TV & RADIO SHOW REVIEW

OCTOBER 1966
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ELECTRONICS, TELEVISION, RADIO, AUDIO

CERES—a sister for CERN?

THREATENED with an American monopoly in almost every advanced technology, the nations of Europe are joining forces in an attempt to compete, technically and commercially. Britain has recently seen some results of this collaboration at the Farnborough Air Show, where co-operatively built aircraft outnumbered new British types and the great Anglo-French Concord, gradually taking shape, loomed in the background. In space technology there are E.S.R.O. and E.L.D.O., now joined by the relatively new C.E.T.S. (Conference of European Telecommunication Satellites).

But where does European electronic technology find a place in all this? The answer is: everywhere, yet nowhere.

Although the most advanced electronics in the world are going into these aircraft, missiles, rockets and satellites, although telecommunication is the very *raison d'être* of the European space programme, electronic technology is being presented to the public as a mere supporting function. It is time that someone pointed out that space technology, the possible benefits accruing from it and the value to industry of its technological "fall-out" have been over-sold in Europe—over-sold by sincere enthusiasts (as aerospace men are), to the detriment of a more balanced consideration of what Europe really needs.

"It is quite absurd for France to complain about American dominance of space," wrote John Davy, Science Correspondent of *The Observer*, on 12th June, "when her computer industry has collapsed and been swallowed by American firms. Computers are infinitely more central to the current industrial revolution than satellites. It is ludicrous for European countries to worry about E.L.D.O. when their airlines buy mainly from Boeing, and their nuclear-power programmes are threatened by Westinghouse and General Electric. . . . if Europe wishes to do battle somewhere for technological independence . . . computers and advanced electronics should undoubtedly have first priority. Not only will these technologies penetrate every aspect of economic life, but the markets are huge and world-wide."

One of the deeper reasons for America's lead in science-based industries like electronics—behind its well-known efficiency in selling and ability to get new developments rapidly into production—is that the U.S.A., with a gross national product greater than that of the whole of Europe, can afford to spend enormous sums on speculative and long-term research. From this prolific source comes a stream of new devices and techniques for U.S. industry to feed on. It seems never likely to run dry. Individual European countries have resigned themselves to the fact that they will never match this output and can see themselves in the future as little more than shopkeepers for U.S. Industry. Why have they not thought of collaboration in electronics research?

The way has already been shown by CERN, the European centre for nuclear research, which is a world leader in its field. Electronics science—by which we mean basic physical research as well as applied research in measurement, telecommunications, control, computing and information handling—is an ideal and worthy subject for a similar project. Achievements would be direct, not just the problematical results of "fall-out." By analogy it might be called CERES—Centre for European Research in Electronic Sciences—a name which by evoking the Greek goddess of Agriculture suggests an activity which likewise is fundamental and fruitful. Such a centre could well start by taking over electronic aspects of the work of E.S.R.O. and proposed projects of C.E.T.S., and by reviving the moribund Anglo-French advanced computer project.

There is nothing anti-American in the desire to compete with the United States. Indeed a technologically advanced Europe is necessary to the health of U.S. industry. Americans are well aware that you cannot sell oscilloscopes to aborigines.

VOL 72 NO 10
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NEW SUPERCONDUCTING DEVICES

By B. D. JOSEPHSON, M.A., Ph.D.

The author outlines devices based on work on superconductivity since 1960. An oscillator, superconducting interferometer and galvanometer are some of the devices referred to which rely on metal-insulator-metal sandwiches. The Josephson effect (named after the author), by which oscillations of 10Gc/s at $10^{-5}\mu$W have been observed, is discussed. Finally, the recently announced superconducting d.c. transformer is described.

UNTIL recently superconductivity—the fact that many metals lose their electrical resistance completely when cooled to temperatures a few degrees above absolute zero—was regarded mainly as a laboratory curiosity with little chance of practical applications. In the last few years, however, new discoveries have led to applications of superconductivity ranging from the manufacture of superconducting solenoids producing fields of 130 kilogauss without consuming any power other than that required for refrigeration, to devices detecting magnetic fields in the nanogauss (10^{-9} gauss) range. The production of large magnetic fields was mainly the consequence of a successful search for better superconducting materials, and in this article I shall concentrate on the other devices, which are essentially new forms of familiar electronic devices such as valves and transistors.

The cryotron

The first type of superconducting device was the cryotron, which was based on the fact that the resistance of a metal in the superconducting state is restored if a sufficiently large magnetic field is applied to it. The cryotron consists of two adjacent superconducting thin films, made of different materials so that one remains superconducting in a larger magnetic field than the other. A current passed through the first film controls the resistance of the second film by switching it from superconducting to normal and vice versa. The cryotron is rather like a relay, except that the resistance change is from zero to a finite value instead of from a finite value to a very large one as in an ordinary relay. It was hoped at the time of its invention that the cryotron would be useful in computer circuits, but improvements in transistors make this application of superconductivity seem rather unlikely at the moment.

Metal insulator—metal sandwiches

The new superconducting devices are almost all based on an experiment carried out in 1960 by Ivar Giaever at the General Electric research laboratories. He made a sandwich consisting of a very thin layer of insulator between two thin metallic films. The metal films were made by evaporation in a high vacuum and the oxide layer was made by exposing the first film to the atmosphere for a few minutes before evaporating the second film on top of it (Fig. 1). Other methods have also been used to make metal-insulator-metal sandwiches. One way is reminiscent of that primitive semiconductor diode, the "cat's whisker," and consists simply of two wires placed in contact with each other. Another method uses a "dry" joint, and consists of a blob of solder surrounding a wire of a metal such as niobium which does not alloy with solder.

The insulating layer is known as the barrier, and its purpose is to control the flow of electrons through it. The proportion of electrons that it lets through decreases exponentially as its thickness is increased, and is about 1 in 10^9 for a barrier of thickness 20 Å (2×10^{-7} cm). Such a barrier behaves as if it has a resistance of a few $\Omega\,mm^2$. However, its characteristics turn out to depend greatly on the nature of the metals on each side, and if one or both metals are superconductors the characteristics are non-linear. One example is shown in Fig. 2*a*. This is the type of characteristic obtained at very low temperatures when both metals are superconducting. It will be seen that the characteristic is composed of two parts. One part consists of a vertical line at zero voltage, and is generally seen only if the barrier has a resistance of a few ohms or less. When the specimen is biased on to this portion of its characteristic there is no dissipation of power and the barrier is in effect superconducting. The other, resistive part of the characteristic is strikingly non-linear. Note that the voltages on the non-linear regions are of the order of millivolts, compared with tenths of a volt for the usual semiconductor devices.

To understand the behaviour of the superconducting sandwiches it is necessary to know a little about what a superconductor is. According to the currently accepted theory of superconductivity, due to Bardeen, Cooper and Schrieffer, superconductivity is the result of the fact that in certain circumstances two electrons in a metal, instead of repelling each other as one might expect, attract each other. When the metal is cooled to

Dr. B. D. Josephson has been at Trinity College, Cambridge, since 1957 except for the past year which he has spent in the Physics Department of the University of Illinois as research assistant professor. He graduated in 1960 and obtained a research fellowship at Trinity College in 1962. His research for his doctorate included both theoretical and experimental investigations into superconductivity. Dr. Josephson's work led to a postulate which has become known as the alternating current Josephson effect and is described in this article. More recently he has also been working on the theory of second-order phase transitions. He is 27.

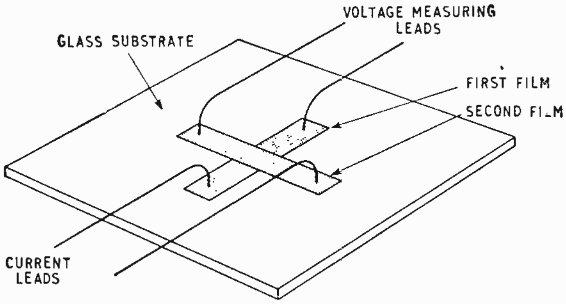


Fig. 1. Construction of a metal-insulator-metal sandwich of the evaporated film type. The films are evaporated through suitably shaped masks at a pressure of 10^{-5} mm or less onto a glass substrate. The insulator is a surface oxide layer formed by exposure to the atmosphere between evaporations. The leads are attached by soldering with indium, which in the molten state wets glass. Often a final evaporated layer of silicon monoxide is used to protect the metal films from deterioration.

a low enough temperature, some of the electrons start joining up in pairs. Once they are in pairs they acquire some very stronge properties, of which I shall have more to say later. However, for the moment, the important point is that once two electrons are combined into a pair a definite amount of energy, which I shall call *Eo,* is needed to separate them.

Now let us return to Giaever's experiment. At very low temperatures (the conditions corresponding to the characteristic in Fig. 2*a*) all the electrons are combined into pairs. One way to make a current flow through the barrier is to send pairs through the barrier without breaking them up. A flow of pairs like this constitutes a supercurrent. This process is responsible for the zero-voltage part of the characteristic, since in normal circumstances supercurrents can flow only when there are no potential differences present. To get a current to flow otherwise (at absolute zero) it is necessary to supply energy to break up pairs. In Giaever's experiment this energy is supplied by the voltage across the barrier. No current flows until this voltage reaches E_o/e, at which point the energy supplied to a single electron of charge e crossing the barrier becomes equal to the energy required to detach it from its partner, and the current starts to increase rapidly.

At higher temperatures the characteristics may take on a more interesting form, such as that in Fig. 2*b*. If we ignore the fact that it is symmetrical about zero voltage, this characteristic is rather like that of an Esaki or tunnel diode. In particular, in certain regions of voltage the current through the device decreases as the applied voltage is increased, so that the a.c. or slope resistance is negative. As a result, barriers between superconductors can in principle be used as active elements in oscillator and amplifier circuits. Oscillation at a frequency of 72.5 Mc/s has in fact been achieved by workers at the A.D. Little research laboratories by this means.

Using a barrier as an amplifier would seem to be an attractive proposition, since the Johnson noise at liquid helium temperatures is very low. However, attempts at making a practical amplifier have not so far been very successful. Another possible application is to the detection of microwaves, since it has been shown that the characteristics of a barrier are modified by the presence of microwave radiation.

The vertical portion of the characteristic, corresponding to pairs of electrons going through the barrier without breaking up, appears at first sight not to be very promising from the point of view of applications, but in fact there are some surprising possibilities. To understand these it is first necessary to remember the fact that in certain circumstances (such as when a beam of electrons is diffracted from the periodic array of atoms in a crystal) electrons can behave like waves. With most electronic devices the wave nature of the electron plays no part whatever, but in a superconductor it is all important. If we think of electrons in terms of waves, a piece of metal should be regarded as a cavity in which waves are propagating to and fro, but waves of a different type from electromagnetic waves such as radio waves and light. In a superconductor the waves associated with the bound pairs of electrons are coherent, like the light waves from a laser: that is, there are well defined wave trains which keep the same form more or less indefinitely. The coherence of the waves is the basis of the applications I am going to describe.

Superconductor interferometer

The first type of device is the superconducting interferometer. This is the electronic analogue of the optical interferometer (Fig. 3*a*), in which a coherent beam of light is split up by a partially silvered mirror into two parts which are later recombined, having travelled along different paths in the meantime. If something is done to change the phase of one of the waves (for example, placing a piece of transparent material in the way of the

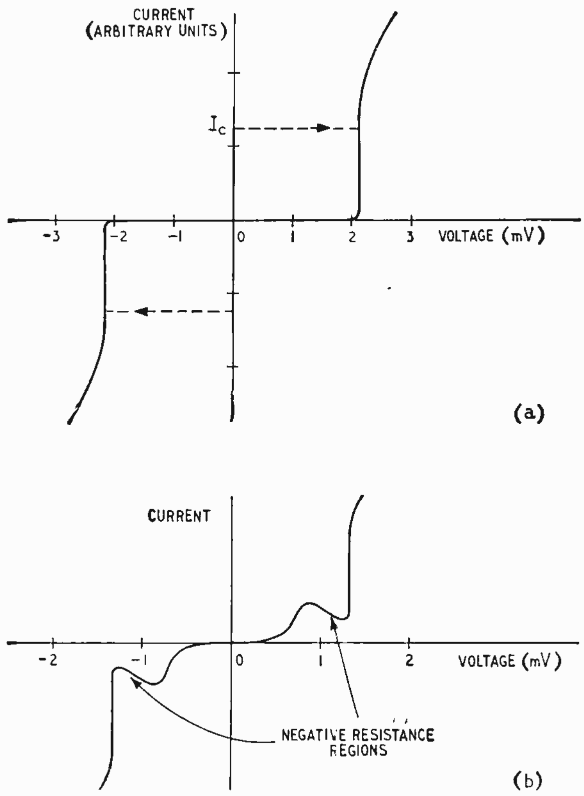


Fig. 2 (a) Current-voltage characteristic of a supercondu:tor-insulator-superconductor sandwich at very low temperatures, consisting of both a non-linear resistive part and zero-voltage superconducting part, the latter being present only if the barrier is sufficiently thin. (b) Characteristic at higher temperatures, when negative resistance regions appear if the two superconductors are dissimilar.

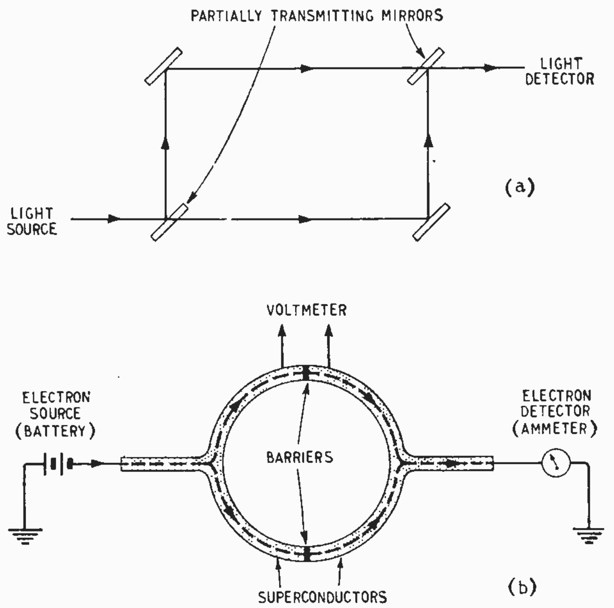


Fig. 3. Optical interferometer (a) and superconducting interferometer (b). Both devices are based on interference between waves which can travel along two different paths. In the superconducting interferometer the quantity measured is the maximum current which can flow before a voltage appears (I_c in Fig. 2a), and this oscillates as the applied magnetic field is varied. The purpose of the barriers is to reduce the steady value of I_c sufficiently for its oscillations to be easily detectable.

beam), the phase relationships between the two waves are changed and so the intensity of the combined beam is altered.

The superconducting interferometer (Fig. 3*b*) does the same kind of thing with electrons. It consists of two pieces of superconductor joined by barriers in two places. The superconducting electrons can flow from one piece to the other by two different routes (through either of the two barriers), so that interference can take place. To observe the interference one looks for changes in the maximum current that can be passed through the barriers before they become resistive (corresponding to changes in light intensity in the optical interferometer). The usefulness of the superconducting interferometer lies in the fact that phase changes in electron waves can be produced by magnetic fields. The phase change turns out to be proportional to the amount of flux threading the closed circuit consisting of fthe two superconductors and the two barriers, and a phase change of 2π corresponds to the fundamental unit of flux, 2.068×10^{-7} gauss cm^2 (equal to $hc/2e$, where h, c and e are Planck's constant, the velocity of light and the charge of the electron respectively). In the most sensitive interferometer made so far (developed at the Ford Motors Scientific Research Laboratory), pointed screws are used to make barriers with adjustable resistance (Fig. 4). The area enclosed is about 1 cm^2, so that as the applied magnetic field is changed the output of the interferometer oscillates, with a period of about 0.2 microgauss.

A galvanometer using the same principle of electron interference has been constructed at Cambridge University. In this device one piece of superconductor consists of a niobium wire and the other of a blob of solder completely surrounding the wire. With this arrangement externally applied magnetic fields are screened out, but the device is sensitive to fields produced by passing a current through the central wire. Since the central wire is superconducting, the galvanometer has zero impedance, and is very suitable for measuring minute voltages in low impedance circuits.

The a.c. Josephson effect

I said earlier that in normal circumstances supercurrents can flow only when no potential differences are present. This is not strictly speaking correct; in fact there always is a supercurrent present whether a voltage is applied to the barrier or not, but when a voltage is present the supercurrent oscillates at a very high frequency and is not normally detected. The oscillations are due to beating between the electron waves on the two sides of the barrier, and their frequency is proportional to the voltage applied to the barrier.† The usual direct supercurrent is a special case, occurring when both the voltage and the frequency are zero. The constant relating to the voltage and the frequency is equal to the ratio between Planck's constant and the charge of an electron pair, which means that an applied voltage of 1 mV produces oscillations at a frequency of 483.6 Gc/s. A barrier between superconductors is the simplest form of oscillator yet devised; if an adjustable direct voltage source is connected to it, coherent electromagnetic radiation at any frequency from d.c. to about 1,000 Gc/s will be produced. The snag is that the amount of power given off is very small, and 10^{-11} watts at 10 Gc/s is the best that has been achieved so far. However, if the problems of impedance matching can be solved, considerably greater power outputs should be obtainable.

An application related to the previous one is the production of a voltage supply whose output impedance at d.c. is accurately zero, and whose variations in output voltage can in principle be made as small as the fluctuations in frequency of an oscillator. The idea is to place a barrier in a cavity containing microwave radiation at a definite frequency. Under certain conditions the frequency of the alternating supercurrent becomes locked to that of the microwaves. Since the former frequency is related *via* fundamental constants

† The phenomenon has been named the a.c. Josephson effect, after the author, who postulated its existence in 1962.

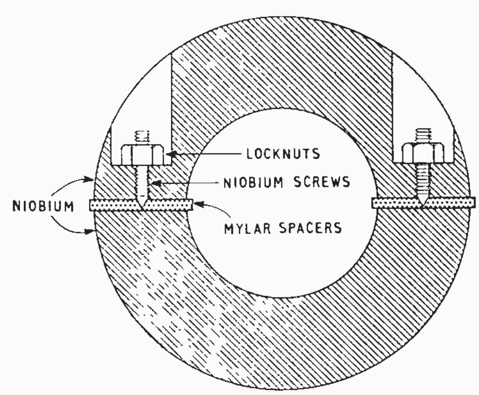


Fig. 4. Design of a high sensitivity superconducting interferometer constructed by J. E. Zimmerman and A. H. Silver at the Ford Motors Scientific Laboratory. The barriers consist of oxide layers between the tips of the-pointed screws and the piece of niobium with which the tips are in contact. Their resistances can be adjusted by rotating the screws. With this device, changes in applied magnetic field as small as 10^{-9} gauss produce detectable changes in I_c.

to the voltage across the barrier, this voltage is itself fixed by the frequency of the microwave field. If a load is connected across the barrier, the power dissipated in the load is supplied by the microwave field, the voltage across the barrier remaining unchanged.

Superconducting d.c. transformer

I should like to conclude by describing a device which is based on completely different properties of superconductors. This is a superconducting transformer which will operate under d.c. conditions. The first working model was made by Giaever himself. It is based on the fact that if a magnetic field is applied perpendicular to a superconducting film it does not penetrate the film uniformly, but only at a number of "flux spots," each carrying the fundamental unit of flux 2.068×10^{-7} gauss cm^2 that we met in connection with the superconducting interferometer. If a sufficiently large current is passed through the film it becomes resistive and the flux spots start to move. The transformer itself consists of two superconducting films (functioning as the primary and secondary), electrically insulated from each other but sufficiently close together that the flux spots in the two films become coupled together magnetically (Fig. 5). If a current is passed through the primary film the flux spots in it start to move, and drag the flux spots in the secondary film along with them. A voltage drop therefore appears across the

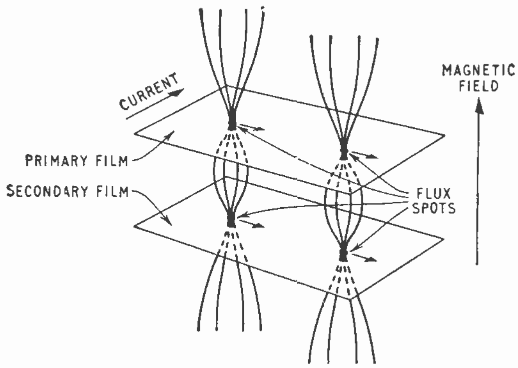


Fig. 5. Superconducting d.c. transformer.

secondary film. The theoretical voltage transformation ratio 1:1, corresponding to perfect coupling of the flux spots, can be achieved under certain conditions, but there is a large leakage current and the net efficiency of the transformer is less than 10 per cent.

These new devices are unlikely to affect those of us who do not have a convenient supply of liquid helium at hand, but some of them are already beginning to be used in low temperature laboratories, and owing to their simplicity they are likely to be used increasingly in the future.

Avionics at Farnborough

The Society of British Aerospace Companies' exhibition took place as we were going to press, and only a few of the items on show can be mentioned here. A fuller report will be published later.

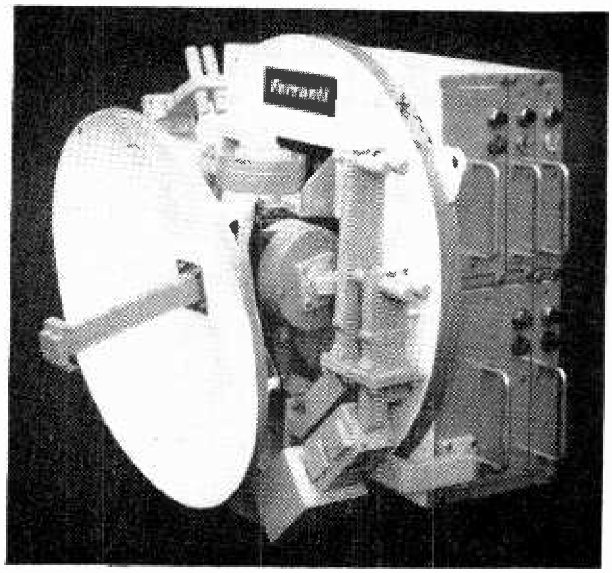
INTEGRATED circuits are being used in more and more airborne equipments, reducing size and weight drastically and promising greater reliability—though some equipment designers still seem doubtful about this. Both Plessey and Cossor showed new transponders for secondary radar (civil S.S.R. or military I.F.F.) which could be comfortably held in the hand. The Cossor SSR2100, for example, measuring 4in × 4in × 6in, uses about 50 flat-pack i.cs plus a number of thin-film circuits and TO-5 packaged solid-state devices. Delay-line encoding and decoding circuits are replaced by digital shift registers housed in the separate control unit. The transmitter output stage, using a miniature ceramic triode valve, gives a peak power of 500 W nominal.

The latest airborne terrain warning and ranging radar, a Ferranti J-band development model, also using i.cs, weighs only 25lb (see picture). Along the radar boresight it provides air-to-air and air-to-surface ranging information, while any ground obstacle initiates a warning to the pilot. The r.f. power output is 2 kW (p.r.f. 3000 p.p.s.) and the 12-inch aerial dish will give 15° of yaw and pitch. Integrated circuits also appear in the Myriad digital computer associated with a new mobile ground radar, for air traffic control or ground controlled interception, shown by Marconi. It comprises a surveillance radar with two back-to-back aerials (S-band for high cover, L-band for low cover): a C-band height-finding radar with computer controlled scanning; and a computer controlled display and data handling unit.

Other new solid-state navigational equipment included an airborne receiver for both the long-range Loran C as well as Loran A; and an improved I.L.S. system for all-weather landing introduced by S.T.C. The I.L.S. incorporates a technique in which the "course" and "clearance" tones are in phase quadrature so that unwanted reflections resulting from the clearance aerial lobes do not interfere with the course signals.

Test instruments included the advanced Solartron digital transfer function analyser JM1600, which is described in an article on dynamic testing in this issue (p. 513).

Ferranti light-weight ranging and terrain warning radar.



TV & RADIO SHOW REPORT

TECHNICAL HIGHLIGHTS: EQUIPMENT SURVEY

AS the International TV & Radio Show held at Earls Court at the end of August was for the trade only we hope the many readers who were therefore unable to attend will find the following survey of technical highlights of particular interest. Following the survey of television and sound radio techniques will be found abridged details of most of the new equipment introduced at the Show or, in the case of one or two manufacturers, at private shows.

TELEVISION

DEVELOPMENTS in monochrome television receivers are now relatively minor, being largely a matter of marginal cost cutting (in response to the intense competition of the domestic market) and a gradual introduction of solid-state circuitry. It is, however, the cost aspect largely which is holding back transistorization, and, indeed. one manufacturer who used a transistor v.h.f. tuner in his last season's models has now reverted to a valve version in his latest sets for this very reason. Similarly, transistor circuits which had been used in certain high-power stages of experimental colour sets have now been hastily abandoned for valves in the pre-production models.

Colour television is, of course, the reigning interest in domestic set manufacture now that a decision has been made to start a colour broadcasting service on BBC-2 in October 1967 using the PAL system. Four set making organizations, K-B, the Pye group (including Dynatron, Ekco, Ferranti, Invicta, Pam), Decca and Rank-Bush-Murphy, have demonstrated pre-production samples of what they will be manufacturing next year. Philips have shown a prototype model (see p. 489), while the Thorn group have demonstrated a kind of "test-bed" for current techniques and components but with a promise of production samples to follow.

Two sizes of shadow-mask colour c.r.t. are now avail-

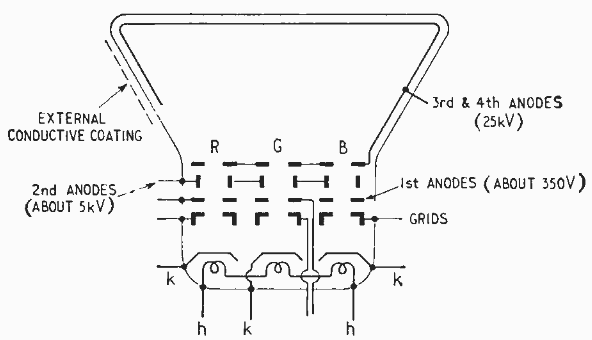


Fig. 1. New graphical symbol in television—the shadow-mask colour c.r.t. (Voltages for 25-inch Mazda V3508A.)

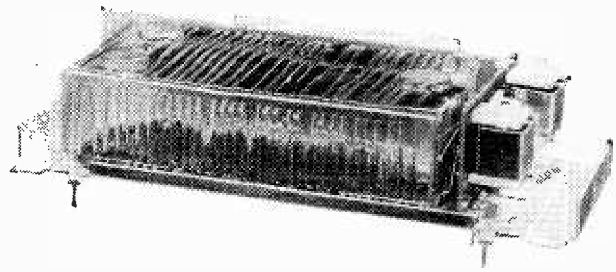


Fig. 2. Interior of 63.943μs folded reflecting glass delay line made by Mullard. Designed for use between 150-Ω source and load, the line has an insertion loss of 10 dB and the output is sufficient to drive a diode demodulator. The delay is pre-set by precision grinding of the reflecting surface and adjustment of built-in inductors.

able in the U.K. from Mullard or Thorn-AEI, 25-inch and 18-inch, but all three production sample sets use 25-inch tubes. As can be seen from Fig. 1, these require an e.h.t. voltage as high as 25 kV. Apart from the shadow-mask tube, the two devices (and associated circuits) which most distinguish a PAL colour receiver from a monochrome set are the 64 μsec delay line (used in the decoder to store temporarily the video information of each line so that it may be added to that of the next line) and the convergence coil assembly on the tube neck (used for ensuring accurate registration of the three electron beams with the RGB phosphor dot triads at all points on the screen). Hitherto these two devices have been imported from foreign manufacturers (e.g. delay lines from Germany, convergence- and scanning-coils from America), but now they are beginning to be available from British sources (Fig. 2).

In other respects, since PAL is a compatible system in which colour information is simply added to the brightness-information channel needed for monochrome sets, the PAL receiver is very like a conventional dual-standard black-and-white receiver. The tuner, i.f. section, luminance video, sound channel, timebases, sync separation and scanning output stages are all very similar. Looking at the set externally (switched off) the only feature that identifies it as a colour receiver is the presence of a saturation control—the one and only extra user control resulting from the addition of colour.

The chrominance information, which is added to the luminance information and can be faded in and out by the viewer by operating his saturation control, is processed in a channel parallel to the luminance or "monochrome" channel; the luminance video being applied to the cathodes of the shadow-mask tube and the chrominance video to the grids. In this chrominance channel the two main sections are the PAL decoder and the colour-difference signal amplifiers. Block schematics of the circuits used in the Pye group receiver are shown in Figs. 3 and 4. (An outline description of this hybrid set and a photograph of the chassis appeared in the September issue, p.442).

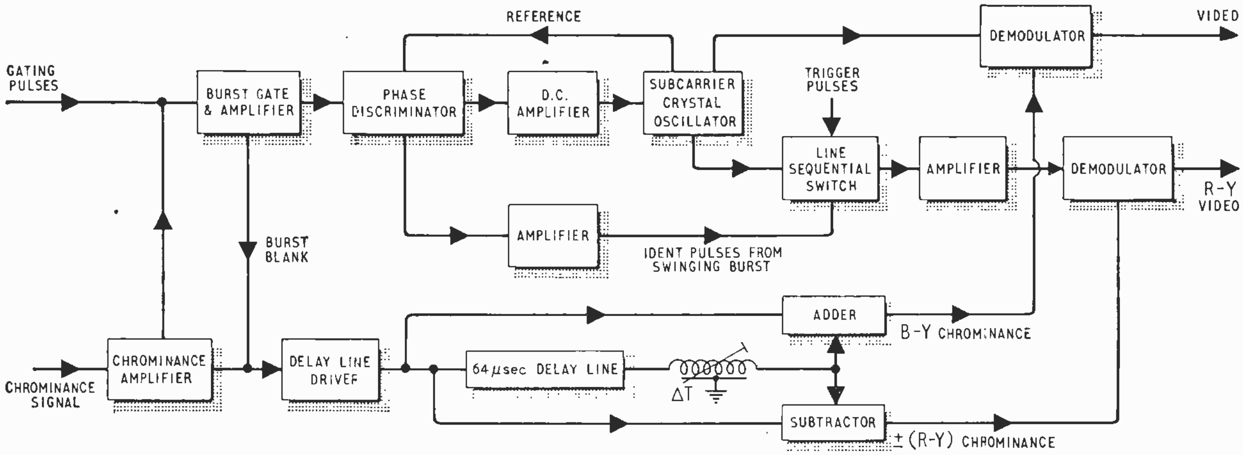
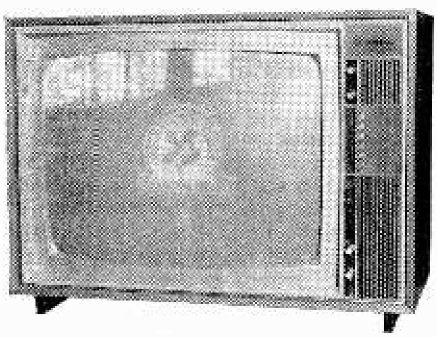


Fig. 3. Schematic of PAL decoder in Pye colour receiver.

In the decoder, Fig. 3, chrominance is extracted from the composite video signal after the first video stage by a tuned circuit in the valve anode, and is applied to a chrominance amplifier. The output signal from this stage is then fed to a transistor driving the delay line and to a gating amplifier which is switched on only during the colour-burst period of the signal by a suitably timed gating pulse. The sub-carrier oscillator needed for R−Y and B−Y demodulation is crystal controlled but also synchronized with the burst. Some of its output is fed back to a phase discriminator where any difference existing between the burst and the oscillator signals, after suitable filtering, causes a change of d.c. conditions in a d.c. amplifier. The output of this amplifier is applied to a varicap diode loading the sub-carrier



Philips prototype colour receiver.

crystal oscillator, and by this control system the oscillator is pulled into synchronism with the transmitted burst.

Part of the oscillator output is applied to the B−Y demodulator which is also fed with B−Y chrominance from an adding circuit on the delay line output. The resulting B−Y video signal is then fed via a 4.43 Mc/s filter to a B−Y colour difference amplifier. Suitably phased oscillator output is also fed to a line sequential switch, the output of which is reversed in phase on alternate lines. After amplification this signal is applied to the R−Y demodulator which is with ±(R−Y) chrominance from a subtracting circuit on the delay line output.

The line-sequential switch is triggered by pulses obtained from the blanking amplifier located in the video section, thereby ensuring that the switch has operated well before the picture starts. However, if its switching mode happens to be wrong it is corrected by pulses derived from the "swinging burst" and obtained from the phase discriminator.

The decoder uses 10 transistors and is constructed on a printed-circuit board, and may be removed for servicing without affecting monochrome reception. The 64 µs delay line is a Telefunken glass double-ended type with a small padder for accurately adjusting the overall delay. R−Y and B−Y output signals from the decoder are approximately 3 V peak-to-peak.

Fig. 4 shows (*a*) the video stages and (*b*) the colour-

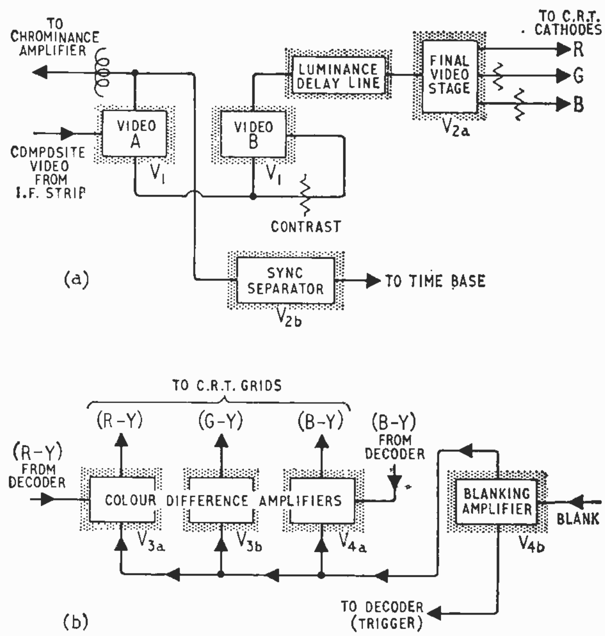


Fig. 4. Schematics of (a) video stages and (b) colour-difference signal amplifiers in the Pye set.

difference signal amplifiers. The video stages are driven by the composite video signal at approximately 2.5 V peak-to-peak. Chrominance and sync are taken from the first amplifier, B, the output of which is fed via a luminance delay line (used for equalizing the delays in the luminance and chrominance channels) to the final video stage V_2a. This supplies the required luminance-information drives to the three cathodes of the shadow-mask tube via potentiometers, which are adjusted to give the required colour temperature to the white light produced by the three electron beams.

In (b) valves V_3a and V_4a receive R−Y and B−Y video signals respectively from the decoder, and the resulting outputs drive the corresponding colour tube grids. The G−Y signal is obtained by driving the cathode of V_4b with suitably matrixed signals.

Video stages, colour difference amplifiers and sync separator are mounted on a printed-circuit board which again is designed for easy removal.

The timebase and scanning section of the receiver is on a printed-circuit board which contains the transistorized frame oscillator, driver and output stages, the line oscillator and flywheel circuits, and part of a 30-volt

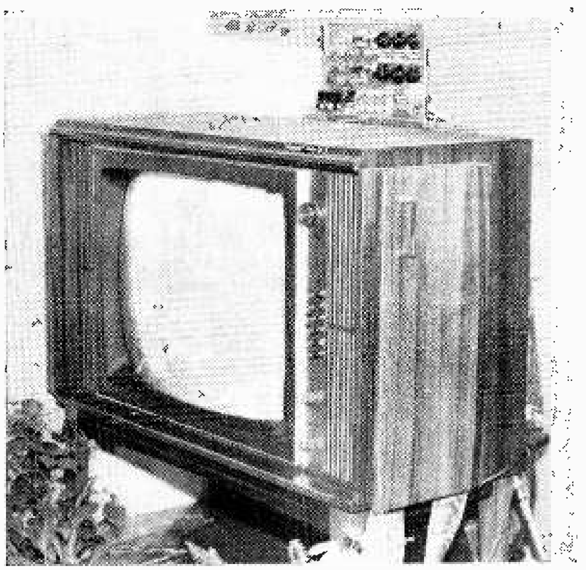


Fig. 5. Murphy colour receiver with hinged convergence control panel swung up and out from rear of set.

power supply for the transistors. This board also carries the audio output section.

The e.h.t. generator is a conventional valve circuit but uses a triode shunt stabilizer and delivers 24 kV at 1.25mA. The e.h.t. rectifier, focus rectifier and shunt stabilizer are incorporated with the line output transformer in a separate screened compartment.

This receiver, like those of other manufacturers, has been designed with ease of servicing in mind. The printed circuit boards have plugs and sockets to allow the units to be removed by field service engineers. The makers envisage that what is being called the "difficult bit"—the decoder that is—will be replaced if necessary in the customer's home by a new unit. The faulty unit may then be repaired at the dealer's service department.

Dynamic convergence of the shadow-mask tube beams in colour receivers is obviously a source of worry to technicians, not only because the convergence circuits are rather complicated, but because the adjustment of the convergence pre-set controls for correct conditions is a somewhat tricky procedure. So concerned are the set makers, in fact, that, temporarily forgetting cost-cutting, they have gone so far as to make the pre-set controls accessible from the front of the set! In the Murphy consolette receiver, for example, these controls are grouped on a hinged board which can be swung up and out from the back of the cabinet, as shown in Fig. 5. In the Pye group set described above the controls are located behind the loudspeaker baffle, which is removed by two screws at the side of the cabinet.

Some idea of the complexity of dynamic convergence circuitry can be gained from Fig. 6 which is a system developed by Thorn-AEI for use with a Mazda shadow-mask colour tube. The convergence coil assembly shown symbolically in the circuit, takes the actual form shown in Fig. 7, with the three separate coils positioned above red, green and blue pole-pieces in the neck of the tube. Convergence currents fed into the coils (and also adjustments of static convergence magnets) result in movements of the electron beams along radial axes, as shown. Perfect convergence over the whole screen would require highly complex current waveforms fed into the coils in synchronism with the scanning process, but in practice sufficiently good approximations to these are obtained from sawtooth and parabolic waveforms obtained from the line and field scanning circuits.

Convergence at the centre of the screen is taken care of by static convergence magnets mounted on the coil assembly, and it is towards the edges of the picture that the dynamic convergence comes into play. The line waveforms are therefore used for dynamic correction at the sides of the picture while the field waveforms are used for the top and bottom, so there are "line" and "field" convergence coils for red, green and blue. Note that the basic circuits in Fig. 6 are duplicated (with different component values) for 625-line and 405-line (monochrome) operation, and suitable switching is provided.

Considering the field-waveform section in Fig. 6 the red "field" coil and the green "field" coil are fed from a matrixing network with an asymmetrical parabolic waveform from the cathode of the field output pentode and with a sawtooth waveform from windings on the field output transformer. Potentiometers control the amounts of parabolic and sawtooth currents fed to these coils. The amount of parabola current varies the total bow in vertical red and green lines (formed by columns of R and G dots) in the centre of the screen, while the amount of sawtooth current varies the tilt, or asymmetry of the bowing, along these lines. These two controls enable vertical red and green lines in the centre of the screen to be made parallel to each other.

Two other potentiometers control differential amounts of parabolic and sawtooth currents respectively fed to the coils, as shown. These enable the spacings of associated horizontal red and green lines to be made equal along the vertical centre line of the screen. Adjustment of red and green magnets then converges the red and green spots all along the centre vertical line of the raster.

The amounts of parabola and sawtooth currents fed to the blue "field" convergence coil are controlled by two potentiometers as shown, and these enable the blue horizontal lines to be equally displaced from the red/green horizontal lines at all points along the centre vertical line of the tube. Adjustment of blue vertical and lateral static shift magnets then gives convergence of the blue with the red and green spots along the centre vertical line.

In the line-waveform section (considering only the 625-line switch position), 120-V positive line pulses are

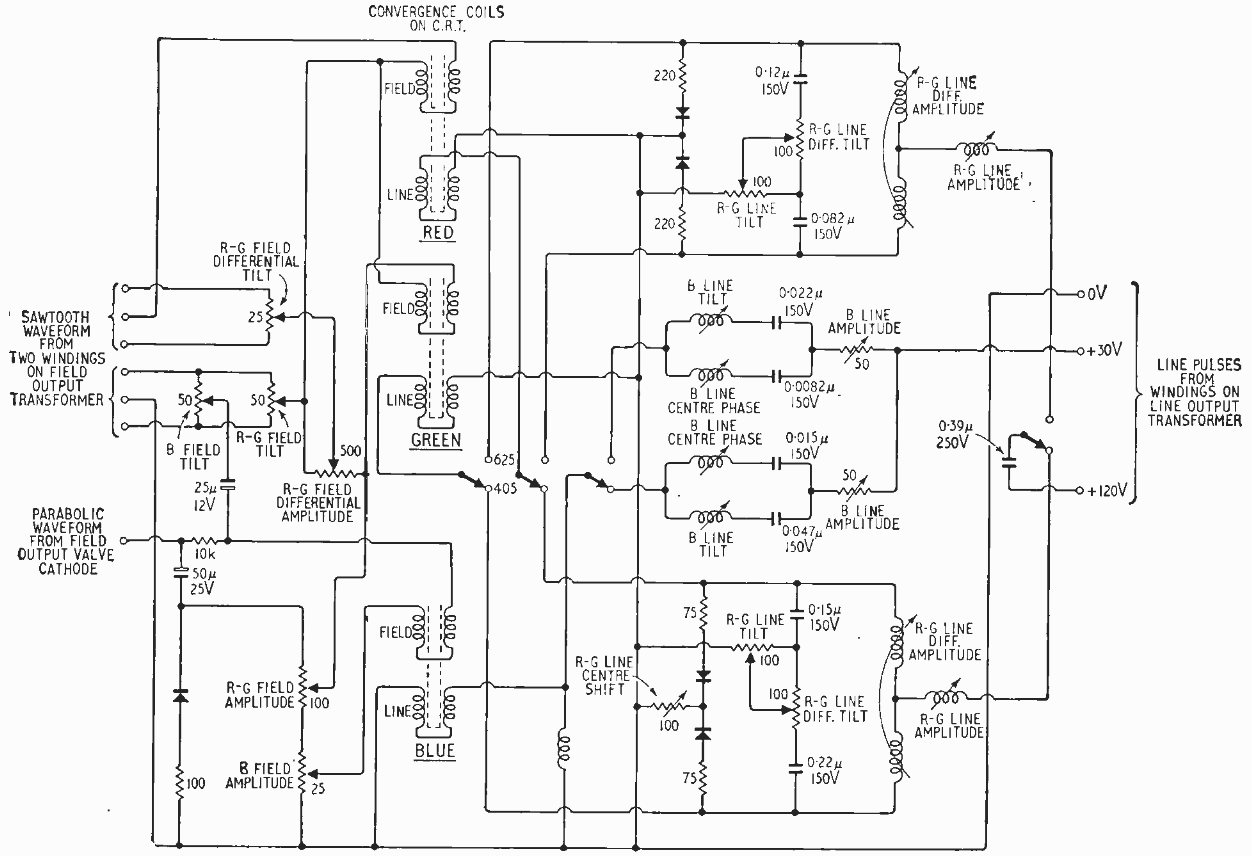


Fig. 6. Convergence circuitry developed by Thorn-AEI. Note separate " line " and " field " convergence coils and duplicated circuits for 625-line and 405-line operation.

fed via the R-G line amplitude control to the centre of the line differential amplitude control. Line differential tilt and line tilt networks are provided as shown. The resulting mixtures of sawtooth and parabola voltage are fed from these networks to the green " line " convergence coil and the red " line " coil. The two diodes apply d.c. restoration to the waveform, to maintain the static convergence at the centre of the screen and also provide some shaping of the waveform. In the 405-line switch position a control is used to vary the d.c. restoration in order that the red/green vertical lines may be brought into convergence without altering the 625-line setting of the static convergence magnets.

For the horizontal blue lines, a 50 Ω potentiometer controls the amplitude of the line pulses fed via the series-parallel LC arrangement to the blue " line " convergence coil. The upper L and C are tuned to approximately the line frequency fundamental, while the lower L and C are tuned to the line frequency 2nd harmonic. The loading inductance on the blue coil allows the variable-inductor controls to have a much bigger effect on the proportions of fundamental and 2nd harmonic fed to the blue coil than would be the case if the coil were not loaded.

The main piece of test gear needed for convergence setting-up is a cross-hatch pattern generator, and in fact this is basically the only extra instrument that is demanded by the addition of colour. Labgear have just introduced one, the type E.5180 (see Fig. 8) suitable for 625-line receivers (a dual-standard version is due to follow next year). The modulated 39.5 Mc/s carrier output of the generator is fed via a 75 Ω coaxial lead into the i.f. vision channel of the set. Three controls are provided: (1) selection of cross-hatch or dot pattern, (2) carrier frequency adjustment, and (3) modulation level adjustment. (See also p. 498.)

Reverting to monochrome television, the use of solid-state circuitry is most evident, of course, where it makes possible small and light battery-powered portable sets. One example among this season's models is the Philips

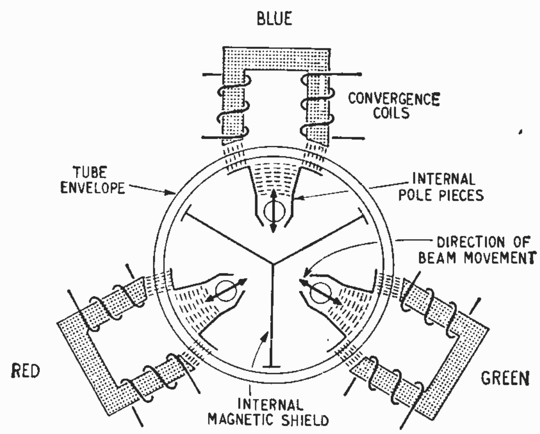


Fig. 7. Arrangement of convergence coils on c.r.t. neck. Permanent magnets for static convergence adjustment are mounted on the coil assembly.

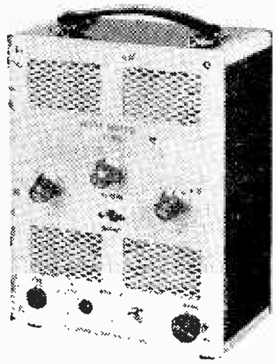


Fig. 8. Labgear cross-hatch generator, Type E5180, for convergence setting-up on colour receivers.

11-inch "T-Vette" battery/mains dual-standard portable receiver. It is intended to operate from an external 12-V accumulator, from which it draws 1.5 A. The most spectacular example of the miniaturization that can be achieved with solid-state circuits is, however, the Sinclaim "Microvision" mentioned on page 499 which has overall dimensions of 4 in × 2½ in × 2 in and a screen size of 2 in.

The latest television receivers are tending to use tubes with darker tinting of the faceplate to allow adequate contrast to be obtained in high levels of ambient lighting. This has necessitated greater screen brightness levels, and the receivers are providing these by using tube e.h.t. voltages as high as 20 kV. Thorn group receivers generate this e.h.t. without requiring excessively large voltage pulses from the line output transformer by using a Cockcroft-Walton voltage tripler circuit incorporating five selenium rectifier sticks, so that the voltage pulses from the line output transformer can be less than 7 kV.

This company, incidentally, in association with Sidney S. Bird, have just introduced a new combined solid-state v.h.f./u.h.f. tuner unit in their latest sets (see Fig. 9). It uses four transistor stages in the tuner proper—a common u.h.f./v.h.f. r.f. amplifier; a u.h.f. oscillator-mixer; a v.h.f. oscillator; and a transistor serving both as v.h.f. mixer and i.f. amplifier on u.h.f. Tuning is by Lecher lines for u.h.f. and variable capacitors for v.h.f. Included in the unit is an i.f. section using a single-transistor i.f. amplifier and a two-transistor a.g.c. amplifier. 625-line/405-line switching is by a solenoid-operated switch.

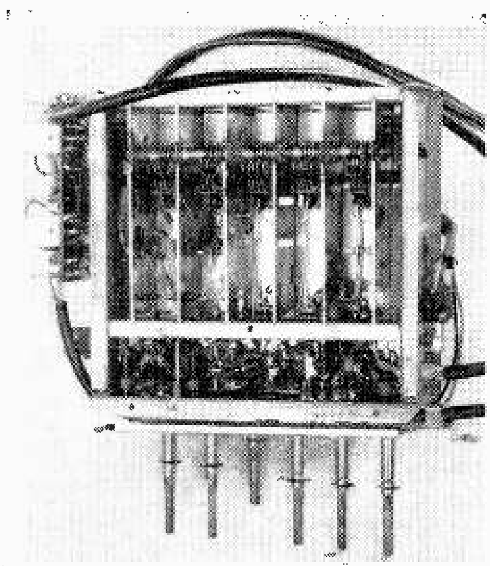


Fig. 9. New solid-state v.h.f./u.h.f. tuner designed by Sidney S. Bird and Thorn for use in latest Thorn group receivers.

SOUND RECEIVERS AND REPRODUCERS

IN last year's review it was observed that modular construction was used on a number of receivers. This year another receiver incorporates such techniques—the Danish Arena T1200 (Fig. 10). The advantages, from the servicing viewpoint, are invaluable and a screwdriver is the only tool necessary to replace a unit. The extra expense involved in replacing a complete sub-assembly rather than a separate component is offset by the time saved. Further, the service engineer does not need to know the exact cause of the complaint, which means that expensive test equipment is not necessary and also less-skilled labour can be used.

Five sub-assemblies about the size of a matchbox are used; these contain about 95% of the components. Another point of interest with this receiver is the elimination of the tuning capacitor in the f.m. tuner module. This is replaced by three silicon diodes with voltage-dependent capacitance characteristics. The receiver is also one of the few using silicon transistors. One of the four wavebands is the 49 m-band, spread over the width of the dial. The T1200 set provides an output of 4 W.

Naturally enough, most of the deviations from normal practice are found in the higher-priced receivers; those less than about £20 generally being predictable in their design. A common line-up of those around £16 seems to be AF117 (mixer-oscillator), 2×AF117 (two-stage i.f. amplifier), OA90 (detector), AC127 (a.f. pre-amplifier), AC128 or OC81D (driver) and AC127-AC128 or AC127-OC81 (complementary output stage). Directly coupled a.f. amplifiers are now more common, but there are still current designs using transformer-coupled stages.

An a.m.-only portable receiver with similar line-up is the Philips 248T. Some time ago many portables were introduced with a portion of the medium-wave band around the Radio Luxembourg wavelength bandspread, so that tuning this and close stations became easier. In the Philips receiver, an electronic fine tuning control is provided which operates anywhere on the short and medium wavebands. Clearly, this is very desirable for tuning s.w. stations. The circuit used is shown in Fig. 11. Since special variable-capacitance diodes are relatively expensive an OA79 has been used. The circuit is connected across the oscillator tuning capacitor and is unusual in that the diode is forward biased rather than reverse biased. The set costs 14½ gn and is probably the lowest priced receiver with this facility. Some other receivers with fine tuning are the KB KR026 and the RGD RR214.

More mains-driven transistor receivers have, incidentally, been announced—the Dynatron Atlantis (TRV 15) and the Pye "Eleven-Eleven." The relative scarcity of these was observed last year. By now there are probably around half-a-dozen of these receivers on the market.

Recorded cassettes. A development for this country is the announcement of cassettes recorded with l.p. disc

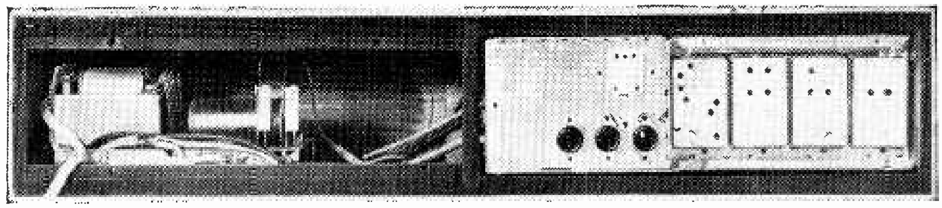
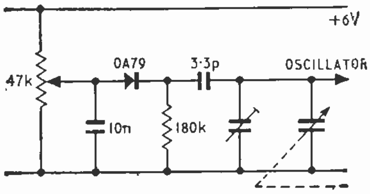
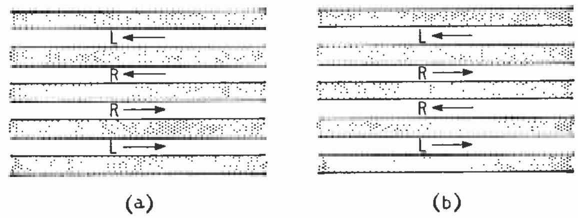


Fig. 10. Modular construction system employed on the Arena T1200 receiver.



Left: Fig. 11. Fine oscillator tuning control operative on all wavebands of the Philips 248T model.



Right: Fig. 12. (a) Arrangement of tracks on Philips recorded stereo cassettes to give compatible recordings, (b) Conventional order of tracks on a four-track tape.

material by Philips and E.M.I. By some time next year over 200 titles will be available on these cassettes and other record companies will no doubt produce recorded cassettes. The cassettes are four track stereo recordings playing for up to 30 min each half. An advantage of the Philips system is that the tracks are arranged as in Fig. 12*a*, as opposed to Fig. 12*b*, enabling a stereo tape to be played on a mono machine, the mono playback head receiving both the left and right channel signals. The playback machines and cassettes are so devised that recorded cassettes cannot readily be erased, whilst blank cassettes, of course, can be. Apart from the established portable cassette tape recorder, two new machines are announced. The mono cassette tape recorder (EL 3310) has a built-in loudspeaker, an output power of 1.8 W, a response from 60 c/s-10 kc/s (±6 dB) with a tape speed of $1\frac{7}{8}$ in/sec. A stereo version (EL 3312) is available, and also separate loudspeakers (GL 559).

The Philips cassette system is used on other machines, such as those of Elizabethan, Van der Molen, Dansette, Monogram, Standard, Loewe-opta, and Stella. The Van der Molen company, who announced their first tape recorder earlier this year (February issue, p. 97), have also produced a 10 W amplifier-loudspeaker unit, in addition to the cassette recorder. This latter uses hybrid circuitry—an ECL86 and transistors evidently being an economic proposition. (Output: about 3.5 W). The Elizabethan cassette tape recorder (L2612) supplies 5 W into a 10 in loudspeaker.

Brushless d.c. motor. An interesting feature of the new Grundig battery tape recorders is the brushless d.c. motor. This is used on the TK6L and the C100 cassette recorder. (The cassette system used by Grundig and some other European manufacturers, incidentally, is not the same as the Philips system). The circuit of the system is shown in Fig. 13. The BFY39 oscillator stage supplies energy *via* a second BFY39 to L4, which couples energy to either L1, L2 or L3 depending on the ferrite rotor position. Assuming L1 receives energy, the corresponding transistor will conduct and energize the field coil F1. This then rotates the rotor shaft, being in the form of a permanent magnet. Then rotation causes energy to be

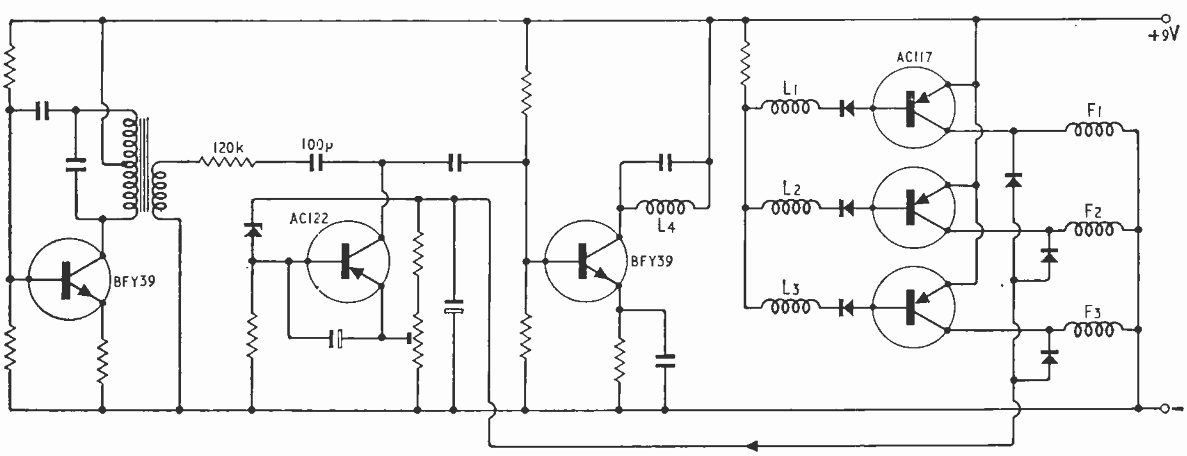


Fig. 13. Basic circuit of the brushless d.c. motor used in the Grundig TK6L and C100 tape recorders.

coupled to the next coil L2, thus energizing F2 and causing further rotation, and so on. The back e.m.f. induced in the two inoperative field coils is passed by diodes to a comparator circuit (AC122); this is then compared with a fixed reference voltage and a correction to the oscillator amplitude made if the speed is not correct.

Remote control unit (Fig. 14) is available for use with the Telefunken Bajazzo 3611. The remote unit controls gain and tuning for the f.m. band.

Stereo decoders. Since publication of the list of available decoders in the September issue, further decoders have come to our attention. These are listed on p. 502. Other manufacturers are, or will be, including decoders in their radiograms; such are Decca, Fidelity, Rank-Bush-Murphy, Philips and no doubt others.

The majority of decoders are transistor types—exceptions to this are Grundig, Eagle and Trio. The Eagle decoder uses a method not commonly found now in which a beam switching valve is used with two anodes. The 38 kc/s switching waveform is fed to two electron beam deflectors which switch the beam alternately between the two anodes, from which the *L* and *R* information is taken. Crosstalk correction is made in the cathode circuit of the valve.

One point about decoder circuitry is that there are a wide variety of circuits in existence, the circuit designer having considerable freedom. The number of transistors used varies from two to seven and some employ silicon transistors. The circuits generally use either the switching method or the envelope method of demodulation. (A typical three transistor circuit using a switching demodulator was given last month.) Often, in a seven transistor design, two are used as *L* and *R* channel amplifiers (sometimes the two emitters are coupled to give crosstalk correction in decoders using a 1:1 switching waveform—as mentioned last month), leaving five to do the work—of which one or two may be used in the indicator. The Arena switching decoder is a seven transistor design, the two a.f. transistors being used as a crosstalk connection circuit. The indicator uses two transistors and is operated by the sub-carrier.

When 38 kc/s oscillators are not used, which now seems quite common, some control is usually required to switch to mono when the pilot drops below a certain level and to maintain constant sub-carrier amplitude; an alternative method to that illustrated last month is to use the d.c. component of the "full-wave" doubler circuit to bias the following transitor on. Another method is utilise a separate 19 kc/s amplifier rectify the output and use the d.c. component to switch on the pilot amplifier, limiter or doubler. Both can be used, the d.c. component due

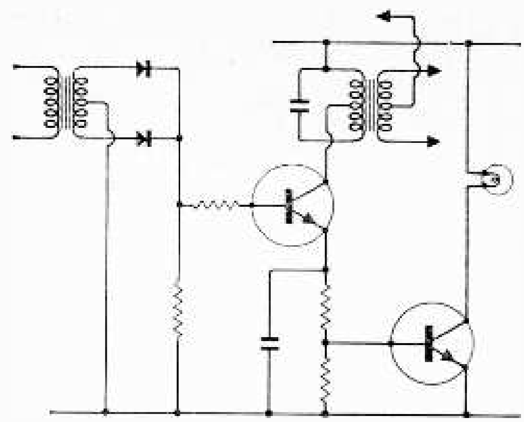
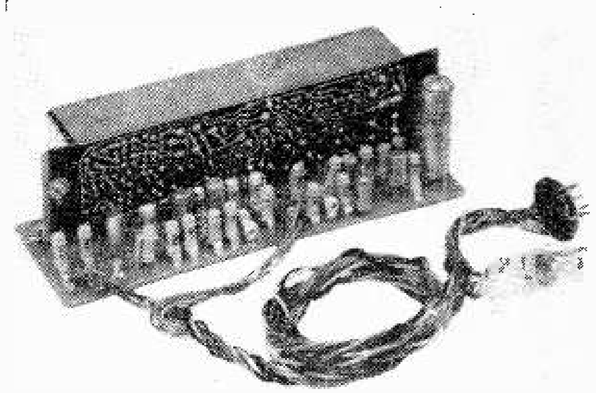


Fig. 15. Using the d.c. component from the 19 kc/s doubler diodes to switch the stereo indicator by direct coupling.



The Dynatron stereo decoder, which uses the new Mullard decoder plus additional circuitry for a pre-amplifier and indicator.

to the doubler diodes operating the stereo indicator (Fig. 15). Some decoders use transistors in the switching demodulator and not the more usual diodes. (Transistors are also used in a design published in these pages some time ago. This circuit is unconventional and the transistors are used bidirectionally.*

A new decoder (LP1167) was announced by Mullard and is intended for equipment manufacturers, but circuit details have not been released. This module is used in the Dynatron equipment with the addition of a beacon and a two transistor pre-amplifier. The distortion quoted is <1.1% and crosstalk given as >30 dB.

The amplitude of the 19 kc/s and 38 kc/s signals at decoder outputs does not seem to be frequently stated. Of course, these signals will be attenuated by the de-emphasis filters anyway and these should give attenuations of nearly 16 dB for the 19 kc/s tone about 22 dB at 38 kc/s. In some cases this attenuation may not be sufficient (e.g. for tape recording). It has also been suggested that the 19 kc/s signal could cause heating of transformers and loudspeakers in some instances, if the response extends up to 20 kc/s). Most decoders, however, do give greater attenuations than these, and for the Quad decoder for example (for which figures are available) attenuations of 36 dB and 40 dB at 19 and 38 kc/s are quoted.

Fig. 14. Remote control unit by Telefunken for f.m. tuning and gain control.

*Stereo decoder, Letters to the Editor, January, 1963, p. 27.

Some equipment seen at the shows

ALTHOUGH limitations of space prohibit more than a brief mention of some of the newest items of equipment featured by manufacturers at Earls Court and private shows, we hope the following summary will be of particular value to readers unable to attend the shows. Prices quoted are in most cases subject to the new 10% purchase tax surcharge.

Philips', Stella, Cossor

IN the range of radio sets introduced by Philips this year, there are several with interesting design techniques. One of them, the 248T "New Yorker" portable (14½gn), employs seven transistors and four diodes with a complementary output stage producing 250 mW from a 5×3 in 8 Ω loud speaker. A new design feature for fine tuning incorporated into this set is known as "Station Focus" (see p. 492). The wavebands covered are l.w., m.w. and s.w. (25 to 50m). The Philips L6X38T f.m./a.m. "Transworld" portable radio has 11 transistors and eight diodes powered by six 1.5 V batteries. Reception over the l.w., m.w., s.w. and v.h.f. bands is effected via twin eight-section telescopic aerials, an internal "ferroceptor," and a collapsible loop aerial. It has seven a.m. tuned circuits and 10 for f.m. with a common three-stage a.f. section feeding a 5 in × 7 in loudspeaker (5 Ω). A meter type tuning indicator doubles as a battery check at the push of a button, and some stabilization is incorporated to counter the distortion due to run-down batteries. The long wave band is sufficiently extended for reliable reception of beacon transmissions, and an azimuth ring is provided, calibrated in degrees to enable this set to be used for d.f. purposes. The rotatable metal stand can be locked at 90° and 270° positions. The wave ranges covered are: 725 to 2,000 metres (l.w.), v.h.f./f.m., and 11.1-580 m in five continuous ranges. The weight is 14½lb including batteries, and the price is 100gn. Also included in the new range of television and radio sets is the T-Vette, a mains/battery (12 V) 11-inch dual-standard transistor television receiver with self-contained adjustable aerials for both 405- and 625-line operation. Provision is made within the set for reception in fringe areas. There is also a new Philips mains operated four-track stereo recorder, two Philips radiograms, two Stella tape recorders, and a Stella radiogram.

Pye, Ekco, Ferranti, Invicta, Pam, Dynatron

PYE products include the "Seafarer" 1112 mains operated table receiver with long-, medium-, and short-wave bands. This set can be powered by 110-125 V and 200-250 V a.c. or d.c. making it useful for some marine applications. The Finlandia 1370 is a four waveband solid-state portable, with sockets for tape recording, personal earphone and external aerial. A stereophonic table radio the "Eleven-Eleven" is a mains operated transistor set complete with a matching extension speaker. The "Mastertouch Nineteen" 50/F is a 19-in transistor dual-standard television receiver that can be operated by a remote control unit, which will select channels, control brightness and volume, and includes an on/off switch.

The Ekco RP600 transistor mains operated portable record player produces 5 W output and provision is made for stereo reproduction by changing the pickup and plugging in a second amplifier/speaker. The SRG450 is a stereophonic radiogram with two channels reproducing treble frequencies, and a centre channel for the bass frequencies. An output of 11 W is obtained from this 23-transistor set, which covers 4 wave bands.

Dynatron, although part of the Pye-Ecko group, have maintained their individual approach to the design, both technically and aesthetically, of their equipment. The new eight-transistor portable (TP36 and 37) is an a.m. only receiver and can be used as a car radio (additional tuned circuits are switched in for car reception). The on/off switching is by push-button, these also being used for the bass boost and treble cut tone controls. Power output is 1 W.

A transistor stereo tape recorder using modular construction (STR1) is also announced. Wow and flutter are below 0.2% and the output is given as 3 W per channel. Bass and treble push-button tone controls and two moving-coil recording level indicators are some of the features (79gn).

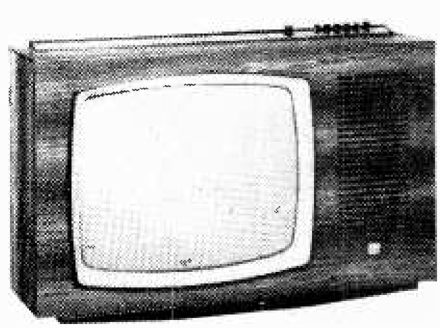
New Ferranti introductions are 19 and 23 in dual-standard television receivers (TC 1156 and 1160). Both are technically similar with as much as 60% of the circuit transistorized. A new 5+5 W stereogram is also announced.

K.B., R.G.D.

THE consumer products division of S.T.C. have introduced a series of five new television receivers under each of the trade names K.B. & R.G.D. In each range there is a 19-in and a 23-in version of two basic designs employing a standard chassis. In the R.G.D. range there is the 19-in RV215 (68 gn) and its 23-in version RV315 (75 gn), the 19-in RV217 (73 gn) and 23-in RV317 (82 gn). The fifth receiver in the range is the 23-in RV318 which has tambour doors (93 gn). The equivalent receivers in the K.B. range are KV015 (68 gn), KV115 (75 gn)—this set is also available for 405 lines only (70 gn), KV017 (73 gn), KV117 (82 gn) and KV119 which has tambour doors and also twin speakers (102 gn). All the sets in both ranges employ the "memomatic" fine tuner which obviates retuning when changing channels. A facility provided in the K.B. portable receivers (KR021 and KR022) covering the l.w. and m.w. bands is that by providing two scales (185-280 and 275-555 m) for the m.w. band tuning is simplified. A similar arrangement is provided in the R.G.D. (portable RR222).

Bush, Murphy

FOR ease of servicing the latest television receivers in both the Bush and the Murphy ranges employ a unit-plan or modular chassis in which all major sub-assemblies can be unplugged and removed from the main chassis for servicing or replacement. The two latest receivers in the Bush range are the 19-in TV145U (73 gn) and the 23-in T148CU (99 gn) which employ the same basic hybrid circuit (7 valves and 24 semi-conductors). The companion sets in the Murphy range



Murphy V179U "acoustic de luxe" receiver which has an 8 x 5 in loudspeaker.

are the V179U (73 gn), which has all controls on the top of the cabinet, and the Consolette (V173CU) which like its Bush counterpart has folding doors.

Bush introduced two new radiograms at the Show. The SRG95 (92 gn) all-transistor stereogram has an output of 5 W per channel. It incorporates an a.m./f.m. receiver which has provision for the addition of stereo decoder unit. It is 52-in wide and houses two 10-in and two 4-in speakers. The SRG 112 (72 gn) is a smaller radiogram with similiar facilities, but two speakers and 3 W output per channel. The latest Murphy stereogram (A882SR), costing 85 gn, has two 10-in speakers in the 46-in wide cabinet which also houses a three-band a.m./f.m. receiver.

Ferguson, H.M.V., Marconiphone, Ultra

NEW Thorn group 19-inch and 23-inch television sets are based on the Mk. II version of the 950 chassis, which is characterized, among other features, by e.h.t. of 20 kV. This, the makers claim, gives a 30% brighter picture and improved focus and contrast. Circuitry is hybrid. Ferguson, H.M.V., Marconiphone and Ultra all have 19-inch and 23-inch dual-standard table models, while H.M.V. and Marconiphone also make 23-inch console versions.

Another new chassis produced by this group is a 12-inch portable receiver, for 405-line transmissions only, intended as a low-priced second set (39½gn). All components (with the exception of the tuner unit and loudspeaker) of the basically valve circuit are mounted on a single printed-circuit board. The set appears as the Ferguson "Junior-12," H.M.V. "Imp," Marconiphone "Mini" and Ultra "Cub."

Ultra have a 25-inch dual-standard table model (6638) intended for group viewing in clubs, hotels, etc.

Recent transistor sound receivers include the Ferguson 3146 a.m./f.m. set which is similar to their 3148 "President" but is housed in a wooden case and has a swivelling stand. Price is 29gn. An addition to the range of radiograms is the "Stereo Major," type 3018, priced at 53gn.

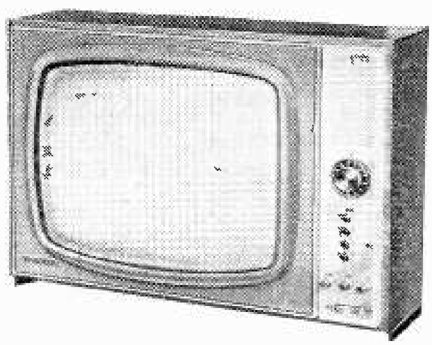
AERIALITE

A NEW range of wideband amplifiers for communal television and f.m. sound distribution has been introduced. Aerialite were also showing examples from their wide range of domestic and communal aerials. Their latest is a range of "co-polarized" aerials designed for use in locations where the polarization of the two stations in an area are in different planes.

ALBA

NEW models are the 243 a.m. portable, 312 and 339 record players, R18 and 19 tape recorders; 9008 f.m./a.m. radiogram and the T1195 television receiver.

The R18 is a four-track valve recorder giving 4 W output (about £30) and the R19 is a two-track transistor recorder (about £25). Both feature automatic recording level circuits.



Alba T1195 19-in receiver

The new television receiver is a 19in model similar to the recently released 23 in model (T1235). Loudspeaker size is 6×4 in. A transistor u.h.f. tuner is used; otherwise the receiver uses valves (68gn).

ANTIFERENCE

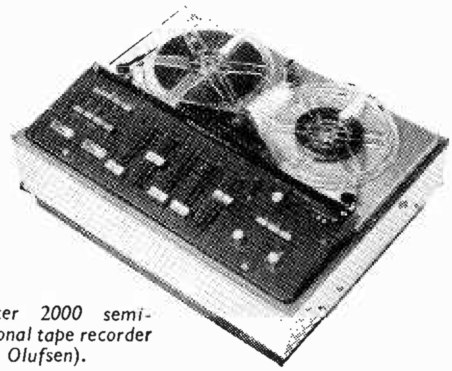
A COMPREHENSIVE range of u.h.f. and v.h.f. aerials for both indoor and outdoor use were exhibited. Improved u.h.f. aerials, with reference to wide bandwidth colour television reception, were featured. Accessories included masts and mounting equipment and a range of diplexers and triplexers.

ARENA

NEW receivers are the T1200, T2400FM, T2500F tuner-amplifier and T2500H. The last two use the same chassis as the new RG2500 radiogram. This a.m./f.m. chassis uses 25 silicon transistors and 18 diodes, and can supply up to 15 W per channel. The f.m. only T2400FM is similar to the T2500 series. The a.m./f.m. T1200 uses modular construction and varactor diode-tuned f.m. circuits (see p. 492) and costs 45gn. Another radiogram is the RG1900, which can be supplied with stereo decoder.

BANG AND OLUFSEN

FEATURES of the Beomaster 2000 tape recorder include such refinements as a built-in 4-channel mixer section with separate channel slider controls. Thus it is now possible



Beomaster 2000 semi-professional tape recorder (Bang & Olufsen).

to control independently the recording and playback levels on each stereo channel by separate sliders. There is one additional channel for variable sound-on-sound, or echo effects on recordings. Separate variable bass and treble controls are provided, and a high- and low-impedance switch is fitted, extending the scope of the radio and pickup inputs. Stereo head-set monitoring and microphone input sockets are provided. This instrument is available with two-track record and playback plus four-track playback facilities for four-track recorded tapes. There is also synchro playback for slide projectors and language teaching. Two versions are available, the 2000T, 139gn, and the 2000K, 135gn.

BELLING-LEE

DISTRIBUTION amplifiers for both the v.h.f. and u.h.f. bands and a wide range of aerials were featured. Among the former was a new hybrid v.h.f. amplifier (L1878) which takes advantage of the low-noise high-gain characteristics of transistors for the input circuits and the high launching voltage of valves in the output stage. The overall gain is 50 dB.

BLUE-SPOT, UHER

A NEW Blaupunkt stereogram—the Arkansas de Luxe—is available (126gn) and an improved version of the Valencia de Luxe (169gn). The latter is a five waveband tropicalized export radiogram with a large storage space which can accommodate a tape recorder. Both include Garrard record

(*Continued on page* 497)

changers. All radiograms in the range are suitable for stereo reception when fitted with a Blaupunkt decoder. A new Uher high-quality tape recorder is the Pilot 1000, a battery operated machine. A single speed of 7½/n/sec is used and the recorder gives "lip" synchronization with cine cameras. The price has not yet been announced.

BUTOBA

A TAPE recorder for use in cars is being marketed in the U.K. by Denham & Morley. The model (ATB70) is used on many 1966 Ford cars in the U.S.A. A tuner (m.w.) can be inporated if desired, and output power (1·5 W) can be increased by a 6 W amplifier. Endless tape cassettes are used on the recorder. Tape speed is 3 in/sec. Automatic recording level circuitry is included and the cost is 59 gn.

DANSETTE, PERDIO

THE Dansette Transit is a slim, lightweight disc player, and is fitted with the compact UA50 record changer. An unusual feature is the dual l.p. styli instead of the more common l.p.-78 combination. Transistor line-up is 2×OC75 and 2×AC128 giving an output of 1 W. (25½gn mains/battery, 9½gn mains only.)

Dansette also produce a transistor cassette tape recorder (JTR 909) which takes the Philips cassettes (see p. 492), 26 gn.

The first Perdio tape recorder is the Shannon using the BSR deck. The recorder costs 24 gn (four track), and 22 gn (two track).

DECCA

THREE new radiograms were shown—all of which may be fitted with stereo decoders. They are the SRG 717, 727, and 737. The 717, priced at about 90 gn, has a Decca DP6 autochanger and a Sonotone 19T cartridge. The output stage delivers 3 W into each of two 8 in 20 Ω loudspeakers. The other two models are "luxury" items. The 727 giving 10 W per channel, and the 737 20 W per channel. This latter model uses the "ffss" pick-up and the acoustic lens.

No new television receivers were announced, and the current range includes three dual standard sets. A preproduction colour receiver was also seen. The three current models are notable in that a more than usual amount of effort was devoted to the sound receiver section, enabling advantage to be taken of the higher-quality potential of television sound broadcasts.

DERRITRON

THE Chapman division of Derritron announced two tuners which are fitted with decoders. The FM1000A v.h.f. tuner has a sensitivity of 5 μV for 20 dB quieting. The tuner type FM1005A is an a.m./f.m. type with the f.m. and a.m. sections separate. An r.f. stage is included in the a.m. section giving a sensitivity of 2 μV for 20 dB s/n ratio.

ELIZABETHAN

TWO new tape recorders are designed to take the Philips cassettes—LZ9102T (27 gn) portable and LZ612 (45 gn). The last model, includes a cassette storage compartment. Output is given as 5½ W into a 10 in loudspeaker. The integrated stereo amplifier, LZ220, was exhibited at the Audio Fair and costs 39 gn. Output is given as 10 W per channel. A portable stereo tape recorder (LZ711) includes many facilities, such as superimposition, three speeds, two recording level indicators, and so on (75 gn). The Elite models are low price mains recorders of all-wood construction. Two- and four-track models are produced and are single speed only (3¾ in/sec) is used (23 and 25 gn).

ELPICO

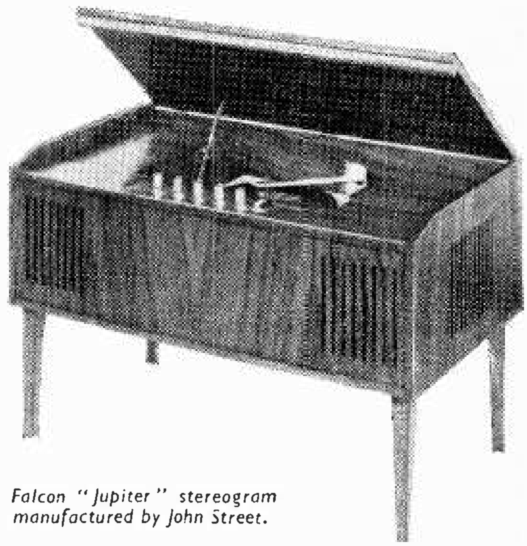
LOW-PRICED car radio receivers shown by Lee Products included the CR303 (12 gn) and the CR655 and CR675 (14 gn). Model RP690 transistor record player costs about £21. Other equipment shown includes valve amplifiers, p.a. apparatus and inexpensive transistor portables.

FIDELITY

A NEW transistor portable is the Comet, originally named Constellation. This covers the long-, medium- and short-wave bands, and functions satisfactorily when battery voltage has dropped from 9 to 6 V. Bandspread is provided at the h.f. end of the m.w. band and the cost is 14 gn. The valve Playtime tape recorder is available in two- and four-track versions costing, respectively, 25 and 27 gn. Three speeds are provided and at the lowest speed (1⅞ in/sec) wow and flutter is less than 0·35 %. (At 7½ in/sec this is reduced to 0·15 %). Power output is 3 W into a 7×3 in loudspeaker. The Playmaster two- and four-track recorders use transistors and cost 22 and 25 gn. Output power is lower—2 W—and the deck is 3¾ in/sec only.

FALCON

ONE of several stereophonic record players in the Falcon range is the Jupiter model (49½ gn). The four speakers are housed in sealed wool-filled chambers, two 6½-in bass units facing sideways and two 3-in treble with crossover, at the front, producing an output of 9 W r.m.s. with a distortion of less than 3%. A B.S.R. UA 30a turntable is fitted with a low mass pick-up arm and a Sonotone 9 TA-C cartridge and diamond stylus. Input sensitivity is 50 mV into 1·5 MΩ for 9 W at an output impedance of 4 to 5 Ω.



Falcon "Jupiter" stereogram manufactured by John Street.

GRUNDIG

ONE Grundig tape recorder employing the "brushless" d.c. motor developed by Grundig for battery operation is the C100. As well as solid state circuitry for eliminating brushes and commutators, associated circuits correct deviations in motor speed (see p. 493). The C100 is a portable cassette tape recorder that will operate with Grundig tape cassettes; the DC 90 cassette for example will give a record and play back time of 1½ hours at a tape speed of 2 in/sec. It has two compensating flywheels to counteract distortion when the machine is operated in transit. Conversion to mains operation is achieved by use of a mains power pack. Complete with microphone and one tape cassette it weighs approximately 7¾ lb and costs 39½ gn.

HACKER RADIO

AMONG the products displayed was the Autocrat RP33 (18½ gn), a nine-transistor l.w./m.w. portable radio with an output of 1 W. Bandpass tuning circuits with higher selectivity offer improved separation of adjacent stations. A change-over aerial circuit is incorporated that permits switching from a ferrite rod aerial to a separate second aerial coil for coupling to a car aerial. The loudspeaker is 6×4 in, and the set is powered by two PP9 batteries.

J-BEAM

THE recently introduced "Parabeam" u.h.f. aerials consist of a skeleton slot and matching reflector unit with director elements, and is claimed to give an improved polar diagram and greatly increased gain. There are 15 indoor and outdoor models ranging from a set-top combined v.h.f./u.h.f. aerial to a double 18 element stack (2PBM18) for fringe area reception.

KÖRTING

MODELS shown by the U.K. agents Europa Electronics were the 400, 600 and 1000 stereo tuner-amplifiers, giving output powers of 10, 15, and 25 W per channel, respectively. One of their amplifiers is said to have a response extending up to 100 kc/s. Decoders are available for stereo reception and these are included in current stereo radiograms.

LABGEAR

A PROTOTYPE crosshatch and dot pattern generator for installing and servicing colour television receivers was introduced. The model shown was for 625 lines but the production model will be a 405-625-line version. There are only three controls (a) function selector (crosshatch or dot pattern), (b) adjust r.f. carrier frequency, and (c) modulation level control. The three colour traces are superimposed to produce a lattice of horizontal and vertical lines which form the crosshatch pattern. The dot is derived by intensifying the brightness at the intersection of the grid lines. Other new products shown by Labgear were a portable television signal strength meter (weighing only 2¾lb and covering all four bands) and a range of communal aerial amplifying equipment.

LOEWE-OPTA

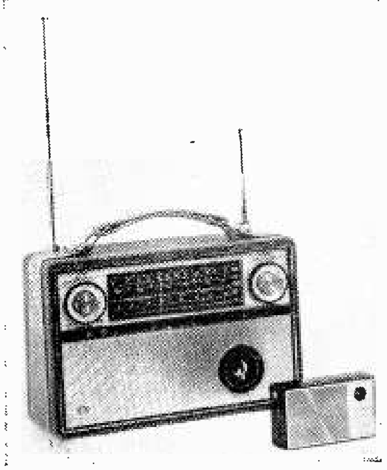
FOUR table receivers, four portables, a radiogram, a tuner-amplifier and a cassette tape recorder are included in the '66/67 range. Two of the table radios are hybrid designs, two or three transistors and three valves and three transistors and six valves being used respectively in the Venus-stereo and the Novella models. The former (59 gn) is provided with a stereo decoder. The portable receivers are mainly updated versions of last year's models.

The battery cassette recorder uses the Philips system and is the Optacord 450. The output power of this recorder is 1·8 W and operates from five 1·5 V cells (39 gn).

The stereo encoder (see "New Products," September issue) was also shown and costs £86.

MONOGRAM

THIS is a new name, introduced at the Show. It is the trade mark of the G.E. Company of America. Equipment shown ranged from a 3 gn transistor portable to a 369 gn f.m./a.m. radiogram. The World Monitor (P990) 17 transistor receiver, covering five wavebands (including v.h.f. and two of the s.w. bands), employs a.f.c. and is fitted with three aerials. Record players ranged from a 15 gn single player (V512) to a stereo portable model (V742) costing 69 gn.



Monogram "World Monitor" portable (42½gn) and its little brother which costs only 3 gn.

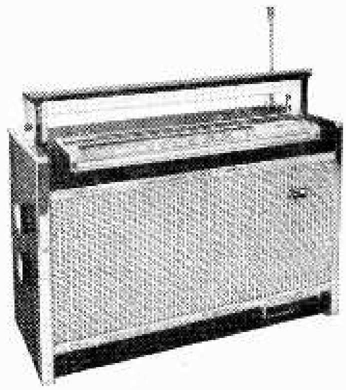
MULLARD

SHADOWMASK tubes (25 and 19 in), valves, semiconductors, a PAL delay line, integrated tuners, and scanning components, all for colour television receivers, were featured by Mullard. The new valves included the PL505 line output pentode claimed to be the highest-rated single-structure valve so far produced. It has a max. peak anode current rating of 1.4 A and "an absolute maximum" anode dissipation of 34 W. The PL802 video output pentode developed specifically for luminance amplifiers has a mutual conductance of 40 mA/V, an input capacitance of only 20 pF, a low knee-voltage and high peak-current rating.

Five additions to the Mullard range of transistor circuit modules for the domestic equipment market were introduced. They are the LP1172—a 1 W audio amplifier; LP 1166—single-tuned i.f. amplifier and mixer stage for a.m. receivers; LP 1159—double-tuned i.f. amplifier and mixer; LP 1164—a.m./f.m. intermediate frequency amplifier, with integral a.m. mixer, for mains and 12 V battery receivers; and LP 1165—a 6 V version of the LP1164.

PHILCO

PHILCO re-introduce themselves to the British domestic consumer market with a wide range of portable receivers



"Transglobe B480 mains/battery portable (Philco).

costing from £6 to over £90. One interesting model is the B480, Super Transglobe, mains/battery set manufactured in their Brazilian factory. With circuitry based on 14 transistors and five diodes, it covers the l.w. and m.w. bands plus the short-wave bands from 2.1 to 7.9 Mc/s with wide band-spread incorporated separately for 31, 25, 19 and 16 metres, and the v.h.f./f.m. band. "Turret" tuning is provided for ease of waveband selection. A "Magnecor" and a 5ft telescopic aerial are provided, as well as a spooled 19ft aerial (stored inside the set) for external use. A 9½in speaker produces an output of 0.75 W. Logging and time charts are contained at the rear of the set. The weight with six U2 (1.5 V) batteries is 13lb and the price is £93 19s 6d. The portable radio 14J65PL (made in Japan) covers the l.w., m.w. bands, the s.w. bands 3-22 Mc/s, as well as f.m. coverage from 88 to 108 Mc/s. A world time chart is displayed on the fascia, and there is a 3ft telescopic and swivelling aerial for s.w. and f.m. reception and a Magnecor aerial for the other bands. Input sockets are fitted for a car aerial, record player, and for mains operation via a battery eliminator. The price is 31gn.

PYGMY

THIS French manufacturer is represented in the U.K. by Europa Electronics. Of the three models featured, the Super 2001 is the most interesting. The transistor receiver is an a.m./f.m. type with 12 wavebands, and the a.m. and f.m. sections are completely separate. Price 69 gn. The other two models are inexpensive portable sets.

RADIONETTE

NOW represented in the U.K. by Denham & Morley, this Norwegian firm is known for its Discmaster 25-disc player, announced some time ago. The Quintet radiogram is capable of receiving stereo broadcasts and fitted with a Garrard 2000 turntable unit. Other products are portable and table receivers and a tape recorder using only one spool (49 gn). The Duet table radio includes separate bass and treble controls and covers the shipping and amateur bands (about 49 gn).

ROBERTS

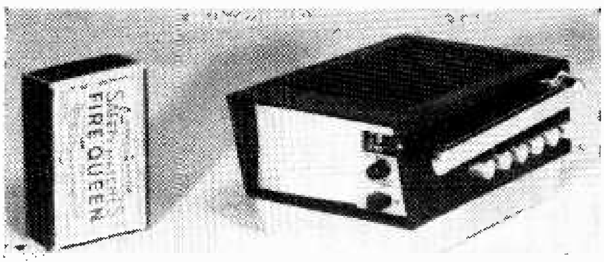
THE latest in the range of receivers from these portable specialists is the f.m./a.m. R700 (29 gn). Fourteen transistors and eight diodes are employed in this battery receiver which has separate chassis for a.m. and f.m. feeding into a common audio amplifier. A.F.C., which can be switched out to facilitate tuning, is provided on v.h.f. It has separate treble and bass controls, a 7 × 4 in loudspeaker, a telescopic aerial and is fitted with a turntable.

SCHAUB-LORENZ

THE most interesting item by Schaub-Lorenz was the music-centre. This is outstanding in that a wide magnetic tape stores programme material and the four-track tape head can be moved to any one of the 126 tracks. Each track lasts 22 min giving a total of 46 hours continuous playing time. Recordings can be made from the radio on the 5001 and from discs and radio on the 5005. At the end of each *recording* (not necessarily track), the mechanism automatically switches to the next track, actuated by a pilot signal. The bass loudspeaker on the equipment, incidentally, faces downward giving a wide distribution.

SINCLAIR

THE "Microvision" television introduced at the Show has a screen size of 2 in and weighs 10·5 oz with batteries. The 30 transistors are powered by 6 penlight cells, and total consumption is 450 mW including less than 100 mW for the tube heater. The magnetic deflection tube specially developed by 20th Century Electronics is just over 3 in long. The set receives all 13 channels in Bands I to III, and the



Sinclair "Microvision" receiver which weighs only 10.5 oz.

speaker is a 2 in piezo-electric transducer with an overall depth of less than $\frac{1}{4}$ in.

TELEFUNKEN

THE Bajazzo range of portable receivers (from 40 to 73 gn) is augmented with the Junior. The Bajazzo models are now fitted with the miniature i.f. amplifier as used on the Operette & Gavotte. New radiograms are the Bolero, Sonata and the Bayreuth. The f.m./a.m. Bolero will be available with decoder. Distortion is 1%, and output power 15 W (music); The Bolero Studio gives an output of 25 W (music) per channel. The Sonata has a similar specification. The Bayreuth Studio however gives a distortion of only 0·2%, and 25 W (music) output per channel. This may also include a stereo decoder, giving a crosstalk of −40 dB.

New tape recorders (shown previously at the Audio Fair) are the M401 cassette type machine designed for vertical and horizontal operation.

THORN-AEI

MAZDA introduced at the Show a new range of eight silicon planar transistors specially designed for a.m. and a.m./f.m. receivers. At present these are available for setmakers only. In addition to prototypes of their new colour television tubes, which are about to go into production, Mazda showed a new monochrome tube. It is the 12-in rectangular CME1201. The scanning voltage required for this 110° tube is reduced by the use of a 20 mm diameter neck instead of the normal 28 mm.

A new line output pentode (Brimar PL504) was announced. It has the same characteristics as the PL500 except that the anode dissipation has been increased from 12 to 16 W.

UNITRA

THESE Polish receivers, which are marketed in this country by Daltrade, include the new DGS 302 stereogram (£76 13s) with an a.m./f.m. receiver. The output is 8 W per channel feeding into two 10 × 7 in loudspeakers. The receiver covers l.w., m.w., v.h.f./f.m. and 6 to 22 Mc/s in two bands. The DGS 302 is $54\frac{1}{2}$ in long and has space for a tape recorder.

VAN DER MOLEN

THIS new company's first product was the VR4 tape recorder, designed for vertical operation (p. 97 February issue). A less expensive version (VR7) is now announced which costs 39 gn. It is a three-speed recorder designed for vertical operation with the 8 in elliptical loudspeaker adjacent to the tape deck. The deck and styling is similar to the VR4. Output is given as 3·5 W. Another new model is the VR9 which is designed to take the Philips cassettes. The machine is a mono type but addition of a separate loudspeaker allows stereo operation (35 gn). Both of the new models use hybrid circuitry—three silicon transistors and an ECL86.

A loudspeaker enclosure with a built-in amplifier is also announced and called the Sonic 10. The unit can be connected to any equipment providing an output of 120 mV or 1 mW at 3, 8, 15 or 600 Ω. Price is $19\frac{1}{2}$ gn.

A tape deck and record/playback amplifier mounted on a teak plinth is also available which gives an output of 1 V at 600 Ω. (VR5).

VERITONE

ONE of the portable receivers shown by Veritone covers marine and aircraft bands in addition to the m.w. and f.m. bands. (NA5018, about 33 gn). The TR777, portable receiver uses seven transistors and costs only $4\frac{1}{2}$ gn. A new stereo amplifier, loudspeakers and turntable unit were announced. The amplifiers provide 5 W each into two bookshelf loudspeakers. Distortion is given as 1%.

Japanese Receivers

AKAI

AN impressive array of professional/amateur recorders, accessories, speakers and microphones are available, with the prices of recorders starting from approximately £29 and rising to just over £250. All but three recorders are stereo/mono. The X-355D (£251) is a 4-track stereo/mono machine for record and playback, at speeds of $3\frac{3}{4}$, $7\frac{1}{2}$, and 15 in/sec. It has four heads, and the motors include a hysteresis synchronous 3-speed motor for the capstan drive, and two 4-pole induction motors for fast forward and rewind speeds. Output is 25 W (music power) per channel from a solid state amplifier, and a maximum 20 W per channel of undistorted power output. The frequency response is 30 c/s to 24 kc/s ± 3 dB at $7\frac{1}{2}$ in/sec. Maximum reel size is $10\frac{1}{2}$in. Special sound effects facilities including reverberation are standard, and there are also facilities for recording f.m. multiplex stereo signals. Model 707 is a two-track mono record and playback recorder and 707s is a four-track mono recorder, and both models have the following features: $3\frac{3}{4}$ and

7½ in/sec tape speeds, a four-pole induction motor, a frequency response of 30 c/s to 12 kc/s±3dB at 7½ in/sec. Maximum power output is 6 W, and the maximum reel size is 7in.

CROWN

TWO new transistor tape recorders were introduced. The CTR3000 is a two-speed battery/mains recorder and the CTR3050 has a built-in mains adaptor (19 gn). The CTR5450 will take 5 in spools, is supplied with a telephone pick-up and costs 29 gn. Other models feature a voice operated switch, a combined portable disc and tape player, combined portable tape recorders with a.m. and f.m. receivers. An f.m./a.m. table receiver is also available which will receive stereo transmissions.

A 4½ in television receiver was also shown. This is combined with an a.m./f.m. sound receiver and the set measures about 4×10×8½ in.

HITACHI

THE Hitachi range includes portable, table and car radio receivers. Model KH-920L is the most expensive set, costing 30 gn. This includes medium, short and v.h.f. wavebands. An output socket is also provided for multiplex stereo, this being a rare facility on portable sets at the present time. A short-wave adaptor (WM-20) is available covering nine wavebands and can be used in conjunction with any car radio model. (14 gn).

ISHIKAWA

THIS Japanese manufacturer, represented by Denham & Morley, specializes in novelty receivers. Sets are available in small liquor bottles, a bowling ball and pin, a car wheel and in other forms. Prices vary between £8 and £16.

NATIONAL

RECEIVERS shown were the R1000, shown last year and with automatic motorized tuning, the R807L, RF820, RF610 and the T100. The R807L is unusual in that a roller is used in place of the tuning knob. (£10 13s). The RF820, which includes the f.m. band, is one of the two portable receivers known to us with a multiplex stereo output socket (£18 13s). Another a.m./f.m. portable is the RF610 at £17. The T100 has two versions with different selections of waveband. The a.m. only version (T100D) incorporates a ceramic i.f. transformer improving selectivity. Output power is 1-2 W (£41 10s).

The tape recorders shown were the 1025, 1055, 1585 and 3005—all prefixed with RQ. The 1025 is battery powered whereas the 1055 has automatic switching for mains or battery operation. Model 3005 has, unusually, a neon recording level indicator and the 1585 includes a voice-operated switch and automatic reversing. All are two-speed mono machines.

REALTONE

AVAILABLE through Winter Trading Co. the latest sound receiver is the 3414 portable model (18½gn). Other models are the 3002 at 16½gn which incorporates m.w., v.h.f. and trawler bands. A desk set with penholders costs 7½gn. Models 4597, 4541 and 4525 are four-waveband receivers, each differing in the wavebands covered. The 4525 includes a b.f.o. All are fitted with fine tuning controls. The TR2663 has four f.m. bands (including an aircraft ground control band) five s.w. bands, m.w. and l.w.

SANYO

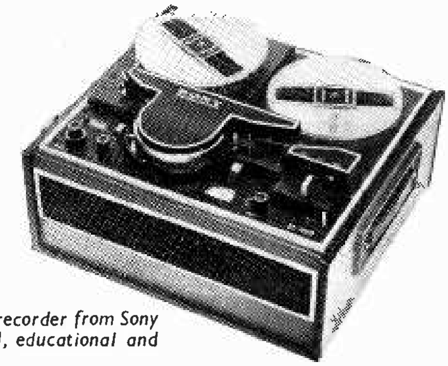
AN 11 in dual standard television receiver was shown. This includes 13 transistors and is powered by rechargeable batteries. A video-tape recorder using ½ in tape and rotary head was also shown. Tape speed is 9½ in/sec giving up to 60 min recording time. A video camera, monitor and remote control switch are also available.

SHARP

RECEIVERS varying in price from £19 to £41, including the Transcontinental mentioned last year, were shown. One of the portables (FW-26L) gives an output power of 2-5 W and is available with a car mounting bracket. Other sets include up to three s.w. bands. The ATR-924 model will provide up to 5 W to an external loudspeaker.

SONY

THE Sony video-tape recorder is supplied complete with a monitor, which can be used as a normal 405-line receiver. The estimated price is 351gn. This instrument uses ½-in tape at a recording speed of 7½ in/sec. Although many professional video recorders employ the "transverse scan" prin-

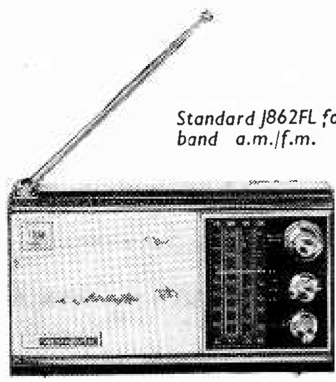


A video-tape recorder from Sony for industrial, educational and domestic use.

ciple for recording, the Sony recorder uses a "helical scan" in which the tape passes around the heads in a helix. This allows a maximum amount of signal information to be recorded on a minimum area of tape, and permits the synchronizing signal, video and audio signals to be recorded on the one ½in tape. A television camera with lens and tripod is available at 125gn.

STANDARD

TWO new tape recorders were shown by the U.K. agents Denham & Morley. The SR-300 is a two-speed portable mains/battery recorder and the SR-100 is a cassette recorder



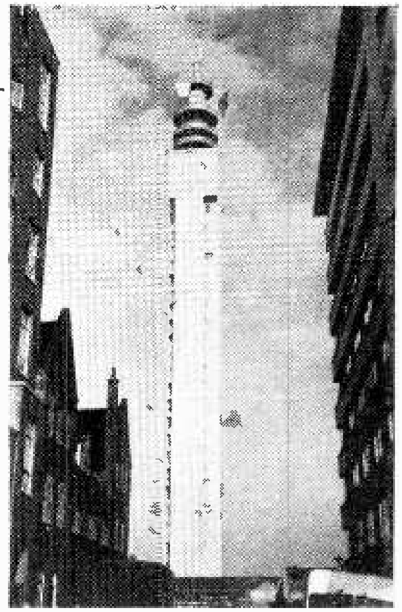
Standard J862FL four waveband a.m./f.m. portable.

using the Philips system (1⅞ in/sec). Portable radio receivers are the J-862FL, with fine tuning control operative on all wavebands (about £27), the J-820F and the Q-771FL; all a.m./f.m.

TRIO

TWO stereo tuner-amplifiers suitable for multiplex stereo reception are available from the U.K. agents—Winter Trading Co. These cost 89 and 99 gn and both use valves. A tuner only is also available for 49gn.

WORLD OF WIRELESS



Birmingham Post Office Tower—Four horn radiators, each 27ft tall, 14ft wide and weighing about 1.5 tons, have been supplied by G.E.C. (Telecommunications) for the 500ft Birmingham Tower which is the first major link between the London Post Office Tower and the North.

Radio Show Policy

THE question on the lips of some exhibitors at, and visitors to, the Earls Court TV & Radio Show (August 22-26) was "is this the last?" The reason being that by comparison with earlier public shows the attendance at this "trade-only" show was very small. However, when the organizers announced the attendance figures, showing a cumulative total of nearly 23,000, they added "with regard to the 1967 International Television and Radio Show, the majority opinion in the industry appears to be in favour of a show which would be open to the public but that, due to the great success of the 1966 trade show, three or four days should be reserved exclusively for the trade."

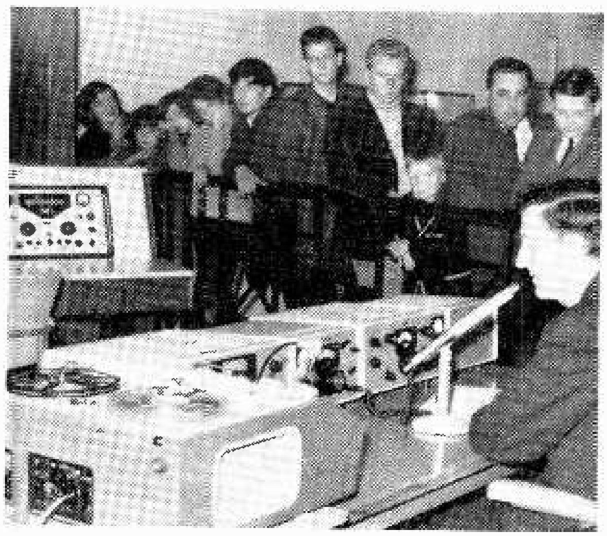
We agree wholeheartedly with their proposal to hold a combined trade-public show and it is interesting to note the order of precedence in the announcement—"open to the public, but that . . . three or four days should be reserved exclusively for the trade." Comparative figures for the past two public shows are: 1962, 350,000; 1964, 122,000 (both of 12 days' duration).

Although we question the advisability of holding an annual show the proposed introduction of colour television next autumn would perhaps make it an opportune time to hold the next show.

C.E.I. Common Examination

SIX months ago the Council of Engineering Institutions issued details of Part 1 of the common examination for corporate membership of the fourteen constituent institutions; including the I.E.E. and I.E.R.E. Part 1 consists of six compulsory subjects in preparation for the much more rigorous Part 2, details of which have now been issued. Part 2, which is at the standard of a degree of a U.K. University, consists of one compulsory paper called "The Engineer in Society" and five others to be selected from 37 optional technological papers. Subjects under the "electrical, electronic and information group" include electrical energy, electromagnetic fields and circuits, electronics, communication engineering, electronic engineering, computer engineering, radar and microwave engineering, and radio and television engineering.

It is stated that exemption from the whole of the Council's examination will be allowed where academic qualifications of equivalent or higher standards are approved. The first Part 2 examination will be held in April 1968.



***Science Museum** amateur transmitting station (GB2SM) operated by G. C. Voller, which was recently used to maintain a link with Tristan da Cunha during the island's celebrations.*

Communications Exhibition

THE annual exhibition sponsored by the Radio Society of Great Britain is again being held at Seymour Hall, Seymour Place, London, W.1, from October 26th-29th. Officially known as the International Radio Communications Exhibition, it will be open daily from 1000-2100; admission 3s. As will be seen from the list of exhibitors below, the Royal Navy, Royal Signals, G.P.O., and various amateur organisations are supporting the exhibition with special features.

Ad Auriema
Ayres, Brian J., & Co.
Amateur Radio Mobile Society
Amateur Tape Recording Magazine
Baden-Powell House Scout Amateur Radio Group
British Amateur Radio Teleprinter Group
British Amateur Television Club
Contactor Switchgear (Electronics)
Daystrom
Enthoven Solders
General Post Office
Grampian Reproducers
Green Electronic & Communications
Imhof
J-Beam Aerials
K.W. Electronics
L.S.T. Components
Multitone Electric Company
Northern Polytechnic
Partridge Electronics
P.F. Ralfe Radio
Philadelphia Electronics
Radio Society of Great Britain
Royal Navy
Royal Signals
Salford Electrical Instruments
Seymour, Peter
Short Wave Magazine
Standard Telephones & Cables
Weller Electric Corporation
Wireless World
Withers (Electronics)

Modifications to the BBC-2 aerial made necessary by the "forthcoming introduction of a colour service" are being carried out at Crystal Palace. Until about the end of the year it will be necessary for the e.r.p. to be somewhat reduced, and on some occasions it may not be possible to radiate the normal daytime test card transmissions. As the relay stations at Hertford and Tunbridge Wells pick up the Crystal Palace transmissions, these stations will be off the air at the same times.

OUR COVER

THE room setting illustrated on this month's cover was photographed at the Design Centre, Haymarket, London. The equipment shown is the Pye 1108 a.m./f.m. receiver, Murphy "A-Major" record player and Ferguson "Junior 12" portable television receiver.

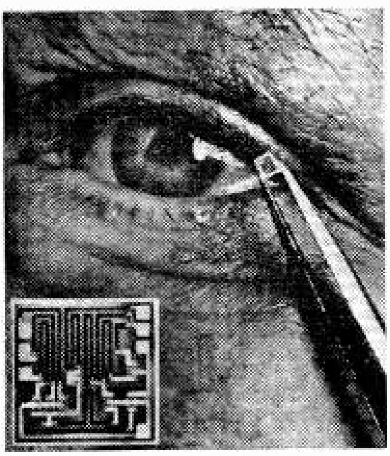
Subscription Television for Sheffield.—Pay-TV Ltd., who started a pilot scheme for a pay-as-you-view television service in the Southwark and Westminster areas of London several months ago, are to open a similar service in Sheffield in November. Pay-TV was the only company which accepted the P.M.G's invitation to introduce pilot schemes in London and provincial towns. It will be on the outcome of these tests over a period of three years that the Government will decide on whether or not subscription television will be permitted as a regular service.

Cabinet Styling Exhibition.—The tenth International Exhibition of Cabinet Styling Accessories organized on behalf of the British Radio Equipment Manufacturers' Association, by Radio Industries Exhibitions Ltd. is being held at the Hotel Russell, London, W.C.1, from September 27th to 29th. Admission is free and further particulars are obtainable from R.I. Exhibitions, 49 Russell Square, London, W.C.1.

Colour Television Engineering.—A course of 24 lectures covering the basic engineering requirements for colour television (systems, receiver design, test equipment, etc.), will be given on Monday evenings at the Northern Polytechnic, Holloway Road, London, N.7. The course begins on October 3rd (fee £2). The college is also conducting colour television servicing evening courses on Tuesdays and Fridays, beginning September 27th and a similar part-time day course on Tuesday mornings and evenings, also from September 27th.

Thyristor Applications.—A six-lecture course on Thursday evenings commencing October 13th is being conducted at the Hendon College of Technology, The Burroughs, London, N.W.4 (fee £2 5s). A 9-lecture course on computing techniques for industrial applications (fee £2 15s) begins on Monday evening October 10th.

Borough Polytechnic.—We have been notified of the following courses during the current session: Digital circuit techniques, five Wednesdays (all day) from October 5th (fee £7 7s); laboratory courses in pulse circuits and digital circuits on Friday afternoons from September 30th (fee £2 10s); and an evening course of ten lectures covering an introduction to transistor theory and applications on Tuesdays from October 4th (fee £2 10s).



Smaller than the pupil of a human eye, *an integrated semiconductor gating circuit manufactured by Telefunken AG. measures only 1.1 mm².* *On the microscopic surface are three inputs and a driver stage with 15 components. The integrated circuit inset in the bottom left hand corner is magnified nearly 20 times.*

Twickenham College of Technology.—In addition to the regular part-time courses detailed in the College Prospectus for 1966/67 there is a 12-lecture evening course on the fundamentals of semiconductor devices which begins on September 26th (fee £4), and a ten-lecture evening course on the analysis of non-linear control systems beginning on October 5th (fee £3).

Five instrument manufacturers are collaborating to present a two-day exhibition of their products in Cardiff, Bristol and Southampton. The firms concerned, Advance, Airmec, Avo, Muirhead and Wayne Kerr, are exhibiting at the Welsh College of Advanced Technology, Cardiff, October 13th/14th; Arno's Court Hotel, Bristol, October 17th/18th; and Cotswold Hotel, Southampton, October 20th/21st.

Grundig (G.B.), Ltd. are holding a trade-public show in the provinces during September/October. It will be at the Hotel Metropole, Leeds, September 28th/29th; Victoria Hotel, Nottingham, October 12th/13th; and Hawthorns Hotel, Bristol, October 25th/26th.

Last Month's Cover:—We omitted to give details of the photograph on the front cover of the September issue. It

is of the new mast at the Winter Hill, Lancs., station of the I.T.A., and the glass-fibre cylindrical top section houses the BBC-2 u.h.f. aerial. The lattice section is for BBC-1 and I.T.A. Band III aerials which will also be enclosed in a 12ft diameter glass-fibre cylinder. The complete 1,065ft length of this mast erected by British Insulated Callender's Construction will then be cylindrical.

Stereo Reception

SINCE publication of the list of available stereo decoders in the September issue (p. 448), further decoders have come to our attention. These are given in the list below.

A.E.G. (Gt. Britain) Ltd. (Telefunken), 27 Chancery Lane, London W.C.2 (available shortly).
Adler, B. & Sons (Radio) Ltd. (Eagle), Eagle Works, Coptic St., London W.C.1 (about £10 6s.).
Armstrong Audio Ltd., Warlters Road, London N.7.[1]
Bosch Ltd. (Blaupunkt or Blue Spot), 205 Great Portland Street, London W.1 (£9 9s.).
Dynatron Radio Ltd., St. Peters Road, Maidenhead, Berks. (£8 8s.).[2]
Europa Electronics Ltd. (Körting), Howard Place, Shelton, Stoke-on-Trent, Staffs. (£9 9s.).
Saba Electronics Ltd., 3 Eden Grove, London N.7 (£15 15s.).

1. It is regretted that due to a typographical error in the list in the September issue the price of the M5 decoder was given as £4 10s instead of £14 10s. For the tuners referred to in the footnote, decoder type M12 is required.
2. Model SD2 is intended for current radiograms and model SD3 for 1965/66 models bearing suffix "S".

A valuable service is being offered by Motion Electronics Ltd., of 39 Pelham Road, Gravesend, Kent, who undertake to convert high quality (only) tuners for stereo reception. The service includes realignment, addition of a decoder and preparation of performance figures of the converted receiver. Interested readers should send full details of their tuner in order that an estimate can be given.

PERSONALITIES

J. A. Ratcliffe, C.B., C.B.E., F.R.S., the new president of the I.E.E., received the Institution's Faraday Medal earlier this year "in recognition of his extensive researches on the physics of the ionosphere and of his studies on the propagation of low-frequency radio waves." Mr. Ratcliffe was from 1960 until his retirement in February this year director of the Radio & Space Research Station of the Science Research Council at Slough, Bucks. Except for the war years, when he was at T.R.E., he was at Sidney Sussex College, Cambridge (where he divided his time between teaching physics and research work on radio propagation) from his graduation in 1927, until his appointment to Slough, in 1960. While at T.R.E. he formed the Post-Design Service which converted experimental gear into serviceable radar equipment for the R.A.F. Mr. Ratcliffe, who is 64, was appointed chairman of I.E.E. Electronics Division on its formation in 1962.

J. A. Ratcliffe

P. A. T. Bevan, C.B.E., the 1966-7 chairman of the Electronics Division of the I.E.E., was the first chief engineer of the Independent Television Authority. Mr. Bevan was released from this post six months ago but is remaining with the Authority as consulant engineer. Before joining the I.T.A. in 1954 he was for 20 years with the B.B.C. where he was latterly a senior member of the planning and installation department of the Engineering Division. After graduating at Cardiff University he was for three years a graduate apprentice with B.T.-H., now part of A.E.I.

A. J. de Q. Colley, B.Sc., who joined the Gresham Lion Group at the end of 1965 to take charge of development and marketing of new products, has been promoted to commercial manager of Gresham Lion Electronics Ltd. He studied at Faraday House Electrical Engineering College, and was a postgraduate student at Southampton University and Imperial College. He was at one time in the Guided Weapons Branch of the Ministry of Aviation.

F. Winston Reynolds, A.M.I.E.R.E., founder and one-time chairman and managing director of Winston Electronics Ltd., has returned to electronics after a three-year interval by becoming chairman of Downham Electronics Ltd., Downham Market, Norfolk. The company was formed two years ago by **J. N. Hawkins** (32) who is managing director. After three years with R.E.M.E. Mr. Hawkins joined Winston Electronics as an electronics engineer and production executive which he left to form his own company to manufacture medical and electronic instruments.

R. J. Clayton, O.B.E., M.A., F.Inst.P., M.I.E.E., has been appointed managing director of G.E.C. (Research) Ltd. and will remain on the board of G.E.C. (Electronics) Ltd. of which he has been managing director since 1963. He joined G.E.C's Research Laboratories (now the Hirst Research Centre) in 1937 and was appointed manager of the group of applied electronics laboratories in 1958. Mr. Clayton was for two years general manager of G.E.C. (Electronics) Ltd., before becoming managing director.

R. J. Clayton

J. Bell, B.Sc., F.Inst.P., who joined the G.E.C. Research Laboratories in 1929, and since 1961 has been managing director of the M-O Valve Company has relinquished this position and joined the board of G.E.C. (Electronics) and become managing director of the company's aerospace and defence division. Mr. Bell was manager of the telecommunications division of the G.E.C. Research Laboratories from 1953 until his appointment as manager of the laboratories in 1958. He was recently elected chairman of VASCA.

T. R. Firth has been appointed general manager of EMI Electronics Ltd., Wells, Somerset. He joined EMI in 1951 and until 1960 was engineer-in-charge of various developments including telemetry for guided weapons, supersonic frequency underwater listening equipment and vibrator spectrum analysis. He was then promoted deputy chief engineer at Wells, with prime responsibility for research and development in military projects, until his appointment a few months ago as deputy general manager. Mr. Firth received a diploma in electrical engineering from the Bradford College of Technology in 1933, and spent ten years in the G.E.C. Research and Development Laboratories. During the war he held a commission in the Royal Corps of Signals and was concerned chiefly with the installation of long-distance communications networks in the Middle East.

John D. Clare, M.Sc., M.I.E.E., director of guided weapons research and development (air) in the Ministry of Aviation from 1960 to 1962, has been appointed vice-president of Raytheon of America and deputy general manager of Raytheon Europe, with special responsibilities for the European operation of the company outside Italy. Mr. Clare will be responsible for the A.C. Cossor group and the Sterling Cable Company in England, Sorensen in France, Sorensen A.G. and Transistor A.G. in Switzerland and Raytheon A.G. in Copenhagen. For the past two years, he has been vice-president and technical director of I.T.T. Europe, prior to which he was managing director and director of research at Standard Telecommunications Laboratory at Harlow. Mr. Clare, who is 46 and a graduate of Birmingham University, was a senior engineer with Sobell Industries from 1945 to 1950. He then went to R.R.E., Malvern, for five years where he was concerned with the development of radar and missile systems.

J. D. Clare

Douglas Stevenson has been appointed executive director of the Components Group of Standard Telephones and Cables Ltd., comprising the eleven electronic-components manufacturing divisions of the company and employing some 7,000 people in 15 factories. Mr. Stevenson, who is 40, joined the company in 1955, initially with K.B., and later became manager of the Components Division, Paignton. In 1962, he was appointed manager of the

D. Stevenson

Components Division of ITT Standard SA, Brussels. He returned to the U.K. in 1964 to become manager of S.T.C. Components Marketing Division and under a year ago succeeded P. H. Spagnoletti as manager of the Components Group.

Dr. E. F. de Haan, assistant director of the Philips Research Laboratories, Eindhoven, who is well known for his work on the Plumbicon tube, is to receive the David Sarnoff Gold Medal of the U.S. Society of Motion Picture and Television Engineers. It will be recalled that Dr. de Haan recently received the Geoffrey Parr Award of the British Television Society on behalf of the team concerned with the development of the Plumbicon tube.

S. M. Bozic, a 39-year-old Yugoslav employed as a group leader in the line systems laboratory of G.E.C. (Telecommunications) Ltd., Coventry, has been awarded the first industrial-based Doctor of Philosophy degree of the new University of Aston, in Birmingham. The award is for research work on the fluctuations of characteristics in semiconductors carried out during a part-time course under Dr. C. S. Bull, reader in physics (physical electronics) at the university—which was then the College of Advanced Technology. Mr. Bozic graduated at Belgrade University in 1951 with a degree in engineering, and then spent two years as assistant to a professor in the electrotechnical faculty, carrying out research into the design of radio receivers and electronic measuring instruments. In 1954 he joined a West German telecommunications firm, as a graduate apprentice, and after a year, rejoined the university to continue his research for a further two years. He has been with the G.E.C. since 1957.

Dr. J. B. Adams, C.M.G., F.R.S., director of the Culham Laboratory of the U.K. Atomic Energy Authority and for the past year controller in the Ministry of Technology, is to become a full-time member of the Authority from October 1st. Dr. Adams, who is 46, worked on the development of centimetric radar at the Telecommunications Research Laboratory throughout the war. From 1946 to 1953 he was working on the design of the 110-inch diameter cyclotron at the Atomic Energy Research Establishment, Harwell. For six years prior to his appointment as director of the Culham Laboratory he was working with the proton and synchrotron group of the European Council for Nuclear Research.

Consequent upon the death of B. E. Talbot (see below) **E. A. W. Spreadbury,** M.I.E.R.E., has been appointed editor of *Electrical & Electronic Trader*. Mr. Spreadbury, who joined the *Trader* in 1937 after spending fourteen years in the radio industry, has been technical editor since 1941. He was for four years chairman of the Radio Trades Examination Board and is at present chairman of the Society of Electronic and Radio Technicians. He is succeeded as technical editor of the *Trader* by **J. H. Weaden,** who joined the staff in 1961 and has been responsible for the preparation of the *Trader* Service Sheets. He was for eight years an area service supervisor with the G.U.S. Group of Companies. **R. J. Elmes,** who for the past seven years has been assistant editor of the journal is appointed news editor.

D. G. Ashton Davies, who has been appointed general sales manager of Electronic Instruments Ltd. was until recently new products manager of I.B.M. (U.K.) Ltd. Prior to that he was

D. G. Ashton Davies

for many years manager of the instrument division of E.M.I. Electronics Ltd. Mr. Ashton Davies began his career with Marconi Instruments Ltd. in 1944.

Professor John Brown, M.A., Ph.D., D.Sc(Eng.), M.I.E.E., professor of electrical engineering at University College, London, has been appointed to the chair of light electrical engineering at the Imperial College of Science & Technology, London, from October next year. Professor Brown, who is 43 and a graduate of Edinburgh University, was a member of the research staff of the Radar Research and Development Establishment (now R.R.E.), Malvern, from 1944 to 1951 when he started his academic career. His first appointment was as lecturer in electrical engineering at Imperial College and he has been at University College since 1955, first as lecturer, then reader, and since 1965 as professor.

T. P. Callaghan has rejoined Standard Telephones and Cables Ltd. as production director. For the past 3½ years he has been with the Plessey group of companies, latterly as works chief executive of the Automatic Telephone and Electric Company, responsible for the

T. P. Callaghan

general management of telecommunications activities. Previously he was for 2½ years in the headquarters production directorate of S.T.C. and was at one time with the Morgan Crucible Company Ltd. as chief production engineer.

A. J. Stephens was recently appointed sales manager of Spembly Electronics, of Andover, Hants, which he joined five years ago. He will be working from the recently opened factory at Enham Arch, Newbury Road, Andover, which now forms the headquarters of the Electronics Division.

OBITUARY

Basil E. Talbot, associate editor of our sister journal *Electrical & Electronic Trader*, died on August 15th at the age of 56. He had spent the whole of his working life with the *Trader* having joined the staff as a technical editorial assistant in 1927. "Jim" Talbot, as he was affectionately known throughout the domestic equipment side of the industry, had been associate editor in charge of the news side of the *Trader* for some years.

Aerial Gain and How it is Measured

By M. F. RADFORD, M.A.

M. F. Radford, who is 37, has been chief of the aerial research group in Marconi's Research Division, Great Baddow, Essex, since 1960. He joined Marconi's as a graduate apprentice in 1953 on coming down from St. John's College, Cambridge, where he read mathematics. He went into the Research Division in 1954.

THE purpose of a receiving aerial is to transform energy from electromagnetic waves in space into electric currents in a transmission line and vice versa at the transmitting end. For some purposes, such as satellite beacons, we need an aerial which radiates in all possible directions, this we call an isotropic aerial. For television broadcasting from a central transmitter we need to radiate in all horizontal directions only, this type of aerial is usually called omnidirectional. For point-to-point links we need to transmit in one direction only, and so we use a directional aerial. Clearly the smaller the solid angle over which we spread the radiated energy, the more concentrated is the energy. This property of energy concentration, which gives an increased signal strength in the direction of maximum transmission, we call gain. There is thus a simple fundamental relationship between the gain of an aerial and its radiation pattern.

Suppose we define unity gain as the gain of a perfect isotropic aerial. By perfect we mean that the aerial is perfectly matched to its feeder, has no ohmic losses, and radiates equally in all directions. Now consider an aerial which radiates equally over a hemispherical zone only but is well matched and lossless. Since the power supplied to it is now only spread over half a sphere, the power density will be doubled. We therefore call the gain of the hemispherical or hemi-isotropic aerial 2. More usually the decibel scale is used, and the gain is written as 3 dB over isotropic. This reasoning leads to a simple general formula for the gain of a directional aerial.

$$\text{Gain} = \frac{\text{Number of "square degrees" subtended by the surface of a sphere}}{\text{Horizontal beam width} \times \text{Vertical beamwidth}}$$

$$= 10 \log_{10} \frac{41253}{B_H \times B_V} \text{ in dB}$$

where B_H and B_V are half power beamwidths in degrees[1].

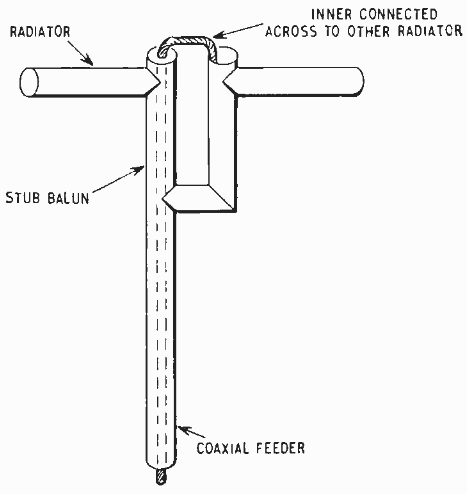


Fig. 1. Sketch of the reference dipole.

While this relationship is obvious for a transmitting aerial it is equally true for a passive receiving aerial, that is an aerial which does not include any active elements such as pre-amplifiers or non-reciprocal devices such as ferrite isolators. It is thus not possible to make a receiving aerial with a greater gain than the beamwidth permits. This is because high gain requires that the collecting area of the aerial should be large, and the area of the aerial limits the angle over which incident waves can be collected and added in phase. Waves arriving from directions outside the aerial beam have a varying phase across the aerial aperture and so cancel each other. The principle that aerial characteristics are the same for transmission and reception is an example of the law of reciprocity. It can be proved theoretically under limited conditions only, and does not apply to active networks or ferrite devices.

When an aerial is small in terms of wavelengths in comparison with its gain, as for example the aerials used in the v.l.f. (3-30 kc/s) band, the aerial can only radiate the required power by carrying a very heavy current. In order to build up this current it is usual to tune the aerial to resonance, and this is done by adding non-radiating reactive elements. Only the radiating portion of the aerial can supply the necessary radiation resistance component, and since the aerial is small its radiation resistance is low. The result is that the aerial has a high Q and a narrow bandwidth. Ohmic losses lower the Q but do not enhance the gain. There is thus a fundamental relationship between gain and bandwidth as well as gain and beamwidth. However, we only find ourselves up against this relationship when we try to make the effective collecting area of the aerial larger than its actual physical aperture. Provided that we are content with the gain given by the physical aperture the bandwidth can be as large as we please.

A discussion of radiation resistance was included in a previous article.[2]

Definitions of gain

We are now in a position to discuss the definition of gain. In order to cope with practical aerials having losses we need two definitions of gain. Power gain takes into account the losses since it is based on power supplied to the aerial. Directivity gain ignores losses and concerns itself only with radiated power.

Terman[3] defines power gain as " the ratio of the power input to a comparison aerial required to develop a particular field strength in the direction of maximum radiation to the power input that must be delivered to the directional aerial to obtain the same field strength in the same direction ". Kraus[4] defines power gain G as

$$G = \frac{\text{maximum radiation intensity}}{\text{maximum radiation intensity from a reference aerial with the same power input}}$$

For all practical purposes these definitions are identical.

Directivity gain is defined by Terman as " the ratio of power that must be radiated by the comparison aerial to develop a particular field strength in the direction of maximum radiation to the power that must be radiated by the directional aerial to obtain the same field strength in the same direction ". Kraus defines the directivity of an aerial as the " ratio of its maximum radiation intensity to its average radiation intensity ". These definitions are only equivalent if Terman's comparison aerial is a perfect isotropic source. The isotropic reference is thus implicit in Kraus' definition although not actually mentioned.

Note that for transmission it is power gain that is important, while for reception in the lower frequency bands where interference masks receiver noise it is directivity that matters.

Choice of reference aerials

The linearly polarized isotropic aerial is an attractive reference because of its theoretical simplicity. It fits neatly into system calculations and so is widely used in practice. It has, however, one overwhelming disadvantage in that nobody has ever succeeded in making one. It is in fact impossible to do so, and this can be shown by a topological analogy.

Consider a small spherical animal entirely covered with fur which it brushes in an attempt to make it lie flat all over. It cannot find a method that does not leave a tuft, crown, parting or vortex somewhere. Let the orientation of the fur represent the polarization of the radiation from a source at the centre of the sphere and the argument is proved. Isotropic aerials can thus only be made if they transmit linear polarization in some directions and elliptical or circular polarization in others, and this makes them valueless as practical reference standards.

Various alternative standards are possible. Perhaps the most frequently used is the half-wave dipole, which has a simple theoretical radiation pattern and at the same time is easily constructed. The gain of a dipole relative to an isotropic source is 1.64 times or 2.15 dB.

Over a ground plane comparisons are more complicated. The usual practical reference is a dipole at the same effective height. Height must be included because the ground reflection increases the field strength of the dipole when the height is correctly chosen, the direct and reflected rays adding in phase. For a horizontal dipole the field strength or voltage is double and the power thus quadrupled. The gain of a horizontal dipole over ground is thus 6.56 times or 8.17 dB as compared with an isotropic source in free space. For vertical polarization only we may also use the quarter-wave monopole or the short vertical radiator. The monopole has exactly half the coverage of a dipole in free space, so that its gain is twice as great, 3.28 times or 5.16 dB. The short vertical has a rather wider beam and its gain is 3 times or 4.77 dB.

Now power gains and directivity gains generally differ by up to 2 dB, because of practical losses. By varying the reference standard and confusing power with directivity gain it is possible to introduce differences of up to around 10 dB between various ways of expressing the gain of the same aerial. For example, an h.f. aerial may have a directivity gain of 15 dB over an isotropic aerial, the former being over ground and the latter in free space. Its power gain may be only 13 dB over isotropic, and its power gain over a dipole at the same effective height $13-8.17=4.83$ dB. The conclusion is obvious: aerial gain is almost meaningless unless we state clearly whether it is power or directivity and also mention the reference aerial. When a manufacturer does not give this information it is safest to assume the worst and regard the gain as directivity compared with an isotropic aerial.

Precise measurement of gain

The precise measurement of gain is a difficult art, complicated by the fact that measured gain can vary significantly according to site. The gain of an installed h.f. aerial on a clear site may vary by perhaps ± 1 dB according to ground conductivity, while the gain of a TV aerial may vary even more because of mutual coupling with nearby aerials, obscuration, roof reflections, or disturbance of the near field by the mounting and downlead. It is thus necessary to measure gain on an open flat site having, in the case of the lower frequency bands, known ground constants.

There are two basic methods of measurement of power gain; comparison with a calibrated reference standard and measurement of path loss between two identical aerials. Whichever method is used, accuracy can be obtained only

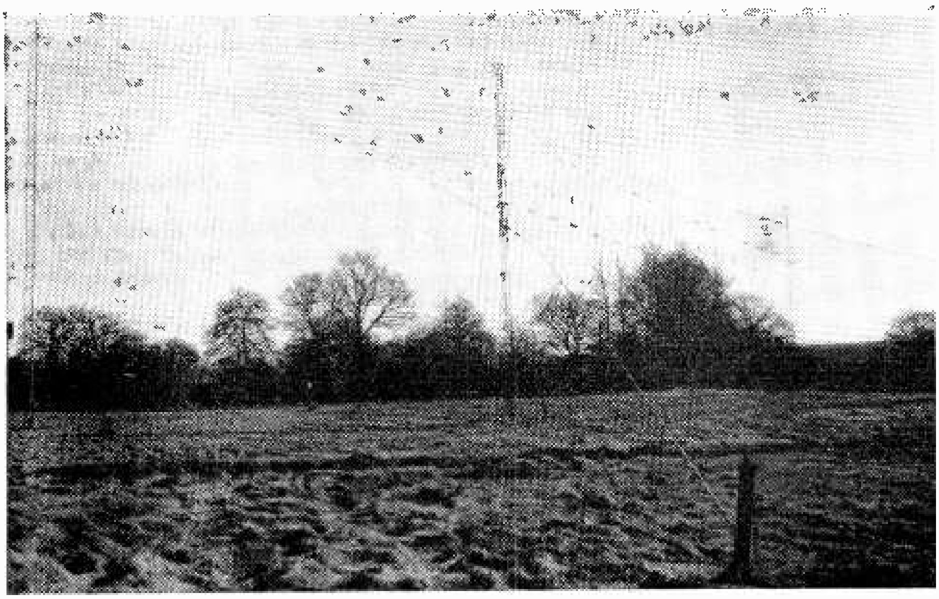


Fig. 2. Logarithmic aerial for the upper part of the h.f. band.

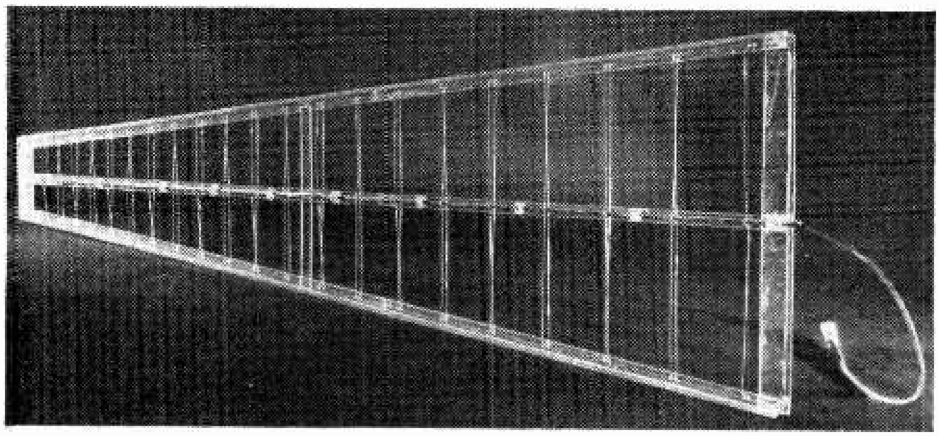


Fig. 3. Scale model of logarithmic aerial for radiation pattern measurements in u.h.f. band.

by meticulous attention to detail, first class equipment, and the repetition of measurements to average out experimental errors.

Simple methods of gain determination

For domestic and amateur applications it is not necessary to know precise gains and simpler methods may be used. There are three different approaches; comparison with a dipole or aerial of known gain, calculation from aerial dimensions and calculation from aerial beamwidth. Of these only the first takes into account aerial losses and the second provides no check of performance at all.

In the comparison method the aerial is mounted close enough to the reference to enjoy the same illuminating field, but far enough to one side to avoid mutual coupling. Two or three wavelengths spacing is sufficient for practical television and amateur aerials. The receiver is switched from one to the other and the signals compared, if possible on a meter which can be calibrated in decibels. A signal generator is useful for this purpose. In the absence of a calibrated receiver an r.f. attenuator may be inserted in the lead of the aerial having the greater gain, and the loss varied until the signals are equal. If no r.f. attenuator is available resistive pads may be used, or even lengths of cable of known loss, provided always that the frequency is not too high for the equipment. The experiment should be repeated several times and the results averaged.

Calculation from known dimensions can be reasonably accurate if the aerial is of one of the better known types. Some of the amateur publications are particularly useful for this purpose.[5] The gain of broadside aerials may be estimated fairly easily from the formula,

$$\text{Directivity gain} = \frac{4\pi A}{\lambda^2}$$

where A is the area and λ the wavelength. This assumes that all incident radiation is collected. In practice aerials are seldom more than 60% efficient since the aperture power distribution is tapered at the edges to improve the sidelobe performance. The formula thus overestimates directivity by 2 to 3 dB. Power gain is lower still because of resistivity losses.

Endfire aerials are more difficult to assess since small dimensional changes can yield considerable reductions in performance. It is only safe to rely on a calculated gain if an exact copy is made of a proven design.

Calculation of gain from beamwidth is more reliable than calculation from dimensions since an inefficient aperture distribution gives a wider beam and is thus taken into account by the formula. The theoretical formula quoted earlier gives an optimistic result since it neglects power wasted in sidelobes. If sidelobe levels are appreciable an allowance should be made. For example, if an aerial has two lobes, each 3 dB down on the main beam, the total sidelobe power is then equal to the main beam power and the formula is 3 dB optimistic. This is an extreme case; in general the formula over-estimates the directivity gain by 1-2 dB. As before, allowance must be made for other losses in computing power gain of an aerial.

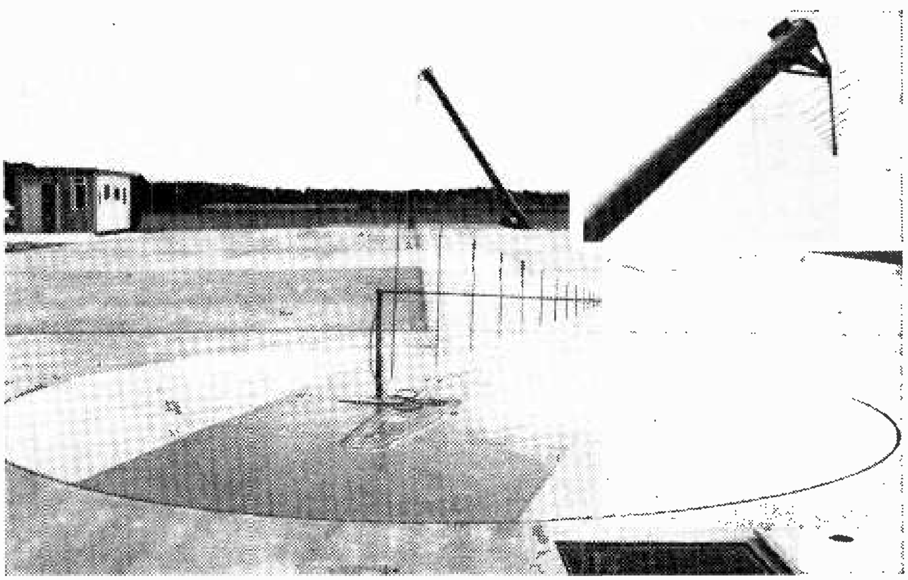


Fig. 4. Part of an aerial test site. The ground plane is of concrete with metal spray finish to give a conducting surface. There is a 20ft diameter turntable at the near end for horizontal radiation pattern measurement, and at the far end a 7ft turntable with a swinging glass fibre boom (see inset) for overhead pattern measurement. The control hut containing the receivers is at the far left.

A useful practical rule of thumb is

$$\text{Directivity gain} = 10 \log_{10} \frac{25000}{B_H \times B_V}$$

Scale modelling of large aerials

When large aerials are being designed it is impractical to optimise the performance by working on the full size prototype. It is usual to build a scale model so that changes can be made and the results assessed in the minimum time.

In a scale model wavelengths, capacitances and inductances are reduced in proportion to the linear dimensions while gains, impedances, dielectric constants and permeabilities are unchanged. Conductivities are the exception and must be increased in inverse proportion to the scale factor[7].

In practice little is lost by scaling aerials of copper, aluminium, brass or silver plated construction. Poor conductors like real earth are very difficult to scale as large scale factors require materials with almost impossible constants.

In choosing the scale we must take into account the size of the test site available and its frequency coverage, the difficulty of model construction and the nature and accuracy of the information required. Models may vary from 1/2 to 1/500 full size. For average work h.f. aerials may conveniently be scaled to the 300-1,000 Mc/s band. A typical h.f. aerial and its scale model are shown in Figs. 2 and 3. The scale model is built of fine wire on a light Perspex frame.

The gain of a scale model is easily measured by comparison with a standard dipole or by calculation from the beamwidths. On a number of occasions the author has been able to compare gains measured by modelling with estimated gains of full-size h.f. aerials. The results have always been in good agreement, but the greatest uncertainty has always been in measuring gain of the full-size aerial. It is in fact not only much cheaper but also more accurate to measure the gain of a large aerial by means of a small model, since the model measurement may be carried out under more nearly ideal conditions. The eventual performance depends upon the quality of the site on which the full-size aerial is installed. It is unfortunately true that many aerials, particularly television receiving aerials are sited in such a way that the full potential gain and sidelobe performance of the aerial can never be realised. Some of our rooftops would look a great deal tidier if we had a better understanding of these things.

The author wishes to thank the Director of Engineering of the Marconi Company for permission to publish this article.

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HYBRID COMPUTERS analogue + digital

WHY THEY ARE NEEDED AND HOW THEY WORK

1—APPLICATIONS

By C. D. DWYER, Dip. Tech., D.L.C., Grad. I.E.E.

THE applications of electronic computing systems range from the performance of mundane clerical duties to the real-time simulation and control of a vehicle designed to put a man on the moon. It is possible that at some time in the future a truly general-purpose machine will be available which will perform such a diverse range of duties in an accurate, convenient and economic manner. In the absence of such a machine we must select from the computing techniques available the one which is most suitable for a particular application. The vast majority of present-day computers are either analogue machines or digital machines, both of which are familiar to engineers. Given a free choice, it is usually obvious which type of machine should be used in a particular application. There are, however, applications for which a machine that combines analogue and digital techniques is desirable. Such a machine is called a hybrid computer.

Early attempts at hybrid computation date back to about 1956. These early systems were built around existing conventional analogue computers. In some cases a complement of digital logic was added and used to control the operation of the analogue computer. In other cases the analogue computer was connected to a general purpose digital computer via interface equipment specially designed to solve the problem of communication between the two machines. As none of the machines

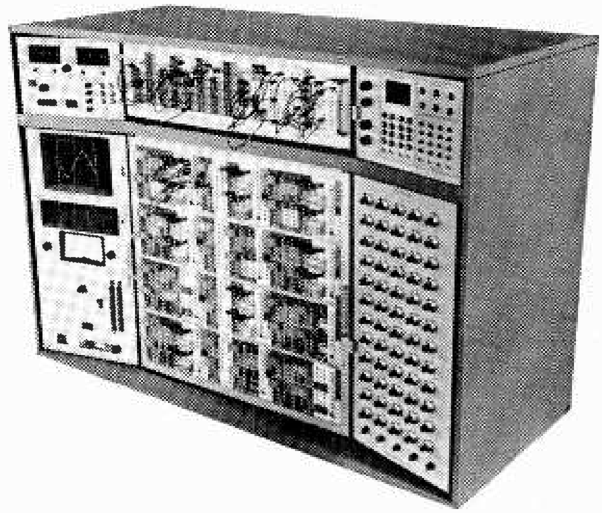
Colin D. Dwyer graduated in electrical engineering at Loughborough College of Technology in 1962 and returned to the college after a year with English Electric to do two years' research in hybrid computation. For the past year he has been in the Heavy Organic Chemicals Division of I.C.I. at Billingham, looking after the analogue computer.

used were designed to be compatible with other computers these unions were not particularly successful. They were difficult to programme and their performance was often severely impaired by the slow speed of operation of one part of the system—usually the digital computer or the interface equipment.

This early work aroused sufficient interest in hybrid computation to stimulate analogue computer manufacturers into designing their present generation of machines with facilities for hybrid computation. A new computer without digital logic and some provision for communicating with a digital computer is a rare creature and several manufacturers market "fully integrated" hybrid systems.

Recent developments in the digital computer, although not aimed specifically at this application, have made much improved hybrid systems possible. A range of machines are available which are much faster, easier to communicate with and often cheaper than their predecessors.

Everyone concerned with hybrid computation seems to have his own definition of what does or does not constitute a hybrid computer. For the purpose of this article the term will be defined in its widest sense as any machine with analogue computation elements and programmable digital facilities.



Example of commercial hybrid computing equipment—a medium-sized transportable model, the "Hybyid 48" developed by Electronic Associotes Ltd.

Need for hybrid computers.—With the ever increasing complexity of engineering systems there is a continuous requirement for more sophisticated simulation techniques. The conventional analogue computer, by virtue of its parallel operation and high-speed integration capacity, is ideally suited to the simulation of dynamic processes. In some respects, however, it is inadequate for the efficient and accurate simulation of many modern engineering systems. Some of the more important of these are listed below:

1. *Simulation capabilties.*—There are a number of important simulation problems which are beyond the capabilties of the conventional analogue computer. Some of these are:

(a) Systems involving dynamic transport delay, multivariable function generation, a wide range of signal frequencies and a large dynamic range.

(b) Processes whose dynamic behaviour is described by partial differential equations.

(c) Digitally controlled processes.

(d) Sampled data systems.

2. *Iterative capabilities.*—The solution of many simulation and optimisation problems requires the use of iterative routines. Often these routines are so sophisticated and complex that it is not feasible for the operator to perform them manually.

3. *Automatic programming techniques.*—The average analogue computer spends a very small proportion of its working life in the "compute" mode. If the machine time is to be utilized more efficiently, it must be possible to pre-programme the system in such a manner that the setting of potentiometers, the performance of static and dynamic checks, the control of computer runs and logging of results can be performed automatically. At the same time it is important to maintain the rapport between the operator and the simulation which has always been a feature of analogue computation.

At the present time a great deal of effort is being concentrated on improving the performance of the general purpose digital computer as a simulation tool. A large number of simulation programmes have been developed, many of which are suitable for use by engineers with no prior knowledge of digital computer programming. A review of these programmes is given in Reference 1. The major obstacle to the more widespread application of these techniques is the manner in which we find it necessary to run our digital computer centres. The time delay between sending data, for example a parameter variation, to the computer centre, and receiving the results of the run, may be anything up to three days. Even if this time delay is only hours, the essential contact between engineer and simulation is completely destroyed. The situation is improving with the development of time-shared, remote, on-line data terminals. Such facilities are, however, only likely to be available to a small number of people for some time to come.

Digital computing equipment has several features which the analogue computer does not possess and which are necessary for a wide range of simulation problems. Those features which are relevant to hybrid computation are:—

(a) Large memory capacity.

(b) Powerful logical capabilities.

(c) Precise arithmetic capabilities.

Obviously, the addition of some or all of these facilities to those of the analogue computer can greatly extend its capabilities.

Hybrid system configurations vary a great deal and depend upon the intended applications of the system. The present generation can be divided into three general categories:

1. Analogue computer + digital logic + serial digital memory.

2. Analogue computer + digital logical + small digital computer.

3. Analogue computer + digital logic + small digital computer + facility for linking small digital machine with a large digital machine.

The hardware will be described in more detail in a subsequent article. It is sufficient to say at this stage that the digital logic is parallel solid-state logic with patch cord programming and the small digital computer is typically a 4,000-8,000-word machine with a memory cycle time of less than 2 microseconds.

The sections which follow are devoted to a brief discussion of a few of the ways in which hybrid facilities have been used.

Hybrid simulation.—In a normal analogue computer simulation problem, dependent variables are continuous functions of time. There are, however, practical systems in which there is a mixture of continuous analogue and discrete digital variables. An obvious example of a system of this type is a digitally controlled process. In a hybrid simulation of such a process the continuous process dynamics are simulated by the analogue section and, depending on the complexity, the digital control algorithm by either the digital logic or the digital computer.

In other problems in which the variables are by nature continuous, it is often found to be necessary to sample continuous analogue functions, perform some manipulation on these samples and to produce digital signals from which continuous analogue functions can be generated. The simplest example of a problem of this type is the simulation of the transport delay of a dynamic variable. Since the digital equipment is only required to store the samples for a specified time and the information is retrieved from storage in the same order as it entered, only serial digital memory is required. Fig. 1 is a schematic diagram of how the problem would be set up on the computer.

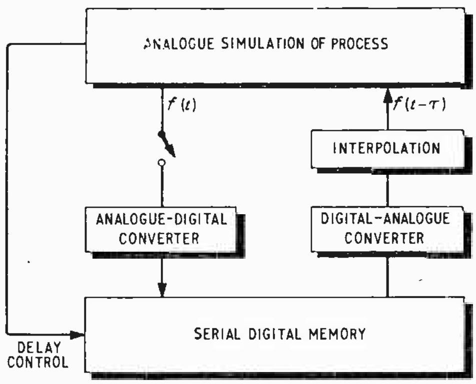


Fig. 1. Simulation of transport delay τ of dynamic variable f.

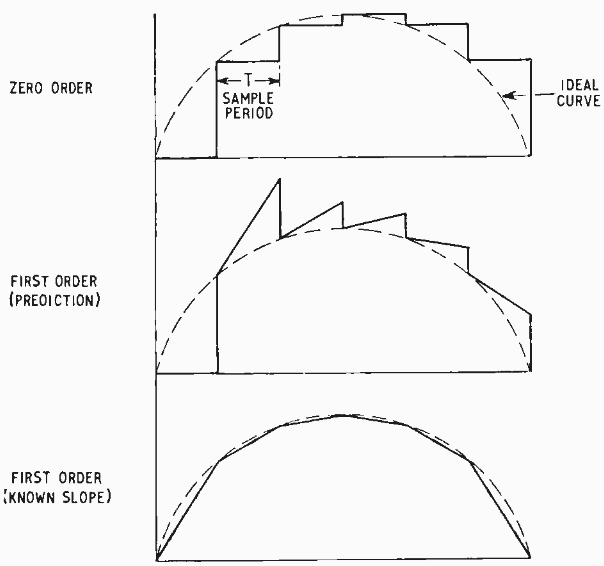


Fig. 2. Interpolation methods: zero order, first order (prediction) and first order (known slope).

Sampling and interpolation.—Shannon's well-known sampled data theorem tells us that a sampling frequency of more than twice the highest frequency component of interest in the signal is necessary if all the information in the signal is to be retained. In practice, however, it is found that the reformation of samples taken at this minimum rate into an accurate representation of the original continuous function requires the use of high-order interpolation techniques. This complicates the digital computer programme and increases the amount of output data and hardware required. In practice, it is not usual to use higher than first-order interpolation techniques. Fig. 2 shows the characteristics of zero and first order filters of the type normally used in hybrid problems. The sampling rate is selected on the basis of the accuracy of representation of the continuous analogue function.

Using the highest frequency component of interest, it is a simple matter to calculate the maximum error for any sampling speed and interpolation method. Figures for a sampling speed of N samples per cycle where $N=100$ are:

Zero order: $$\text{maximum error} = 2 \sin \frac{360}{2N} = 6{\cdot}3\%.$$

First order (prediction):
$$\text{maximum error} = 2\left(1 - \cos \frac{360}{N}\right) = 0{\cdot}4\%$$

First order (known slope):
$$\text{maximum error} = 1 - \cos \frac{360}{2N} = 0{\cdot}05\%$$

The finite operating time of the digital computer and the converters causes a phase error in the signal. This error is usually constant for a particular programme and can, therefore, be compensated for in a simple manner.

The round-off on the samples is another source of error in hybrid simulation. The most precise modern analogue computers have component accuracies of 0·01% and problem solutions better than 0·1% are rare indeed A data transfer word length of 12 bits, comprising an 11-bit binary number plus a sign bit, gives a sample accuracy of 0·1%, and 15 bits will give very nearly 0·01%. For the majority of problems an accuracy 0·1% is adequate. However, where sequential calculations based on results previously stored in the digital memory are being performed, for example, in the solution of partial differential equations by finite difference techniques, it is possible for gross errors due to round-off to occur. A 15-bit binary data transfer and careful programming are required to minimize these errors.

Another application in which the digital computer memory can be used effectively in a hybrid simulation is the storage of multivariable arbitrary functions—a very difficult problem on the analogue computer. The variables are sampled and the corresponding value of the function looked up and transmitted to the analogue section of the simulation. Economies in storage requirements can be made by the use of interpolation between the stored points. Although a certain amount can be achieved with serial memory units this problem is much more easily solved with random access memory and, if interpolation is required, with digital arithmetic; in other words with a digital computer.

The simulation of systems in which the variables have

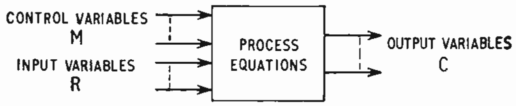


Fig. 3. Generalized schematic of a process to be optimized.

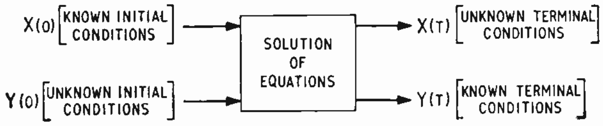


Fig. 4. Two-point boundary problem.

a very wide dynamic range has been called the "classic" hybrid problem. The original hybrid computers were built specifically to solve problems of this type which occurred in connection with the U.S. aerospace programme. Typically, the high speed dynamics of a space vehicle are simulated on the analogue computer while the digital computer performs the precise integration of the vehicle velocities in order to obtain its position during a long-range flight. There are many more down-to-earth examples of problems of this type.

Optimization problems.—In the past decade a great deal of effort has been concentrated on the development of optimization techniques. Powerful analytical methods have been developed which make it possible to express optimization problems in a theoretically soluble form. In practice the solution of all but the most trivial problems requires the application of sophisticated computing techniques. The hybrid computer is particularly suitable for the solution of a whole range of problems in this field.

In its most general form the process optimization problem (see Fig. 3) is one of calculating the manner in which the control variables M should be varied in order to minimize (or maximize) a function of M, input variables R, output variables C and time t.

If, as is often the case in the chemical industry, only steady-state outputs for particular steady inputs are of interest, then the problem degenerates into one of calculating the best set points for the process controllers. The problem can be studied on a hybrid computer by setting up the system equations on the analogue section and using the digital logic to perform a hill-climbing routine† on the control variables. If the number of variables is large then a problem of this type will probably be solved by linear programming techniques using a conventional digital computer.

If an optimal control policy is required for a dynamic process then more sophisticated techniques must be used. Two which have been used successfully in a wide range of applications are the Maximum Principle of Pontryagin and the Method of Dynamic Programming developed by Bellman.

If the Maximum Principle, or the classical calculus of variations from which it derives, is used then the problem is reduced to one of calculating boundary conditions on sets of nonlinear differential equations. This is a two-point boundary value problem of the type shown in Fig. 4 and is solved by iterative techniques. The optimal control policies are generated as continuous analogue functions.

†See "Hill-climbing in Control Systems," by K. C. Ng. *Wireless World*, June, 1966.

The sets of nonlinear differential equations are much more amenable to solution by analogue than digital techniques whereas the iterative algorithm is better performed digitally. Difficulties are caused by the instability of the equations and the high sensitivity of the optimal trajectories to the initial conditions. However, the difficulties can be overcome and this is an eminently suitable application for a hybrid computer.

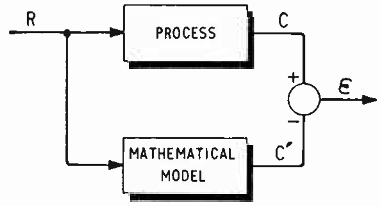
In the dynamic programming approach the problem is formulated in terms of an N- stage decision process. The control policy is approximated by N discrete values of each control variable. The computation of the optimal policy is wholly digital but requires solutions to the process equations which may be more readily obtained by analogue means. In other cases the dynamic programming routine may be part of an on-line digital computer programme. A hybrid computer simulation is the ideal tool for the development and testing of this programme.

Parameter estimation studies.—The inadequacy or lack of techniques for the measurement of process variablet causes serious limitations on the scope of process control systems. Fig. 5 illustrates a method of reducing this measurement problem by eliminating most of the direct measurement.

The object of the exercise is to produce a mathematical model which approximates the behaviour of the process in such a way that a function of the error ϵ is minimized. This model is then used for control calculations.

In recent years this problem has received a great deal

Fig. 5. Parameter estimation problem: R and C are as in Fig. 3.



of attention and numerous methods of solution have been suggested. Many of these techniques can be conveniently studied on a hybrid computer. In such a study a process is simulated on the analogue section and the digital section is programmed to perform such functions as:

1. The generation of special test disturbances with well defined randomness properties.
2. Cross-correlation of the simulated process input and output.
3. Calculation of the process impulse or frequency response from correlation functions or other sampled functions of the simulated process input and output. Reference 2 describes a system of this type.
4. Hill climbing routines on the parameters of an analogue model.

The use of a hybrid computer for these studies can eliminate the necessity for building complex special purpose equipment.

The future.—An attempt has been made above to give a cross-section of some of the applications of hybrid computers from the somewhat biased viewpoint of an engineer interested in process simulation and control. The discussion has been restricted to the types of hybrid system which make up the vast majority of the present generation of systems, i.e. the "all parallel" machine comprising an analogue computer and parallel digital logic and the linkage systems in which a general purpose analogue machine is connected to a general purpose digital machine. No mention has been made of the small but interesting band of "true hybrids" which contain neither an analogue nor a digital computer, e.g. The University of Arizona ASTRAC system and a machine developed at The College of Aeronautics, Cranfield, which uses delta modulation techniques; nor have the machines in which the analogue equipment is used to provide high speed subroutines for the digital computer been discussed. Machines of this type have been developed at M.I.T. and U.C.L.A. and may well be the next logical step in the long term trend towards digital simulation. Workers in this field claim that systems of this type increase the power of the digital processor by a factor of 10 or more in simulation applications.

As digital machines become faster and programming techniques are improved they encroach more and more on the specialized preserves of the analogue computer. However, analogue techniques still have much to offer in terms of speed, economics and convenience.

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2. P. C. Young and C. D. Dwyer, "A Hybrid Self Adaptive Control System," PACE Award Paper 1965.

OCTOBER MEETINGS

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

LONDON

3rd. I.E.E.—Discussion on "The Mossbauer spectrometer" at 5.30 at Savoy Pl., W.C.2.

3rd. I.E.E.—Discussion on "Parameters which need to be standardized to specify a p.c.m. interface" at 5.30 at Savoy Pl., W.C.2.

5th. I.E.R.E. & I.E.E.—"Measurement of arterial blood flow by the pressure gradient method" by Dr. I. Gabe and Dr. S. Montgomery at 6.0 at I.E.R.E., 9 Bedford Sq., W.C.1.

5th. B.K.S.T.S.—"The weakest aspects of modern pickup arm designs" by J. Walton at 7.30 at C.O.I., Hercules Rd., S.E.1.

6th. I.E.E.—"The ionosphere and the engineer."—Inaugural address by J. A. Ratcliffe (president) at 5.30 at Savoy Pl., W.C.2.

6th. U.H.F. Group.—"Satellite reception and aerials" by Peter Blair (G3LTF) at 7.30 at the "Bull & Mouth," Bloomsbury Way, Holborn.

10th. I.E.E. & I.E.R.E.—Colloquium on "Micro-programming and fixed stores" at 2.30 at I.E.E. Savoy Pl., W.C.2.

10th. I.E.E.—"Dielectric properties of polythene for submarine telephone cables" by J. T. Barrie, K. A. Buckingham and W. Reddish at 5.30 at Savoy Pl., W.C.2.

11th.—Soc. Relay Engrs.—Symposium on "Relay aspects of educational television" at 2.30 at I.E.E. Savoy Pl., W.C.2.

11th. I.E.E.—"Automation and industry—the technical and economic approach to wider utilization" by S. S. Carlisle (chairman, Control and Automation Division) at 5.30 at Savoy Pl., W.C.2.

12th. S.E.R.T.—"Hybrid television receivers" by H. A. Heins at 7.0 at Royal Society of Arts, John Adam Street, W.C.2.

13th. I.E.E.—Discussion "Engineering Industry Training Board—a new climate in training" at 5.30 at Savoy Pl., W.C.2.

17th. I.E.E.T.E.—"Technical education in the modern world" by Lord Bowden at 6.0 at the I.E.E., Savoy Pl., W.C.2.

18th. I.E.E.—"Dubrovnik symposium report—the control of powered artificial limbs" at 5.30 at Savoy Pl., W.C.2.

18th. I.E.E.—Discussion on "Transfer-function-measuring instruments" at 5.30 at Savoy Pl., W.C.2.

19th. I.E.E.—"Some highlights in the engineering of the Independent Television Service" by P. A. T. Bevan (Electronics Div. chairman) at 5.30 at Savoy Pl., W.C.2.

19th. B.K.S.T.S.—"Supermarionation for 'Thunderbirds'—electronic and other aids to puppet filming" by G. Anderson at 7.30 at C.O.I., Hercules Rd., S.E.1.

24th. I.E.E., I.E.R.E. & Television Soc. —"A slow-motion video tape recorder" by P. Rainger at 5.30 at I.E.E., Savoy Pl., W.C.2.

26th. B.K.S.T.S.—"Audio-frequency transistor amplifiers" by Dr. A. R. Bailey at 7.30 at C.O.I., Hercules Rd., S.E.1.

27th. I.E.E.—"Mechanisms of microwave generation in Gunn oscillators and avalanche diodes" by A. Chynoweth at 5.30 at Savoy Pl., W.C.2.

27th. I.E.E. Grads.—"Colour television systems" by A. V. Lord at 6.30 at Hendon College of Technology, The Burroughs, N.W.4.

BIRMINGHAM

12th. I.E.E.T.E.—"Development and research in control engineering" by Dr. J. H. Westcott at 7.0 at the University of Aston, Gosta Green.

27th. I.E.R.E.—"Radiophonic effects in the B.B.C." by C. Brooker at 7.15 at the Dept. of Electronic and Electrical Engineering, The University.

BRISTOL

12th. I.E.R.E.—"Commercial personal portable communications scheme" by D. A. S. Dryborough at 7.0 at Bristol Technical College, Ashley Down.

CAMBRIDGE

20th. I.E.E.T.E.—"Control by computer" by A. St. Johnston at 6.30 at the University Engineering Dept., Trumpington St.

EDINBURGH

5th. I.E.R.E.—"Colour television" by Prof. G. N. Patchett at 7.0 at Dept. of Natural Philosophy, The University, Drummond St.

FARNBOROUGH

13th. I.E.R.E.—"M.O.S. transistors" by G. G. Bloodworth at 7.0 at the Technical College.

GLASGOW

6th. I.E.R.E.—"Colour television" by Prof. G. N. Patchett at 7.0 at the Inst. of Engineers and Shipbuilders, 39 Elmbank Crescent, C.2.

HARLOW

19th. I.E.R.E.—"Micro-electronics" by P. L. Hawkes at 7.0 at A.E.I. Research Laboratories, West Road, Temple Fields.

HORNCHURCH

5th. I.E.R.E.—"The development of satellite communications" by J. K. S. Jowett at 7.0 at the College of Further Education, 42 Ardleigh Green Road.

HUDDERSFIELD

13th. I.E.R.E.—"Education and training of electronic engineers" by R. A. Elsdon at 7.0 at the Technical Teachers' Training College.

LEEDS

20th. S.E.R.T.—"Record playing units" by E. W. Mortimer at 7.30 at Branch College of Engineering, Cookridge St.

LIVERPOOL

19th. I.E.R.E.—"Numerical control of machine tools" by D. S. Walker at 6.30 at the Walker Art Gallery, William Brown St.

NEWCASTLE-ON-TYNE

5th S.E.R.T.—"Colour television" by B. J. Rogers at 7.15 at Charles Trevelyan College, Maple Terrace.

12th. I.E.R.E.—"The communications aspects of the Post Office Tower" by L. R. N. Mills at 6.0 at Inst. of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

READING

26th. I.E.R.E.—"Reliability of electronic components and microelectronic circuits" by K. G. Nichols at 7.30 at the Lecture Theatre, the College of Technology.

SOUTHAMPTON

12th. S.E.R.T.—"Colour television" by E. J. Finn at 7.30 at the College of Technology, East Park Terrace.

25th. I.E.R.E.—"Plasma spectroscopy" by D. W. Braggins at 6.30 at Physics Dept. Lecture Theatre No. 1, The University.

SWANSEA

26th. S.E.R.T.—"Television systems" by E. A. W. Spreadbury at 7.15 at the College of Technology, Mount Pleasant.

WOLVERHAMPTON

12th. I.E.R.E.—"The principles of f.d.m., t.d.m., and p.c.m., as applied to telephone transmission" by A. C. Frost at 7.15 at the College of Technology, Wolfruna St.

Dynamic Testing Instruments

MEASURING TECHNIQUES FOR TRANSFER-FUNCTION PERFORMANCE TESTING OF SYSTEMS

By JAMES FRANKLIN

UNDER the pressure of systems engineering requirements a distinct class of instruments for dynamic measurements is being evolved. Whereas the more familiar instruments measure single physical variables in systems like voltage, frequency, force, temperature, flowrate, these newer types measure the output/input relationships of systems in order to indicate system *behaviour* in quantitative terms. One example—a digital transfer function analyser—is shown in Fig. 1.

The behaviour in time of an electrical or mechanical system when excitation is applied to it is determined by the opposing forces set up by its resistive and reactive elements in proportion to displacement, velocity and acceleration values of the excitation time-function—whether this excitation be physically generated by a moving mechanical part or a moving electric charge (i.e., a current). These opposing forces modify the excitation force, and the modified version of the excitation time-function is, of course, the response of the system. The output/input, or response/excitation, relationship also depends on whether power is supplied to or extracted from the system, and this introduces the concept of " d.c. " gain or attenuation.

In order to measure such output/input relationships, the dynamic testing instruments must, of course, operate from primary variables such as force and voltage, and transducers may be necessary to convert the information into suitable form. But the final result of the measurement may be quite independent of these primary variables, and indeed, may be dimensionless. A familiar example is the gain factor of an electronic amplifier, which, being a ratio of the form $K=dV_{out}/dV_{in}$, is simply a number.

Dynamic testing instruments can be divided into two broad classes: (a) those depending on *deterministic* principles—meaning that the system output/input relationship is described by a mathematical equation from which the future behaviour of the system can be predicted with certainty; and (b) those depending on *stochastic* principles—meaning that the output/input relationship is expressed in statistical terms (e.g. a cross-correlation function) from which the future behaviour can be predicted with a certain value of probability. Statistical measurement techniques have already been dealt with to some extent in articles by D. A. Bell and W. D. T. Davies earlier this year, so the present discussion is confined to deterministic methods.

A characteristic feature of dynamic testing instruments is that since they are concerned basically with system behaviour they are " not interested in " the physical structure of the system which produces the behaviour. They will operate whether the system is electrical, mechanical, hydrodynamic, thermal or uses any other type of " hardware," provided suitable signals can be obtained by transducers. The fact that engineering systems with widely differing " hardware " can have similar mathematical relationships describing their behaviour has been recognized for many years. The similarity of D'Alembert's and Kirchhoff's laws about forces and voltages equating to zero in systems is one well-known example. Awareness of these analogous relationships has increased as engineering techniques have grown more analytical. This is because a mathematical description, such as a differential equation, tends to highlight the behavioural aspect of a system and takes very little notice of whether it is physically an electrical network using *R*s, *L*s and *C*s or a chemical process using pipes, vessels and pumps. It also draws attention to the fact that very different kinds of equipment can be described in terms of common functional parameters such as gain, phase and impedance. When different types of hardware are integrated into complete systems these common parameters and equations can be used to evaluate the behaviour of the systems during design and testing.

As an example of systems engineering, consider an automatic landing system for an aircraft. Here the input to the steering part of the airborne equipment depends on the radio beam pattern from the I.L.S. " localizer " transmitter on the runway and the output is the angular displacement of the aircraft's rudder. For correct operation it may be important to determine the overall output/input relationship of the system—the response of the rudder for a given change in the signal received from the localizer—while in the process of design and testing it may be necessary to determine the output/input relationships of the individual units—electronic, electrical, mechanical—which make up the complete system. It may be necessary therefore to make an output/input measurement encompassing a number of units in which the " signal " undergoes several transformations between electrical and mechanical forms. Obtaining suitable signals for the measurement is only a matter of using appropriate transducers, but clearly

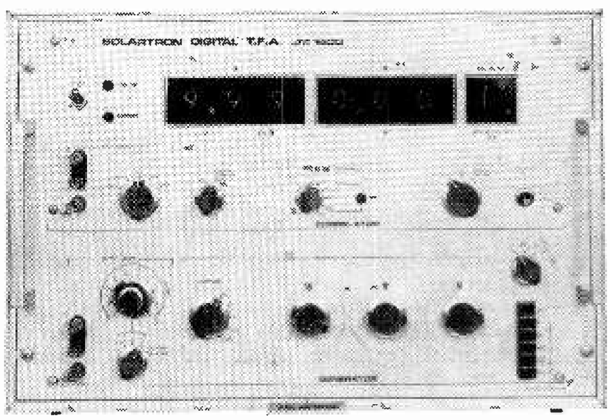


Fig. 1. Digital transfer function analyser recently introduced by Solartron. A block schematic is given in Fig. 7.

the measured output/input relationship must be such that it gives meaningful information about the behaviour of the electrical and mechanical elements of the system while it is functioning.

The formal, quantitative expression of the output/input relationship which gives this meaningful information is, of course, the transfer function.[1] This is an expression in the form of the ratio

$$\frac{\text{Response } (p)}{\text{Excitation } (p)}$$

in which the numerator and denominator are written in operational form, as functions of p, to simplify algebraic manipulation—in particular, combination with other transfer functions. The universality of the transfer function comes from the fact that it expresses the two fundamental characteristics of any system—the extent by which the system modifies (a) the magnitude and (b) the behaviour in time of the input—independently of the " hardware " from which the system is constructed. In steady-state electrical circuits these two are usually represented by *modulus* (which takes account of gain and attenuation) and *phase.*

This generality of the transfer function can be illustrated by considering the two analogous simple systems shown in Fig. 2, one an RC network and the other a mechanical combination of a spring (compliance c) and a dashpot (friction f), and deriving the transfer function of each. Using the impedance concept, the transfer function of the RC network works out to

$$\frac{\text{Response } (\omega)}{\text{Excitation } (\omega)} = \frac{V_o(\omega)}{V_i(\omega)} = \frac{1}{1+j\omega T}$$

where ω is the angular frequency of the input voltage V_i, and T is the time constant RC. This, of course, is only valid for sinusoidal excitation. If the transfer function is derived directly from the differential equation of the circuit in terms of an instantaneous input voltage e_i and its response, e_o, the result is

$$\frac{e_o(D)}{e_i(D)} = \frac{1}{1+DT}$$

Where $D = d/dt$. Both of these results can, however, be expressed in more general form by using operational algebra and substituting p for $j\omega$ or D. Then

$$\frac{\text{Response } (p)}{\text{Excitation } (p)} = \frac{1}{1+pT} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

which is valid for any kind of excitation signal.

The transfer function of the mechanical system (Response/Excitation = output displacement x_o/input displacement x_i) can be found from the differential equation of the system, which equates the opposing forces to the applied force. This works out to

$$\frac{\text{Response } (p)}{\text{Excitation } (p)} = \frac{x_o(p)}{x_i(p)} = \frac{1}{1+pfc} \ldots \quad \ldots \quad (2)$$

where f = viscous friction and c = spring compliance. The product fc has the dimensions of time since, like the product RC in the electrical network, it determines the time that the output variable $x_o (\equiv V_o)$ takes to build up in response to the excitation. Thus if fc is written as a time constant, T, the two transfer functions (1) and (2) become identical.

The reason why they are identical is, of course, that the two physical linear systems are governed by analogous linear differential equations, from which the transfer functions are derived.

The two aspects (a) modification of magnitude, and (b) modification of time-behaviour, mentioned earlier are, in fact, both represented quantitatively in equations (1) and (2). The quantity sensitive to time (or excitation frequency) is obviously pT or pfc. If the input signal is unchanging with time (" d.c.") then pT and $pfc = 0$ and the expressions (1) and (2) become simply 1/1, which is the magnitude quantity and can be considered as a gain factor of unity. Thus, looking at a transfer function expression such as equation (1) analytically, one sees that it really consists of a magnitude or gain factor which can be called K, here 1/1, multiplied by a time-dependent factor which can be called G, here $1/(1+pT)$. If an amplifier with a voltage gain of 20 had been added to Fig. 1 (a) the overall transfer function would have been $20/(1+pT)$. We know from experience, of course, that the behaviour of the two systems is similar. The transfer function analysis simply expresses this knowledge in an exact, quantitative form. (Note that transfer functions (1) and (2) contain all the necessary information to provide amplitude/frequency and phase/frequency plots, so that measured frequency response curves constitute evaluated transfer functions in term of ω).

The first-order systems in Fig. 1 and their respective transfer functions are of course very simple ones and hardly need special instruments to measure them. Systems met in practice are more complex and difficult to deal with. For example the addition of inductance, L to system (a) or mass M to system (b) adds a third term to the differential equation, $L\frac{di}{dt}$ or $M\frac{dv}{dt}$, representing a new opposing force due to acceleration (rate of change of current i in one case and of velocity v in the other). Such second-order systems, introducing the possibility of resonance and instability, are encountered in many practical equipments. A fourth term representing an opposing force due to rate-of-change of acceleration, $\frac{d^2v}{dt^2}$, (sometimes called " jerk ") might be present; and so on, with $\frac{d^3v}{dt^3} \ldots \frac{d^nv}{dt^n}$.

In fact the opposing forces are represented in the system differential equation by a series of derivative terms of successively higher orders, multiplied by constants such as L and M. Thus the response, r, of a system is the excitation, e, modified by opposing forces given by successive derivatives of the excitation. This state of affairs is expressed by a generalized differential equation for linear systems:

$$\left(A_o r + A_1\frac{dr}{dt} + A_2\frac{d^2r}{dt^2} \ldots\right) = \left(B_o e + B_1\frac{de}{dt} + B_2\frac{d^2e}{dt^2} \ldots\right) \quad (3)$$

where the coefficients A_o, A_1 etc. B_o, B_1 etc. represent physical constants of the system. With a simple system of the Fig. 1 type, of course, the value of many of the terms in eqn. (3) turns out to be 0 or 1, so that one is

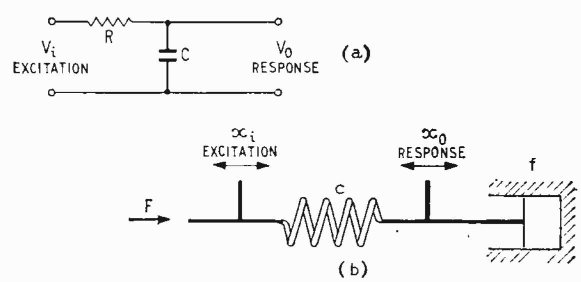


Fig. 2. Simple analogous first order systems: (a) RC circuit; (b) mechanical spring-damper combination.

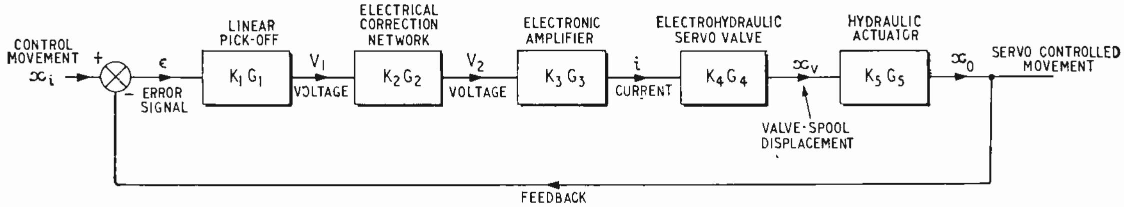


Fig. 3. Schematic of electrohydraulic position-control servo showing transformations of information through system. K_n G_n are the magnitude and time-dependent parts respectively of the transfer functions.

left with a correspondingly simpler differential equation.

From eqn. (3) it is a straightforward matter to derive a generalized form of transfer function, and if the operator p is written for d/dt in (3) this is given by:

$$\frac{\text{Response }(p)}{\text{Excitation }(p)} = \frac{r(p)}{e(p)} = \frac{B_o + B_1p + B_2p^2 \ldots \text{etc.}}{A_o + A_1p + A_2p^2 \ldots \text{etc.}} \quad (4)$$

Because system behaviour can be put in this quantitative form the transfer function becomes a useful tool in the evaluation and design of engineering systems—particularly those in which the information passes through various transformations between electrical and mechanical variables. Transfer functions of individual units in a system may be calculated or measured.

Once the various transfer functions of the units have been derived they can be combined by calculation and/or graphical techniques to obtain the overall system transfer function and hence the performance. Combining is a matter of dealing with the magnitude and time (phase) information separately. With frequency response measurements, for example, at each frequency one multiplies all the gain factors to get overall gain or attenuation and adds up all the phase shifts to get overall phase shift. For this to be possible, of course, it is essential that the individual units have linear input/output characteristic so that the principle of superposition applies. Few practical devices are completely linear (since it is always possible to produce some kind of saturation by overloading). But experience shows that in the majority of cases worth-while results can be obtained by working on a limited part of the input/output characteristics which can for all practical purposes be considered a straight line.

In some applications it might be desirable to measure the overall transfer function of the system, or perhaps that of a large group of units. Which approach is adopted depends on practical convenience, the nature of the hardware usually making calculation the obvious choice for some units and measurement the obvious choice for others (e.g. where signals suitable for the measuring instruments are available). The system in Fig. 3 is an example of mixed electrical and mechanical hardware, actually an electrohydraulic closed-loop position-control servo[2], and for this a combination of methods would be used for performance evaluation.

As explained earlier, the transfer function of each unit can be represented by two factors, a steady-state or "d.c." gain factor, K (here resulting from the introduction of electrical or mechanical energy into some of the units) and a factor G representing the opposing forces set up by resistive and reactive elements (this being the frequency sensitive part if one is considering frequency response). Thus in the linear pick-off the mechanical resistive and reactive forces resulting from the velocities and accelerations in the system would be negligible, so that G could be considered as unity and the transfer function would be simply the gain factor K_1. The electrical network is a correcting circuit (needed to achieve a suitable open-loop gain/stability compromise for optimum servo performance) and here, obviously, the G_2 is highly significant. Equally obviously the electronic amplifier has a significant gain factor K_3, while its G_3 factor is virtually unity. The electrohydraulic servo has a complicated transfer function and in practice this is usually obtained from measured gain-phase frequency response curves. The hydraulic actuator transfer function has a substantial gain factor (actuator output displacement: servo valve spool displacement) and also a significant factor G_5 determined by such reactive elements as the piston (load) mass and the oil compliance.

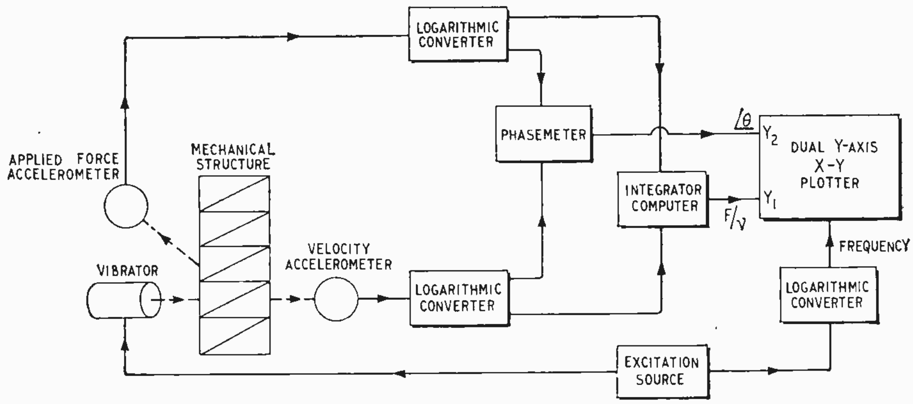
During the design of such a system some of these transfer functions could conveniently be calculated, using manufacturers' data, but others might be obtained more readily by measurement. But even the calculated ones would probably have to be measured as well, in order to verify the paper design work. Thus it can be seen that there is a considerable need for measuring techniques in such work, often on units with different input and output variables. Within the deterministic class of measuring techniques dealt with here there are three broad groups of dynamic testing instruments which give output/input behaviour information of the kind discussed:—

Groups of instruments

1. Impedance measuring instruments which evaluate the K and G factors in terms of modulus and phase of a vector (or its $a+jb$ resolved components). The response/excitation evaluation obtained here is, of course, a driving-point function taking the form of a voltage/current or force/velocity ratio.
2. Instruments using frequency-response testing technique to measure K and G in terms of the output/input amplitude ratio and the output/input phase change.
3. Instruments using analogue-computer "modelling" technique to give K and G as direct readings of the numerator and denominator of the transfer function.

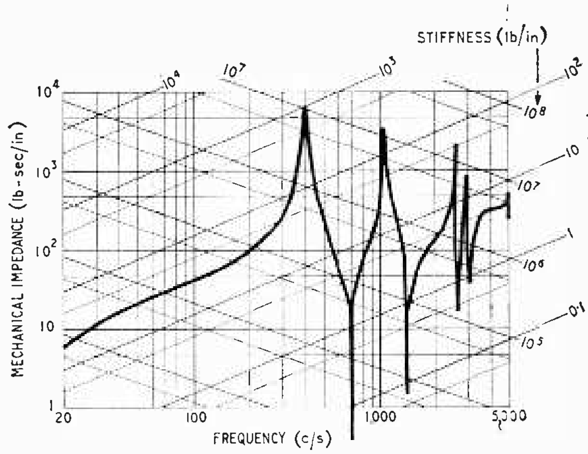
The impedance measuring instruments in Group 1 can be illustrated by two examples, a Hewlett Packard impedance meter, which is intended basically for use on electrical systems, and a Spectral Dynamics mechanical impedance measuring equipment. The H-P Vector Impedance Meter, Model 4800A, is a self-contained instrument giving direct readings of the impedance of circuits or components over the continuous frequency range 5 c/s to 500 kc/s. A sinusoidal excitation signal is applied to the device to be measured from a built-in source and, once the required excitation frequency and impedance range have been selected, the modulus Z and phase angle θ are displayed on two meters on the front panel. There are seven Z ranges, from 0-10Ω to 0-10MΩ, and for θ the total range is 0° to ±90°.

On the lower impedance ranges, measurement is performed by applying a constant a.c. excitation current to the device and reading the a.c. voltage developed across it,



Left: Fig. 4. Simplified schematic of Spectral Dynamics mechanical impedance measuring equipment. The actual instrument includes a tracking filter to remove noise and harmonics from the response sine-wave.

Below: Fig. 5. Typical mechanical impedance plot obtained with Fig. 4 instrument.



which is proportional to the modulus. On the higher ranges a constant voltage (minimized to allow measurement of non-linear devices) is applied, and the current is read. Phase angle is obtained by a synchronous detector which measures the difference between the current phase and the voltage phase. Output signals proportional to Z and θ are available for operating an X-Y plotter so that plots of impedance as a function of frequency can be obtained.

The Spectral Dynamics mechanical impedance measuring equipment Type SD-1002 (available in the U.K. from Pye-Ling, Ltd.) is intended mainly for use in vibration testing of mechanical structures. The mechanical impedance of a structure subjected to sinusoidal mechanical excitation from a vibrator is the ratio of the force applied by the vibrator to the velocity of the resulting movement of the structure, F/v.

Since the measuring equipment is electronic, transducers must be used to convert these mechanical variables into electrical signals. These transducers are in fact two accelerometers, as shown in Fig. 4. One accelerometer gives a signal directly proportional to the applied force, F (since, with a given mass, force applied $\propto$ resulting acceleration), while the other accelerometer provides an acceleration signal which is subsequently integrated to give velocity v. The ratio of the F and v signal amplitudes is electronically computed to give a d.c. signal proportional to mechanical impedance, F/v, or, if required, mobility, v/F, which is analogous to electrical admittance. This signal, modified to give a logarithmic scale, is applied to an X-Y plotter to give vertical deflection, while a similar d.c. signal proportional to the logarithm of excitation frequency gives horizontal deflection of the plotter, thereby producing an impedance/frequency curve. At the same time the phase angle between the force and velocity signals is measured by a phasemeter and is similarly plotted against frequency on logarithmic scales (if necessary on the same graph paper, by using a dual Y-axis plotter).

The instrument can also be used to measure apparent mass (force/acceleration), stiffness (force/displacement) and compliance (displacement/force). A typical impedance plot, showing mechanical resonances, is reproduced in Fig. 5. From this it can be seen, for example, that at 360 c/s the specimen has an impedance of 1,000lb-sec/in, an apparent mass of about 150lb and a dynamic stiffness of about 2×10^6lb/in.

The next class of instruments (2) are similar to those outlined above in that they are intended for frequency response testing and make measurements in terms of $a + jb$ or modulus and phase angle, but are used for measuring not a driving-point characteristic of a system but a transfer characteristic. The basic principle is shown in Fig. 6. Sinewave excitation of frequency f_E is applied to the system and the magnitude and phase angle of this wave are considered as reference values. The instrument then measures the in-phase and quadrature components of the response wave vector with respect to the reference magnitude. From these Cartesian co-ordinates the modulus and phase angle (polar co-ordinates) of the response vector can be derived, or, in some instruments, measured directly. The reference magnitude is also measured, and so the gain and phase shift introduced by the system at the excitation frequency f_E are obtained. Measurements are made at a number of frequencies and the readings obtained can be plotted on a Bode diagram, Nyquist diagram or Nicholls chart. The resulting curves giving magnitude and phase information then constitute graphical representations of the system transfer function.

In practice it is necessary to provide suitable transducers to apply the excitation and detect the response, also means for filtering out noise and harmonics from the response waveform. Mechanical sinewave excitation can be provided by a crank mechanism rotated by a shaft, with a transducer mounted on this shaft producing an electrical signal to which the electrical sinewave excitation source is locked or synchronized. One instrument, developed in France for testing process control systems, is completely pneumatic in operation.

A commercial instrument which uses the very latest techniques is the Solartron Digital Transfer Function Analyser shown in Fig. 1. The manufacturers have been producing analogue Transfer Function Analysers for some

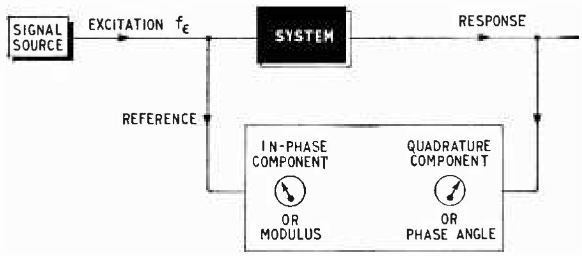


Fig. 6. General principle of magnitude and phase measurement with transfer function analysers.

years, but the digital version has been developed to satisfy an increasing demand for faster and more accurate measurement of dynamic performance, particularly at very low frequencies. Use of digital technique throughout the instrument ensures amplitude stability over the whole frequency range of excitation. The excitation waveform itself is constructed from a sequence of binary numbers and can give frequencies down to 1 cycle/day. Measuring accuracy and stability of measurement are similarly improved by the digital circuit technique, and facilities for print-out of results and remote programming of main parameters are available.

The principle of operation is outlined in Fig. 7. In the "excitation section" on the top, the excitation sinewave f_E is constructed from a sequence of amplitude values produced as binary numbers from a digital oscillator. This oscillator receives pulses at a frequency of $1688f_E$ from a crystal oscillator and frequency divider, on which the desired frequency is set. A digital-analogue converter transforms the sequence of numbers into a continuous sinusoidal function of time.

The measuring part of the instrument is called a "correlator" because it uses correlation technique to achieve the effect of an extremely narrow-band filter for removing the noise and harmonics. First the analogue response signal is converted to a sequence of pulses in which the spacing (p.r.f). varies in proportion to the amplitude of the response time function. These are frequency divided by the same amount as in the "excitation" channel (thus approximately changing the time constants in the measuring section consistent with the excitation frequency) and then applied to the digital correlator. Here the principle is that the response wave is correlated with a pure sinewave of identical frequency derived from the "excitation" channel. The resulting correlation function approaches sinusoidal form, and the greater the number of cycles of f_E over which correlation is performed the nearer this correlation function comes to a pure sinewave, and, consequently, the narrower the pass-band of the "filter" removing the noise and harmonics. As in analogue correlation computers, the fundamental operations are multiplication and integration with time, but here the multiplier is digital, giving a pulse rate proportional to the product (of the digital amplitude values of the two waves) and the integrator is a pulse counter. The number of cycles of f_E over which the correlation function is computed is determined by setting the number of pulses which shall be counted by the integrator, and this setting (1, 10, 100 or 1000 cycles of f_E) is made according to the degree of contamination of the response sinewave by noise and harmonics. Noise rejection of $>$60dB and harmonic rejection of $>$40dB can be obtained.

By correlating the response wave twice, once with a signal sin ωt and once with a quadrature signal cos ωt, both obtained from the digital oscillator ($\omega = 2\pi f_E$), the resulting sinusoidal correlation functions are made to represent the in-phase and quadrature resolved components of the response wave vector. (For an analysis of this technique as used in analogue form see "Random Signal Testing for Evaluating System Dynamics" by W. D. T. Davies, *W.W.* August 1966, p. 408). The two resolved components' values are obtained from the integrators as binary-coded decimal numbers and are presented on two 3-digit numerical displays. A third numerical indicator shows the quadrant in which the response wave vector occurs. Alternatively the vector can be presented in polar co-ordinates on the same digital read-out with an amplitude resolution of 0.1%, and a

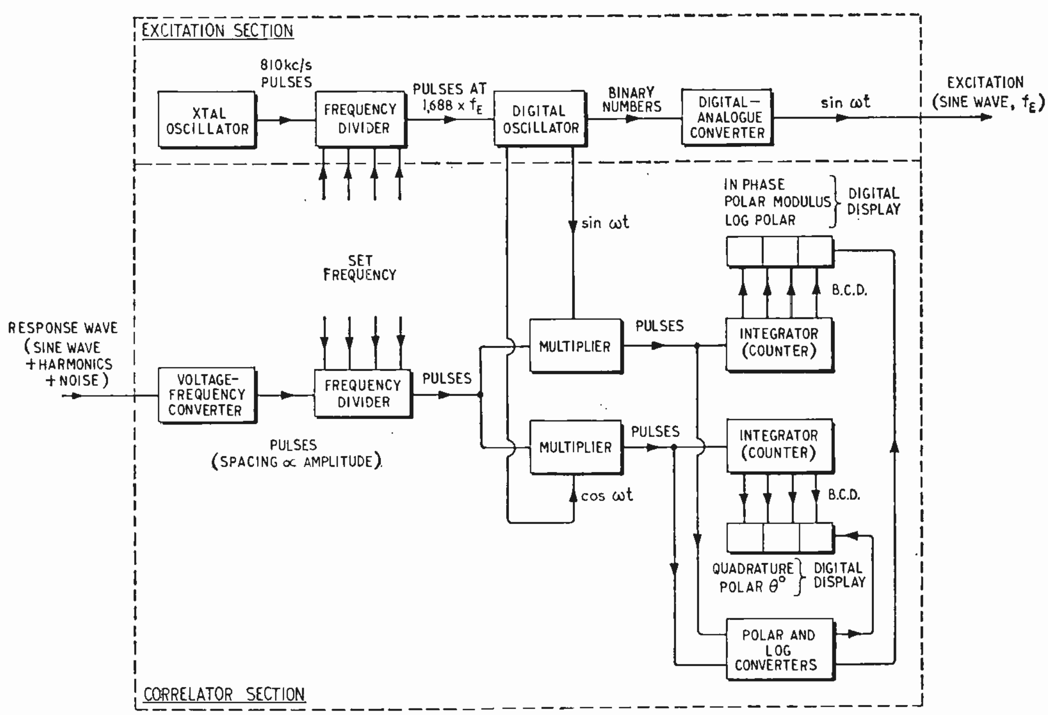


Fig. 7. Simplified schematic of Solartron digital transfer function analyser shown in Fig. 1.

phase resolution of 10′ arc. Often the information is required in logarithmic form for the purpose of gain and phase comparison and for point-to-point measurements within systems under test. For this, a third mode of presentation is provided, with log modulus and phase displayed on the digital read-out.

In the third category of instruments the transfer function as expressed in general form in eqn. (4) is measured directly. The instrumentation technique relies on the fact that the differential equation (3) relates the response and its successive rates-or-change to the excitation and its successive rates of change. If the various coefficients A_0, $A_1 \ldots B_0$, $B_1 \ldots$ etc. are all constants, a knowledge of their numerical values is sufficient to define the system completely, and it is in fact these coefficients which are measured. By the use of integrating circuits it is possible to operate on the excitation and the response respectively to produce two signals corresponding to the two sides of eqn. (3). These two signals are compared, using a visual display device, and the various coefficients in the analogous equation may be adjusted systematically to produce a null balance, thereby reproducing the equation of the actual system. The method is therefore a combination of analogue-computer "modelling" technique[3] and bridge-type balancing, although here the forces to be balanced are complex and combine the simultaneous effects of electrical or mechanical displacement, velocity and acceleration.

A number of different ways of utilizing this general principle have been worked out by Wayne Kerr, who have developed the idea over some years. One of the simpler commercial instruments based on the technique is called a Servo Performance Meter. Referring to the block diagram, Fig. 8, two signals are derived from a closed-loop variable frequency function generator based on electronic integrators. Each of these signals consists of a repetitive waveform V (sinusoidal, ramp or square) plus successive derivatives of it (obtained from the inputs of the electronic integrators with respect to their outputs), as indicated by the two polynomials in operational form. Here only two successive derivatives are provided for, but in more advanced instruments to be mentioned later third and fourth derivatives are available.

The desired response for the servo under test is set by adjustment of the polynomial coefficient controls; these are actually potentiometers by which variable proportions of the derivatives are added to the complete signal. One polynomial provides the excitation to the servo and determines the denominator terms of the system transfer function, as indicated. The resulting response signal of the servo is fed to the Y plates of a cathode-ray tube comparator. The second polynomial is fed to the X plates and gives the numerator terms of the system transfer function. On the c.r.t. the Lissajous figure resulting from the two signals is an ellipse, and this becomes a straight line when the transfer function of the system corresponds with that set on the coefficient controls. In the servo, gain and damping are adjusted until this correspondence is achieved.

Excitation frequencies range from 0.5 c/s to 24 c/s for sinewave operation and from 0.1 c/s to 1.2 c/s for repetitive ramp and square-wave excitation.

A convenient way of looking at the tester is as an "equalizer" connected in series with the system to nullify the opposing forces set up in the system. Here V becomes the excitation, and this is modified by the introduction of derivatives of V in an "equalizer," represented by the denominator polynomial block, *before* it is applied to the system.

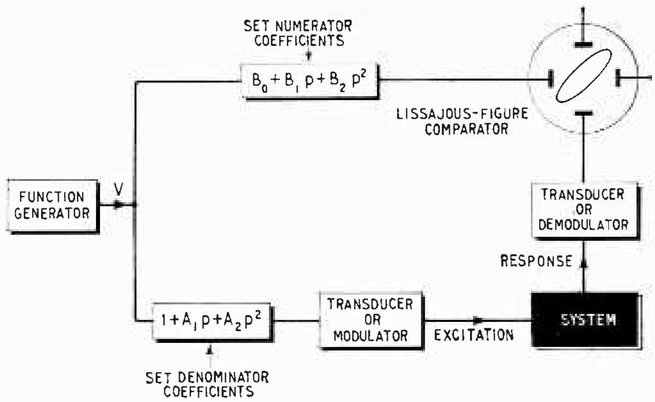


Fig. 8. Principle of Wayne Kerr's Servo Performance Meter giving direct measurement of transfer functions.

Thus the opposing forces in the system due to displacement, velocity and acceleration are overcome by the appropriate matching derivative components already added to V in the "equalizer". Consequently the response of the system becomes identical to the original excitation V. If the value of the numerator polynomial is simply unity, as in eqns. (1) and (2), then V is applied to both the X plates and the Y plates of the c.r.t. and a null balance is obtained.

The actual coefficients set on the controls are non-dimensional, being time-scaled by the integrator time constants. Thus the generalized transfer function eqn. (4) becomes

$$\frac{\text{Response}\,(pT)}{\text{Excitation}\,(pT)} = \frac{(b_0 + b_1pT + b_2(pT)^2 + \ldots)}{(a_0 + a_1pT + a_2(pT)^2 + \ldots)} \qquad (5)$$

For the Fig. 1 (a) system, for example, $b_0=1$, $a_0=1$, and $a_1T=CR$ seconds, all other coefficients being zero.

The "d.c." gain, K, of the system is given in these generalized equations (4) and (5) by the ratio B_0/A_0 or b_0/a_0. In the servo tester, however, $A_0 = 1$, as can be seen, so the K factor is simply given by the numerical value set on the B_0 coefficient control.

The arrangement in Fig. 8 is described by the makers, as "series-mode" operation, but there are other methods of connecting the "model" in relation to the system. Present work is concentrated on a "pi-mode" connection which is more versatile in application and avoids the disadvantage of the series connection—that the excitation level to the system is altered during adjustment of the model, making measurements on non-linear systems more difficult. In this pi connection the "model" (the two polynomial boxes) and the excitation source are independent of each other.

The Wayne Kerr instruments also lend themselves to gain and phase measurements: a_0 is set to unity, and in the null condition $\pm b_0$ and $\pm b_1pT$ represent the resolved components of the system's response to the excitation frequency.

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Simple Receiver for Low-Voltage Operation

By G. W. SHORT

T.R.F. TRANSISTOR SET POWERED FROM THE SUN OR A DRY CELL — SUITABLE FOR CHILDREN AND OTHERS WHO FORGET TO SWITCH OFF

THE personal radio receiver described here was designed as a child's toy. This placed certain restrictions on the design. A receiver for a small child must be easy to operate, and this rules out variable reaction circuits and any other tricky adjustments. It also makes pre-set tuning desirable. Another important fact is that children *will* forget to switch their sets off. Since mains operation is ruled out by considerations of safety, this means using either a cheap long-life battery, or no battery at all, and keeping the drain low. In the present instance, the receiver was designed to operate from a supply of about 1·3 V, and since the current required is only about 3 mA, operation from four cheap selenium photo cells is quite practicable, even under the usual clouded-over conditions of an English summer. As I write this on a September morning in London, with the sun breaking through thin cloud, enough power is available to provide 1·4 mA, and seven stations are comfortably audible. Alternatively, one dry cell may be used—and you can buy a lot of U2s for the price of four photocells, even at three or four shillings per photocell.

A t.r.f. circuit was adopted for simplicity. This does not save transistors, since there are three transistors in the wideband r.f. amplifier, but transistors are relatively cheap. What it does save are expensive i.f. cans and alignment adjustments. With a six-inch ferrite rod aerial, sensitivity is quite good enough in the medium-wave band, and while the selectivity obviously leaves something to be desired the set is usable on most strong stations.

A sun-powered radio will sometimes be operated out of doors in full sunlight, and it will therefore get hot. The simplest answer to temperature drift problems is to use silicon transistors, and these are desirable anyway, in a wide-band amplifier, since their cost in pence per megacycle of cut-off frequency is less than that of germanium transistors. Also, the usual germanium alloy-diffused transistors do not work well at 1·3 V because of their high "knee" voltage.

The circuitry (see Fig. 1) is very simple. Advantage is taken of the fact that silicon planar transistors lend themselves very well to direct coupling. This is because the working base-emitter voltage V_{BE} of about 0·6 V is comfortably in excess of the collector knee voltage (0·2-0·3 V) at collector currents of 1 mA or less. Thus V_{BE} is a suitable collector-emitter voltage. Transistors Tr1, Tr2 and Tr3 form the wide-band amplifier, and overall d.c. feedback is used to set up the currents in the three stages. Note that the collector potential of Tr3 must be above 0·6 V, in order to switch on Tr1. This makes a pure resistance load impracticable, since it would have to be so low that gain would be seriously reduced. An inductance L_3 of a few millihenries is used, in series with a resistance of a few hundred ohms to provide the d.c. feedback.

The forward bias for detector diode D_1 is provided by connecting the anode of the diode directly to the collector of Tr3. This fixes the optimum size of the detector load resistance at about 25 kΩ to 100 kΩ, and a 50 kΩ potentiometer is used here.

Two useful variations on the r.f. tuning are shown in Fig. 2. These have some fixed-tuned positions and one variable-tuned position. In Fig. 2(b) a single-tuned circuit is used for the pre-set stations, and a band-pass coupler in the tunable position. It is essential to use a tuning capacitor whose sections are well screened from one another, otherwise there will be so much stray "top capacitance coupling" that a wide double-humped response will be obtained at the h.f. end of the band. Even with a well-screened capacitor there is usually enough stray capacitance in the wiring to provide adequate coupling at the higher frequencies in the m.w. band. To maintain the required coupling at the low-frequency end

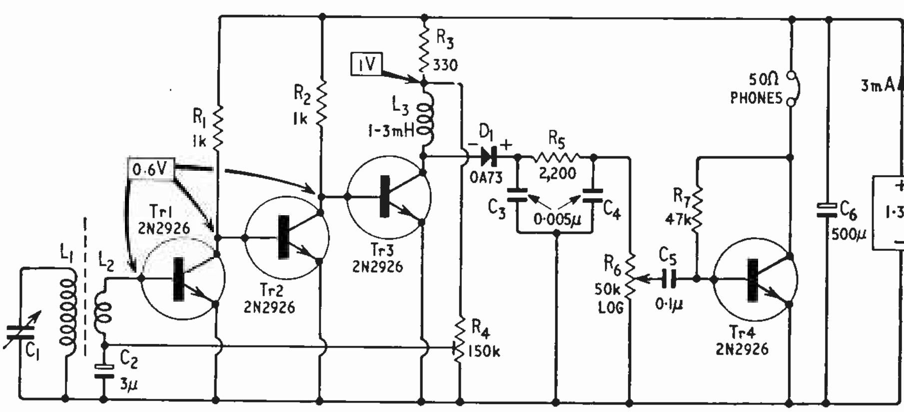


Fig. 1. Complete receiver circuit. All transistors are 2N2926 "Orange." Boxed voltages are as measured with a high-resistance d.c. meter, with respect to negative battery. Resistors may be 10% tolerance, 0.1 watt. The turns ratio of L_1/L_2 is about 15 for medium-wave operation.

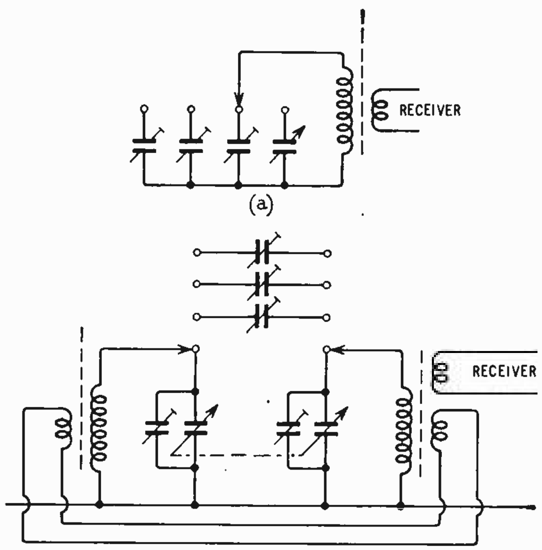


Fig. 2. Switching arrangements for combination of pre-tuned and tunable positions: (a) single-tuned only; (b) single tuned on pre-set station, band-pass tuned in tunable position.

of the band some additional coupling can be introduced, either in the form of a one-turn link, as indicated, or by orienting the coils, or by "bottom capacitance coupling" using 0·05 μF or 0·1 μF. Getting the coupling of a band-pass tuner correctly adjusted is not at all easy, and it should not be attempted without the aid of a wobbulator and oscilloscope. But if it can be done, it provides much better selectivity.

Since the r.f. gain is high, a single a.f. stage is enough

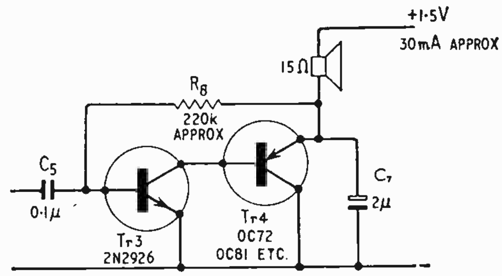


Fig. 3. Modification for loudspeaker operation.

for earphone listening. Good volume was obtained with a government surplus S.G. Brown CLR 50Ω earpiece, but a high-impedance earphone would no doubt give improved sensitivity. (The little earpieces designed for use with personal portables are generally very insensitive, and need a matching transformer.)

If the unit is battery-operated, and a current drain of about 30 mA is permissible, low-volume loudspeaker reception becomes possible, using an extra stage. All the writer's attempts to add a conventional stage were frustrated by motor-boating, and in the end a non-inverting output stage was adopted (Fig. 3). The circuit was then stable even without C_6, but it was found that, with a flat battery, omitting this capacitor resulted in a loss of volume. The resistance of the speech coil provides d.c. feedback, and the circuit is temperature-stable even though Tr4 is a germanium device. Loudspeakers of different speech-coil impedance may be used, and the optimum value for R_8 is best found by trial and error. C_7 is a "tone control" device, but also prevents any residual r.f. currents from reaching the positive line.

Construction presents only one difficulty. The wide-band amplifier has quite a high gain, and should be kept as far away as possible from the aerial, or screened, to avoid instability.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse opinions expressed by his correspondents

"International" PAL

I WAS heartened to read in your September Editorial that, at the recent C.C.I.R. Conference in Oslo, it was said of the PAL colour television system that it "may be regarded as much as a development of the SECAM system as of the N.T.S.C." It surprises me that this view was not universally accepted since the history of the development of colour television systems includes the following facts:—

1. G. Valensi (France) first proposed a compatible system using XYZ transmission primaries, but did not recognize the in-built constant luminance feature.

2. R.C.A. (U.S.A.) first proposed an all-electronic and compatible system using RGB transmission primaries.

3. B. D. Loughlin (U.S.A.) as a member of the N.T.S.C. first showed the way to a reproportioning of the numbers in the R.C.A. system so that it did use Y and (an approximation to) XZ signals. He also first pointed out the inherent constant luminance nature of the system.

4. B. D. Loughlin first proposed and demonstrated a system of Phase Alternation Line. However, he submitted a Phase Alternation Field variant to the N.T.S.C. for field testing in favour of the line alternation which was found to be less satisfactory.

5. The N.T.S.C. system with Phase Alternation of the R-Y) axis, subsequently of the I axis, was indeed field tested but reverted to plain N.T.S.C. before the petitioning of the F.C.C.

6. H. G. de France (France) first proposed a system similar to N.T.S.C. which used luminance with line sequential chrominance and a line period delay in the receiver.

7. W. Bruch (W. Germany) first proposed the use of such a delay device in the receiver with a system of N.T.S.C. with PAL. This used phase alternation of the I axis and subsequently of the (R-Y) axis.

That the French were agreeable at Oslo to studying a.m. SECAM (with N.T.S.C. on alternate lines) with an implied intent of dropping f.m. SECAM, indicates an admission of no catholic superiority of the latter. Bearing in mind that Valensi was the first television engineer to demonstrate an advanced understanding of colorimetry and that de France was the first to propose the use of a line period delay, these contributions can be maintained to be essentially French features of "N.T.S.C. with PAL."

So, Sir, the Danes were correct for the most generous of reasons. Bruch said in London only last year that the use of Phase Alternation Line "made possible the best reception of N.T.S.C." Let the uncommitted world adopt this system of N.T.S.C. with PAL and be thankful for its international development.

Ware, Herts. I. MACWHIRTER

Receiving Stereo Broadcasts

WITH regard to the article on page 445 of the September 1966 issue, the correct representation of the pilot-tone system in terms of the multiplex signal requires some care in regard to the use of sines and cosines, because an essential part of the system is the convention for the phasing of the 19 kc/s pilot-tone. Thus the signal can be correctly represented as

$$0.9\left(\frac{L+R}{2}+\frac{L-R}{2}\sin\omega_s t\right)+0.09\sin\tfrac{1}{2}\omega_s t$$

where L, R are the left and right audio signals and ω_s is the (angular) subcarrier frequency. If cosine functions are used, however, as in the above-mentioned article, a phase constant must be used in one of the terms:

$$0{\cdot}9\left(\frac{L+R}{2}+\frac{L-R}{2}\cos\omega_s t\right)+0.09\cos\left(\tfrac{1}{2}\omega_s t-\pi/4\right)$$

This accords with the requirement that, for $L>R$, an upward zero crossing of the subcarrier signal should occur at the same time as a zero crossing of the pilot signal. The diagrams (j), (*k*) and (*l*) of Fig. 2 showed this correctly.

Two further points of interest might also be made. First, with regard to bandwidth, I think it is important to realize that better control of pass-band shape, rather than greater bandwidth is the main requirement; i.f. amplifier bandwidths exceeding 250 kc/s are undesirable in a design for general use because adjacent-channel interference could become troublesome in certain areas.

Secondly, in stating that the amplitude of the regenerated subcarrier is dependent on the signal strength unless a locked oscillator is used, one might add that it is not difficult to overcome this by incorporating a limiter action in the doubler and so avoid the need for an oscillator. I fully agree that means of preventing modulation of the pilot-tone (which can arise from noise, interference, or multipath propagation) from affecting the amplitude or phase of the regenerated 38 kc/s subcarrier is important for any good design of decoder, but experience has shown that a locked oscillator circuit is not necessarily the easiest way of achieving this.

B.B.C. Research Dept., G. J. PHILLIPS
Tadworth, Surrey.

Dr. Phillips is, of course, correct in his assertion that the representation of the multiplex signal should strictly involve sine functions and not cosine functions. The use of cosines in place of sines and *vice versa* appears to be quite a frequent occurrence—possibly a *cos* is easier to scribble than a *sin*! In many cases it is of no consequence which is used, but for stereo broadcasting convention has it that the phase relationships be as in Fig. 2, which demands that sines and not cosines be used. (Incidentally, a brief reference to a collection of papers and articles on stereo broadcasting has revealed that eight or more authors have used the cosine function.) It is regretted that the error was perpetuated.

Regarding greater receiver bandwidth, it was not stated that this was the main requirement—only the most obvious. It was, unfortunately, not possible to discuss in the space available all the factors which enter into receiver design and which deserve consideration for stereo reception.

We regret that the short paragraph on subcarrier regeneration was not clear; the last sentence should have conveyed that a limiting action or hysteresis effect could overcome the disadvantage mentioned.—ED.

"Is There a Shoenberg in the House?"

EXTRAPOLATION is notoriously an unreliable guide, and in using it for planning a future for television "Radiophare" has given us yet another awful warning of that fact.

His argument, briefly, is that because E.M.I.'s 405-line system was, in 1936, a daring advance on current thought and turned out to be a brilliant success, the appropriate action now is again to increase the number of lines beyond what ordinary people consider reasonable, and history will thereupon repeat itself and put Britain once again ahead of the field. He uses precisely the same argument to push carrier frequencies "as near the infrared as it is possible to get . . ." He doesn't hazard a guess as to the cost, which could hardly be expressed in fewer than 10 figures.

One aspect of the matter that he does not appear to have considered at all is the extent of the demand for what he urges television research engineers to work miracles to provide. The procedure he outlines would be somewhat expensive in human and material resources if its sole purpose were to satisfy his and a few others' desire for technological elegance. If he had considered this he would at once have seen the fallacy in his argument.

For the step from 30 lines 12½ frames/sec to 405 lines 50 frames/sec was from a standard quite unacceptable for entertainment to one which was and is acceptable to the millions. Such a step cannot be repeated by extrapolation. The curve of viewer satisfaction against line standard bends over and approaches theoretical perfection asymptotically. Even if the standard could be lifted from the present to perfection, that would be a smaller step than the historic one on which "Radiophare" bases his recommendations.

Has he any convincing evidence of public demand for a higher picture standard? If so, why did he not quote it in support of his case? If viewers were shown a picture making as good use of 2,000 lines as their present sets make of 405, of course they would choose 2,000—other things being equal. But would they be equal? Even now that a large part of the British viewing public can compare at home 625 lines with 405, there has been no spontaneous wave of enthusiasm for 625, still less an insistent demand for yet better. I doubt if there are many, whose attention has not actually been drawn to the difference in definition, who have even noticed it. Any potential improvement is easily outweighed by (for example) less effective approach to the theoretical definition, or greater liability to "ghosts." Interest in even the greater improvement achievable with 2,000 lines would melt away if some quite small disadvantage appeared in association.

If "Radiophare" had considered the sound side of television instead of completely ignoring it, he would have seen the truth of this. Right now, without waiting for any long-term problematical research, just by using well-known and not extravagently costly techniques, a substantial improvement could be made on the quality of sound issuing from the present-day television set. But because it would cost a few pounds more, viewers are not interested. The demand seems to be insufficient to support the marketing of even one really "hi fi" television model.

It would be generally agreed, I think, that colour has greater popular attractiveness than any conceivable advance in definition. If our television industry were to take "Radiophare's" advice and embark on a comparably expensive programme to achieve a high-line standard, would they get their money back? If we look to history for guidance, we see that it was not the idealistic Duisenburg that made the American car industry a force to be reckoned with; it was the low-performance but cheap and reliable Model T Ford.

Last October's Editorial "Hi Fi Television," and the correspondence it stirred up, mentioned plenty of shortcomings in present-day television, at both ends, for which solutions could be comparatively quickly and inexpensively found, if there was a will. Long experience leads to the conclusion that even if "Radiophare's" dream came true the technical quality of transmissions would seldom justify it. In the meantime, until some of the easy things are demanded and accomplished one may reasonably be sceptical about attempting the hard ones.

So far from being imaginative, as "Radiophare" describes it, his proposal is no more than repeating on the same subject the same kind of development found successful in the past. Such a major effort as he envisages would be justified only if it opened up some entirely new commercial field, as Shoenberg and his fellow-workers did.

One thing on which we do agree (but for different reasons) is in deploring the introduction of 625 lines. I imagine I was not alone in watching with amazement our television industry falling for the fervent but not disinterested individual campaign waged in favour of that standard. It is interesting that in the same week as "Radiophare's" proposal appeared there was a feature article in *The Times* (24th Aug.) by such an experienced authority as Paul Adorian making a last-minute plea that colour (if in the present state of our national economy we must have it at all) should be on 405 lines and that we should cut our losses and abandon 625 as soon as possible. Again in the same week, at the Earls Court Radio Show, there were demonstrations of 625-line colour television on a number of stands, and they were notably inferior to some seen at the I.E.E. Television Convention *more than 14 years ago.* So much for progress.

Trying to get ahead of the line-standard Jonses now is neither particularly imaginative nor likely to be profitable. My guess is that the public would be more interested in such things as flat television sets that can be hung on the wall (*by then* there might well be a good case for more lines), or Model T colour sets, or really cheap video recorders. Meanwhile, how about making better use of what we have got?

"CATHODE RAY"

The author replies:—

As a long-time admirer of "Cathode Ray" I must confess to surprise and disappointment to find him in the ranks of the "What was good enough for father" brigade. Nevertheless, I have a feeling that I am going to agree with many of his statements while drawing quite different conclusions from them.

With all due respect for his arguments, they do not alter the fact that British television is in a horrible mess, with the receiver industry teetering on the brink of disaster. While I agree wholeheartedly that we could well make better use of what we have got, this will do nothing to stave off catastrophe. There is, as I see it, no immediate panacea. The article was intended as a plea for some professional constructive thinking to take care of the future and thus get back on the lost road to leadership.

Satellite television is bound to come, probably well within the next decade and ultimately with sufficient signal strength to provide direct reception by the home receiver. When that day arrives, it will emancipate us from the constraints of v.h.f. and u.h.f. and provide a much greater bandwidth potential. What would "Cathode Ray" have us do? Put 405 or 625 lines on it?

Cost. "Cathode Ray" charges me with advocating a programme which will run into ten figures. At this stage all computations are "guestimates," but a reasonable one, allowing a generous margin, would appear to be £80M—£100M for a complete 3-satellite system. (These figures are based on estimates by General Sarnoff of R.C.A.) Compare these with that of £120M for the duplication of existing B.B.C.-1 and I.T.A. services in the u.h.f. band, with provision for a second I.T.A. service.

"Cathode Ray" asks whether I have evidence of a public demand for a higher picture standard. The answer is "No." But neither was there any public demand for locomotives better than the "Rocket" or for the transition from propeller-driven airliners to jets. By the same token there was no public demand for television in 1936. Public demand has to be created. If it can be demonstrated that the new way is significantly superior to the old but that the domestic purse does not suffer *pro. rata*, then the growth of demand is a certainty. I fully agree with his remarks regarding the 625-line u.h.f. service; it is a white elephant because it does not fulfil the "demand" criteria. Colour, on the other hand, fulfils one criterion but not both, which is why its growth even in the U.S.A. is slow. But by the future time we are considering, it will have gained considerable favour and as there is no reason to suppose that a 2,000-line receiver (or its quality-equivalent, whatever form it takes) will be more expensive than its 405 or 625 line counterpart, it follows that a public demand would be rapidly created.

In his final paragraph "Cathode Ray" inadvertently underlines one of the points I was trying to make. Certainly the public would like flat television sets or rather flat displays. They would like them at least home movie screen size or even wall size. But imagine 405 or 625 lines blown up to wall dimensions! This is a classic instance of how progress is being atrophied by the line limitation. No, it's high time we moved on from Model T television!

"RADIOPHARE"

AS a photographer, I find the technical quality of the television picture intolerably bad. The 625-line picture is only a marginal improvement on the 405.

In 35-mm photography of moderate quality, one expects a resolution of about 100 lines/mm. This is 3,600 lines across the whole width of the negative, or 2,400 lines in the height. With resolution of this kind one can produce adequate (not excellent) 20×16 inch prints suitable for viewing at distances of 1-6ft, or a projected image about 6ft across to be viewed from about

12ft. Most professionals insist on better quality than can be obtained from 35 mm film.

Thus a 2,400-line system may be regarded as a reasonable minimum, and the current standards as abysmally low. I, for one, would be ashamed to foist such images on the public and charge several pounds a year for them.

A further advantage of a 2,400-line system would be to raise the whistle of the scanning apparatus well above audibility. The current whistle drives me out of a room containing a television set after a maximum of 15 minutes. Of course, most people who are old enough to make decisions about broadcasting systems are also deaf above 10 kc/s.

As regards transmission, a waveguide for modulated light or infra-red will surely be cheaper than elaborate coaxial cable for frequencies between infra-red and u.h.f. Even in its present early stage of development it is apparent that the hologram is the first fully adequate visual stereo technique, and this seems likely to combine more readily with modulated light transmission than with microwave. Wavelengths shorter than the near ultraviolet, on the other hand, are too dangerous to the human body to be used in domestic equipment.

Whether a satellite system with a telescope on the roof of every house, or a nation-wide fiber optics system analogous to the telephone system, or something between the two, would be cheapest requires investigation.

If there were a few more people in the electronics industry with the sense of Radiophare, we might stop muddling around adding chromium trim to mediaeval receivers and begin to plan ahead a little way.

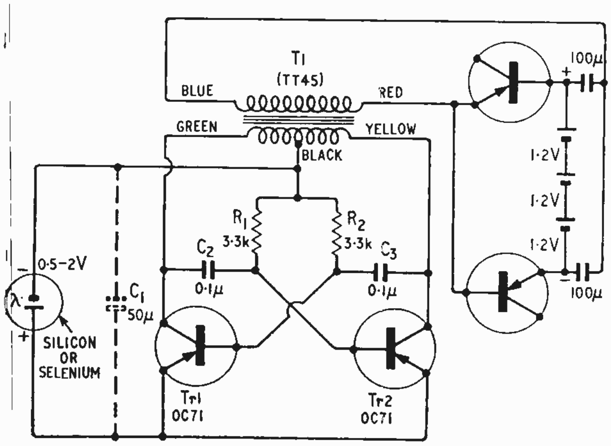
Cambridge. W. D. G. COX

Solar Battery Charger

THE interesting article under the above heading by D. Bollen appearing in your July issue has stimulated me to try to "better the instruction." This I have done with the addition of three extra components; two sub-miniature 15 V electrolytic capacitors of 100 μF each and an extra transistor-diode.

I think, on behalf of other tyros like myself, I ought to thank Mr. Bollen for having brought to my attention the fact that base emitter diodes have only about half the forward resistance of the ordinary diode, and are thus admirably suited to their purpose in this circuit.

As the diagram shows, I have merely added a voltage-doubler to the output transformer, (1) without raising the impedance in the circuit, and (2) improving the efficiency with full-wave rectification.



The output voltage measured, as recommended by Mr. Bollen, with a large capacitor (5,000 μF) across the output terminals rises to 12·5 V in bright sunlight.

The best applied voltage for the largest charging current over a wide range of illumination (using a four silicon solar cell unit) appears to lie between 3 and 4 volts. Thus, 3 Deac cells in series may be charged.

Incidentally, I have found that both perspex and pyrex glass are highly permeable to the wide spectral range of the silicon cell, reducing the charging current in each case by only one microampere.

Cheltenham, Glos. de L. E. EDMONDS

Impulse Response Testing

IN your August issue Mr. Davies presents an excellent case for the use of the pseudo-random binary pulse sequence technique as a convenient means of obtaining the impulse response of a system; it seems to me unfortunate that he didn't spend a little more space telling us what to do with it when we'd got it!

I may be old-fashioned, but I cannot see any other way of reliably assessing the suitability of a servo system for the job it has to do, save that of defining its closed-loop gain and phase shift as functions of frequency. The fact that, having done this, one is then also in a position to define its "stability" in terms of phase and gain margins (for which one's experience suggests suitable values), is convenient but perhaps not essential. Obviously similar stability criteria could be devised, and with experience applied, purely in terms of the impulse response, which will appear "less damped" if the margins are small: though I must admit I would be at a loss to decide which of the two margins was inadequate in a given case. (This latter point matters, since the remedies are often different.) However, surely the main point is that in a particular application, a given pass-band and given phase-shift limits are generally required of the closed-loop system, and there is no obvious way of judging from the impulse response how well these requirements are met. To express the problem by borrowing and twisting one of the author's own examples, given the impulse response of a stereo amplifier channel, how would one decide how good an amplifier it was?

Obviously one could design the impulse-testing equipment to punch out the answers on tape, and then feed the result into a computer for curve-fitting and Laplace-transformation, but this rather destroys the handiness of the idea, doesn't it?

Portsmouth, Hants. K. MOILLIET

The author replies:—

I agree to a certain extent with what Mr. Moilliet says. Although there are many advantages in obtaining time-domain characteristics, there are also disadvantages. The main one is, of course, the sensitivity of the impulse response curve, i.e., slight differences in the measurement of $g(t)$ in general lead to relatively significant changes in the corresponding transfer function.

However, this disadvantage can very often be turned into an advantage if one has enough experience with using the impulse response curve. When determining the characteristics of a servo system, for example, with experience one can learn what the desired impulse response looks like and what the non-ideal one looks like. Again, with experience (there is unfortunately no substitute), one can correlate the mis-match with one of a few sensitive parameters in the system, allowing these erroneous parameters to be corrected. The advantage thus appears here, for example if a parameter is only slightly in error, then again gain/phase analysis will not show this error, due to its insensitivity, whereas the impulse-response test will almost certainly show it.

This feature becomes doubly important when this identification is used as a part of a self-adaptive control loop. The impulse-response test will pick out small differences in a time varying parameter, hence enabling a very tight and rapidly correcting control loop to be designed.

Mr. Moilliet's other point was that he wasn't very sure of what the impulse response curve, once obtained, meant in terms of the system being investigated. I sympathise here, and must agree that not much work has been reported on this aspect, and until experience in this field is obtained the only alternative is to transform the impulse response into a more well known characteristic such as the transfer function or the frequency response curve. However, this transformation need not necessarily be very difficult; there are quite a few convenient "tricks" available enabling such transformations to be done by pencil and paper rather than with a digital computer.

Two final points that might help Mr. Moilliet are:—

(a) The area under the impulse response curve is proportional to the final value of the system when subjected to an unity step input.

(b) If the system being investigated is known to be second-order then the ratio of the "positive areas" under the impulse response curve to the "negative areas" is directly proportional to the system damping ratio.

Other such characteristics can obviously be obtained for higher order systems, although with increasing complexity.

The big advantage with this method is obviously the relatively short time taken to obtain an impulse response curve (all the points are obtained in one run), compared to the correspondingly much longer time required to plot a complete frequency response curve. In fact, I venture to claim that it would take a shorter time to obtain a frequency response by Fourier transformation of the impulse response curve than it would to obtain it by conventional methods.

Other advantages of this chain code technique are the obvious ones, i.e., it saves time (and money), the experiment can be carried out by unskilled operators (they only have to press buttons or turn switches), and the main one of making on-line identification a possibility, whereas this would be quite out of the question with the more conventional techniques.

Pangbourne, Berks. W. D. T. DAVIES

Pick-up Arm Design

I AM sorry Mr. Bickerstaffe (August "Letters") should be confused as to my meaning. Perhaps, for the benefit of other readers, I might be permitted to define a few terms.

There are two basic resonances associated with an arm/cartridge combination, namely: —

(1) h.f. *arm* resonance. This is a function of arm material and construction, together with any modifying factors such as the weight of the cartridge on the end of the tube. In this mode the arm vibrates in the manner of a tuning fork and nominally there is no movement about the vertical bearing. Obviously such vibration may be damped by the application of an acoustically dead material as a tuning-fork could be damped by, for example, covering its prongs with plasticene.

(2) l.f. *system* resonance. This is the resonance of the arm/cartridge combination, and depends on the mass of the arm as seen by the stylus and on the stylus compliance. A good design should place this resonance between about 5 c/s and 15 c/s, these being, respectively, above the worst "warped record" frequency, and below the lowest recorded frequency. Evidently any damping applied for (1) will have no effect on this lower resonance since in this mode the arm is rigid and all the movement is about the vertifical bearing or pivot, which is where any damping would have to be applied.

The above are the only two over which an arm-designer has any control, and I have specifically left out items like slack bearings, since this is an assembly fault.

The resonance to which Mr. Bickerstaffe refers as "h.f. resonance of a pick-up . . . " is of no consequence as it is dependent on stylus tip-mass and record material and no form of *arm* damping will affect it.

Ideally, resonance (1) should be placed above the audio range by making the arm sufficiently stiff, but the mass required to do this would be prohibitive. Resonance (2) is affected by the cartridge, and hence an arm should preferably be designed for a particular cartridge, although usually a range can be tolerated.

H.F. and l.f. in this context are "relative to audio frequencies," and Mr. Bickerstaffe refers, incorrectly, to the "h.f. resonance of the arm and stylus compliance" —I hope that this resonance in his arm is not, in fact, high, because the needle would never stay in the groove!

Finally, I can assure Mr. Bickerstaffe that I am aware of the other possibilities, but the trouble is certainly arm resonance (h.f.!). Regrettably, however, since my last letter, I have, after several years, abandoned the struggle and purchased "the best pick-up arm in the world," and worth every penny of it!

Langford, Beds. ANTHONY H. KING

SOME confusion seems to have arisen from a misprint in my August letter. "The h.f. resonance of the arm and stylus compliance . . . " should have read "the l.f. resonance . . . ". This, of course, referred to the resonance which Mr. King defines as "the l.f. system resonance" and has nothing to do with what I call "tone arm resonances" or what Mr. King (as suspected) knows as "arm resonances," except in that it marks the frequency above which the stylus compliance will tend to decouple the resonant modes of the arm from groove modulation.

Comparing the resonant modes of a pick-up arm to those of a tuning fork is over-simplifying things a little since for a start, the mass distribution of a tuning fork is normally uniform whereas in a pick-up the mass is mainly concentrated at two points i.e. the head and the counterweight.

A pick-up arm usually has many resonant modes, not necessarily harmonically related, ranging in frequency from around 100-200 c/s upwards. The higher frequency modes, due to the decreased coupling between arm and groove at these frequencies, are normally far less troublesome than the lowest frequency mode around 100-200 c/s where the coupling is "tighter." It is these lower resonances for which a compliantly mounted counterweight (arranged to resonate on its mounting around these frequencies) was found to be the best answer.

The mechanism of arm resonances and their effects on pick-up response seems very involved and it is realized that this correspondence has merely scratched the surface of the problem.

Appleby, Westmorland. J. BICKERSTAFFE

OBITUARY

H. J. Round — Radio Pioneer

BY the death of Captain H. J. Round, M.C., A.R.C.Sc., on 17th August at the age of 85, we have lost the last—but by no means the least—of the small band of wireless engineers and technologists who rose to eminence during the early years of the present century. Round's career was unique, if only for its length. In the 50th anniversary number of *Wireless World* (April, 1961) there was a paragraph reading "A name that has constantly recurred in our pages—and happily still recurs—is that of H. J. Round. . . ." His activities continued after that time, the last of the 117 patents granted to him was dated 1962 and, indeed, he was planning to set up a new laboratory a few days before his death.

One of the earliest mentions of his name in the journal was a brief announcement in 1912 headed "Movements of Engineers," "H. J. Round from Head Office to Manaus." Behind that bald statement lies an adventure story typical of Round's earlier exploits. He could almost always be depended upon to produce a quick solution of the technical problem of the moment. The Marconi Company had recently installed two high-power stations for point-to-point working along the upper reaches of the Amazon. Due to atmospheric disturbances and unexpectedly high signal attenuation over the dense Brazilian jungle communication was poor. At a time when hardly anything was known about day/night propagation effects Round, far from sources of supply, decided to double the wavelengths of the stations for daytime working. By miracles of improvisation the necessary alterations were made and the required traffic-handling capacity was achieved.

In the same year Round wrote an article containing by a big margin the first mention of what we would now call electronics to appear in this journal. He described the use of a Fleming diode as a valve voltmeter—an instrument not in widespread use until a good ten years later.

Henry Joseph Round, born on 2nd June, 1881, at Kingswinford, Staffordshire, received his technical education at the Royal College of Science, where he studied under Dr. W. H. Eccles, "the first of the radio physicists." He joined the Marconi Company in 1902 and was then sent to North America, where one of his earliest jobs was training wireless operators. Later he installed stations on the Canadian coast and in the Gulf of St. Lawrence.

On his return to England he became a personal assistant to Marconi and then worked on the Clifden - Glace Bay transatlantic link. The record is lamentably vague as to precisely what part he played in the redesigning of those highly successful but now almost legendary stations, which achieved practically continuous communication both by day and night at a range of nearly 2,000 miles at a time when no others in the world could manage as much as 1,000 miles. We know he was at Clifden in 1910-11, when the station was entirely rebuilt, and at Glace Bay (Nova Scotia) in 1912.

At about this time he produced the balanced crystal limiting receiver. Though that device did not offer a complete solution of the problem of reception through atmospheric interference it was the best available at the time.

Round's work as a prolific inventor of devices of fundamental importance then began in earnest. The "soft" valve named after him, though tricky to handle, gave receivers a hitherto undreamed-of sensitivity. Its use in direction-finders for which he was responsible enabled German naval movements to be tracked during the First World War, leading directly to the fleet encounter at Jutland. D.F. bearings were taken with an accuracy that could hardly be bettered to-day. His patent for amplification by regeneration narrowly missed a claim for priority in the use of the valve as a generator of oscillations. Later work included the design of tubular valves of low inter-electrode capacitance (the V24 and "Q" types) which he used in some of the most effective cascade r.f. amplifiers of the period. After the war he produced high-power transmitting valves and undertook the conversion of the Caernarvon transatlantic station from spark to valve. He patented a screened-grid valve in 1926 and an r.f. pentode a year later, though his work on multi-electrode valves went back much earlier.

With the start of broadcasting in the early 1920s, Round's output became prodigious. He designed the London broadcasting station 2LO, which became the B.B.C.'s first transmitter, was partly responsible for the Sykes-Round microphone and produced systems for electrical gramophone recording and sound-on-film. He had already been made head of the Marconi research group. In 1931 he resigned from the company to become a consultant but never entirely severed his connection. In the last war he worked for the Admiralty on anti-submarine devices.

Round was one of the last survivors of the era of the individualistic inventor, as opposed to the team. He was fortunate in that fate led him into his chosen field at a time when it was wide open to his considerable talents. These he exercised with untiring energy and almost boyish enthusiasm to the end.—H. F. S.

Another tribute

IT is perhaps fortunate that H. J. Round was born to flourish in a previous engineering era for he was far too much of an individualist to have fitted comfortably into the disciplines of a large electronics research laboratory of today. Round was an originator; a man who teemed with ideas and was wont to pursue them with a sublime disregard for protocol which, even in his own period did nothing to endear him to his Head Office. His energy was tremendous.

His big chance came when Guglielmo Marconi selected him as one of his personal assistants, for as such he became one of a small *corps elite* which, in between special assignments, were permitted considerable individual freedom of choice in research work. To the wisdom of this policy Round's 117 patent applications bear tribute.

Those who were junior engineers under "H.J." in his hey-day recall him as one who did not suffer fools gladly. Nevertheless an honest try by a subordinate was always rewarded with kindly encouragement and constructive criticism.

One of the facets of Round's genius lay in his ability to clear the dead wood of irrelevancies from a given problem and reduce it to its simplest proportions for final demolition. One of his great aversions was the cult of technical mystique and obscurantism in technical papers and any engineer guilty of such practices would provoke his formidable scorn.

No appraisal of his character, however brief, would be complete without reference to his lifelong friend and rival within the Marconi Company, C. S. Franklin. In private, each had a profound and unstinting admiration for the other's talents, but in public they had, over the years, built up a cross-talk act —it was no more than that—in which they would swipe at each other's achievements with cheerful abandon. Franklin's portrait was prominent in Round's private laboratory and the death of his old colleague in 1964 affected Round deeply.

To the younger generation of engineers the era which H. J. Round represented may seem as remote as the Middle Ages. But let there be no doubt as to the debt which the electronics industry and the nation owes to him. That debt, to our eternal discredit, was never paid by his own country. Not a single British civil honour was ever conferred on him and it was left to the United States to underline this ingratitude by presenting him with the prized Armstrong Gold Medal in 1953.—W. J. B.

WESCON 1966

L.S.I. AND OTHER HIGHLIGHTS FROM THE 120 PAPERS PRESENTED

THIS year the annual Western Electronic Show and Convention (WESCON) was held in August in Los Angeles, which is the largest metropolitan area in the western part of the U.S. and in it is concentrated much of the electronic and aerospace activity for the whole country. The magnitude of the show is formidable: some 800 exhibitors occupying about 1,500 stands have to divide their exhibits between two locations, as there is not a single exhibition building large enough to house them all together.

Apart from the equipment show, the organizers took the opportunity of arranging a number of other features. These included: the Future Engineers' Show, where technical experiments of talented high school students were displayed; the Industrial Design Awards, in which four winners were chosen from some 100 or so entries competing for excellence in functional design; and a Science Film Cinema giving continuous shows every day of interesting engineering and scientific films.

In addition to all this, and probably the most important part of WESCON, are the technical meetings. Some 120 papers were read at 27 technical sessions during the four days of the show and the highlights of a few of the papers considered to be of particular interest to readers of *W.W.* are given below.

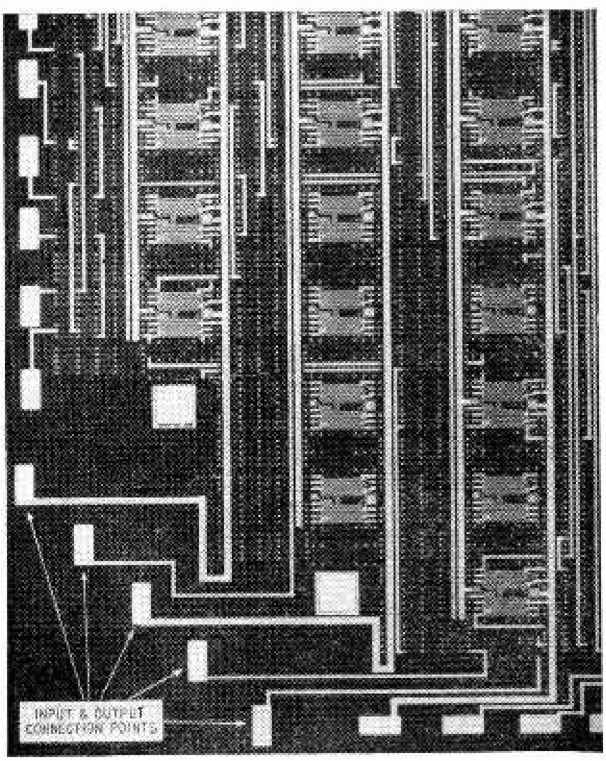


Fig. 1. Part of an l.s.i. wafer containing many logic cells.

Large scale integration (or L.S.I.) is an interesting trend in the field of integrated electronics technology, which is sometimes referred to as "array technology," or as "computers on a slice." A total of six papers were presented on this subject.

It was pointed out that semiconductor technology is now in its third principal stage of development. The first stage was that of the development of transistor and diode applications; the second was the conception and development of simple integrated circuits such as flip-flops and gates; and the third is that of micro-technology in which the equivalent of many conventional circuit functions are built on a single chip, wafer or slice of crystal.

Richard L. Petritz (Texas Instruments) presented a review of the present state-of-the-art. He indicated that a major problem in L.S.I. technology concerns the interconnection of unit cells into one electronic function. In the simple integrated circuit manufacturing process, each semiconductor cell on the slice is scribed into bars and then tested. The L.S.I. process differs from this in that the slice is not scribed; instead, the individual unit cells are tested on the slice by probing. The results of the probing are fed into a computer, which generates a wiring pattern. This wiring pattern is then used to interconnect only the usable unit cells on the slice. After the cells are interconnected, the array is assembled into a larger package, and tested as an overall function rather than as an individual gate. The advantage of this technique is that the final testing is performed on the basis of an array function instead of as a discrete device. Each individual cell has only to work in a given part of the circuit. Accordingly, its specification may be less restrictive than that of a discrete device which must be suited to use in a variety of circuit functions.

By the use of L.S.I. techniques, the development of sub-nanosecond switching machines may be advanced because of the practicability of extremely short interconnections between unit cells. Considering the normal electromagnetic signal propagation time of 1 to 1·5 nanosecond per 12 inches of wire, the reduction of transmission time between gates with L.S.I. techniques is indeed dramatic.

System considerations of L.S.I. were discussed by M. C. Smith (IBM), who predicted that the devices will be used initially in systems characterized by stringent high performance requirements and low part-number quantities, and mainly in storage type applications.

In a hardware price comparison of a hypothetical machine, Mr. Smith estimated that the use of L.S.I. logic modules would cost only one-quarter as much as unit logic implementation. However, for memory array functions, the cost reduction would be only 20 per cent.

H. Freitag (IBM) in a paper discussing a programmed interconnection process for L.S.I. described how the unit cells on a wafer (which need not all be of the same type of circuit) are interconnected to produce a large logic function, by computer control. Automation is essential

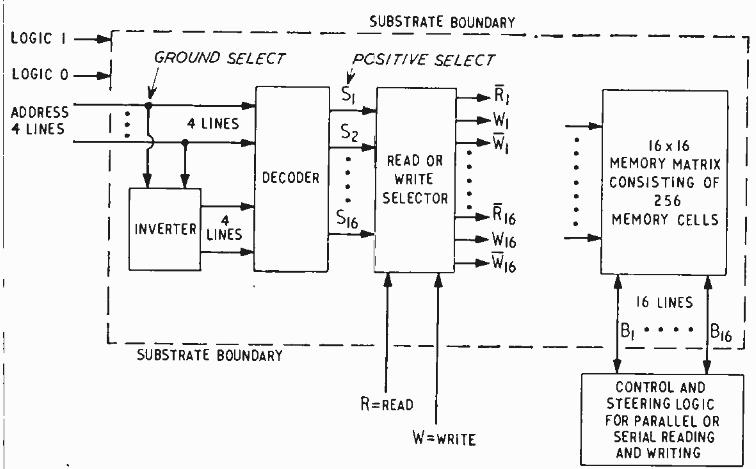


Fig. 2. Block diagram of a single-chip memory and external logic.

for the success of this technique. In this action, the computer determines how the unit interconnection may be minimized, and identifies the most desirable input or output tab for the interface connections (Fig. 1). This is an interesting example of a computer helping to design other computers!

A technique using a silicon-on-sapphire (S.O.S.) process for L.S.I., was the subject discussed by A. C. Lowell, T. Mitsutom, and S. A. White (Autonetics). This technology offers the essential attributes of electrical isolation and design flexibility which are necessary for these complex and functional integrated circuits. An example of a 256-bit memory and logic circuit on a single chip was cited (see Fig. 2). The size of the device was 0·3 by 0·22in. There were 24 leads connected to the chip. Its standby power rating was 6μW at 25°C; its power rating increased to 800μW at 100°C.

One aspect of transistor design which is receiving much attention from device designers is that of r.f. and microwave operation. In a paper entitled "Microwave power transistors," H. C. Lee (RCA) indicated that the prime requirements for operation in microwave equipment are power output, power gain, and efficiency. A particularly efficient device for these frequencies is the "overlay" transistor, which has a construction providing a substantial increase in the ratio of emitter periphery to emitter area, and has high current handling capacity. This is achieved by reducing the size of the emitter, and connecting many of them in parallel by "overlaying" them with aluminium. The 2N3733 overlay transistor has 312 emitters; at present, development types include as many as 408 emitters.

The present state-of-the-art power output of overlay transistors in the range of 200 Mc/s to 2 Gc/s is shown in Fig. 3. This represents the performance of development devices operated at 28 V, and indicates a c.w. output of 7 W at 1 Gc/s. However, in the commercially available 2N4012 overlay transistor, the c.w. power output obtainable at this frequency is of the order of 3 W, and at 1·3 Gc/s it is 1·5 W.

An important application of the overlay transistor uses its harmonic-frequency mode of operation. The non-linear collector-base junction acts as a varactor and generates harmonics of the input drive frequency. The overlay transistor acts as a frequency multiplier and a power amplifier simultaneously. A single transistor of this type can be used to replace a varactor diode frequency multiplier and a power amplifier. Although there is not much difference in the conversion efficiency of the two methods, the overlay transistor multiplier is less costly and much simpler. It is hoped that this mode of operation will extend by a factor of two the frequency spectrum for transistor circuits.

Some recent, and possible future, developments in cathode-ray tubes for television were described by F. H. Townsend (Westinghouse). Considering the case of the all-transistor television receiver, it has been found costly and difficult to provide adequate power for beam deflection in sets equipped with conventional c.r.ts. Some tubes are now being produced with 20mm necks, which require much less power for beam deflection than in tubes with the normal 28 or 35mm necks. However, these are not practicable for the larger sizes of tube face. An alternative solution to the narrow neck may be in the suggestion that the deflection coils or pole pieces be built within the glass envelope of the c.r.t.

Another requirement for the all-transistor television receiver is a c.r.t. which matches the zero warm-up time of the transistors themselves. Two solutions are possible here. One is the return to the directly heated cathode; the other is by the artifice of maintaining the heater of the c.r.t. at a standby temperature that is just below the point of appreciable emission. In the latter, when normal operating voltage is supplied, the cathode reaches emission temperature almost instantly.

As evidence of the further encroachment of integrated circuitry into another of the fields previously dominated by the discrete components, J. E. Jennings (Westinghouse) and E. A. Karcher (ITT) discussed the design of a monolithic voltage regulator. The device they described was a silicon integrated circuit regulator capable of 0·2% regulation with a source voltage variation of ±20% for a range of load currents from 0·5 to 2·5 A. A schematic of a simple voltage regulator circuit is shown in Fig. 4 with the integrated portion indicated. This type of circuit requires a very low output impedance for maximum usefulness; measured values for this device ranged between 0·002 and 0·004 ohm.

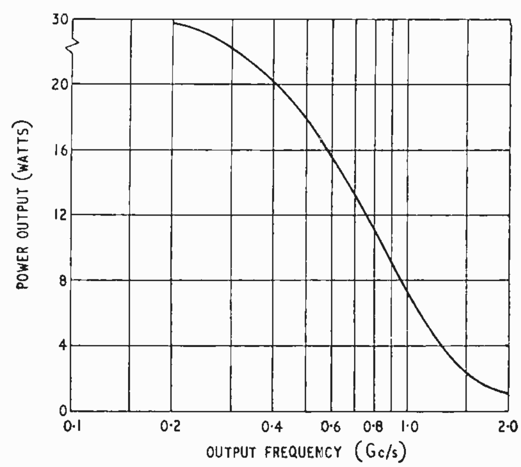


Fig. 3. State-of-the-art power output of overlay transistors as a function of frequency.

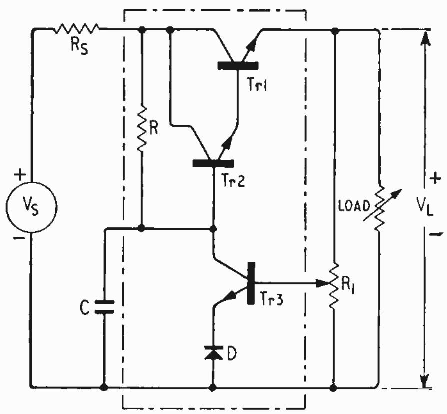


Fig. 4. Simple voltage regulator. The integrated circuit is within the dotted lines.

The regulator was produced by a planar epitaxial technique with a sub-epitaxial floating collector diffusion. The dimensions of the chip are 0·14 by 0·12in. The voltage reference diode (D), shown in the diagram, is a 6·2 V avalanche type. This component has a very low impedance at the operating current; its positive temperature coefficient approximately tracks the negative temperature coefficient of the emitter-base junction of the error amplifier transistor (Tr3).

There has been much interest recently in the applications of millimetre waves to meteorological and radar communications studies. Certain types of clouds cannot be detected by radar meteorology at centimetric wavelengths. However, useful high resolution results have been obtained at millimetric wavelengths which will detect rain, fog or clouds. These wavelengths are used also to investigate atmospheric turbulence over forward scatter and tropospheric scatter paths. Radiometric techniques using millimetre wavelengths permit the determination of the overall characteristics of tropospheric temperature.

A series of papers describing the solving of circuit engineering problems by means of digital computers, were presented by members of the IBM Corporation. A computer-aided design of a servo mechanism was described by D. B. Gasich. The servo described was of the rotary motion type for rotating and positioning a bin of cells, handling mylar strips by means of a hydraulic actuator. The complete simulation of angular position, speed, and angular error versus time was completed in 67 seconds. At an operating cost of $600 (£214) per hour for the use of a model 7090 computer, the processing cost for the simulation totals about $11 (£4). The time required to write the programme, which is frequently a time-consuming job, was less than one hour.

Linear Systems Analysis (L.I.S.A.), which is a method that uses Laplace transforms for the analysis of electrical networks such as two-block control systems, or in fact, any system of linear equations whose coefficient matrix has polynomial elements, was described by K. L. Deckert and E. T. Johnson. The method can be applied to a broad range of scientific and engineering problems which can be described by linear expressions. One aspect of future work to which L.I.S.A. can be applied, is in providing for the interconnection of two-port networks, permitting large networks to be handled by the solving of a number of smaller two-port sections.—Aubrey Harris.

LITERATURE RECEIVED

Technical data sheets on **temperature recorders, controllers and ancillary equipments** have been issued by Cambridge Instrument Co. Ltd., 13, Grosvenor Place, S.W.1. The new recorders and recorder controllers incorporate fluid expansion systems and are offered in a range of standard forms for many different industries.
WW 328 for further details

A 24-page **list of transistor types** from the Telefunken headquarters, 7100 Heilbronn, Rosskampfstrasse 12, Postfach 1042, summarises the salient data only, and is intended as a quick guide to the most suitable germanium or silicon a.f. or r.f. transistor for a particular application. Silicon and germanium diodes are also listed.
WW 329 for further details

"**The Statham Universal Transducing Cell**" leaflet, gives details of a basic strain gauge element, that will, with special accessories, measure force, weight, pressure, displacement, hardness, spherical radius, strain and surface tension. Available in the U.K. from B. & K. Instruments Ltd., 59, Union Street, London, S.E.1.
WW 330 for further details

New techniques for **investigating high speed phenomena by betagraphy** are described in a 12-page Technical Bulletin, Vol. 5, No. 2, issued by the Field Emission Corporation, U.S.A. An electron source is used to produce a shadowgraph on high resolution photographic film and exposure times are as short as 15 ns. Available from Livingston Electronics Ltd., Livingston House, Greycaines Road, North Watford, Herts.
WW 331 for further details

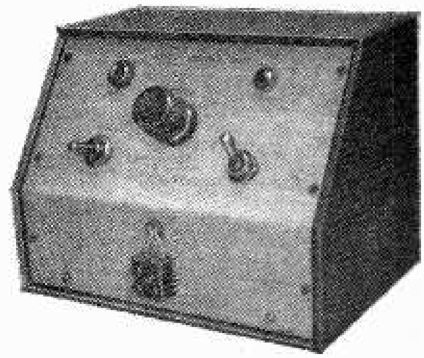
Three new guides to **Mullard industrial products** for 1966 are the 35-page "Industrial Components," 35-page "Industrial Semiconductors," and the 40-page "Industrial Valves and Tubes" with which there is a separate equivalents guide. Details of products added since 1965 are presented in bold type. Copies of these guides may be obtained from Mullard Ltd., Industrial Markets Division, Mullard House, Torrington Place, W.C.1.
WW 332 for further details

"**Where to use storage scopes**" is the title of a 4-page product application note EEM File 2900, received from Tektronix U.K. Ltd., Beaverton House, Station Approach, Harpenden, Herts. It discusses applications such as the retention of single waveform events (non repetitive); direct comparison by simultaneous display of events, and the recording of information from very slow-moving traces.
WW 333 for further details

Product bulletin (U.K. edition) of Bishop Instrument, U.S.A., contains details and specifications of shielded adaptors for **making a conversion between 3/4 in. spaced terminals and BNC coaxial connectors.** The four-page bulletin can be obtained from the U.K. agents Claude Lyons Ltd., Hoddesdon, Herts.
WW 334 for further details

The latest 208-page **Home Radio (Mitcham) Ltd. catalogue** (Reprint No. 12) has been received complete with supplement No. 3 listing prices, and transistor and valve types. Among new items now included are dry reed switches, operating magnets, and a tape stroboscope. The price is 7s 6d from Home Radio (Mitcham) Ltd., 187, London Road, Mitcham, Surrey.

Electronic Control for Model Locomotives



MODEL RAILWAY CONTROLLER USING VARIATION OF PULSE WIDTH TO GIVE IMPROVED CONTROL

By T. E. ESTAUGH

ONE of the major snags of the small d.c. motor, as used in model locomotives, is that very poor speed control is obtained when using conventional forms of control unit. This poor control is particularly well illustrated in the model electric train, where very jerky starting and stopping are obtained, no matter how carefully the normal speed regulator is handled.

A popular form of control circuit, as shown in Fig. 1*a*, consists simply of a variable resistor, RV_1, wired in series with the d.c. motor, with a voltage supply, usually 12 V, connected across the combination as indicated. RV_1 controls the voltage applied to the motor at different currents, and thus controls its speed.

The major snag with this form of control arises from the fact that the starting current of the motor is considerably greater than the running current. Typically, the starting current may be 1 A, and the running current 200 mA, with a similar variation in driving currents between full load and no-load. Now, referring to Fig. 1*a*, if an attempt is made to make the train move off slowly from a standing start, the value of RV_1 may be reduced to, say, 8 Ω before the motor begins to move, at which point it will draw 1 A and thus have 4 V developed across it; as soon as the motor begins to turn, however, the running current falls to about 200 mA, so that only 1·6 V is dropped across RV_1, and the remaining 10.4 V is applied to the motor, which thus builds up to a very considerable speed. Very poor low-speed starting is thus obtained.

Similarly, if the speed is to be maintained as the motor load is increased, as, for example, when the train runs up an incline, the value of RV_1 must be reduced to maintain the voltage across the motor as the load current increases, but in this case the applied voltage will be increased sharply as the train reaches the top of the incline and the load current falls, with the result that the model will accelerate wildly.

As well as giving very poor speed regulation, this system is also very wasteful of power, since the total input power is distributed between the motor and the variable resistor.

Proportional control

A far superior method of motor control relies on the switching method of operation, shown in Fig. 1*b*. Here, the full supply voltage is alternately applied to the motor and switched off again, at a frequency of a few hundred times per second. Thus, by varying the on and off periods of the switch, the total power fed to the motor can be varied and the speed controlled, without involving any difficulties due to the variations between starting, running, and load currents. When the switch is on the motor turns, but when the switch is off the motor stops,

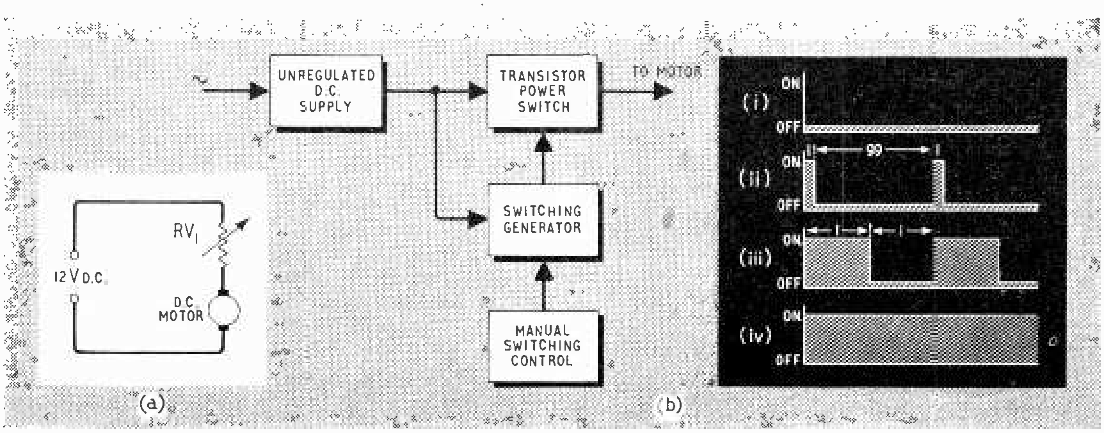


Fig. 1. (a) Common method of speed control giving poor regulation. (b) Basis of the proportional control method. The waveforms (i)-(iv) correspond to zero, 1/100th max, ½ max, and maximum motor speed respectively.

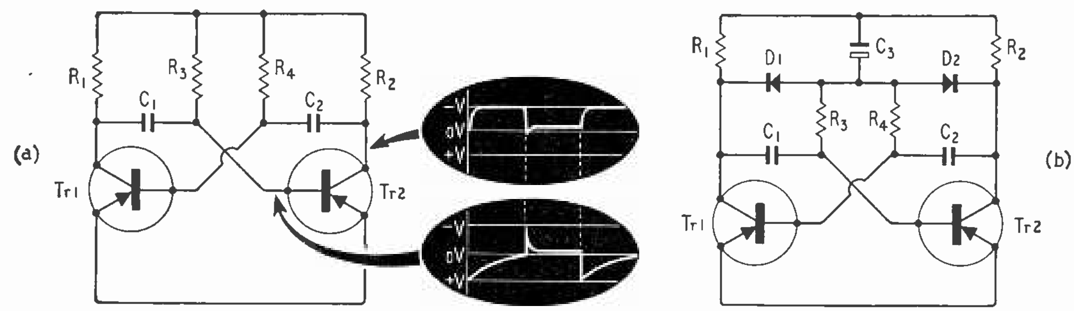
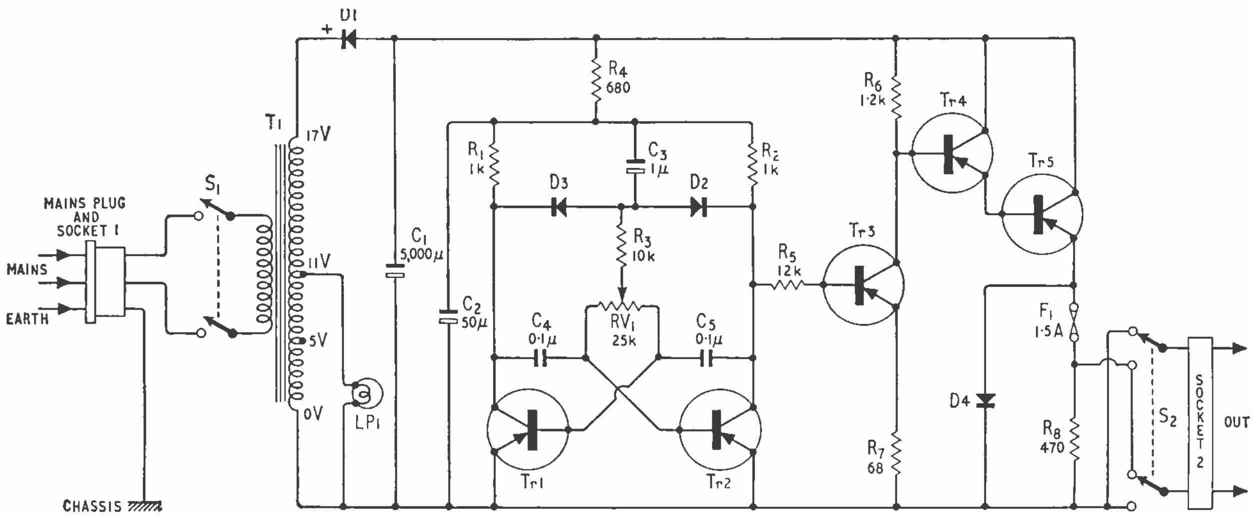
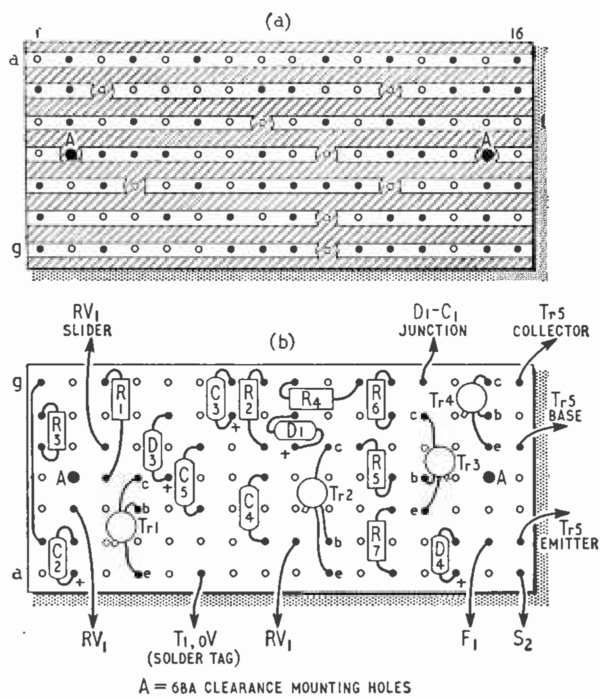


Fig. 2 (a) Normal astable multivibrator. (b) Astable circuit modified for "sure start".



▲ *Fig. 3. Circuit of the complete motor control unit.*

◀ *Fig. 4. Wiring diagram of sub-assembly.*



so that if the switch is on for only $\frac{1}{10}$th of each switching cycle, the speed will be $\frac{1}{10}$th of the maximum possible rev/min, irrespective of the load conditions. By operating the switch several hundred times per second, the motor is made to seem to turn smoothly, instead of in a series of jerks, the speed of the motor being unaffected by the frequency of the input signal.

The unregulated d.c. supply is derived from the mains and provides the power needed to operate the motor and the electronic circuitry. The power is fed to the motor *via* the transistor power switch, which in turn is activated by the switching generator. The on/off ratio of this generator can be controlled by means of the manual switching control mounted on the front panel of the finished unit.

It should be noted that, as well as giving very smooth control of the motor, this method of operation has a very high order of efficiency, since ideally the switch is either on (short circuit) or off (open circuit), and thus consumes negligible power.

The unit that forms the basis of this article is designed for driving a 12 V model train, at currents up to $1\frac{1}{2}$ A. Any motor operating at voltages within the range $1\frac{1}{2}$-24 V can be operated by the unit, however, by simply modifying the d.c. supply to give the required voltage output. Similarly, the output current can be increased by simply increasing the ratings of the power supply components.

The unit is provided with a forward/reverse switch for changing the polarity of the output signal, and thus reversing the direction of the motor.

Circuit description

The most complex part of the circuit is the switching generator, and the development of this part of the circuit will be dealt with before dealing with the full circuit of the finished unit.

This generator is derived from the standard astable multivibrator, shown in Fig. 2*a*. The periods are controlled by the time constants C_1R_3 and C_2R_1, so that by suitably selecting these component values the operating frequency and the on/off or mark/space ratios of the circuit can be altered.

It should be noted that the voltage swing on the base of each transistor is equal to almost twice the supply voltage, so that, if an 18 V supply is used, the transistors should be rated for 36 V operation; alternatively, the supply voltage can be reduced by a decoupled series resistor.

The major snag of the conventional astable multivibrator is that, under certain circumstances, both transistors tend to switch on at the same time, and when this happens the circuit cannot oscillate. This locking of the circuit can occur if the power supply is connected to the circuit gradually, starting at zero volts and building up, or more important, it can occur when extremely wide mark space ratios are used.

This unfortunate business of locking can be overcome by modifying the circuit as shown in Fig. 2*b*. Here, the two diodes are connected back to back between the collectors of Tr1 and Tr2, and the two timing resistors, R_3 and R_1, are common to the junction of the two diodes. Thus, if both transistors were to switch on at the same time, the D1-D2 junction would fall to near ground potential, and the base bias of both transistors would fall to near zero, switching the transistors off. It is thus impossible for both transistors to lock on at the same time and, if the mark/space ratio is not too great, the circuit cannot fail to start. If the mark/space ratio is

COMPONENTS LIST

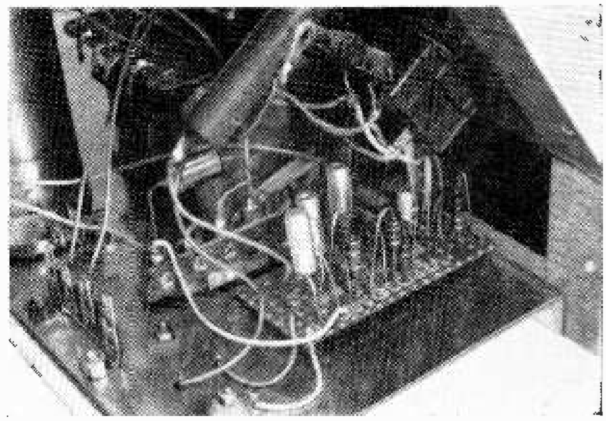
Resistors:—
R_1 1 kΩ
R_2 1 kΩ
R_3 10 kΩ
R_4 680 Ω
R_5 12 kΩ
R_6 1.2 kΩ
R_7 68 Ω
R_8 470 Ω, 1 W.
RV_1 25 kΩ Linear
All ½ W, 10% unless otherwise stated.

Capacitors:—
C_1 5000 μF 25 V
C_2 50 μF 15 V
C_3 1 μF 15 V
C_4 0.1 μF (sub-min.)
C_5 0.1 μF (sub-min.)

Semiconductor devices:—
D1 50 p.i.v., 1.5A rectifier
D2, D3, D4 OA202

Tr1-Tr3 OC71, NKT214, etc.
Tr4 OC81, NKT271, 2N381, etc.
Tr5 OC35, NKT404, 2N456, etc.

Miscellaneous:—
T1 Battery charger transformer. Secondary 5, 11, 17 V at 1.5 A
SKT1 Bulgin 3 pin, type P73, with plug
SKT2 2-way connecting block, screw connections
Lpl Bulgin signal lamp with 12 V bulb
S1 2 p. 2-way on/off toggle switch
S2 2 p. 2-way change-over toggle switch
F1 1.5 A fuse and holder, panel mounting


View of the control unit removed from the cabinet to show wiring.

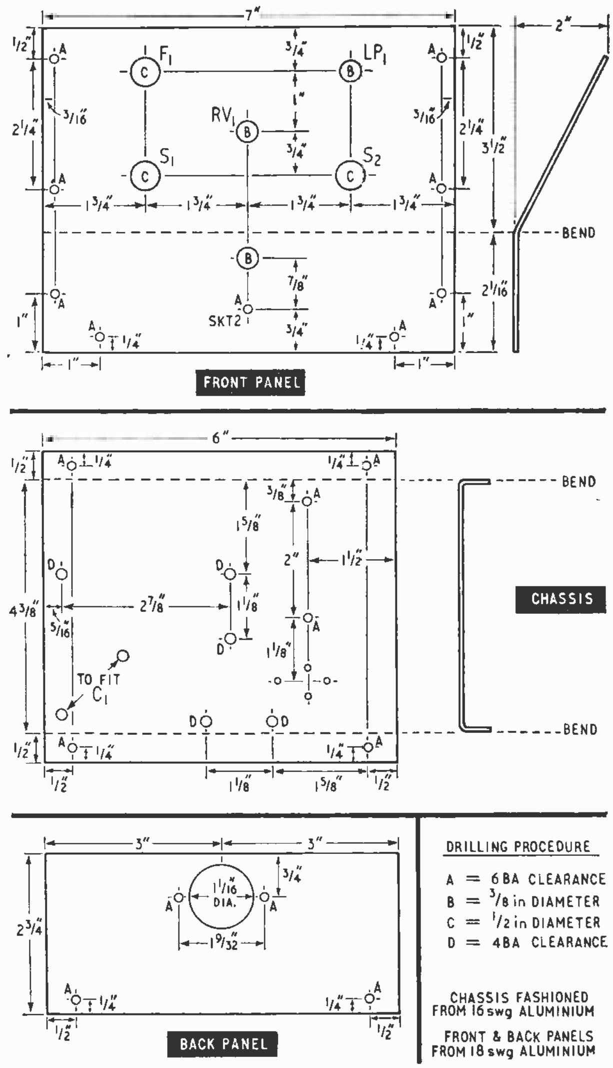


Fig. 5. Dimensions of front panel, chassis and back plate.

too great, the circuit will cease to oscillate, but only one transistor will lock on. This is, of course, precisely the action that is required of the switching generator.

Having cleared up these points, we can now deal with the final circuit of the complete motor control unit. Referring to Fig 3, the mains supply is connected to transformer T1 *via* the on/off switch, S1. The transformer used has secondary tappings at 5, 11, and 17 V, and the 11 V tapping is used to feed the indicator lamp, LP1. The 17 V tapping feeds the rectifier, D1, and the output is smoothed by the large electrolytic capacitor, C_1, giving a final d.c. output at about 22 V.

Tr1 and Tr2 are connected as a sure-start astable multivibrator, with continuously variable mark/space ratio, RV_1 acting as the speed control. As mentioned earlier, the transistors in this circuit must be rated for operation at approximately twice the supply line potential, i.e. 44 V in this case, and to overcome this snag the supply to the circuit is reduced by R_1, decoupled by C_2, so that 30 V transistors can be used.

This move reduces the peak-to-peak swing at the output of the circuit, taken from Tr2 collector, and so limits the drive signal to the power switch. To overcome this, Tr2 collector is d.c. coupled *via* R_5 to the base of Tr3, which is wired as a common emitter amplifier and gives an output swing at its collector of about 20 V.

The power switch comprises Tr4 and Tr5, wired as a Darlington or "super-alpha" pair emitter follower, with the input drive signal direct coupled to Tr4 base from Tr3 collector, and the output taken from Tr5 emitter at low impedance. Fuse F1 is in series with Tr5 emitter to prevent damage to the transistor in the event of a short circuit at the output terminals, and R_8 is used as a permanent output load. The d.c. motor that is driven by the unit is largely inductive, and D4 is used to swamp any back e.m.f. that might occur from it.

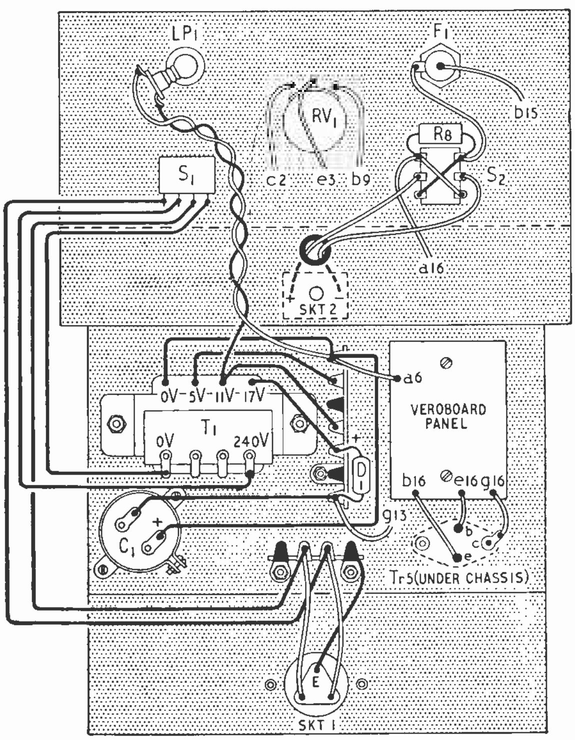


Fig. 6. Exposed view of unit.

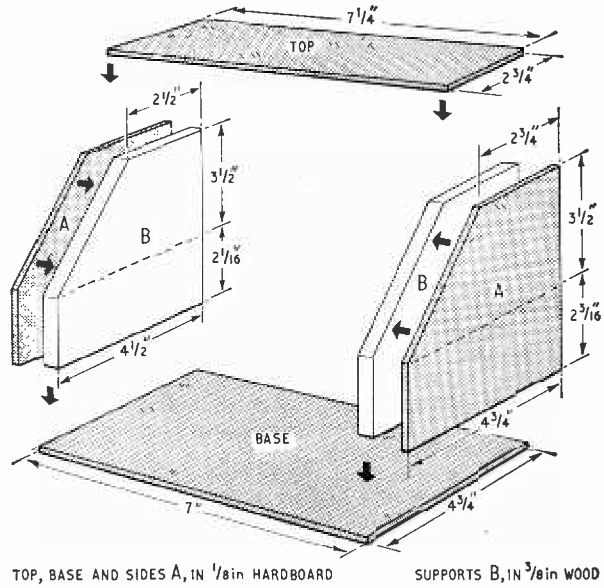


Fig. 7. Cabinet details.

The final output to the output socket is taken from Tr5 emitter *via* the 2-pole, 2-way switch, S2, which enables the polarity of the output signal to be selected at will to give either forward or reverse drive to the d.c. motor.

Construction

For ease of construction, the major part of the electronic circuitry can be wired up on a small piece of Veroboard panel with the components mounted vertically.

The metalwork can now be made up as shown in Fig. 5. Start by cutting the front panel to size, as shown in Fig. 5*a*, then bend, as indicated, and drill the panel as shown. When the front panel is complete, it can be covered with a self-adhesive decorative plastic material; a material with a light wood-grained finish was used on the prototype. The main chassis and back plate (Figs. 5*b* and 5*c*) complete the metalwork.

The Veroboard panel is secured to the chassis with two 6 BA screws and nuts, using small rubber grommets between the Veroboard and the chassis as spacers and insulators. The large power transistor, Tr5, is bolted to the underside of the chassis, and care should be taken to use an insulated spacer and washers.

The unit should now be given a functional check by connecting a d.c. voltmeter across the output socket and switching the unit on; it should be possible to vary the readings of the voltmeter between approximately zero and 18 V by varying the setting of the speed control, RV_1. If this test is satisfactory, a d.c. motor can be connected across the output terminals and the unit given a final check. The power transistor should not become appreciably warm during these tests.

The cabinet can now be made up as shown in Fig. 7. Note that $\frac{1}{8}$ in hardboard is used for the major part of the construction, with two $\frac{3}{8}$ in internal wooden side pieces added for strength. The unit can be given a professional finish by marking the front panel with Blick pressure sensitive lettering. These lettering sheets are available from most stationers.

NEWS FROM INDUSTRY

COLOUR TV TUBE PRODUCTION

THORN-AEI announce that they are starting the large-scale production of colour tubes at their Brimsdown, just North of London, factory in September. These 90° shadowmask tubes (Mazda V3503A) use rare earth phosphors and are fitted with integral metal suspension lugs. Initially production will be concentrated on 25in rectangular tubes. It is understood that scanning and associated neck components for use with Mazda colour tubes are being developed in Britain by the Plessey Company. Although Thorn and Sylvania of America at one time jointly owned a company (Sylvania-Thorn) for the production of tubes in this country, this company no longer operates. Sylvania still have a financial interest in the Thorn organization and a reciprocal agreement exists for the exchange of technical information on television tubes between the two companies. Development of the new Mazda shadowmask tubes and the design of much of the production equipment performing key operations, has been carried out entirely at the Thorn-AEI, Brimsdown, laboratories.

RCA Colour Tubes

A joint statement by the Radio Corporation of America and Radio Rentals Ltd., has announced the formation of a new company to manufacture RCA colour television tubes in this country. Two-thirds of the equity in the new company, RCA Colour Tubes Ltd., which initially has a capital of £1M, is being held by RCA Great Britain, on behalf of the American Company, and one third by Radio Rentals. A factory is being built at Skelmersdale, Lancs, and production is planned to begin in mid-1967. Initially some components may have to be imported for the 25in and 19in rectangular tubes to be produced. Although, of course, Radio Rentals will be using these tubes in their Baird colour receivers, it is intended that RCA Colour Tubes "will offer its products freely to the whole trade on competitive terms." Tubes will be sold both in the U.K. and overseas. Incidentally, Baird receivers will be manufactured at Radio Rentals Bradford plant where considerable research has been going on in the development of a colour receiver.

The formation of the new company is RCA's first major move into the European colour market. It is understood that they are not contemplating set production in this country, such colour receivers as have been available so far have been imported by RCA Great Britain.

The directorate of RCA Colour Tubes is headed by D. W. Heightman (chairman) who is also director of engineering, Radio Rentaset Ltd. Dr. H. R. L. Lamont, director, European Technical Relations, RCA International Division, is the only other director named so far.

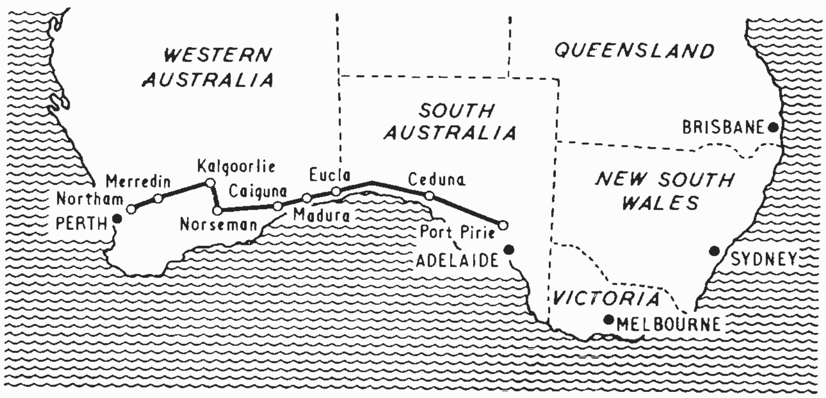
The B.B.C. has awarded a contract worth more than £500,000 to **Pye TVT Ltd.** of Cambridge for the supply and installation of eight transmitters at BBC-2 u.h.f. stations in Somerset, Hampshire, Sussex, Staffordshire, Flintshire, Londonderry, Angus, and East Lothian or Fife. Scheduled for delivery during 1968, the transmitters at three stations will have peak sync outputs of 25 kW and 10 kW at the other five. Both the sound and vision power amplifiers are vapour phase-cooled klystrons. Should either klystron fail, then the automatic fall-back system will combine the sound and vision input signals and feed them to the operating klystron, providing a low-power emergency service without standby equipment.

The National Computing Centre, which was set up last year with headquarters now being built in Manchester, has ordered its first computer—the English Electric-Leo-Marconi KDF9 worth approximately £400,000. The computer will have a 32678-word store, ten magnetic tape units and a large magnetic disc file capable of storing 31 million characters. The Computing Centre, under the directorship of Professor Gordon Black, will be concerned initially with computer education and is to start a course in collaboration with Imperial College for systems analysts. It is also planned to build up an index of all the computer programmes available throughout the country and also to encourage the use of computers by industry.

Flexible Printed Wiring.—Painton & Co. Ltd., in conjunction with their subsidiary Electroprints Ltd., have entered into a licence agreement with G. T. Scjeldahl Company, of Northfield, Minnesota, covering the manufacture in the United Kingdom of flexible printed circuitry by a continuous roll process. This new process is said to significantly lower manufacturing costs.

Redifon Ltd. has formed a new division to handle marine communications equipment and radio navigational aids. This Marine Division headed by J. S. Turner, will operate from Wandsworth.

The E.M.I. **television O.B. vehicle** which was demonstrated at the British Industrial Exhibition in Moscow has been sold to the Russian Television Service for operation in Tbilisi, Georgia. The equipment includes four image orthicon turret camera channels and associated monitors, vision and sound mixers and audio tape recorder. Solid-state circuitry is employed throughout the equipment.



£3.2M communications system for Australia.—A 1,500 mile microwave communication link is to be constructed by G.E.C. (Telecommunications) Ltd. between South and West Australia for service in 1969. Although terminating at Northam and Port Pirie the link will connect with Perth and Adelaide via the existing radio relay network. A main channel carrying 600 telephone circuits, and one standby channel will be provided between Port Pirie and Kalgoorlie. From Kalgoorlie to Northam similar facilities will be provided plus a television channel. The solid state equipment will operate in the 2000 Mc/s band, and it is expected that the system will eventually carry up to four extra radio channels of similar capacity. The 60 repeater stations will be spaced at 25-mile intervals. As well as handling East-West "through traffic" additional telephone circuits will be provided for Ceduna, Eucla, Caiguna, Norseman and Kalgoorlie.

NEW PRODUCTS

equipment systems components

Fault Detection Probe

DETECTING and locating electronic faults that radiate r.f. energy is made easier by the Honeywell R.F. Probe. This instrument exploits the fact that when circuits and components are energized, certain types of faults generate minute electrical arcs, which in turn create r.f. noise in their vicinity. The probe consists of a radio frequency amplifier, an audio amplifier, a pick-up device which is in the form of a tuned air-core loop aerial, rechargeable batteries, control and display panel, and earphones. The circuitry or equipment is slowly scanned with the pick-up, while the r.f. noise level is monitored through the earphones. It is stated that tapping the suspected equipment with a non-conducting rod will stimulate a burst of r.f. noise from the fault. When such a noise spike occurs, the operator can pinpoint the location of the fault by reducing the amplifier gain, and varying the position of the pick-up device. Among the many intermittent faults that can be detected are bad solder or weld joints, intermittent connections, loose and frayed wiring. In components, it will detect and locate fractures in active elements and faulty lead wire connections. Another application is the prediction of faults that may lead to the malfunctioning of complete systems. In addition to its audio output (earphones), the probe can be used for recorder or oscilloscope presentation (100 kΩ source impedance), and meter display of battery condition and audio signal. The stated sensitivity of the r.f. amplifier is −100 dBm minimum. Power is provided by internal nickel cadmium cells and these are recharged by a built-in battery charger requiring 115 V 60 c/s, or 220-240 V 50 c/s. Size is $7\frac{1}{2} \times 7\frac{1}{2} \times 6\frac{1}{4}$ in, and the weight is 5lb. Honeywell Controls Ltd., Honeywell House, Great West Road, Brentford, Middlesex.

WW 301 for further details

Power Frequency Monitors

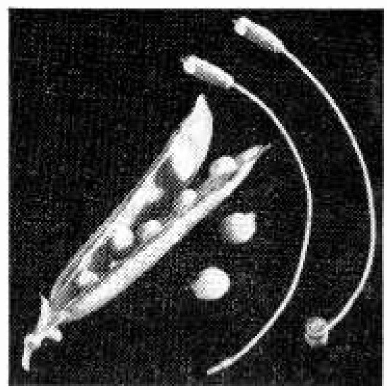
DIRECT monitoring of power supply frequencies is essential when checking the accuracy of performance of frequency dependent equipment and instruments. Variations in frequency may also be critical in such applications as chronometers, aircraft equipment, tape recorders, servo systems (military and industrial), and in industrial applications such as paper making and wire drawing. The Dawe digital frequency monitors (types 728-50, 60, and 400) are intended to check variations in 50, 60, and 400 c/s supplies, respectively. Measuring techniques used measure one cycle of an input, which would mean that a 50 c/s supply could be checked in 20 ms. The sampling rate for any frequency is 0.5 s. Accuracy of the monitors is ±0.02 % at the nominal frequency, but at other frequencies a low reading error occurs that is equal to −0.2% at −5% and +4% (limits of the indicated range) of the nominal value. Although this error is fundamental to the circuit, it follows a predictable curve, thus a correction curve is provided to enable the accuracy of frequency calculation to be within ±0.02% over the stated range. Dawe Instruments Ltd., Western Avenue, Acton, W.3.

WW 302 for further details

Silicon Controlled Rectifier

TWO 50 V planar silicon controlled rectifiers are being marketed by SGS Fairchild Ltd., Stonefield Way, Ruislip, Middlesex. The SC60 is rated at 2.2 A, and the SC61 at 6.5 A. They are intended for applications such as power supply protection, regulation of industrial circuits requiring output currents of 0.5 A or above or as low-voltage inverters, for fluorescent lighting from 12 V or 24 V batteries in vehicles. There are also possible applications in domestic equipment, such as the safety control of electric blankets. No voltage derating is required for junction temperatures of up to 125°C. Turn-on time is 1.5 μs and turn-off time is 30 μs. A special feature of both types is an integrated resistor of 100 Ω between gate and cathode, to prevent accidental firing of the device. The SC60 is available in a TO-5 can, and the SC61 in a TO-3 can.

WW 303 for further details



MINIATURE ACCELEROMETERS

WEIGHING only 1.8 gm, the Consolidated Electrodynamics 4-275 piezoelectric accelerometer is suitable for a wide range of aerospace and industrial applications, ranging from vibration testing of miniature assemblies to accoustical studies. One model has a flat mounting base for adhesive mounting, and a second model is equipped with an integral mounting stud. True mechanical isolation is claimed for both models which have a voltage sensitivity of 5.5 mV/g. The frequency response is 4 c/s to 15 kc/s and the operating temperature range is −100 to +250 °F. An interesting feature of the 4-275 is its detachable cable. From Consolidated Electrodynamics (division of Bell & Howell Ltd.), 14, Commercial Road, Woking, Surrey.

WW 304 for further details

ENCAPSULATED UNIJUNCTION TRANSISTOR

TEXAS Instruments' unijunction transistor, the TIS43, is a product of new planar technology combined with advanced plastic packaging techniques. One advantage claimed as a result of this is a current leakage rate that is twenty times lower than that stated for conventional silicon alloy unijunctions. The leakage characteristic (I_{EO}) for the TIS43 is 10 nA max at 25 °C, making it suitable for precision timing circuits, oscillators, multivibrators, wave-form generators. It also has an application as a triggering device for s.c.rs. Other characteristics are r_{bb} = 4.0 kΩ minimum, and 9.1 kΩ maximum; η (intrinsic standoff ratio) = 0.55 minimum and 0.80 maximum, and V_{oB1} (base 1 peak pulse voltage) = 3 V minimum. By employing the more rugged planar construction and one-piece encapsulation, vibration and shock resistance have been increased by a factor of three, and in life tests these planar UJT devices have operated for 155,000 hours without failure. The encapsulation conforms to the JEDEC TO-92 outline. Texas Instruments Ltd., Manton Lane, Bedford.

WW 305 for further details

Pulse Generators

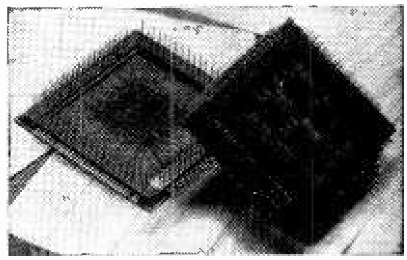
A RANGE of Elma (Swiss manufacture) type G pulse generators is available from Radiatron, 7, Sheen Park, Richmond, Surrey. A mains operated (50-60 c/s) synchronous motor drives a shaped cam, which in turn operates a micro-switch or sealed reed relay. Pulse rates are available from 1 pulse per minute up to 20 pulses per second. Used with suitable electro-mechanical counters, they can be employed in the construction of elapsed timers, control timers, and digital clocks. Constructed as a plug-in module, they have a front panel measuring 56 × 69mm.

WW 306 for further details

MATRICES FOR DESK CALCULATORS

LITHIUM-NICKEL ferrite cores are employed in the construction of single-plane core matrices manufactured by Mullard Ltd., for small electronic desk calculators. It is claimed that any data stored is retained even if the machine is disconnected from the power supply. Using these cores yields operational stability over the temperature range 0 to 70 °C. Operation at low drive current (190 mA) is achieved by employing 2-turn X, Y, and Z windings, which reduce the drive requirements. This in turn permits relatively simple drive and selection circuits to be used. The core assembly is supported in a rigid frame, while the cores are lacquered to a paper-laminate backing plate. For more humid conditions epoxy coated frames are available. The matrix pin connection tags are secured in the frame, and are disposed over a 0.1 in grid for direct soldering on to printed wiring boards. Matrices in stacks of up to four planes with series connected drive wires can be obtained. The number of cores available in the standard range of planes are 16 × 16 (AW 3526), 4 × 8 × 8 (AW 3527), 4 × 12 × 12 (AW 3529), 4 × 16 × 16 (AW 3531) and 32 × 32 (AW 3532). Mullard Ltd., Mullard House, Torrington Place, London, W.C.1.

WW 307 for further details



Echo Sounder Test Set

SPECIALLY designed for servicing echo sounders, sonar equipment, and similar ultrasonic apparatus, the Elliott Instruments Test Set UL3 is a signal

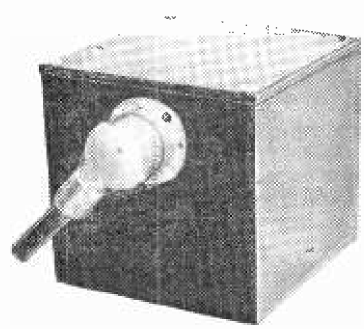
generator and output meter combined. The sine wave output is derived from a Wien bridge oscillator that is continuously variable from 7 to 60 kc/s, with a calibration accuracy of ±2½%. A built-in attenuator permits outputs from 1 to 1,000 μV r.m.s. in three ranges at an impedance of 1 Ω, and from 1 to 1,000 mV r.m.s. in three ranges at an impedance of 1 kΩ. Calibration accuracy is ±5% of the range in use. Model UL3 has monitoring facilities for gain measurements on echo sounder amplifiers, the meter of the instrument being connected directly to the amplifier output. This will indicate either 10 V d.c. (full scale) at 10 kΩ for wet paper recorders, or 500 V a.c. (full scale) at 200 kΩ for dry paper recorders. Completely portable and of transistor circuit design, the current drain is approximately 15 mA from internal dry batteries. The Model UL3 costs £44 10s and the UL3a, without monitoring facilities, £41 10s. The size is 8 × 6½ × 2in and the weight is 4lb. From Elliott Instruments Co. Ltd., Bigods Hall, Dunmow, Essex.

WW 308 for further details

SAFETY TRANSFORMERS

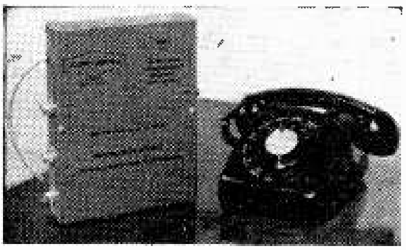
THE SKOT safety transformer is designed to comply with B.S.794, and is intended to minimize the risk of electric shock from portable power tools. It is provided with an earthed shield, fuses, and an outlet socket that prevents tools from being connected accidentally to the wrong voltage supply. The input is 200-240 V and the output is 110 V, 400 W. The price is £12. SKOT Transformers, Crossroad Works, Hanley Swan, Worcester.

WW 309 for further details



Communal Aerial Amplifier

DISTRIBUTION amplifiers for both large and small communal aerial systems manufactured by Teleng Ltd., Church Road, Harold Wood, Romford, Essex, are known as the Teleng-Jerrold Essex series. This equipment is based on two types of amplifier. One is a wideband output amplifier capable of handling six to seven channels and the other is a series of single-channel pre-amplifiers, each with a gain of about 20 dB. Output levels from the wideband amplifier are sufficient (100-200 mV) to supply large installations of up to 150 points, provided their physical disposition is suitable. The assembly known as SX5303 can comprise one or two pre-amplifiers fitted with selective bandpass filters, in series with the 20 dB wideband amplifier, thus yielding a gain of 20, 40 or 60 dB per channel as required. A simpler assembly SX5302 for smaller systems is a wideband unit only, with a gain of 24-29 dB, yet delivering the same output signals as the larger units. Prices are SX53/32 from £37 10s, and the SX5302 £23.

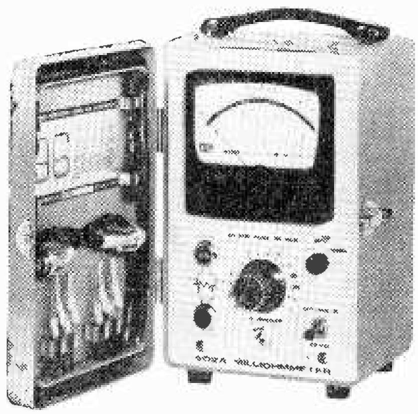


WW 310 for further details

PORTABLE MILLIOHMMETER

TWO modes for measuring resistance are used in the Keithley Instrument (U.S.A.) milliohmeter, model 502A. In the "normal mode," the power dissipated through the sample to be measured is reduced to 2 μW, which allows measurements to be made with an accuracy of ±3 % from 0.001 Ω to 1 kΩ. The "voltage limiting mode" restricts the voltage applied across a sample to 25 mV pk to pk, with a maximum power dissipation of 65 μW, regardless of voltage settings. In this mode, measurement of fuses, explosive devices, and dry joints can be effected with ease. Other applications include the measurement of semiconductor junctions, conduction in electrolytic capacitors, and thermal variation in thermistors. This battery operated portable instrument possesses thirteen full-scale resistance ranges from 0.001 Ω to 1 kΩ. The price is £182, and it is available in the U.K. through Livingston Laboratories Ltd., Livingston House, Greycaines Estate, North Watford, Herts.

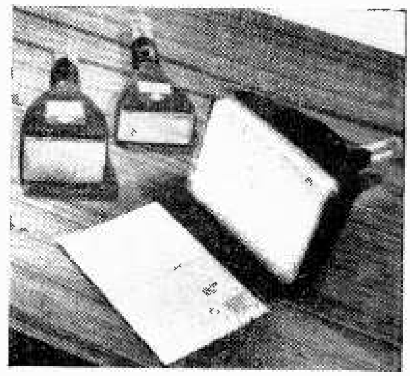
WW 311 for further details



Construction System

MASTERBOX is a modular box system originally conceived for the quick construction of small switchboards, indicator panels, and control boxes. The simplicity of construction (only a screwdriver is required) and flexibility of the whole system, also make it useful for the amateur, and in the experimental laboratory where prototype chassis and units are required, and for exhibitions and display units. Although the boxes are complete, the face panels must be cut and drilled by conventional methods for the mounting of the requisite components. There are two sizes of standard unit, possessing face areas of 3in × 3in and 6in × 6in, both with a 2in nominal depth (1.90in internal). The side panels have a dark green "otter" finish in p.v.c. laminate. Steel nuts and screws are bright cadmium plated. Masterbox parts are available separately or in kit form, the latter being unit, extension, and corner kits in both the 3in × 3in and the 6in × 6in sizes; mounting brackets can also be provided. Cockrobin Controls, 36, Villiers Avenue, Surbiton, Surrey.

WW 312 for further details



CATHODE RAY TUBES

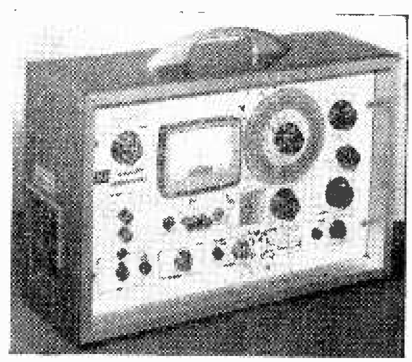
TELEFUNKEN'S M17-11 c.r.t. with magnetic deflection has been designed for battery operated equipment. A rectangular screen with a 17 cm diagonal, presents a useful screen area of 95 mm × 125 mm, and a neck diameter of 21 mm. At a filament voltage of 11 V the heating current requirements amount to 55 mA. M17-11 can be supplied with a white screen (M17-11 W), or a long persistence screen (M17-11 GM and LF) for slow event observations. No safety plates are required. Telefunken AG, 1 Berlin 10, Ernst-Reuter-Platz 7. U.K. agents, Britimpex Ltd., 16-22. Great Russell Street, W.C.1.

WW 313 for further details

Transistor Analyser/Tester

THE M L Transistor Analyser/Tester can be used to measure collector-base voltage, collector current, hybrid parameters, zener slope resistance, breakdown voltage, and other parameters. As an analyser it is intended for use in circuit analysis, assessment of semiconductor performance and characteristics, and the matching of such devices. A secondary application is in the teaching of physics, basic electronic theory, and the use of semiconductors. Price £186. M. L. Industrial Products, 292, Leigh Road, Slough Trading Estate, Bucks.

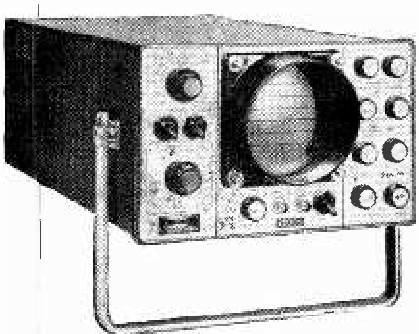
WW 314 for further details



ULTRASONIC FLAW DETECTOR

COMPLETELY self-contained, the Kelvin Mk. 8 ultrasonic flaw detector possesses a built-in alarm, attenuator and battery unit. It will operate from the mains supply, or from internal batteries which will give eight hours service at maximum consumption and it is claimed that they have an average life of 1,000 charge/discharge cycles. The timebases are calibrated in centimetres and there is a fine range control. Single or double probe operation is carried out in the range 0·5 to 10 Mc/s. Both the amplifier range and the delay circuit functions are linear. This instrument is weatherproof, and will operate within the temperature range $-10°C$ to $+50°C$. It measures $6\frac{1}{4} \times 10 \times 17\frac{1}{8}$ in. The weight is 29·5 lb, with detachable mains/charger. Kelvin Electronics Co., Kelvin House, Wembley Park Drive, Wembley, Middlesex.

WW 315 for further details



Plug-in Silicon Rectifiers

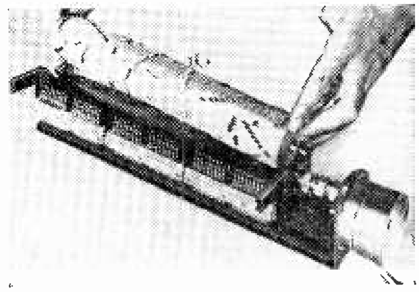
SOLID-STATE substitutes for valve and mercury vapour tube rectifiers have been developed by International Rectifier as direct plug-in replacements. For example type ST-14 will directly replace 5AV4, 5AW4, 5AZ4, 5T4, 5U4, 5V4, 5W4, 5Y3 and 5Z4 thermionic valves. Advantages of these components are stated to be; no warm-up time, long life, and high temperature operation with minimum heat generation. This series covers ratings up to 40 kV and 1.25 A. International Rectifier, Hurst Green, Oxted, Surrey.

WW 316 for further details

Programme Switches

ACTAN programme drum switches by Sealectro are designed to facilitate the easy exchange of programme drums. The drum is removed from the switch assembly by the release of two levers and replaced by another drum with a completely different programme in less than 1 minute. Speed of drum rotation can be changed by replacing the timing motor with one of a different speed. This ACTAN programmer with replaceable drum and timing motor is available with 60 positions, and can be produced to control from 16 to 57 circuits. The colour coded actuators on any single drum can be individually adjusted. Sealectro Ltd., Farlington, Portsmouth, Hants.

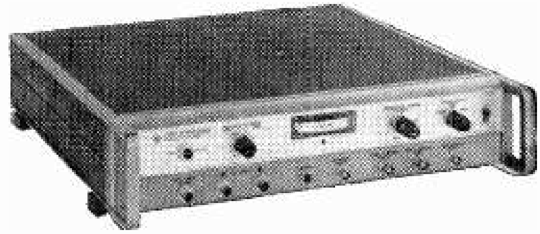
WW 317 for further details



Frequency Synchronizer

IMPROVED frequency stability of generated signals above 50 kc/s is stated to be possible by use of the Hewlett-Packard Model 8708A signal generator synchronizer. This instrument has been designed to provide the Hewlett-Packard 606B and 608F signal generators with crystal-oscillator frequency stability. Phase-lock techniques are used to provide test signals that are stable to within 2 parts in 10^7 over a ten-minute period. This is claimed to be an improvement factor of 250 over stability previously available with signal generators operating in this frequency range. Frequency stabilization can be accomplished at any frequency from 50 kc/s to 455 Mc/s, and internal frequency reference stability within the temperature range 0 to 55°C is 2 parts in 10^7/°C, and with a 10% voltage change it remains at 2 parts in 10^7. The stabilized signal has high spectral purity, with non-harmonically related spurious signals better than 60 dB down. With this stability, and precise control over the tuning of the reference oscillator with the aid of a frequency vernier, testing of closely spaced communications channels, or steep skirted filters can be carried out. The 8708A also possesses facilities for narrow band frequency and phase modulation with very low distortion (better than 1% linearity). It operates on 115 V or 230 V ±10%, 50 to 400 c/s, while the power consumption is approximately 48 W. Hewlett-Packard, Ltd., 224, Bath Road, Slough, Bucks.

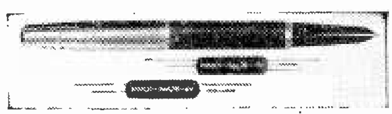
WW 318 for further details



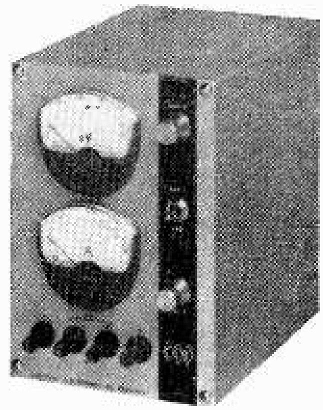
Miniature Reed Relay

A SMALL, high speed reed relay, sealed against humidity by a hot moulded epoxy resin, is manufactured by Erg Industrial Corporation Ltd. It is produced as the MM01 Series with closure speeds of 0.5ms (excluding bounce). The contact arrangements in this series are s.p.s.t. or s.p.d.t., with current ratings of up to 1 A, and a claimed operational life of a thousand million cycles, in signal switching circuit applications. Coils are available in the standard range for 6, 12 and 24 V operation, and up to 48 V on request. The MM01 series measures 1.125 in long × 0.290 in diameter with axial terminations, and will operate in the temperature range of $-55°C$ to $+125°C$. The weight is 4 gm. Erg Industrial Corporation Ltd., Luton Road, Dunstable, Beds.

WW 319 for further details



Variable Power Supplies



A SERIES of bench variable d.c. power supplies is available from Coutant Electronics Ltd. These units, employing silicon devices, offer voltage ranges of 0-15 to 0-50 V, with current ratings from 1 to 10 A. Voltage and current are monitored on separate meters. The power requirements for this series are 100-125 V or 200-250 V at 45 to 400 c/s. Transient recovery time is 10 μs for a 10 mV change in output voltage, and the ripple and hum content is lower than 1 m V at full load. The stabilization ratio is 2000:1 at maximum output. The constant current overload protection may be set at the required level by a front panel control, and the units may be worked in series and into any type of load. The output impedance of these units is <0.005Ω. Coutant Electronics Ltd., 3, Trafford Road, Richfield Estate, Reading, Berks.

WW 320 for further details

TEST PROBE SOCKET

MONITORING and testing of printed circuits in operating conditions can be made easier by the use of a Hellermann probe socket. This socket, which can be placed permanently in position on a printed circuit board, will accept 0.080in diameter probes from such equipment as oscilloscopes and test meters, without the necessity for disturbing the operation of the circuit. The standard socket is spring brass with gold or silver plating but other materials and finishes are available on request. Insulation sleeves in p.v.c. (available in ten colours) are rated at 90°C while the voltage breakdown of the sleeve is 2,500 V. The socket produces a voltage drop of 3 mV at 3 A. Hellermann Terminals Ltd., Gatwick Road, Crawley, Sussex.

WW 321 for further details

Low-noise Amplifier

THE low-noise amplifier LA350 made by Brookdeal Electronics Ltd. has a frequency range of 3 c/s to 300 kc/s and a maximum gain of 100 dB. It can be used as a general purpose systems amplifier for measuring signals from a.c. bridges, microwave crystals, photomultipliers, transducers, photoconductive cells, thermocouples, Golay cells, etc. It also has applications as an oscilloscope pre-amplifier, microvoltmeter, and phase sensitive detection amplifier. It possesses two input modes, high and low source impedances (2 MΩ and 40 kΩ respectively) that are switch selectable. The LA350 includes distributed feedback attenuators (0 to -55 dB) which operate over successive stages to prevent amplifier overload, and function by changing the closed loop gain, so that any noise is attenuated by the same factor as the signal. The noise figure measured at 1 kc/s with a 100 kΩ source is 1 dB typical, and the noise voltage measured over a 1 kc/s band (500 c/s to 1.5 kc/s) with a 1 kΩ source is 0.15 μV. The h.f. filters cover 10 c/s to 300 kc/s in ten positions and the l.f. filters 3 c/s to 100 kc/s in ten positions. The voltmeter sensitivity is 20 μV full-scale. The power supply has a stabilization ratio in excess of 20,000 : 1 coupled with a toroidal mains transformer. The long internal time constants necessary to achieve the 3 c/s response are reduced automatically when the high-pass filter is set to 30 c/s or more, making recovery from overload almost instantaneous. Brookdeal Electronics Ltd., Myron Place, London, S.E.13

WW 322 for further details

POWER CAPACITORS

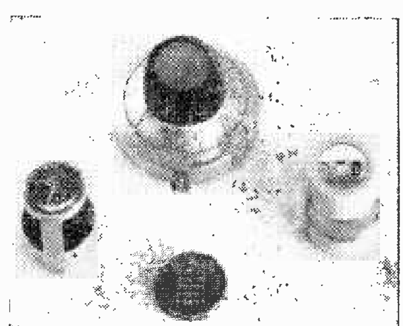
"LECTROFLASH" capacitors designed for electronic flash, discharge welding, and laser applications, are manufactured by T.C.C. These electrolytic capacitors are designed to yield minimum leakage currents, and to maintain correct charging characteristics, in spite of possible long periods of inactivity. Values of capacitance range from 200 up to 1,750 μF, with d.c. working voltages from 180 to 500. Discharge energies lie between 16 and 92 joules. Cases are from 4 to 4½ in high. and 1½ to 2½ in diameter. Telegraph Condenser Co. Ltd.. North Acton, London, W.3.

WW 323 for further details

Precision Dials

CALIBRATED multi-turn precision dials of French manufacture are supplied by Kynmore Engineering Co. Ltd. 19, Buckingham Street, London, W.C.2. The Micro-Clockdial, with clockface presentation of information, is a ten-turn analogue dial with 50 marked divisions per turn. The diameter is 22 mm and the depth 29 mm. The fifteen-turn analogue dial US45 is a conventional type with 100 marked divisions per turn. The dimensions of this dial are 45.5 mm in diameter and 30.5 mm deep. A miniature digital dial, Flash 22, is a hundred-turn dial with magnified readout, and ten numbered divisions per turn. It has a 23.4 mm diameter and is 35.2 mm deep. These three dials are suitable for 6 mm diameter shafts, and can be locked at any position, by brake levers.

WW 324 for further details



I.F. Transistor

THE G.E. (U.S.A.) 2N3856A n-p-n silicon planar epitaxial transistor is available from Jermyn Industries, Vestry Estate, Vestry Road, Sevenoaks, Kent. Intended for i.f. stages, and converter applications in a.m. and f.m. receivers, it has a collector-to-emitter rating of 30 V minimum and a minimum forward current transfer ratio of 100. The output capacitance is 3·5 pF maximum. The following gains are said to be obtainable for f.m. reception:—i.f. stage gain of 25dB with reference to 10.7 Mc/s; 30 dB at 4.5 Mc/s; an r.f. stage gain of 15 dB at 100 Mc/s. A video-i.f. gain of 21 dB is obtainable at 45 Mc/s. The price is 5s 5d.

WW 325 for further details

High-Gain F.E.Ts

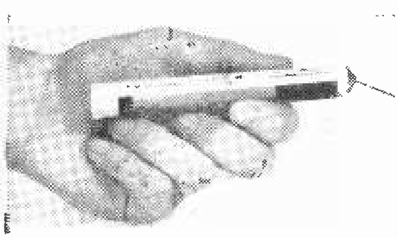
A SERIES of high-gain field effect transistors is being manufactured by Texas Instruments Ltd., Manton Lane, Bedford. The types 2N3821 to 2N3824 are of symmetrical "N" channel epitaxial planar silicon construction (*Wireless World*, Jan. 1966, pp. 2-6 and July 1966, pp. 357-359. Types 2N3821 and 2N3822 are described as low level, low noise amplifiers for small signal applications, and they offer low leakage, low input capacitance, and a high Y_{fs}/C_{iss} ratio. 2N3823 is intended for r.f. amplifier and mixer applications up to 500 Mc/s. Type 2N3824, for high speed commutator and chopper applications, has a low r_{ds} (on), a low I_d (off) and a low C_{rss} (drain-gate capacitance).

WW 326 for further details

Solder Dispenser

A DISPENSER holding 21 feet of Multicore 5-core fine solder (22 s.w.g.) permits the solder to be drawn through an end nozzle as required. Formed as a coil inside the dispenser, the solder wire cannot slip back inside, or become entangled. Price 3s. Multicore Solders Ltd., Hemel Hempstead, Herts.

WW 327 for further details



OCTOBER CONFERENCES, SYMPOSIA AND EXHIBITIONS

Further details are available from addresses in parentheses

LONDON

Oct. 11-12 — St. Ermin's Hotel
Ultrasonics for Industry
(*Ultrasonics*, Dorset House, Stamford St., S.E.1)

Oct. 26-29 — Seymour Hall
R.S.G.B. Radio Communications Exhibition
(Radio Society of G.B., Little Russell St., W.C.1)

BELFAST

Oct. 7-15 — Ulster Hall
Radio, TV and Electrical Appliances Show
(N.I. Radio Retailers' Assoc, 12 Malone Rd., Belfast 9)

OVERSEAS

Oct. 2-7 — Los Angeles
S.M.P.T.E. 50th Anniversary Conference
(S.M.P.T.E., 2 E.41st St., N.Y.10017)

Oct. 3-5 — Washington
Aerospace and Electronic Systems Convention
(I.E.E.E., 345 East 47th St., N.Y.10017)

Oct. 3-5 — Chicago
National Electronics Conference
(N.E.C., 228 N. La Salle St., Chicago, Ill.)

Oct. 3-5 — Chicago
Consumer Electronics Symposium
(I.E.E.E., 345 E. 47th St., N.Y.10017)

Oct. 7-12 — Genoa
International Communications Congress
(Instituto Internazionale della Communicazioni, Viale Brigate Partigione 18, Genoa)

Oct. 10-14 — Amsterdam
Fiarex—Components & Equipment Exhibition
(Fiarex Secretariat, Minervalaan 82hs, Amsterdam)

Oct. 11-15 — Budapest
Magnetic Recording Conference
(Hungarian Society for Optics, Acoustics & Filmtechnics, Szabadság tér 17, Budapest V)

Oct. 12-14 — Budapest
Microwave Measurement Symposium
(Scientific Society for Measurement & Automation, P.O.B. 457, Budapest V)

Oct. 13-14 — Montreal
Canadian Symposium on Communications
(Prof. G. W. Farnell, McGill Univ., Montreal)

Oct. 13-14 — Darmstadt
Signal Detection in Communications and Control Systems
(H. H. Burghoff, Stresemann Allee 21, 6 Frankfurt 70)

Oct. 17-18 — Washington
Systems Science and Cybernetics
(J. E. Matheson, Stanford Research Inst., California 94025)

Oct. 17-22 — Basle
ILMAC—Laboratory Measurement and Automation Techniques in Chemistry
(ILMAC Secretariat, P.O.B. CH4000, Basle 21)

Oct. 19-30 — Mexico City
British Industrial Exhibition
(British Overseas Fairs, 21 Tothill St., London, S.W.1)

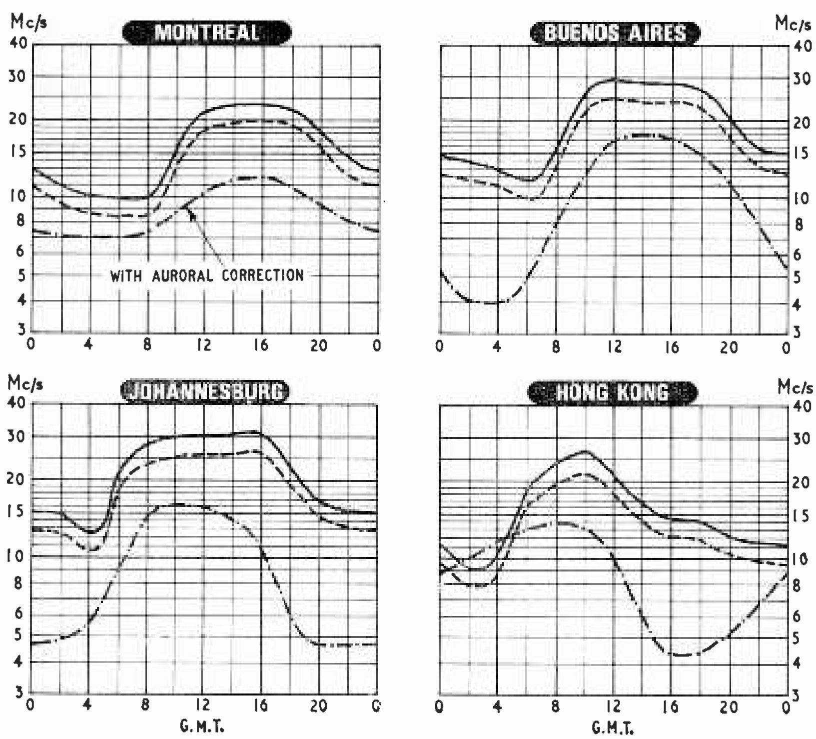
Oct. 20-26 — Munich
Electronica—Electronic Components & Instruments Exhibition
(U.K. Agents: Exhibition Consultants Ltd., 11 Manchester Sq., London, W.1)

Oct. 24-26 — Munich
Microelectronics Symposium
(Internationaler Elektronik-Arbeitskreis, Theresienhöhe 15, 8000 Munich 12)

Oct. 24-27 — New York
Instrument-Automation Conference & Exhibition
(Instrument Society of America, 530 William Penn Pl., Pittsburgh 15219)

Oct. 26-28 — Berkeley, Calif.
Switching & Automata Theory
(D. E. Muller, Maths Dept., University of Illinois, Urbana, Ill.)

Oct. 26-28 — Washington
Electron Devices
(I.E.E.E., 345 East 47th St., N.Y.10017)



——— MEDIAN STANDARD M U F
- - - - - OPTIMUM TRAFFIC FREQUENCY
-·-·-·- LOWEST USABLE H F

H. F. PREDICTIONS OCTOBER

The effects of sporadic-E ionization are becoming less significant as winter conditions set in, and this month it is unlikely that sporadic-E will permit operation above the MUF. The seasonal change in shape of the MUF curve is becoming apparent. The very flat curve of the summer months is slowly being replaced by the slightly higher, more peaky, curve characteristic of the winter months.

The prediction curves show the median standard MUF, optimum traffic frequency and the lowest usable frequency (LUF) for reception in this country. Unlike the standard MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, and the type of modulation. The LUF curves were drawn by Cable and Wireless Ltd. for commercial telegraphy and assume the use of transmitter power of several kilowatts and aerials of the rhombic type.

THE QUEEN'S AWARD TO INDUSTRY 1966

The world's finest cored solder

ERSIN Multicore 5 CORE SOLDER

- Contains 5 cores of non-corrosive high speed Ersin flux. Removes surface oxides and prevents their formation during soldering. Complies with B.S. 219, 441, DTD 599A, B.S.3252, U.S. Spec. QQ-S-571d.
- Savbit alloy contains a small percentage of copper and thus prolongs the life of copper soldering iron bits 10 times. Liquidus melting temperature is 215C°—419°F. Ministry approved under ref. DTD/900/4535
- Solder Tape, Rings, Preforms and Washers, Cored or Solid, are available in a wide range of specifications.
- Liquid fluxes and printed circuit soldering materials comply with Government specifications. Ask for special details.

FOR THE FACTORY

STANDARD GAUGES IN WHICH MOST ALLOYS ARE MADE AND LENGTHS PER LB. IN FEET.

S.W.G.	INS.	M.M.	FT. PER LB. 60/40	FT. PER LB. SAVBIT
10	.128	3.251	25.6	24
12	.104	2.642	38.8	36
14	.080	2.032	65.7	60.8
16	.064	1.626	102	96.2
18	.048	1.219	182	170
19	.040	1.016	262	244
20	.036	.914	324	307
22	.028	.711	536	508
24	.022	.558	865	856
26	.018	.46	1292	1279
28	.014	.375	1911	1892
30	.012	.314	2730	2695
32	.010	.274	3585	3552
34	.009	.233	4950	4895

STANDARD ALLOYS INCLUDE

TIN/LEAD	B.S. GRADE	LIQUIDUS MELTING TEMP °C.	LIQUIDUS MELTING TEMP °F.
60/40	K	188	370
Savbit No 1	—	215	419
50/50	F	212	414
45/55	R	215	419
40/60	G	234	453
30/70	J	255	491
20/80	V	275	527

HIGH AND LOW MELTING POINT ALLOYS

ALLOY	DESCRIPTION	MELTING TEMP. °C.	MELTING TEMP. °F.
T.L.C.	Tin/Lead/Cadmium with very low melting point	145	293
L.M.P.	Contains 2% Silver for soldering silver coated surfaces	179	354
P.T.	Made from Pure Tin for use when a lead free solder is essential	232	450
H.M.P	High melting point solder to B.S. Grade 5S	296-301	565-574

FOR THE MAINTENANCE ENGINEER AND ELECTRONICS ENTHUSIAST

SAVBIT ALLOY REDUCES WEAR OF SOLDERING IRON BITS.

Size 12 reel 15/- (subject)
Contains 102 ft. approx. 18 s.w.g. on a plastic reel.

Size 1 carton 5/- (subject)
C1SAV14 11 ft. of 14 s.w.g.
C1SAV16 16 ft. of 16 s.w.g.
C1SAV18 30 ft. of 18 s.w.g.

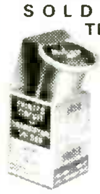
Size 5 dispenser 2/6 (subject)
Contains 12 ft. of 18 s.w.g. in a handy dispenser.

60/40 HIGH TIN CONTENT

Size 1 carton 5/- (subject)
C16014 9 ft. approx. 14 s.w.g.
C16018 29 ft. approx. 18 s.w.g.

Size 4A Dispenser 2/6 (subject)
Contains 9 ft. of 18 s.w.g. 60/40 alloy in a handy dispenser.

PRINTED CIRCUIT AND TRANSISTOR SOLDER, FOR SOLDERING TEMPERATURE SENSITIVE COMPONENTS



Size 10 15/- (subject)
Contains 212 ft. of 22 s.w.g. 60/40 alloy on a plastic reel.

New! Size 15 Dispenser 3/- (subject)
21 ft. coil of 60/40 alloy, 22 s.w.g. Solder used direct from dispenser, cannot tangle or fall back inside.

BIB INSTRUMENT CLEANER

Anti-static cleaner for tape heads, dials, plastic, glass and chrome. **4/6** (subject)

MODEL 3 BIB WIRE STRIPPER AND CUTTER

Strips insulation, cuts wires and splits plastic twin flex. **4/-** (subject)

Write for full details to:
MULTICORE SOLDERS LTD., MAYLANDS AVENUE, HEMEL HEMPSTEAD, HERTS. (HEMEL HEMPSTEAD 3636)