which the potentiometers can be used is −40 to +100°C.

The use of a low-pressure wiper system employing precious metal alloy multiple contacts ensures low torque and a contact resistance of approximately 1% of the total resistance value.

At present, only linear and loading-correction laws are available, but other functions will shortly be introduced.

10WW 322 for further details

Electronic Counter

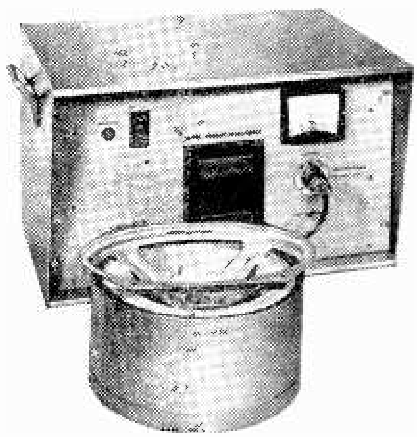
THE solid-state counter Type TF2401 (Marconi Instruments) comprises a basic instrument into which plugs a frequency range unit and a function unit. The former unit determines the maximum frequency which may be measured and the latter the type of measurement. At present the units available permit the instrument to be used for frequency, period, multi-period, time-interval and frequency-ratio measurements. Direct counting up to 50 Mc/s only is permitted at present, but a 500 Mc/s converter is also available. The readout consists of an 8-digit display. The counter can also be used as a time-interval generator providing pulses from 0.01 c/s to 1 Mc/s in decade steps.

10WW 323 for further details

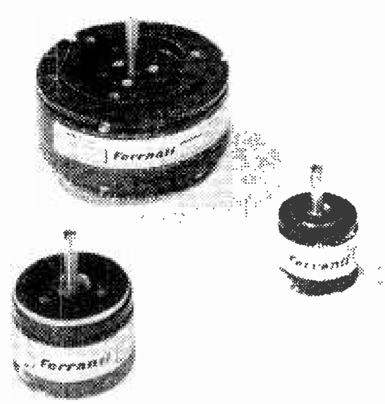
Measuring Instrument

THE Model 300 "Portametric voltmeter bridge," manufactured by Electro Scientific Industries, combines in one instrument a differential voltmeter (with 5-digit resolution), an eight-range ammeter and a Kelvin resistance bridge for two-, three- or four-terminal resistance measurement. The basic accuracy of the equipment is nominally ±0.02% of reading, and direct-voltage measurements may be made from 0 to 511.1V in 5 ranges. Current measurements can be made from 0 to 5.111A. Other features include a detector sensitivity of 5μV and a long-term stability of ±5μV. The instrument is battery powered. Costing £308, exclusive of duty, the equipment is available from Livingston Laboratories.

10WW 324 for further details

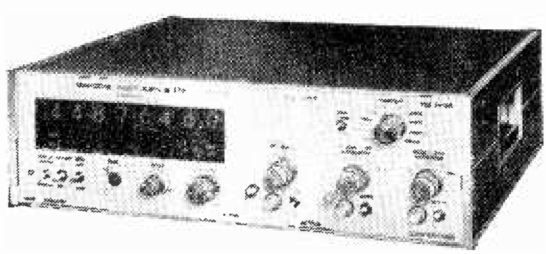


Hirst MC2 magnet charger with assembled loudspeaker magnet in Type J5 charging fixture. ◀

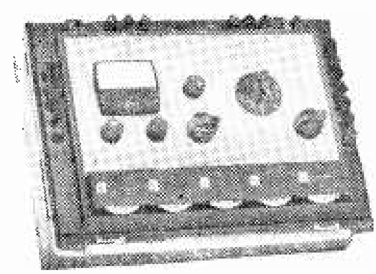


Potentiometers from the Ferranti carbon-film range. ▶

Solid-state counter type TF2401 (Marconi Instruments) ▼



Model 300 "Portametric voltmeter bridge." ▶



NEWS FROM INDUSTRY

Television Set Despatches.—According to figures issued by the British Radio Equipment Manufacturers' Association nearly half a million television receivers (498,000) were despatched to the home trade during the first quarter of this year, an increase of 37% over the same period last year and 68% over that in 1962. Radiogram despatches for the same period at 72,000 were 23% higher than the previous year, whilst radio receiver despatches of 486,000 show a drop of 19%, when compared with 1963. These estimates are net figures of deliveries by manufacturers to the home trade and include those supplied to the specialist rental and relay companies.

Elliott-Automation Ltd. has received a contract to supply the basic communications system for the Army Light Helicopter being delivered to the Ministry of Aviation by Westland Aircraft Ltd. The contract calls for 150 sets of aircraft equipment, each of which will include the AN/ARC-44 frequency-modulated v.h.f. transceiver and AN/ARA-31 direction finder.

Decca Radar Ltd. has received a substantial order from the Royal Navy for true motion radar presentation equipment. It will be fitted to the standard surface radar in current service in the fleet.

Racal Electronics Ltd., of Bracknell, Berks., is forming a North American subsidiary company with factories in Canada and in the United States. Mr. R. F. Brown, Racal's 43-year-old chairman, stated that it is his company's aim to start production of its better known products in N. America by the autumn. He also said that Racal is entering the television field for the first time. Under a licence agreement, currently being arranged with Rohde & Schwarz, the company intends to manufacture television transmitting aerial systems.

£250,000 Marconi Microwave Contract.—The Marconi Company has provided British Railways with a microwave system linking York, Darlington and Newcastle, a distance of 75 miles. The system, which has now been installed, has a capacity of 300 telephone circuits although only 159 will be used initially. The radio equipment, which operates at 7,500 Mc/s, was manufactured by Marconi Italiana and the carrier channelling equipment by the Automatic Telephone and Electric Company.

Transitron Electronic Ltd., the British marketing organization for the American parent Transitron Electronic Corporation of Wakefield, Mass., has announced that it is to set up a plant for the manufacture of semiconductors in the United Kingdom. The location of the new premises is not yet known. The company's sales organization at present operates from Bilton House, Uxbridge Road, London, W.5.

Research Extension.—A new £250,000 extension to Standard Telecommunication Laboratories in Harlow, Essex, was opened in May. This new wing to the main research laboratories, which were opened four years ago and house 500 staff, will provide accommodation space for another 100.

E.E.V. Tubes to be made in U.S.A.—As a result of a reciprocal agreement between the English Electric Valve Company and C.S.F. of France, E.E.V. tubes may be manufactured in the United States through the C.S.F. subsidiary Warnecke Electron Tubes Inc., Chicago.

C.S.F. Agreement.—Controls and Communications Ltd. have, through one of their subsidiary companies, signed a licensing agreement with Compagnie Générale de Télégraphie Sans Fil for the manufacturing rights of the C.S.F. range of u.h.f. fixed and mobile equipment in England. It is understood that the subsidiary British Communications Corporation will manufacture and market this equipment in the United Kingdom and in most of the Commonwealth countries.

Rediffusion Ltd. has been awarded a £75,000 long-term contract to install and maintain a system, providing wired radio and television, closed-circuit television, background music and public address, at the Europa Hotel, Grosvenor Square, London. Each of the 300 bedrooms is to be fitted with a 19 in television receiver.

A.P.T. Electronic Industries Ltd., of Byfleet, Surrey, has received an order from the Swedish Standard Radio and Telephone Company for £53,000 worth of transistorized power supply units. This is a repeat order and follows earlier orders totalling £35,000.

A mobile satellite communications station, comprising a 30-foot van and three trailer units, has been set up in Spain by the International Telephone and Telegraph Corporation, of the U.S.A. The van houses the bulk of the electronic equipment, including a 10 kW transmitter and complementary receiver, and the three trailers carry sections of a 30-foot diameter, dish-shaped aerial.

The flight deck of one of the Vickers VC 10 aircraft, which entered service with the British Overseas Airways Corporation earlier this year. She carries quite an impressive range of communications and navigational equipment, including the latest version of the Marconi Doppler Navigator, Type AD 560, which requires no ground-based aids. Other Marconi equipment includes v.h.f. communications gear, V.O.R. navigation system, I.L.S., automatic direction finder, teleprinter receiver, selective calling equipment, and a notch aerial tuning unit for use with the Collins Type 618S-1 h.f. transceiver. The aircraft's weather radar was supplied by Ekco, its transponder by Cossor, and Distance Measuring Equipment by R.C.A.(G.B.). The intercom and public address systems were provided by Ultra.

Associated Electrical Industries Ltd. has received an order, valued at £250,000, to supply and install terminal equipment for the first phase of SEACOM, the South East Asia section of the Commonwealth telephone cable.

Union Carbide Form New Division.—In readiness to exploit a number of projects currently under development by the Union Carbide Corporation, of America, the British subsidiary company has formed an engineering products division. This new division has absorbed the Kemet division and the Alloys division, and is responsible for marketing the company's range of electronic products. This includes tantalum capacitors, laser and maser crystals and laser units, as well as their range of cryogenic equipment.

Telefunken, to adjust its financial year to that of its parent, A.E.G., had a "year" of only nine months in 1963. Reporting on the results the company states that sales for the nine months to 31st December were DM760,000,000 compared with DM572,000,000 for the corresponding period in 1962. The net profit was DM17,300,000, over £1,500,000.

The net consolidated profit of the **Ever Ready Company** for the year ended 29th February, after all charges, including taxation of £1,959,003, amounted to £2,244,817. This is an increase of £295,216 on the previous year's result.

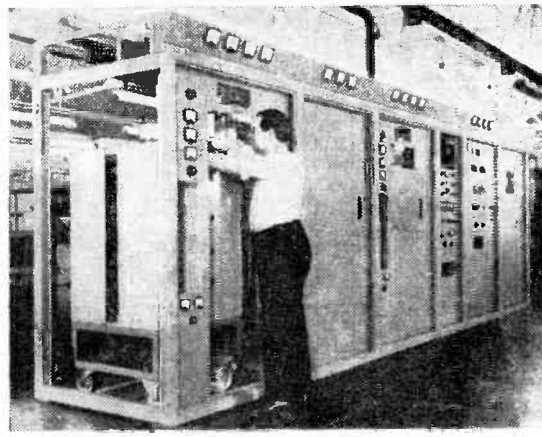
Perdio Electronics' financial statement for the year ended 2nd February shows a group loss of £70,313. In the previous financial year Perdio made a group pre-tax profit of £209,028.

Reddifitters Ltd. has been formed by E. A. Pell and G. L. Boston to specialize in the design and manufacture of electrical, electro-mechanical and electronic control, and communication equipment. The company will operate from 8a, Ainger Road, London, N.W.3.

A jointly owned **Anglo-American** company, based in the United States, has been formed by the British Derritron Electronics Group and the Aero Geo Astro Corporation of America to specialize in the manufacture of equipment for use in the environmental testing field. Cdr. V. G. P. Weake, Derritron's chairman, said the new company is to be known as AGA-Derritron and has an authorized capital of one million dollars.

(*Continued on page* 372)

The **Greibach Instrument Corporation,** of New Rochelle, U.S.A., who manufactures precision electrical measurement and indicating instruments, has appointed the instruments division of Claude Lyons Ltd. to act as its U.K. representative. Claude Lyons head office is at 76 Old Hall Street, Liverpool, 3. Its southern offices are in Hoddesdon, Herts.



This is the first of twelve u.h.f. 25kW transmitters Pye are building for the B.B.C.'s new television programme. The total cost of these 625-line transmitters is about £600,000.

A.E.I. Computer Centre.—Associated Electrical Industries Ltd. has opened a computer processing centre at its London headquarters, 33 Grosvenor Place, S.W.1. The new service is known as Dataline and is staffed by over 60 specialists. It can process either punched paper tape or punched cards.

An order for thirty-five automatic 7kW h.f. transmitters has been placed with **Standard Telephones and Cables Ltd.** by the Navy Department of the Ministry of Defence. These will be used to improve long-distance communications between Admiralty stations at home and abroad.

Ruby Laser Rangefinder.—The Hughes Aircraft Company, of California, has signed a licensing agreement with Barr & Stroud Ltd., of Glasgow, under which the British firm will develop and manufacture the Hughes ruby laser rangefinder to meet British requirements.

Daven, of Livington, New Jersey, whose products include precision wire-wound resistors, switches and attenuators, have appointed Ultra Electronics (Components) Ltd., of Industrial Estate, Long Drive, Greenford, Middx., their sole U.K. representative.

Semitron Ltd., of Cricklade, Wilts., recently formed by K. J. H. Adams, C. G. Howard and J. F. W. Sweet to produce specialized semiconductor devices, has put on the market a range of field effect transistors.

Fidelity Radio Ltd. has moved from 11 Blechynden Street to 6 Olaf Street, London, W.11. The telephone number is—PARk 0131.

The sole distributors of the **Danish L & H** "Signalmaster" f.m. tuner, which has a built-in pre-amplifier, are Britimpex Ltd., of 16 Great Russell Street, London, W.C.1.

Elcom (Northampton) Ltd. has moved into new premises within the same industrial estate off Weedon Road, Northampton. The new premises, which cover 50,000 sq ft, are approximately three times the size of the previous plant.

Brush Clevite, of Hythe, has begun building new headquarters on the outskirts of Southampton, at Thornhill. The headquarters will provide a factory, laboratory and offices with an immediate floor area of 45,000 sq ft.

Marconi "Raymarc" radar, recently introduced, uses transistors throughout the 12in display and the inverter units. Peak power is 20kW, giving a range of up to 36 miles. Particularly neat is the arrangement of thum-operated push button controls parallel with the two handrails, and also the hinged and removable side pannels carrying sub-assemblies. The price ex works is £985.