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NOVEMBER 1966
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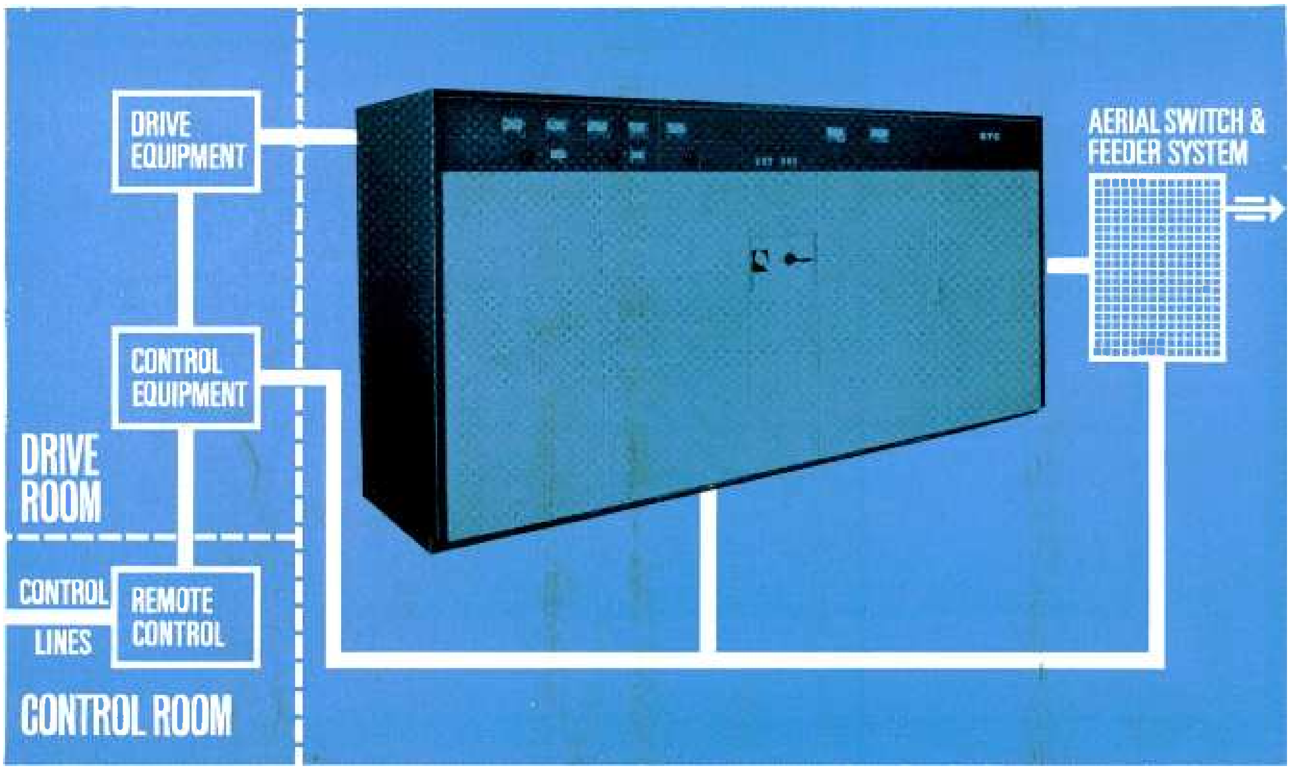

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Wireless World

ELECTRONICS, TELEVISION, RADIO, AUDIO

"Electronics and the future"

THIS is the title of the report on the industry by the Economic Development Committee for Electronics which covers its first two years' work. In it the 22-member committee* surveys the performance and prospects of each of the three main sectors of the industry, namely: capital goods, consumer goods, and components. Conclusions are drawn from its investigations on the problems facing the industry and recommendations made as to how they should be overcome.

The Committee concentrated on imports and exports, "partly because these throw light on the vitality and competitiveness of our industry compared with those of other countries, and partly because reducing imports and increasing exports are important economic objectives in themselves." The conclusions on the whole are those which have been arrived at so often by other committees and individuals as, for instance, this one: "There will be a rapid expansion in the use of microelectronic circuits, which will require quick changes in policy by the [capital equipment] industry" or this one on consumer goods: "Output is static and exports are low in all but a few fields."

The Committee's recommendations cover R. & D., Government-industrial relations, export subsidies, provision of international standards to facilitate exports, etc., but we are tempted to ask: "Where do we go from here?" About one-third of the 36-page report is devoted to statistics giving some interesting facts and figures on production and exports in each of the main sectors, but for whose benefit?

Where do the findings of this Government-appointed committee fit into the overall plans of, for instance, the industry's sponsoring body, the Ministry of Technology? True, both the E.D.C. and the Ministry of Technology occupy adjacent sections of Millbank Tower, in London, but to the outsider there seems little liaison between them.

Recently the Ministry of Technology has set up a Technical Advisory Committee on Electronics under the chairmanship of Ieuan Maddock, deputy controller in the Ministry, whose terms of reference include: "to identify within the field of electronics both research and development projects relating to systems, equipments, components and production technologies, the exploitation of which is important industrially and commercially. In relation to these projects to identify areas where effort and available facilities are considered to be too fragmented or on too small a scale." From a perusal of the list of members† it is obvious that it includes top level men in the industry who, incidentally, have been appointed in their personal capacity and not as representatives of their companies.

Are there not too many Government committees investigating the activities of the industry and offering advice or making recommendations? Looking down the "corridors of power" the number of committees directly or indirectly concerned with the radio and electronics industry is legion. It is to be hoped that Mr. Maddock's committee set up by our sponsoring Ministry will not be just one more "taking minutes and wasting hours." It is encouraging to see that the emphasis is "technical" for it is felt that all too often those who study our industry with a view to increasing its competitive power or strengthening its position know little, if anything, of the peculiarities of an industry based on a technology which is changing so rapidly.

---

* Under the chairmanship of Sir Edward Playfair until May this year but now led by Sir Donald Stokes, deputy chairman and managing director of Leyland Motor Corporation.

† R. J. Clayton, managing director, G.E.C. (Electronics); P. D. Hall, director, I.C.T.; D. S. Ridler, technical director, S.T.C.; P. E. Trier, director, Mullard; A. J. Young, managing director, English Electric Valve Co.; Dr. G. G. MacFarlane, director, R. R. E., Malvern: W. Makinson, National Research Development Corp.; J. H. Merriman, deputy engineer-in-chief, G.P.O.; J. R. Mills, Electronics and Instrumentation Division, Ministry of Technology; Dr. W. H. Penley, deputy controller, electronics, Ministry of Aviation; A. W. Ross, Director of Physical Research (Naval), Ministry of Defence; and Mrs. M. Swaffield, Electronics and Instrumentation Division, Ministry of Technology. (Secretary, Dr. J. R. M. Granville, R.R.E.)

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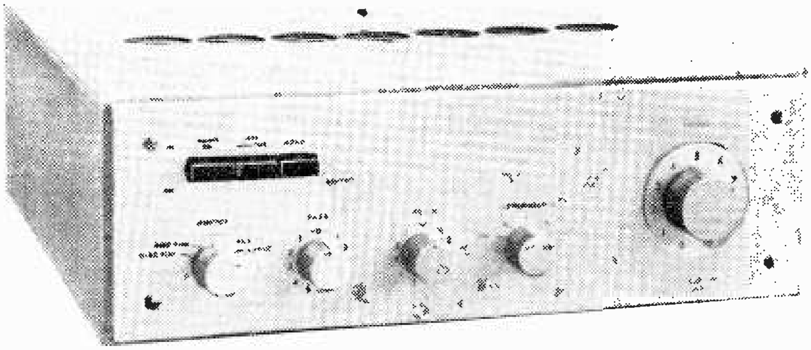

1.—DESIGN FOR A 20W POWER AMPLIFIER

HIGH-PERFORMANCE TRANSISTOR AMPLIFIER

By A. R. BAILEY, Ph.D., M.Sc.(Eng.), A.M.I.E.E.

OVER the past few years there has been a proliferation of designs for audio-frequency amplifiers, and the reader would be well justified in asking if any more were necessary. Unfortunately, transistor amplifier design has, for the most part, been inferior to that of the best valve amplifiers. Listener-fatigue is quite common and there are many inherent defects in circuits that can degrade performance without it being apparent from the specification of the amplifier.

Over two years ago the author was asked by a manufacturer to look into the design of transistor amplifiers and it has taken this length of time to come up with an answer that he feels can stand comparison with the best valve amplifiers available.

Part of the answer lies in the flood of relatively cheap planar epitaxial transistors that have just recently become available. The high current gain of these devices along with the high cut-off frequencies obtainable has greatly eased design problems. Even so there are design problems that seem to have been either overlooked or ignored in the past, particularly that of overload capability. These have been examined in some detail in producing the present circuit, and this is why some parts are definitely unorthodox.

Initial considerations

Before discussing the circuit finally produced, it may be advantageous to examine the reasons for discarding certain circuits. Many circuits appear promising at first sight but further investigation shows inherent defects in their performance. A typical example is the π mode class AB system where the circuit is class A for small inputs but biases back to class B with full sine-wave drive. With an input waveform having a smaller ratio of peak-to-mean than a sine wave the circuit will bias back into class C under full drive conditions. As the bias conditions are modified to take care of these very square type of waveforms it can be shown that in the limiting case the bias becomes pure class A.

Similarly the pulse-width modulated amplifier appears to have many advantages, but in practice the spurious frequency generation produced in the demodulation process is excessive.*

Pure class A output stages give low distortion, but the heat dissipation becomes a serious problem and the heat sink size for the output transistors becomes excessive. In addition there is a far greater risk of breaking down output transistors in a class A stage by reactive loads. This is due to the greater transistor dissipation in this mode of operation.

Class B operation was therefore chosen using the normal series output connection so as to avoid the use of an output transformer. The drive to the output transistors is somewhat unusual in that a driver transformer is used. Purists may wince at the thought of using transformer drive but nevertheless a good transformer offers many advantages. The transformer removes the need for a phase-splitting transistor as this is done by balanced secondary windings. The low resistance of these windings greatly reduces the effect of leakage currents on the standing transistor currents. This gives very good temperature stability even when germanium output transistors are used.

Silicon or germanium ?

The complete circuit is shown in Fig. 1. Here it will be seen that the first stage is a conventional common emitter stage followed by a direct-coupled emitter-

Dr. A. R. Bailey, after taking his London B.Sc. degree at Bradford Technical College in 1953, stayed on to undertake research into precision three-phase a.c. voltage stabilizers under a D.S.I.R. grant. He then went into industry for a short time but returned to join the staff of the college, which became the Bradford Institute of Technology, where he is a lecturer in the Electrical Engineering Department. The Institute became the University of Bradford this month. Dr. Bailey is consultant to Radford Electronics Ltd.

★ "Distortion and Power Output of Pulse Duration Modulated Amplifiers." E. C. Bell and T. Sergent, *Electronic Engineering,* August 1965.

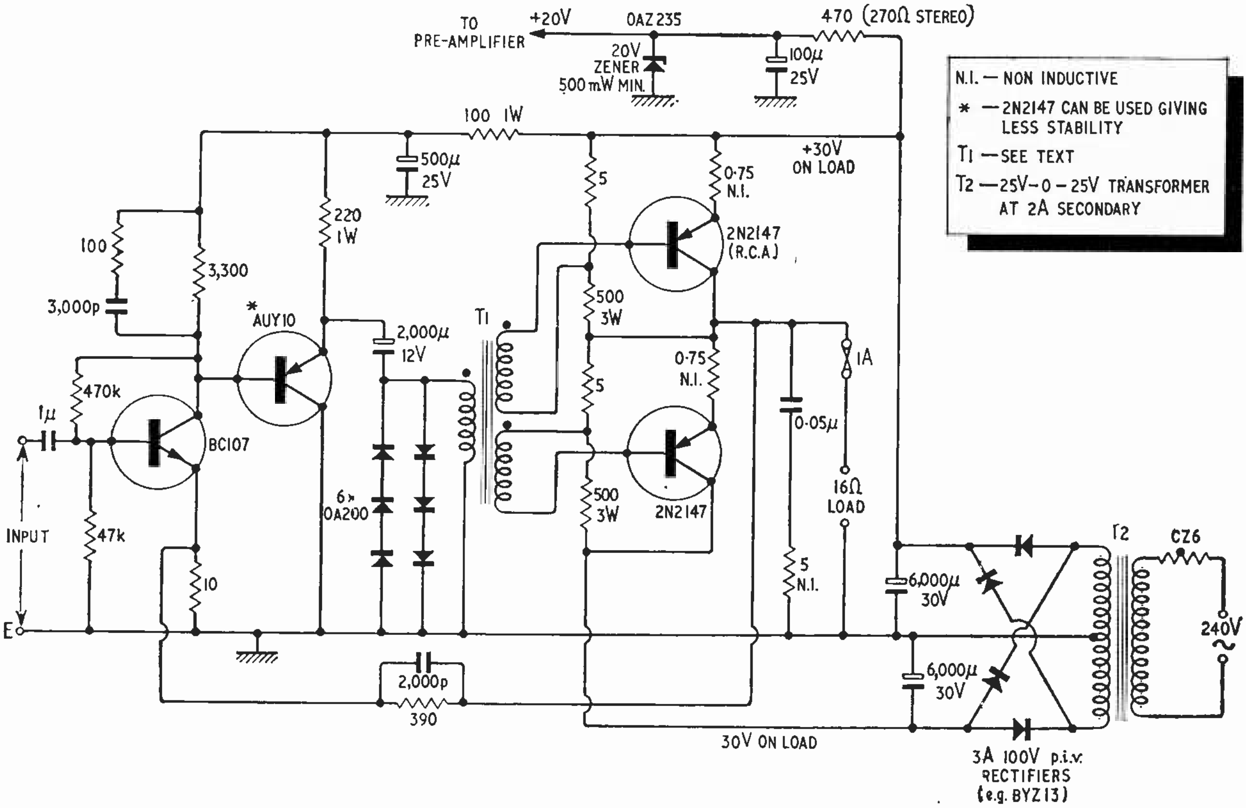

Fig. 1. Circuit of complete power amplifier.

follower. This drives the driver transformer and the output stage at low impedance, thus assisting the distortion and bandwidth properties of the amplifier.

The size of heat sink required for the output transistors depends on the ambient temperature range, the type of output transistor and the type of service considered. For example the most severe test is for germanium transistors tested under full load current conditions into a reactive load and at a high ambient temperature. Rather than deal with large heat sinks for arduous duty, the author feels that it is better to specify silicon output transistors where severe conditions are likely to be encountered. For normal domestic duty into loudspeaker loads the cheaper option of germanium transistors is perfectly satisfactory. In fact germanium transistors usually give far lower distortion due to their better linearity.

Two output circuits are therefore given, the silicon n-p-n circuit appearing in Fig. 2. The supply polarity is unchanged so that the same power supply will drive either configuration. The amplifier chassis is a perfectly adequate heat sink for the two circuits, although it is not wise to test the germanium circuit under odd load conditions for more than short periods.

Output stage protection

The protection of transistor amplifiers against load conditions is one of the factors that has restricted the use of these amplifiers in the past. Anyone who has experimented with power output stages will have discovered the extreme speed with which output transistors can be destroyed. Indeed the author has a very large graveyard of power transistors that were sacrificed in trying to find a complete answer to the problem.

The protection system used in this amplifier is the best compromise that can be reached at reasonable cost. The author has not managed to blow up any transistors with the circuit given even under severe reactive loads, so 100% protection should be given to any accidental short-circuits of the loudspeaker leads. Performance

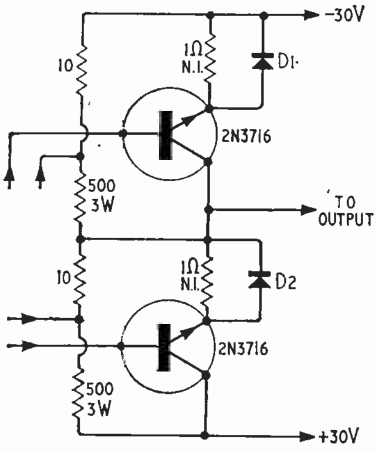

Fig. 2. Alternative output circuit for silicon power transistors.

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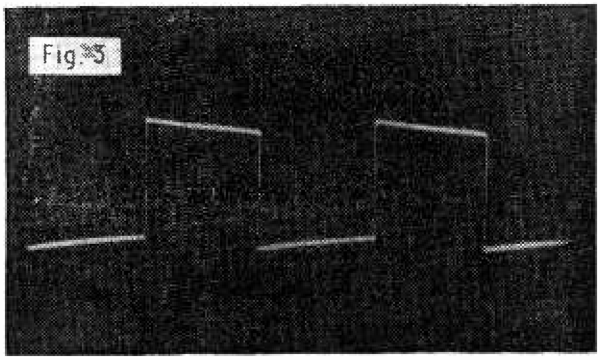
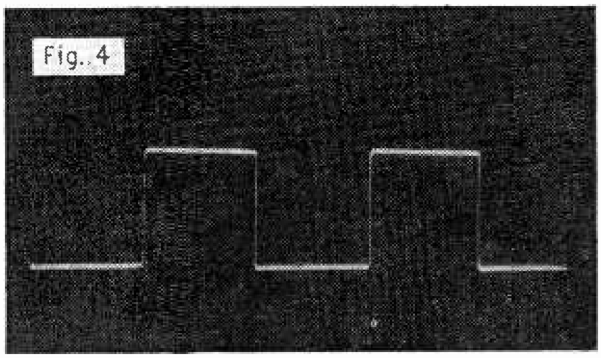
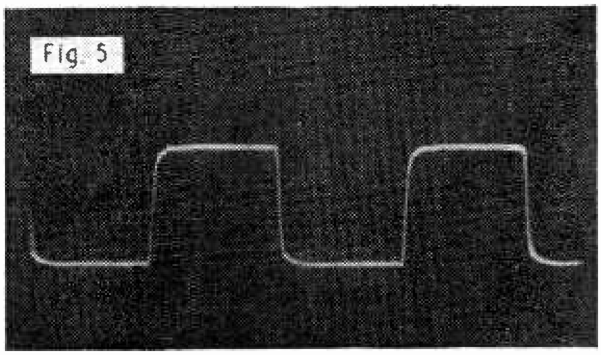






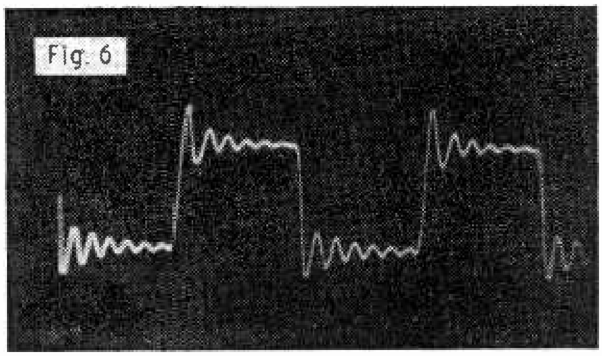


Fig. 3. Amplifier response to 100 c/s square wave with 16 Ω resistive load.

Fig. 4. Response to 1 kc/s square wave, 16 Ω resistive load.

Fig. 5. Response to 10 kc/s square wave with 16 Ω resistive load.

Fig. 6. Response to 10 kc/s square wave with pure capacitance load of 0.47 μF.

with electrostatic speakers is also good, and no power transistors have been lost due to the low reactance of such speakers at high frequencies.

The protection is split into two parts. First, the power output transistors are arranged to give automatic current limiting at about 130 per cent of rated peak output current. This is produced by the diodes strapped across the primary of the driver transformer. The drive voltage to the output transistors is nearly directly proportional to the load current due to the voltage developed across the emitter resistors. Hence limiting the peak drive voltage automatically limits the peak output current available.

The second line of protection is that of conventional fusing. This fuse is in the speaker output lead, and is necessary to prevent over-dissipation of the output transistors, particularly at low frequencies. If the amplifier is driven hard into a short circuit, then the power dissipation in the output transistors will be high even with the limited current available. To prevent breakdown it is therefore necessary to remove the short circuit before the output transistor temperature rises to excessive limits. A standard quick-blow fuse gives quite adequate protection and blows in less than half a second under full-drive and short-circuit conditions. With the silicon transistors in the output this fuse may not be necessary, but it is felt advisable in view of the cost of power transistors.

Performance

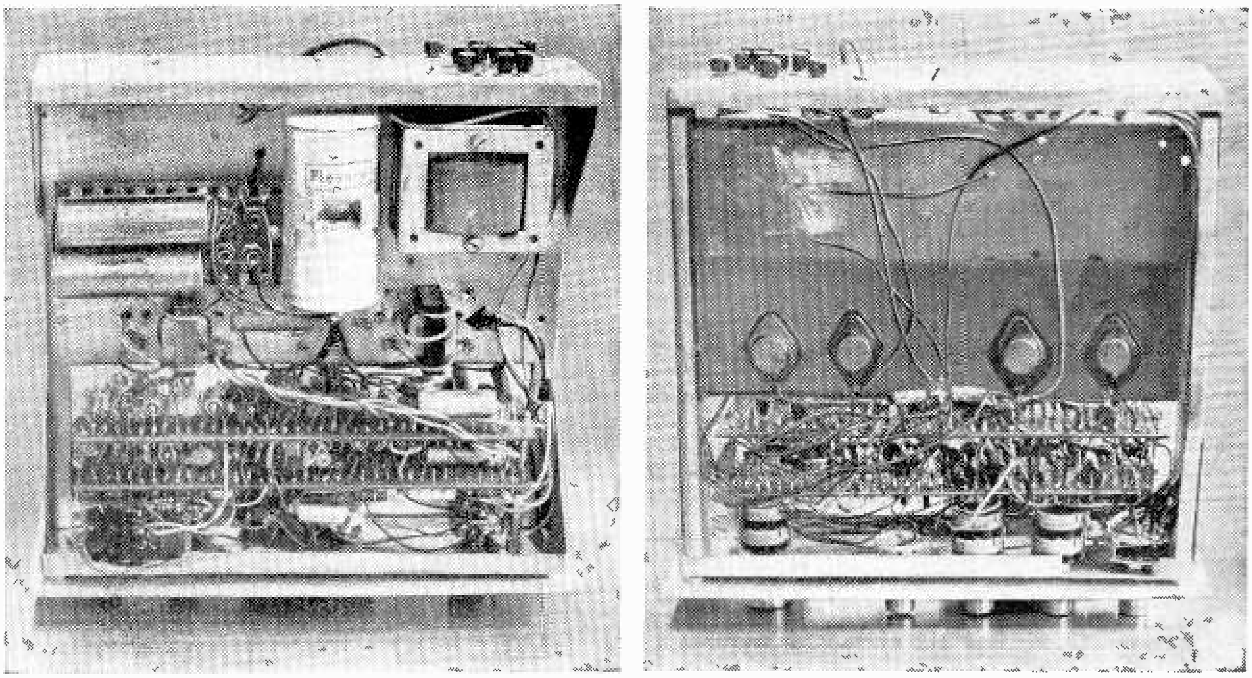
The final performance of the amplifier is well up to the standards expected of the best valve amplifiers and it does not sound appreciably different. The transient response is perhaps slightly "cleaner" than the best valve amplifiers, but the difference is very slight indeed. There is no "transistor-sound" whatever, and very little listening fatigue even after long periods of listening. As the output stage runs effectively in class A for small inputs and the distortion rises slowly with drive, this effect might be expected. Far too many amplifiers run class B output stages at very low levels of quiescent current so as to economize on heat sink design. This gives rise to bad low-level distortion and consequent fatigue effects.

No attempt has been made to obtain very fast rise-times for the amplifier—after all the amplifier is designed to reproduce the audio frequency range rather than be a transmitter The stabilizing networks are therefore designed to give the best overall balance between h.f. distortion and stability and the rise-time was left to look after itself. Even so the results are very good as can be seen from the square-wave tests shown in Figs. 3 to 6.

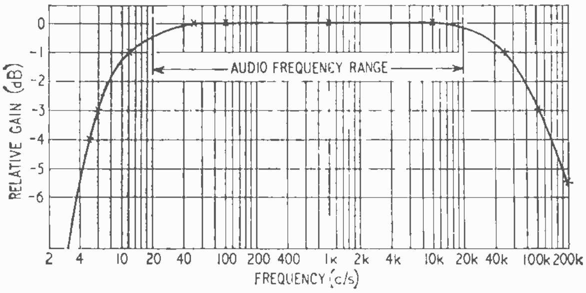
The droop on the 100 c/s square wave is due to the size of the amplifier input capacitor. This droop is not important as is shown by the frequency response in Fig. 7.

The higher frequency square-wave tests are very satisfactory, the rise-time turning out at about 3.5 microseconds. The more important factor of h.f. stability is shown to be adequate as the worst case of pure capacitive load (about 0.5 μF in this case) gives fairly well damped oscillations. Unconditional load stability such as this is not common in valve amplifiers and is very unusual in transistor amplifiers.

The step-network in the collector of the first transistor cuts the loop gain at the high-frequency end of the spectrum and assists in the stabilization of the amplifier. The lower the frequency at which this cut starts, the better is the h.f. stability but the poorer is the h.f. distortion. The time-constants chosen in the circuit are about the optimum, as the distortion at full power output is only about 0.4% at 32 kc/s. The distortion characteristics are

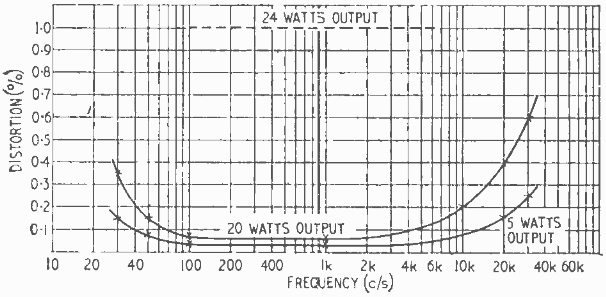


Top and underside views of the complete chassis. Note the heat sink for the output transistors.



Left:—Fig. 7. Overall response of power amplifier.

Below:—Fig. 8. Distortion characteristics of cascaded amplifier and preamplifier, 16 Ω resistive load.



shown plotted in Fig. 8, where it is seen that full power output is obtainable up to over 40 kc/s. The distortion over the range of 20 c/s to 20 kc/s is very low compared with normal valve and transistor amplifiers which generally have rapidly rising distortion characteristics at the extremes of the audio range. Indeed quite a few amplifiers are unable to deliver full power output at 20 kc/s.

To obtain this performance it is necessary to have a well-regulated power supply so that the main h.t. is maintained under full drive conditions. After several attempts at various circuits it was decided to use an unregulated h.t. supply with a capacitor input filter. Provided that the transformer is of adequate size, then the regulation can be held to about five volts swing. This is quite adequate, and the complexity and cost of a regulated supply were felt to be unnecessary—particularly as two supply lines are involved.

Constructional notes

The driver transformer is wound with 200 turns of 30 s.w.g. d.s.c. trifilar wire on a $\frac{3}{8}$in square core made of Radiometal. The author is not aware of any source of trifilar wire, so this means in practice that three wires are

SPECIFICATION

Rated input for 20 W output into 16 Ω load: 500 mV.

Distortion at rated power output at 1 kc/s: <0.1 %

Load stability: unconditional.

Hum and noise: >80 dB down on full output.

Rise-time: $<4\ \mu$s.

Short-circuit load performance: proof against accidental drive into short-circuit loads for short time periods. For long overload periods there is a small region of continuous sine-wave driving level where the output transistors can be damaged by overdissipation. This is most unlikely to be met in practice, and with music or speech drive will not be significant.

wound on the core at the same time and as close together as possible. This method of winding gives an extremely low value of leakage inductance and in practice is negligible.

The emitter resistors of the output stage must be very low in inductance. A zig-zag of resistance wire is quite suitable, but a coil may double the distortion at 20 kc/s. For this reason commercial wire-wound resistors are not suitable as they stand. Even one foot of straight wire in the emitter circuit produces a noticeable effect on the distortion at 20 kc/s.

The size of the heat sinks for the output transistors will depend on the ambient temperature range and type of service. For laboratory use it would be advisable to use heat sinks having a thermal capacity of better than 3 deg C per watt, but this is felt to be unnecessary for music reproduction. Three inch squares of $\frac{1}{8}$in blackened aluminium will be quite adequate, or alternatively the author's method of $\frac{1}{8}$in blackened aluminium plate bolted to the amplifier main chassis enables the area to be reduced below this figure. In this case, however, it is essential that thin mica washers and silicone grease are used for insulation to prevent short-circuits.

The thermal stability of the output stage is best checked with a millivoltmeter across one of the emitter resistors. This voltage should not rise above 100 millivolts when the amplifier is undriven after a period of operation into its correct load. If this value is exceeded there is the risk that thermal runaway will result, and this indicates that the heat sink size is inadequate.

Caution must be taken with the wiring so as to avoid spurious feedback effects. In particular, the output stage emitter and collector leads must be kept as short as possible, and the main h.t. decoupling and smoothing capacitors as close as possible. The shorter the leads carrying these heavy current class B waveforms the better. If care is taken with the wiring, then there is no reason why the specification given should not be met.

(Details of a pre-amplifier design will be published next month.)

LASER TELEVISION DISPLAY

AN experimental television display system using deflection and modulation of a laser light beam instead of an electron beam has been developed by a group of workers at the Zenith Radio Corporation, Chicago, U.S.A. The methods of deflection and modulation, which both depend on diffraction of a laser light beam in ultrasonic waves in a water cell, were outlined by Dr. R. Adler at the recent Sixth International Conference on Microwave and Optical Generation and Amplification sponsored jointly by the I.E.E. and I.E.R.E. at Cambridge (sees also p. 572). A helium-neon gas laser, producing red light, is used. Deflection angles achieved are small, but are sufficient to allow 200 picture points to be resolved along a scanning line and a 3-Mc/s video signal to be displayed on a screen.

In the deflection system, the laser beam is directed into a water cell through which ultrasonic waves of length Λ are propagated by a transducer driven from an 18 to 34 Mc/s sinewave source. The light rays, of wavelength λ, strike the water wavefronts at a narrow glancing angle, θ. The acoustic waves produce an optical diffraction "grating" in the water composed of strata of different refractive indexes (i.e. strata of different densities resulting from the compressions and rarefactions set up by the transducer). The spatial period of this "grating" is, of course, Λ, the acoustic wavelength. A diffracted beam of light (composed of the in-phase diffracted rays) emerges from the cell, and this also is at an angle θ to the wavefronts. In this phenomenon, called "Bragg reflection" after Professor Bragg's famous work that led to X-ray crystallography, the angle θ at which the emerging light is at maximum intensity is given by $2\theta=\lambda/\Lambda=\lambda f/v$, where λ and Λ are as defined above, f is the frequency of the ultrasonic waves and v is the velocity of these waves in water. As can be seen from this law, variation of the ultrasonic frequency causes the angle of the emergent beam to vary, and it is this phenomenon which is used for scanning. The transducer drive frequency is, in fact, varied over the 18 to 34 Mc/s range mentioned above in a sawtooth function of time to give a line scan. Dr. Adler stated that all the incident laser light could be diffracted with an electrical input of less than 1 watt.

For very small scanning angles the mechanism described above is satisfactory, but theoretically the water cell should be rotated with the deflection of the emergent beam, and to obtain the larger scanning angles needed for a television display this rotation is, in fact, necessary. In the Zenith system the effect of cell rotation is obtained by rotating the ultrasonic wavefronts as the transducer drive frequency changes, using a phased array of transducer elements. The number of resolvable light spots on a screen, N, which can be obtained by the system is given by $N=\Delta f.\tau$ where Δf is the ultrasonic frequency change and τ is the transit time of the acoustic waves across the optical aperture.

Intensity modulation of the laser beam is obtained by a similar diffraction process in an acoustic cell, and this was first used by Scophony Ltd. in London before World War II, for modulating light from an arc lamp in a large-screen television system.* The basis of the method is that the intensity of the light beam diffracted by the acoustic cell is proportional to the amplitude of the ultrasonic waves in the water, so the video signal is used to amplitude-modulate the signal driving the cell transducer. The laser beam traversing the intensity modulating cell is made wide enough to encompass several picture elements, which travel across the beam at the velocity of the acoustic waves. As in the Scophony system, the horizontal beam deflection process nullifies the apparent motion of these elements and makes them stand still on the screen.

One of the British organizations working on deflection of laser beams is Mullard Research Laboratories. Both they and Zenith are interested in other applications besides television, such as information storage for electronic data processing systems.

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* "Scophony Television System," *Wireless World*, 23rd July 1937, p. 78. Also "The Supersonic Light Control and its Application to Television with Special Reference to the Scophony Television Receiver," by D. M. Robinson, *Proc. I.R.E.*, August 1939.

Corona-generated Noise in Aircraft

MEASUREMENT AND CONTROL TECHNIQUES

By C. E. COOPER

EITHER by charging action in the Van de Graff manner, or by the mere fact of its irregular shape in existing atmospheric electrostatic fields, an aircraft in flight can produce locally intense dielectric stress in the layers of air immediately adjacent to its skin. With sufficiently high stress the air dielectric becomes ionized, and resultant current flow or "corona" can generate radio noise which, coupled into the aircraft's receiving aerials, is quite capable of totally disrupting communication and radio navigation.

The effect is usually most serious on the lower-frequency systems, such as a.d.f. (automatic direction finding) which operates from 150 kc/s to 2 Mc/s. In this system, the processed outputs of a loop (or goniometer search coil) and an omni-directional or sense-finding aerial are used to operate servo motors which drive the loop towards a null and remotely indicate this null position. The system provides both relative heading and homing facilities, and in the presence of noise the dial indicator may either "hunt" erratically or even (much worse) indicate a false bearing.

The frictional, or tribo-electric, charging process results from the high-speed brushing of air or airborne particles past the aircraft skin. Charge magnitudes from this process can be substantially affected by the nature of skin finish materials, treatments and adulterants, but the highest charge rates occur where ice crystals are precipitating out from a very cold, moist atmosphere.

Charge magnitudes have been further extended by the widespread use of pure-jet engines, which gulp fantastic quantities of air (together with particle content and the occasional bird) past their internal surfaces, and so supplement charge generation from normal airflow over the aircraft skin. This tribo-electric charging by the engines is itself additional to that arising out of the combustion processes.

Fig. 1(a) shows a typical recording of charge rate during take-off and climb of a EAC 1-11 aircraft. The circumstances are of constant throttle setting, implying no local restrictions upon engine noise. Following take-off, charge rate rises rapidly to a maximum after some few minutes (and thousands of feet) of climb. As automatic processes reduce fuel consumption rate with increasing altitude and speed, charge rate also decreases, but more slowly than it rose, becoming virtually constant by some 15,000 ft of altitude. A marked step down can be seen where throttle setting is reduced at the top of the climb, some 26,500 ft in this case.

C. E. Cooper is general manager of Chelton (Electrostatics) Ltd., manufacturers of aircraft aerials and aircraft static discharger systems. After working with Mazda on valve development he became a lecturer at South West Essex Technical College. He then joined Easco Electrical Ltd., becoming works technical manager. Before going to Chelton, he jointly formed two small service companies but later sold these interests "when lack of technical interest outweighed the financial advantages of company ownership".

In Fig. 1(a) the greater part of the charge can be assumed to be due to combustion effects, with the climb being entirely through clear air, in which tribo-electric charging is at a minimum, though not non-existent. For comparison, Fig. 1(b) shows (to a different scale) the far more erratic variations in charge rate when the aircraft is in level flight through light precipitation conditions. In this case, with the jets throttled back, charge from combustion products is small.

However generated, charge becomes stored in the capacitance between the aircraft skin and some ill-defined outer field boundary, stressing the air dielectric between them. Such stress may be either supplemented or opposed, depending upon the polarity of any existing atmospheric potential gradient, as is experienced when

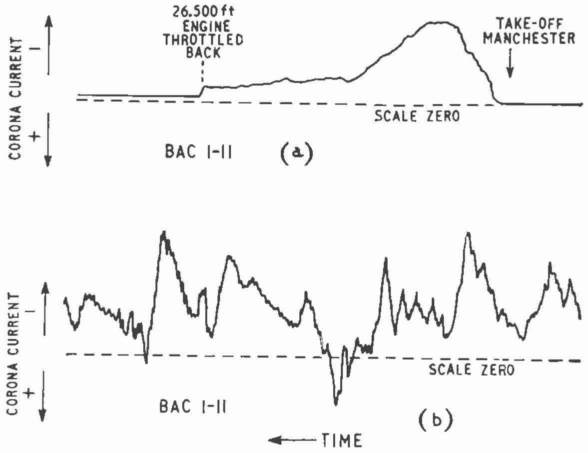
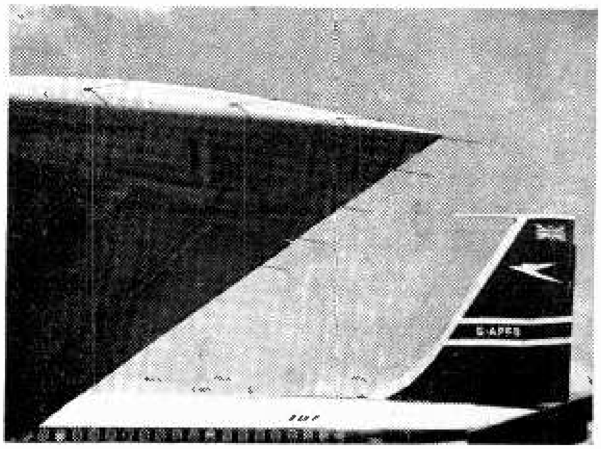


Fig. 1. Corona current measured during flights of BAC 1-11 aircraft: (a) following take-off in clear air; (b) level flight in conditions of ice precipitation.



Dischargers on trailing edge and tip of a wing on a Boeing 707.

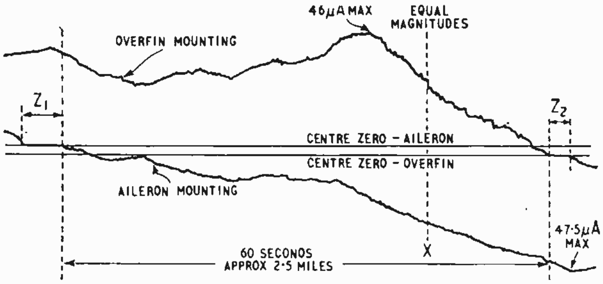
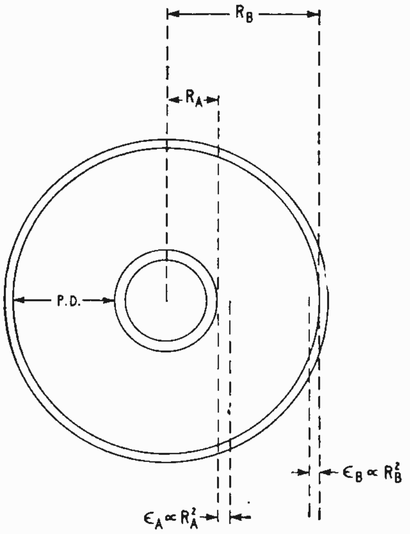
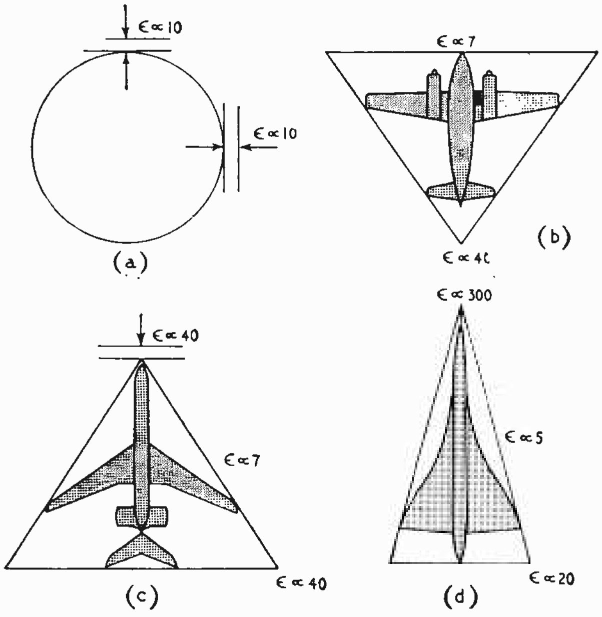


Fig. 2. Section of corona current recordings made at two extremities in an HS.125 twin-jet executive aircraft flying between charged clouds (altitude 9,000ft, air speed 150 knots). Each trace shows corona current through a single discharger mounted as shown. Z_1 and Z_2 indicate periods of zero discharge.



Left: Fig. 3. Potential gradient between two concentric spheres A and B with radii R_A and R_B

Below: Fig. 4. Potential gradient variations with different slopes: (a) circular disc; (b) older type of aircraft; (c) modern jet aircraft shape; (d) supersonic jet aircraft.



the aircraft changes height or flies between charged cloud formations.

The trace recording of Fig. 2 provides indirect indication of the variations of electrostatic field as measured at two different extremities of an HS.125 aircraft flying obliquely between charged cloud areas. During the sixty-odd seconds of this recording, stress changes from maximum at the tail fin to maximum in reverse polarity at one wing tip, passing through a stage at "X" of considerable and equal but opposite stresses at these two measuring sites. At this instant, the net aircraft charge accumulation is zero, but because of aircraft span in the spatial field, intense dielectric stress exists in air layers adjacent to the aircraft extremities. Since the overall effects are similar, though not identical, to those frictionally produced, they are initially considered as a third form of aircraft charging.

No aircraft system at present used suffers from the mere existence of charge, but since the charging processes are typically of constant-current form, p.d. between aircraft and boundary rises continuously until limited by some form of dielectric breakdown. In extreme circumstances, this could be a minor lightning flash, but, far more commonly, limitation occurs at much lower potential by the process of atmospheric ionization, permitting release of current back into the atmosphere at a rate balancing that of acquisition.

The ionization condition, and consequent radio noise generation, can be reached in seconds and continuously maintained from the rates of charge which have to be anticipated for possibly 5% of total short-stage flying time. Consideration of the function of devices used to control these effects requires an understanding of how gradient magnification occurs.

Potential Gradient Between Spheres

With p.d. between two concentric spheres A and B, as shown in Fig 3, then immediately adjacent to the two spheres the respective gradients ϵ_A and ϵ_B will be in proportion to the surface areas, i.e. to the squares of the radii. An increase of outer sphere radius (only) will therefore increase the disparity between ϵ_A and ϵ_B in greater proportion than that of the spacing increase. This in turn means that to maintain constant gradient ϵ_A by the inner sphere requires an increase of p.d. which is less than proportional to the spacing increase. For a sufficient disparity of dimensions, the radius of a small object virtually fixes its immediately adjacent gradient in proportion to applied p.d., regardless of the distance across which it is applied and hence also of the shape of the field outer boundary.

For a spherical object, gradient is of course the same across any fixed distance radially from any part of the surface, but for any non-spherical shape, a constant applied potential will produce different gradients adjacent to every different radius. In adapting this principle to aircraft circumstances, aerodynamic shapes are such that consideration must initially be restricted to two-dimensional forms. If potential applied between the flat circular disc (flying saucer?) of Fig. 4(a) and some distant boundary is such as to produce ten units of gradient adjacent to any place on the edge, changing to the almost equilateral triangle of Fig. 4(b) might produce some 7 units at the centre of each flat side, and perhaps 40 units at each apex, depending upon their tip sharpness. As shown, the triangle at (b) can contain the idealized outline of an older shape of aircraft; in (c) the triangle is reversed to contain a later aircraft shape. The significant difference is that, in the latter

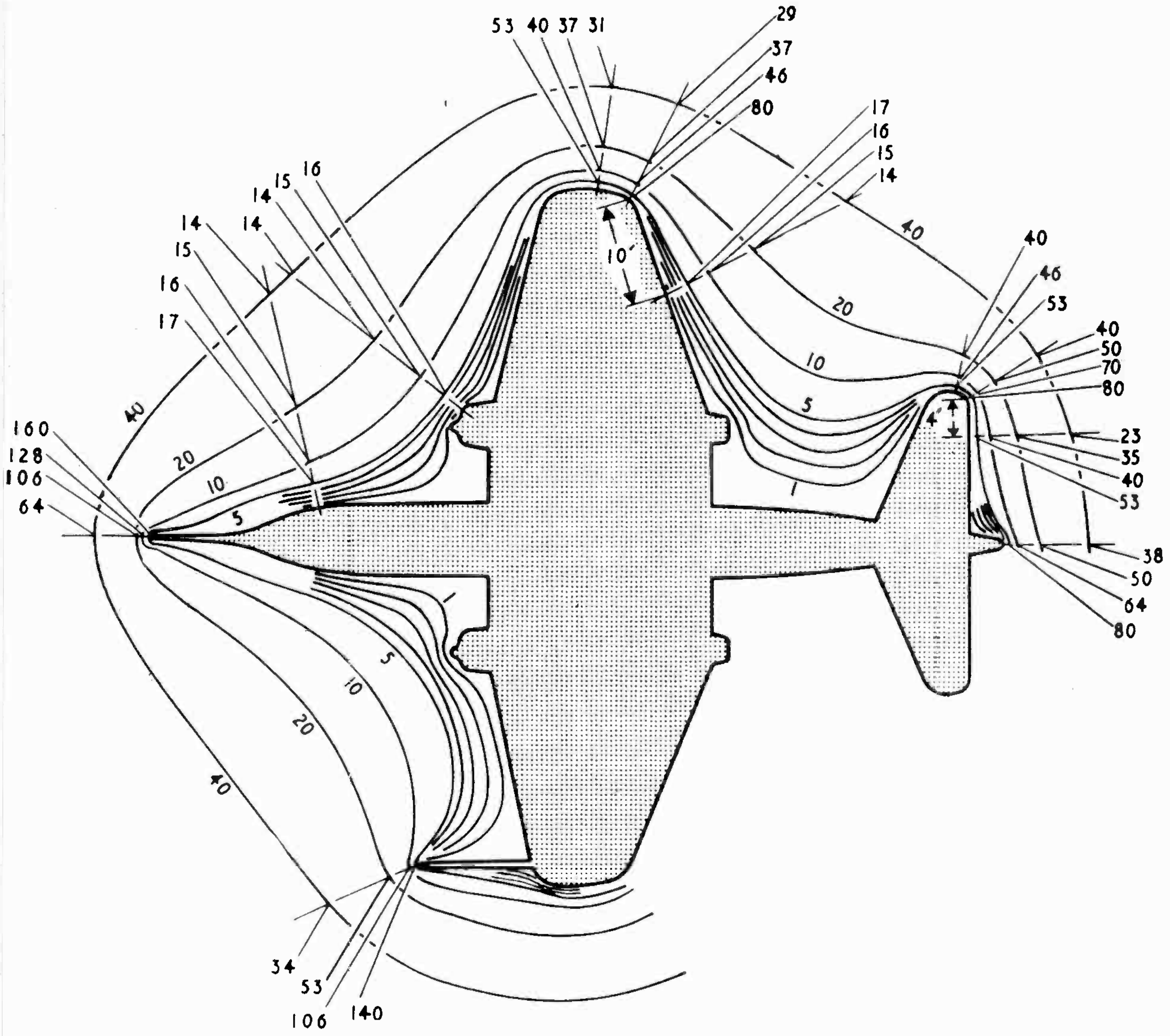


Fig. 5. Equipotential contours and derived gradients (groups of four figures) for the Canberra aircraft.

case, one of the high-gradient positions looks in the forward direction, imposing practical difficulties not present when high-gradient positions look only aft or athwart.

In all these shapes, the relative gradients indicated are still only the mean values over some arbitrarily chosen distance from the outline. Fig. 5 shows how these mean values vary with span of measurement for a Canberra aircraft. Gradients (in purely relative units) are derived from the equipotential contours, and each row of four figures averages the gradients out to contours 5, 10, 20 and 40 respectively. The projection of the nose and wingtip pitot tubes from the main bulk produces adjacent gradients which are higher than for any other part of the aircraft.

The figures marked are best regarded as the *local* mean gradients, as determined by aircraft shape out of the *general* mean gradient existing around the aircraft as a whole (p.d. between aircraft and surroundings).

Consider a p.d. applied between two spaced equal spheres; provided the gap between them is smallish relative to sphere radius then gradient will be constant across the gap. Halving the gap by moving the spheres closer together will result in the mean gradient being doubled without changing its constancy of division. The same doubling of *mean* gradient could otherwise have been produced by bridging half the gap with a sharp-pointed spike, but in this case the gradient immediately adjacent to the point may be up to hundreds of times *above* the mean, balanced by a more moderate reduction *below* the mean across most of the gap.

The degree of gradient magnification depends mainly upon the point radius, but is also affected by stem thickness behind the point, and by its projection length from the main bulk of conducting surface. This process of magnification can be utilized to control the positions at which local gradient is highest, and hence at which corona will start for the lowest possible aircraft potential. Corona is gaseous ionization, occurring when sufficient p.d. exists between electrodes whose shape and spacing are such as to produce intense local increase of gradient above the average across the gap. Thus corona occurs adjacent to both electrodes in a point-to-point gap, but at only one in a point-to-flat surface gap. It can also occur at both extremities of an isolated conductor in an otherwise linear field, which represents the HS.125 conditions at "X" in Fig. 2.

The radio interference produced by ionized gas or vapour in a neon tube is quite well known, but r.f. noise signals can be radiated from ionized gas without necessarily also producing visible light.

Noise signals are radiated directly from ionized gas, with a random frequency spectrum, and magnitudes tending to inverse relationship with frequency but often significant up to the v.h.f. band. After reception via a channel of finite bandwidth, the noise signals are comparable with a suppressed carrier modulated by white or random noise, producing a characteristic "hiss" after detection.

Where conditions produce a gradient only slightly above the ionization threshold, the corona discharge can have an interrupted or pulsed form, and this results in the received and detected noise having some predominant pitch of note. For increasing gradient around the threshold condition, this note typically changes from a "ticking" sound, through some very rough, guttural notes to a whistle of pitch eventually rising above audibility or response.

CONTROL METHODS

There is no effective method known to prevent the processes of charge acquisition by an aircraft, which, with a capacitance typically some hundreds of pF, will rise in potential at a rate of 100,000 volts per second from a charge rate of microamperes. Rates up to a milliamp or more have been recorded, still without including thunderstorm conditions. With potental rising at such rates, even the mythically smooth-outlined aircraft of publicity pictures must very quickly reach the condition where corona occurs from some or many parts of the aircraft.

Paradoxically perhaps, therefore, the simplest approach to noise control is to make corona occur more easily. This can be done by placing sharp projections at aircraft extremities to produce corona by large magnification of only quite low general gradient. With the corona path confined to dimensions comparable to the point radii, noise radiation is drastically reduced.

The numerous practical objections to an aircraft bristling with rigid sharp points have led to the development of the discharge tip shown in Fig. 6, which in various assemblies, has recently become virtually standard for almost all British and many other aircraft types. The tip comprises a small tuft of a hundred or so nichrome wires of about ½ thou' diameter (51 s.w.g.), spread into a crown around a tiny plug inside a supporting tube. If allowed to bunch they would function only as single blunt point, so the flared polythene moulding is fitted to create turbulence in the airflow and so keep sufficient number of the wires separated to function as individual sharp points.

Release of corona via a very sharp point provides substantial, but still insufficient, reduction of r.f. noise generation, and the process is extended by inclusion of high series resistance. The actual value used is a compromise between greatest reduction of noise and the avoidance of undue restriction of the d.c. component of corona current. Major current restriction is provided by the gaseous corona path itself, with a slope resistance around $10^9\,\Omega$ for the tip of Fig. 6. Series resistance additions of up to some 50 MΩ are therefore feasible without substantially restricting current. The series resistance appears both to reduce the ratio of noise-current-to-d.c. component, and also to act in conjunction with tip stray capacitance to reduce the length of path through which noise current flows, and so confine radiation principally to the ionized air. To have maximum effect series resistance needs to be concentrated as closely as possible to the corona point.

A complete discharger device is constructed with the corona-tip supported on a 9-inch tapered rod of glass-fibre, surface coated with high resistance material. Some 10 to 40 dischargers of this type are commonly grouped in trailing or semi-trailing positions near to the various outermost extremities of an aircraft.

To maintain the essential semi-trailing position for the corona tip, forward facing assemblies have been produced recently; these units are designed to mount on pitot heads or the lightning diverter probe often fitted at the apex of a radome. The three discharger tips on each unit are critically angled, with spiral resistance tracks around the mounting cone.

Simulation and measuring equipment.—To optimize design and demonstrate performance of discharger devices, the equipment shown in Fig. 7 was constructed in simulation of an aircraft wing section. The high voltage generator is of the Cockcroft-Walton type, with 20 stages providing an off-load rectified output of some 120 kV from the 5 kV 50 c/s available from the transformer, and adjusted by a Variac. The d.c. output voltage is measured by a 10-microamp meter in series with a long chain of five-hundred 20 MΩ resistors contained within about 50 ft of coiled-up polythene tubing.

High voltage is applied to the wing section through

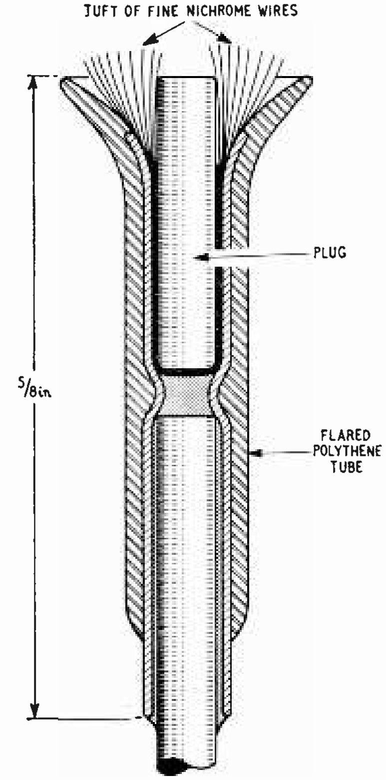


Fig. 6. Cross-section of tip of discharger fitted to aircraft.

a pair of microammeters set into the wing, separately measuring corona released directly via the wing or via lightly insulated inset tabs, on which dischargers under test are normally fitted. Measurements are generally in terms of the applied potential and other conditions which result in various standard values of corona current, ranging from threshold (taken as 1.0 μA) up to 50 μA Comparative noise measurements are then made for the various conditions and currents.

Noise radiated during corona discharge is picked up by a capacitance type aerial, too small to approach resonance within the 0.5 to 5.0 Mc/s pass-band of the receiver aperiodic amplifier. This pass-band was chosen to overlap into the frequency ranges used for m.f. automatic direction-finding and h.f. communication, but subsequent interest has moved more towards the lower frequencies used by Decca and other long-range navigational systems.

Amplified r.f. output is conventionally rectified, passed via a calibrated attenuator to a transistor a.f. amplifier, and then switched to either a speaker or a noise meter. The whole receiving and measuring equipment is mounted in, or on, the wing section, since it all necessarily operates at the high potential of the wing.

The applied potential which will produce less than a microamp of corona from, say, an exposed bolt-head will produce perhaps 10 to 15 microamps from a typical discharger, but with a received noise level some 50 dB lower. Even this residual white noise will be less objectionable in form than the typically rough note due to corona from the bolt-head or similar minor projection.

Certain discharger designs show marked directional or polarization effects in their noise radiation, with fairly sharp nulls as the corona point is oriented. By optimization of this characteristic attempts have been made to secure even better than the 50 dB noise reduction mentioned, but there is considerable doubt over the possibility of maintaining or even knowing the true null positions in aircraft service. In fact, the noise level radiated by the discharger design shown has proved acceptable, and the major problem is to prevent even trifling corona current from starting elsewhere than at the dischargers.

The optimum installation is a complex function of discharger type, number and siting. It has to include such factors as air pressure differentials, exposure of sharp extensions during control-surface action, and the nature of the various normal projections, particularly aerials. It is quite possible for an m.f. system to collect and suffer from noise radiated during discharge off the aerial of, say, a v.h.f. system not itself affected by the noise.

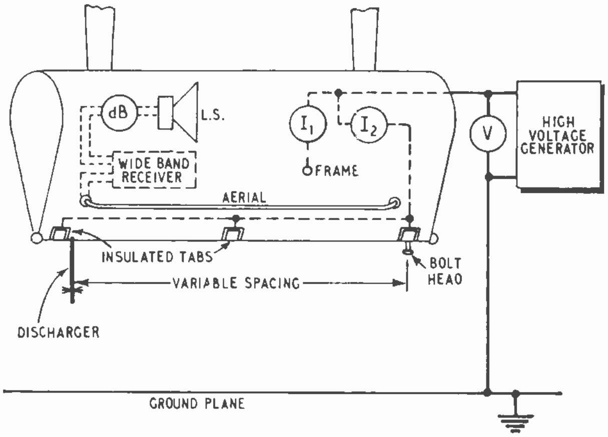


Fig. 7. Block diagram of test and measuring apparatus mounted inside simulated aircraft wing section.

The field configuration which will exist around a particular aircraft is most readily determined to a sufficient degree of accuracy by a few two-dimensional plots on resistance analogue paper. This graphite-impregnated material has a fairly uniform resistance of about 3000Ω per square (i.e. between opposite edges of a square of any dimensions). A representation of the aircraft shape, or some section of it, together with a surrounding field boundary, are first outlined in wax pencil, and then edged or filled-in solid with brush application of a highly conducting paint (Fig. 8). The material used is a dispersion of metallic silver powder in methyl iso-butyl ketone, which air dries to a few ohms per square, a negligible value compared with the paper resistance. It should be noted that most of the so-called "metallic" paints are in fact non-conducting. Contact to the conducting areas can conveniently be made via pieces of aluminium foil, held in place by small strips of self-adhesive tape, and brushed over by the conducting paint.

For present purposes the shape of the field boundary is immaterial, provided its minimum spacing to aircraft shape is not less than about half the aircraft's largest dimension (in scale, of course). At this minimum spacing, the field pattern adjacent to aircraft shape is substantially unaffected by boundary shape. Potential now applied between the shape and the boundary will

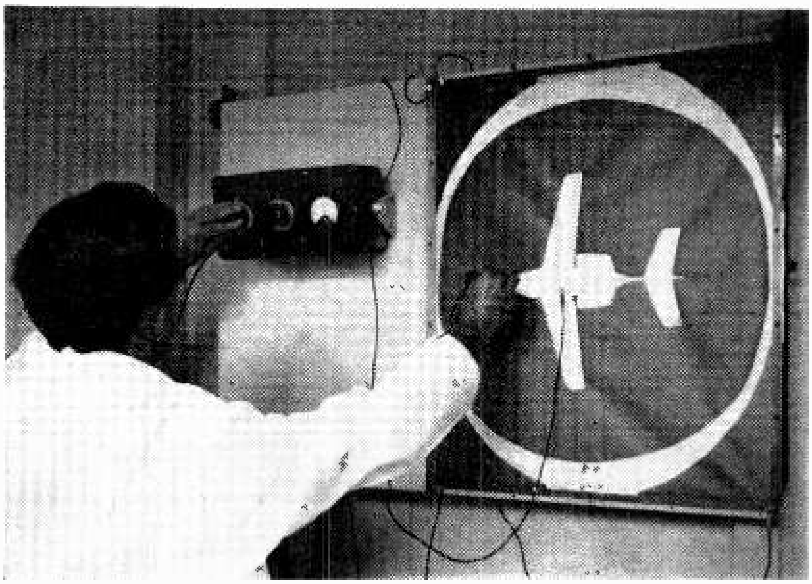


Fig. 8. Apparatus for plotting analogues of equipotential electric fields surrounding various shapes of aircraft.

distribute itself across the intervening resistance paper areas as an analogue of the electrostatic field which would exist around similar shapes in air, or any uniform dielectric. The potential distribution can be explored with a high-resistance voltmeter, but is far better done by forming a suitable bridge circuit, and exploring for null balance against a series of potentiometer settings to produce equipotential contours.

Instead of random exploration, it has been found easier to explore along a series of lines normal to their origin at the aircraft shape, as previously marked onto the resistance paper in wax pencil (i.e. non-conducting). It is better still to mark these lines along the quite readily estimated direction of maximum gradient away from their origins, and so achieve the highest sensitivity of off-balance indication.

Use of a d.c. (9 V) supply for the resistance-paper bridge has been found useful in providing indication of the direction of probe movement needed to approach balance. The four-transistor d.c. amplifier used provides off-balance indication down to below a millivolt, with input resistance sufficiently high that an off-balance setting does not materially load the paper bridge to distort potential distribution.

Exploration is conveniently made by a probe formed of a ball-point pen tip (minus ink, of course) which can be rolled across the paper without need to lift and reapply. Located balance positions are then marked on, again in wax pencil, although better accuracy is achieved by using a sharp-pointed probe for exploration, which can then prick through the resistance paper to mark an underlying cartridge paper or similar. Joining up each series of equipotential positions provides contours as in Fig. 5 of correct shape but in purely relative terms, from which the relative gradients can be obtained by measurement either of the spacing out to a particular contour, or by interpolation to the contour reached by some constant spacing.

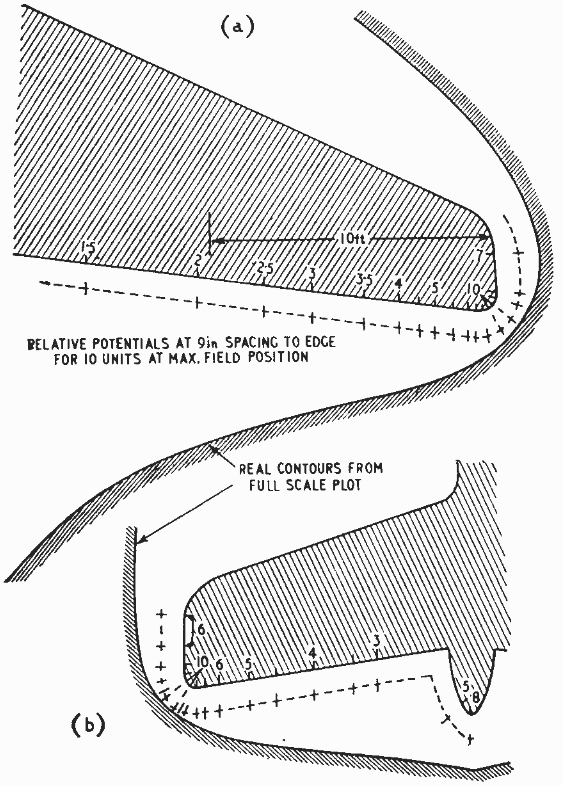


Fig. 9. Potential gradients at (a) wing and (b) tail of HS. 125 executive aircraft.

This last-mentioned is of most interest in order to provide the relative mean gradients effective over the length by which a discharger will project from the airframe. To obtain better accuracy across such a dimension, a final plot is made of each significant extension, using as field boundary one of the contours previously plotted, possibly with corrections to include effect of the third dimension, as estimated by comparison with plots in other planes. Since the contour boundary has true shape, there is no minimum spacing limit imposed, and the plot can be large scale.

In Fig. 9 the dotted line indicates the scaled dimension of discharger projection out from its mounting surface. Potential applied across the resistance paper from wingshape to contour boundary is set (by a series rheostat) to produce a convenient whole number of voltage at the discharger line where it most closely approaches the boundary, i.e. the position of highest gradient. Other gradients relative to the maximum can now be plotted for various distances away from that of maximum.

This information is then used in conjunction with that from graphs of discharger performance grouped at different spacings to produce an aircraft layout at graded spacings which will approach the ideal of equal current released by all dischargers at any given aircraft potential.

In-flight corona recordings are achieved by fitting special dischargers insulated from the airframe, each with a single wire brought in to a multi-channel strip paper recorder, with circuit completed to a common airframe connection. Each channel needs to be protected by shunt diodes against the excessive currents which will flow when in the vicinity of thunderstorm activity.

The measurement is one of fluctuating unidirectional current, with electrons normally leaving the discharger, i.e. the aircraft having negative polarity relative to its surroundings. As already indicated in Fig. 2, reverse direction of current flow is also possible, due to atmospheric gradients rather than aircraft charging. For this reverse polarity, the dischargers have closely similar threshold potential, but a rather higher slope resistance.

The area from which charge is released does not directly indicate the area or method of acquisition, but such information can, with experience, be derived from the pattern of corona variations with time and the differentials, if any, between corona in areas of known equal exposure.

To gain the necessary statistical information, an airline aircraft has for some months past been making corona recordings during its normal passenger flights over most of the European continent. Whenever practicable, the corona recordings are accompanied by taped observations of the ambient conditions, the radio noise level during discharges, and the overall effects upon particular navigational systems. The results of this programme are hoped to provide the first objective standards by which to make comparitive assessments of the susceptibility of different aircraft designs in experiencing static charge effects, and of the value of various discharge systems in minimizing the effects.

Titanium Cone Loudspeaker

EVOLUTION AND DESIGN

By **E. J. JORDAN**, Assoc.I.E.R.E.

SOME years ago a friend gave me a book which he had purchased for 6d from an old bookshop. It was McLachlan's "Elements of Loud Speaker Practice" published in 1935. It makes fascinating and, for the author, somewhat sobering reading, inasmuch as that in over 30 years there has been so little apparent progress in loudspeaker development. Among the many possible loudspeaker types described are the full range push-pull electrostatic loudspeaker and the Blatthaller loudspeaker, forerunner of the French Orthophase. The last chapter is headed "Recent Developments" and introduces firstly the concept of a large moving-coil loudspeaker used together with a horn loaded tweeter in conjunction with a crossover system, and secondly a moving-coil loudspeaker having a small auxiliary cone attached to the centre of the main cone to handle the high frequencies (Voigt, of course). The frequency response of the last-mentioned is comparable to that of many modern hi-fi loudspeakers and is reproduced in Fig. 1. For direct comparison the frequency response of a modern 12 in twin-cone loudspeaker is shown in Fig. 2.

Undoubtedly one of the main reasons for the slow progress has been that at the time the book was written loudspeaker design thinking was well ahead of the availability of suitable materials and engineering techniques with which to implement the ideas. Modern technology has now provided us with a vast range of metals, ceramics and plastics that allow us to realize the principles established so long ago.

Once valve amplifiers had reached the stage where a few relatively low distortion watts were available, the single paper cone moving-coil loudspeaker emerged as by far the most satisfactory compromise between quality and economics, and continues so to be. With the progressive improvement of broadcasting and recording quality there came a demand for a wider frequency range than could then be obtained from the single paper cone and crossover systems, and double-cone systems were extensively developed. In addition to Voigt, Goodmans Industries were largely responsible for the sophistication of double-cone techniques. This is apparent in their famous "Axiom" range. Many companies developed excellent crossover systems and it is worth noting that, while widely varying techniques were used in tweeter design, the low frequencies were invariably handled by the ever faithful paper cone moving-coil loudspeaker.

The difficulty in obtaining a smooth extended high frequency response from a single cone was practical rather than theoretical. As we shall show later it is necessary to use a flared cone in order to obtain a good high frequency performance, but because of their poor strength/weight ratio paper flared cones were prone to non-linear flexing at low frequencies, resulting in harmonic and intermodulation distortion. Metal cones were tried on and off right from the start but the highly resonant nature of metal precluded these as a satisfactory material for many years. A significant breakthrough in this respect was made by Hugh Brittain of G.E.C. Research Laboratories by using a 6 in straight sided Duralumin cone having a plastics (p.v.c.) edge termination which, together with a controlled deformation in the cone body, largely overcame the resonance problems associated with metal. This resulted in a loudspeaker with a very acceptable frequency response and a harmonic distortion level which was so low that it has not yet been improved upon. Details of this were published in *Wireless World*, Nov-

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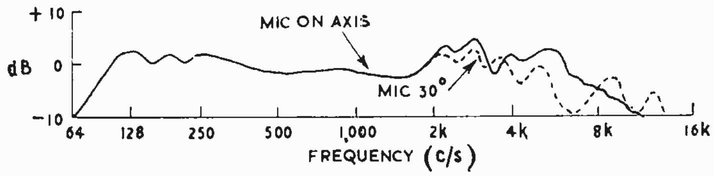
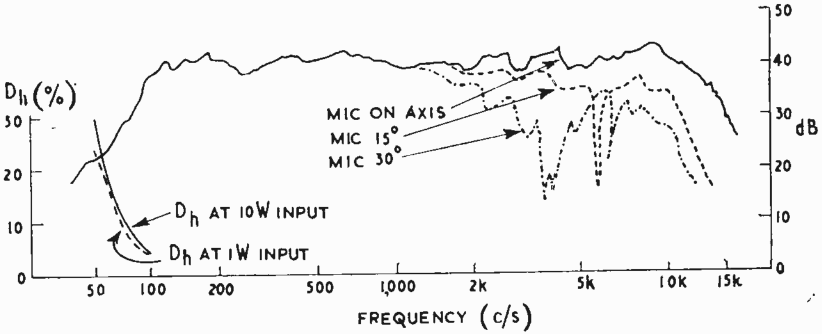
E. J. JORDAN, who recently joined Audio & Design Ltd., of Maidenhead, as a director, started his career in the service department of G.E.C. He then spent twelve years with Goodmans Industries and in 1964 became technical director of Jordan-Watts Ltd. of Hayes, Middx., where he produced the first "modular" loudspeaker.



Above:—Fig. 1. Response curve of twin diaphragm m.c. loudspeaker (Voigt) with tractrix horn about 4ft long and 4ft square at mouth (Reproduced from "Elements of Loud Speaker Practice"—McLachlan, 1935).



Right:—Fig. 2. Response, distribution and total harmonic distortion curves of 12 in twin cone m.c. loudspeaker in enclosure.

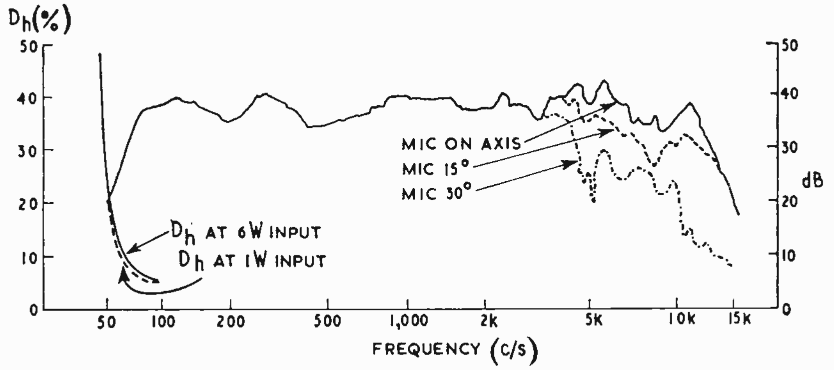


Fig. 3. Performance curves of 8 in hyperbolic paper cone m.c. loudspeaker.

ember-December 1952 and January 1953.

Shortly after this the author worked on the problems associated with flared cones and discovered that the distortion could be reduced to acceptable proportions by the use of (a) a very flexible surround, and (b) a flare following a hyperbolic law. The resulting loudspeaker, now known as the "Axiette," is still marketed by Goodmans. Its response curve is shown in Fig. 3.

Throughout these years the improvement in materials was most apparent in the realm of permanent magnets, which, for a given total flux were a fraction of the size of their pre-war counterparts. Plastics technology was forging ahead and most loudspeaker engineers were keeping a very close watch on this industry, hoping for a plastics panacea to the problems of cone design. This came —not, however, to the protagonists of cone loudspeakers but to the full-range electrostatic loudspeaker.

A direction in which remarkable advances have since been made has been the reduction in the overall size of loudspeaker systems. Theoretically efficiency may be traded for size for a given low frequency limit *reductio ad absurdum*. As usual, practical mechanical problems set a limit, but the vast majority of present-day hi-fi loudspeakers are very much smaller and less efficient than their earlier counterparts—an approach now made acceptable by the availability of domestic power amplifiers with outputs of up to 100 watts. This trend was started by Edgar Vilcher in the U.S.A. when he developed the "acoustic suspension system" which basically comprises a large massive bass cone loudspeaker fitted with a highly flexible suspension and housed in a small airtight enclosure. Implicit in this approach is the use of some form of crossover system and separate radiators in the high frequencies.

The birth of the now well-known full-range electrostatic loudspeaker was announced in a series of articles in *Wireless World* in 1956 and a completely new standard in sound reproduction was established.

The most significant advantage of the electrostatic loudspeaker over existing loudspeakers was in its transient performance. The importance of transient response has been stressed often enough over the years by the pundits but it has been played down to a large extent by many manufacturers and grossly underrated by the hi-fi public generally. The reason for this may be due to the difficulties associated with making measurements of transient performance compared with simple frequency response curves.

Some indication of transient performance can be obtained from response curves[1]. For example, the ability of the moving system to allow sufficient acceleration to adequately reproduce transient sounds is directly related to its high frequency performance. The worst aspect of transient performance, however, is the prolonged "ringing" that can follow a transient. Any transient is composed of a series of harmonically related overtones and any sharp resonances in the system which fall into this range of overtones are often not very apparent on the response curve except to the experienced observer, who can recognize them as tiny, near vertical changes of level. Even this is not entirely reliable because such effects can be produced by other causes. The situation is illustrated by reference to the two hypothetical response curves shown in Fig. 4. It is extremely likely that loudspeaker A would reproduce sounds with a far higher degree of accuracy than loudspeaker B. Even though B has the flatter curve, the transient ringing associated with the small sharp changes could result in extreme colouration and very poor definition. Curve B could well be described as "angry."

The electrostatic loudspeaker is a perfect example of the above argument. Its measured response curve is unusual and certainly not level (Fig. 5), but it has the one outstanding quality that renders its shortcomings relatively unimportant, and this is the complete lack of colouration (or, in the words of the advertisements, "this loudspeaker lacks character"). It is a salutary lesson to listen to white noise on a loudspeaker comparator while switching between various high quality systems including the electrostatic loudspeaker. All the conventional cabinet systems have pronounced "vowel" sounds which are entirely absent from the e.s.l. (Incidentally, for purposes of educating the ear a good "live" white noise is the sound of car tyres on a wet road.)

All of which brings us back to about the present time. We have inherited a veritable fund of basic principles, the advantage of over 30 years of further development and an almost unlimited range of materials and techniques. Whither now? Faced with this situation, the author adopted the approach now to be described.

Design objective.—The problem was to recreate sound as accurately as possible within the confines of the listening area—in this case the domestic living room or lounge. As a starting point we will assume a medium room of 2,000 cubic feet. The programme material likely to make the greatest demands on the available sound power and frequency range is that provided by a full concert orchestra. We will assume the listening level to be such as to provide a peak intensity at the ears similar to that experienced in a typical seat in a concert hall, and finally we will let the low frequency limit be 30 c/s. For domestic reproduction this frequency is quite low enough since very few recordings extend as low as this and the room dimensions limit bass reproduction to a frequency given by:

$$f = \frac{560}{\text{longest dimension in feet}}$$

From the above information can be calculated the total acoustic power required in the room and hence the volume velocity (diaphragm area × excursion × frequency) required from the loudspeaker (Appendix 1). It is necessary to choose a suitable ratio of diaphragm area to excursion. However, the choice of diaphragm dimensions must be determined in part by a number of other factors which we will now consider.

The loudspeaker diaphragm has to draw its energy from the electrical output of the amplifier and transfer it to the air in the form of sound waves. This transfer is profoundly affected by the impedance of the air load, which in turn is determined by the diaphragm dimensions and frequency. It is well known that the radiation resistance curve abruptly changes shape about the point where $kr=2$*. This corresponds to the frequency where, assuming a circular diaphragm, the circumference is equal to 2 wavelengths.

Although the entire radiation resistance curve may be exactly represented as a Bessel function, it is usually considered adequate to use the two approximate expressions given in Appendix 2 dealing with the parts of the curve above and below the "knee" respectively.

Consider first those frequencies below the "knee." It can be shown that for the radiated power to be independent of frequency the diaphragm must be rigid and either have a mechanical impedance that is very much lower than the air load or a mechanical impedance that is dominantly mass (known as the condition of mass control). Either of these conditions are realizable in practice but the condition of mass control offers a number of advantages:

1. It renders the low frequency performance less dependent on room acoustics.
2. Performance is less critically dependent on the position of the loudspeaker in the room.
3. It makes domestically acceptable enclosure systems which are necessary in order to secure an adequate low frequency performance.

Above the "knee" of the curve a mass-controlled diaphragm will cause the radiated power to fall as frequency rises at the rate of 6 dB per octave. The polar response becomes progressively more narrow as frequency rises. These two factors obviously render a mass-controlled rigid diaphragm unsuitable for high frequencies. There are two solutions to the problem. One is to provide a smaller diaphragm and use some form of mechanical or electrical crossover system. The other is to cause the existing diaphragm to reduce its effective diameter as frequency rises. The effect of this is also to reduce the mass of the diaphragm, and since at these frequencies the radiated power is proportional to the effective area and inversely proportional to the square of the mass it follows that the smaller the cone the higher will be the efficiency, the mass and the area being directly proportional to each other (see Appendix 3). Provided the correct ratio of diameter to frequency could be maintained both the radiated power response and the polar response could theoretically be independent of frequency.

Again it is seen that a choice has to be made and it is clearly seen in theory at least that the second arrangement is to be preferred, inasmuch as it does not introduce any abrupt discontinuities in the system. Any arrangement using multiple diaphragm crossover techniques is likely to suffer from three serious drawbacks. First, at the crossover frequency the radiated power is shared between two diaphragms of different size and hence different polar response. This means that there must be an abrupt change in the power response if the axial pressure response is to be maintained, or vice versa. Secondly, the electrical impedance looking into a loudspeaker system incorporating electrical crossover networks must inevitably exhibit considerable phase change about the crossover frequencies. Crossover frequency networks are designed to be matched by constant resistance at all of their terminations, a condition which is never fulfilled in practice. The effects of such a load applied to the output of an amplifier may in many cases considerably affect the phase of the negative feedback voltages, thereby degrading the performance of the amplifier. Thirdly, the inevitably resonant nature of the crossover system will introduce transient distortion of the type discussed above.

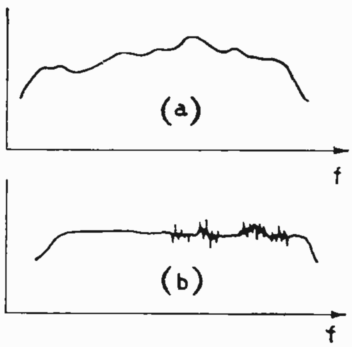


Fig. 4. Curve (b), although flatter, has the "angry" appearance associated with a poor transient response and is less acceptable than curve (a).

Accepting then the desirability of the "reducing diameter" approach we find that one of the simplest ways of achieving this in practice is to apply the driving force at the centre of the diaphragm only. It can readily be visualized that if the diaphragm were, for example, a stretched membrane of some low-loss material, at the higher frequencies ripples would spread out from the driving point and travel to the edge. If some damping media were applied to such a diaphragm the ripples would undergo severe attenuation as they moved outwards, so that the displacement at the point of application of the force was considerably greater than at any other point and most of the sound radiation would be from this central point. Clearly with such an arrangement as this the effective central working area would be a function of

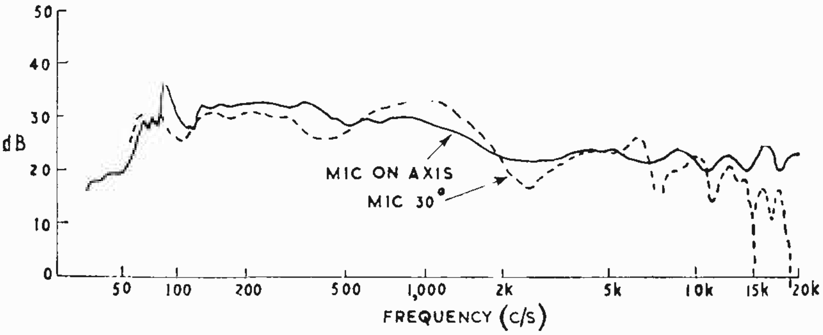


Fig. 5. Performance curves of full range electrostatic loudspeaker.

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*Radiation resistance is the real part of the acoustic impedance of the air load. It is plotted vertically in normalized form $R_{MA}/\pi r2\rho c$ against normalized frequency kr $(=2\pi r\lambda/)$ plotted horizontally (where R_{MA} – radiation resistance in newton-seconds/metre, r = diaphragm radius in metres; ρ – density of air in kg/m³; c = velocity of sound in m/sec λ – sound wavelength in metres; and $k=2\pi/\lambda$).

wavelength and therefore frequency, thus giving us the type of operation we require.

It is fairly obvious at this point that we have talked ourselves willy-nilly into a fair description of the operation of a single-cone loudspeaker at high frequencies. The single-cone loudspeaker, by its very nature, has intrinsically the right sort of characteristics necessary for full range sound reproduction, and even the poorest examples of this type of loudspeaker provide very acceptable results. This was appreciated, in principle if not in detail, 40 years ago, and, as we have already indicated, this loudspeaker has by far the most satisfactory all round performance for general purpose applications. Its performance has been limited at low frequencies for the want of a good suspension system. The problem at high frequencies is that of producing a cone of such form, material and dimensions as will operate to the precise requirements.

In fact it is no less a problem to define the "precise requirements" in material terms. There has been no tractable mathematical approach for dealing with this other than the author's own very limited contribution which gives no more than an indication of the relationship between the various physical parameters of the cone. This is outlined in Appendix 3. Fig. 6 shows how the effective cone diameter reduces as frequency rises due to cone flexure. The expressions in Appendix 3 show that in order to secure a level response the first mode of flexure must start at the "knee" frequency and that a flared profile is necessary to provide the correct rate of area reduction with rising frequency. By the choice of suitable profiles the radiated power response may be made to rise or remain level or to fall. The high frequency limit of a loudspeaker is reached when the radiating area has been reduced to a point where its effective mass becomes equal to that of the voice coil. The last-mentioned provides a non-reducing factor in the total moving mass and above this frequency the efficiency falls. It may be mentioned at this stage that the further loss of efficiency at high frequencies is incurred by voice coil inductance, but from what has been said it will be seen that this can be compensated by means of the cone design. In practice, however, the more we make use of the facility of increasing efficiency as frequency rises the more restricted will be the ultimate high frequency limit. The overall high frequency efficiency over the frequency range above the "knee" is largely a function of the material from which the cone is made.

Apart from the considerations of the response curve a high overall high frequency efficiency is extremely desirable, inasmuch as it permits the use of damping techniques to avoid transient ringing. Any form of damping reduces overall efficiency and the greater the intrinsic efficiency of the cone the more freely can we apply damping media to improve the transient performance.

Generally speaking the higher the velocity of sound within the material the greater will be the efficiency and therefore the more extended may be the high frequency response. Further, high sound velocities are usually associated with materials having a high strength/weight ratio. This is also the property necessary to eliminate the distortion associated with flared cones. As we have previously said, the strength/weight ratio of paper is not particularly high and, in addition, paper is a relatively inexact and unstable material in mechanical terms. The reasons why the single-cone approach has not received greater attention are now becoming apparent.

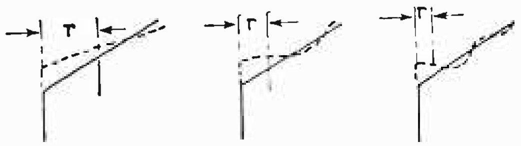


Fig. 6. Indicating how the effective cone radius (r) may decrease with rising frequency.

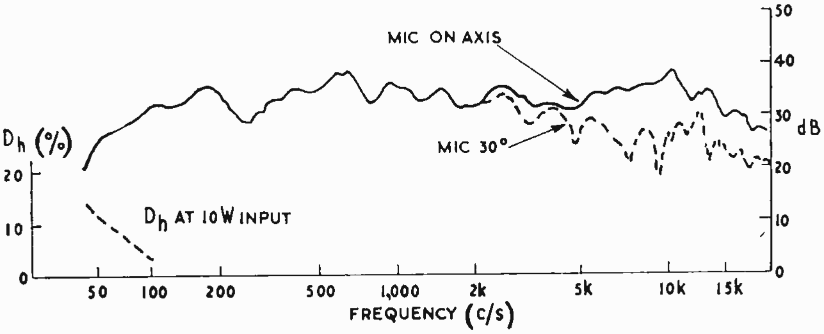
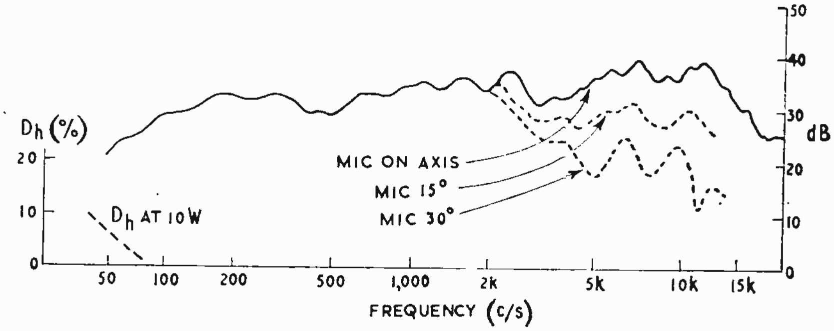


Fig. 7. Performance curves of 4 in dia. aluminium cone having a hyperbolic profile approaching a radius.

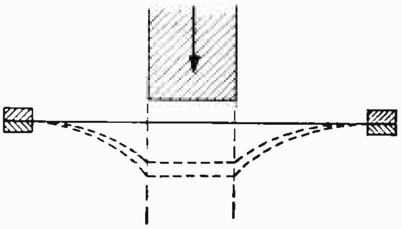
We now see that we are faced with the problem of determining the cone material, shape and dimensions with very little mathematical assistance, yet in order to secure a smooth extended high frequency response devoid of colouration it is imperative to be able to determine these factors very accurately and further to retain this accuracy throughout manufacture. The approach has therefore to be entirely experimental. The tooling necessary to produce cones of almost any form is very complex, and such experimental work demands that cone tools be made and discarded until the correct parameters are obtained. Naturally one cannot afford to be haphazard in this approach, and each cone form tested must result from a logical assessment of the performance of the previous one. Nevertheless this work is very time-consuming and very expensive and it is easy to understand why this problem has not been previously tackled with any degree of thoroughness, especially when one considers that all there is to show at the end is a single-cone loudspeaker with little or no "gimmick value."

Some 12 years after developing the hyperbolic paper cone 8 in loudspeaker, the author experimented with small aluminium cones, which led to the development of the Jordan-Watts module. This cone had a hyperbolic flare which closely approached a pure radius. The frequency response of this unit is shown in Fig. 7. It will be noted that the axial frequency response is fairly smooth and level but the off-axis response is falling towards the high end. This indicates that the mean hemispherical power response (m.h.p.r.) is falling. The shape of the mean hemispherical power response is of far greater importance than that of the axial pressure response.

It was not until three years later that the author had the opportunity to experiment with a variety of alternative flares, and he discovered that



Above: Fig. 8. Performance curves of 4in dia. aluminium cone having a hyperbolic profile given by $y = 0.75/x$.



Right: Fig. 9. Showing the formation of a hyperbolic form by displacement at the centre of a stretched membrane.

although he could raise the m.h.p.r. it was at the expense of the high frequency limit. An acceptable compromise is shown in Fig. 8, which is the response of a unit similar to the previous one but employing an aluminium cone with a flare given by the law $y=0{\cdot}75/x$. Although this curve does not appear to be as good as the previous one there was, on listening tests, considerably less colouration, and the improved transient performance gave the impression of a more extended top response. This range of experiments virtually exhausted the possibilities of aluminium as a cone material which, although it gave results considerably superior to those of paper cones, still left something to be desired, and again the search was on for a new material.

The clue was given in an advertisement by Imperial Metal Industries Ltd. describing titanium as having "a greater strength weight ratio than any other structural metal." Samples were immediately ordered and duly received. As a starting point one of the sample pieces was placed in the tool used for the previous aluminium cone and when pressure was applied the material immediately shattered; and the author's company was then faced with the agonizing prospect of having to find out how to tool for titanium before knowing if the metal was going to be satisfactory in any case. This was done, however, and the advantages of titanium became immediately apparent, and experiments were once again undertaken to determine the correct cone law. Shortly after this another breakthrough was made whereby it became immediately possible to obtain the correct flare in any material without any further tests.

This came as the realization that a stretched membrane displaced at its centre would follow a hyperbolic curve (Fig. 9). If the displacing force is oscillating the lines of stress and strain will lie along the natural hyperbolic curve and there will be no tendency whatever for the material to be displaced from this curve at any point. This is exactly the situation required in a loudspeaker cone to avoid unwanted "break-up," and not only shows the advantage of the hyperbolic law in principle but also tells us exactly how to achieve it in practice—i.e. a sheet of the proposed material, in this case titanium, is subjected to considerable tension, placed in an annular clamp and the centre displaced by a cylindrical tool. This is the technique now used in the manufacture of titanium cone loudspeaker modules and systems marketed by Audio & Design Ltd.

The metal titanium.—Out of interest readers may like to know that titanium is the fourth most abundant metal found in the Earth's surface. It is an element and the material used in loudspeaker cones is 99·9% pure. In addition to its exceptionally high strength/weight ratio it does not corrode and will withstand extremely high temperatures. It is produced in this country by Imperial Metal Industries (Kynock) Ltd., Birmingham, a subsidiary of I.C.I. It has become commercially available only during the past 10 years and, because of its properties, its principal applications are in the aerospace industry. In spite of the abundance of the crude ore the metal is expensive, owing to the very elaborate refining and milling processes required. The material is extremely difficult to work with and the rate of tool wear is high. In our application the grain size is of very great importance.

The coil.—The voice coil of the loudspeaker has to be as light as possible consistent with reasonable efficiency. Considerations of high frequency performance have led us to an actual cone (piston) diameter of about 4in. From this we have calculated (see Appendix 1) a peak displacement of $\pm\frac{1}{8}$ inch in order to provide the required low frequency radiated power level, assuming reflex loading. Thus, in order to provide a constant driving force either the coil must be $\frac{1}{4}$in longer than the depth of the magnetic gap or vice versa. In the interests of lightness the short-coil, deep-gap approach is used, and this incidentally also provides a higher magnetic efficiency.

Considerations of total magnetic flux and flux density led to the adoption of a magnetic gap diameter, and therefore coil diameter, of approximately $1\frac{1}{2}$in. The coil itself comprises a $\frac{1}{4}$in aluminium winding on an aluminium former of thickness 0.0015in. The winding is immersed into the centre of a $\frac{1}{2}$in deep magnetic gap.

The mechanical attachment between the top of the coil former and the cone neck is of paramount importance and must be effected by means of a very thin layer of hard-setting adhesive. Any flexibility at this join will lead to three severe defects: (a) premature mechanical failure (the forces developed across the glue line are very considerable); (b) attenuation of the high frequency response and colouration due to the resonance resulting from the mass of the cone and the compliance of the adhesive; and (c) harmonic and intermodulation distortion at high frequencies due to the inevitable nonlinearity of the compliance.

The flexible surround.—Since the cone is moving and the supporting framework is not, the cone must be supported at its edge by means of a flexible coupling which has to perform the following quite separate functions:

1. To permit complete freedom of the cone to move axially and to

restrict any sideways movement.

2. To provide an airtight seal between the edge of the cone and the enclosure. Further in this respect it must appear acoustically opaque to back-pressures emanating within the enclosure.

3. To provide a satisfactory termination to the cone at high frequencies in order to effect as much as possible the complete absorption of the incident flexure waves arriving at the cone edge. Failure to do this will result in reflected waves, leading to interference effects and colouration.

4. The rim must be intrinsically non-resonant.

5. The rim must be made of a material that does not age and is mechanically stable under all conditions of climate.

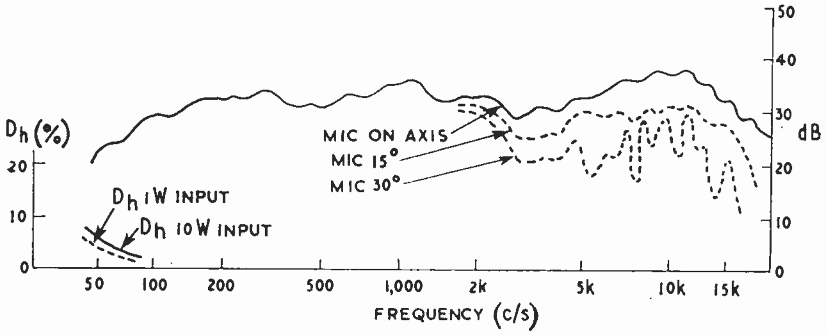
One technique employed by the author was to use a composite plastics rim, attached to which was an annular metal spring. This spring had two natural positions, a normal and an inverted cone frustum, i.e., it would always attempt to spring either up or down away from the flat position. When attached to the plastic rim, it was held against its will in the flat position, and by carefully balancing the force of the spring against the rim stiffness a cone surround was obtained that offered almost zero stiffness to axial movement and complied perfectly with the first two of the above requirements. However, extreme difficulty was experienced in meeting requirement 4.

The problems were finally overcome by the use of an impregnated polyether foam. The method of impregnation, which is novel, is such as to produce the effect of a "tapered" transmission line between the edge of the cone and the chassis.

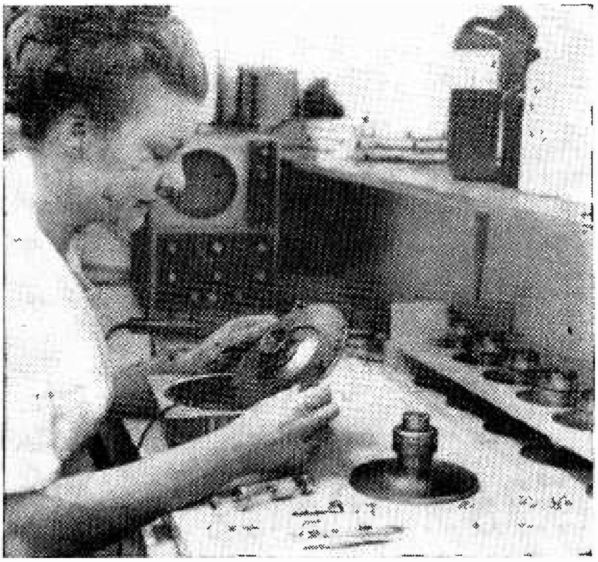
Restoring force.—In the interests of mechanical stability it is essential that the cone assembly be provided with a restoring force to ensure that the coil always moves relative to a fixed mean position in the centre of the magnetic field. It is important for this restoring force *not* to be applied at the cone edge since this would incur cone flexing at low frequencies. The ideal position for the restoring force is at the rear of the cone where it acts also as a means of centring to maintain the coil in its correct axial position within the magnetic gap. If the axis of the cone is arranged in the horizontal position the location of the suspension system should be such as to support the cone and coil system at its centre of gravity (acknowledgement to Percy Wilson).

As a result of the restoring force the complete system will exhibit a resonance below which the condition of mass control will be no longer operative. The resonant frequency must therefore be near the lower limit of the required frequency range.

One very important requirement for the suspension system is that it must be completely linear over the full range of cone displacement. Failure to be so results in the very high harmonic distortion apparent in the extreme bass response of many loudspeakers. The suspension system itself must be mechanically stable, and this requirement led to the use of three tangentially disposed beryllium copper cantilevers (two of which are used to carry the voice coil current). The cantilevers are attached at their inner ends to a rigid insulating annulus surrounding the coil and attached to the coil via a "lossy" compliant medium the purpose of which is to ensure that the mass of the suspension system is decoupled from the coil at high frequencies.



Above: Fig. 10. Performance curves of 4in diameter titanium cone loudspeaker.



Left: Assembling a titanium-cone loudspeaker. The entire moving assembly is mounted on a detachable ring. The outer housing is vented.

Chassis.—In the loudspeaker described the entire moving assembly is built up on a removable top plate which in turn is screwed to four supporting members attached to the magnet system. The entire assembly is suspended in a vented housing via an insulating medium to avoid transmission of energy to the housing and mechanical resonances. The detachable moving assembly is readily replaced in the event of misuse or damage, as shown in the photograph. The entire assembly is produced under laboratory conditions in a state of clinical cleanliness.

Enclosure.—The titanium cone loudspeaker module was designed for reflex loading which, if correctly designed provides an extended low frequency performance having a very low distortion level within an enclosure of acceptable domestic dimensions.

It can be shown that for optimum performance the Q of the fundamental cone resonance in free air should be 0.62^2. If the internal volume of the enclosure is then such that the enclosed air stiffness is 1.62 of the suspension stiffness and the reflex vent is arranged to tune the enclosure to the free air resonance of the loudspeaker, the overall frequency response will be perfectly level down to that frequency. By an appropriate increase in enclosure size and retuning, the response can be extended to as much as an octave below this frequency with a response variation of not more than ±3dB.

A source of difficulty sometimes encountered with reflex loading is that at very low frequencies, i.e. below 20 c/s, the acoustic load applied to the cone falls very considerably and factors such as motor rumble can cause very considerable cone displacement. A solution to this problem has been found in the provision of a semi-flexible plastics diaphragm spanning the inside of the enclosure between the loudspeaker and vent. This has virtually no effect upon frequency down to the enclosure resonance, but below this it provides a progressively increasing stiffness controlled load.

Performance data.—The power response, axial pressure response, polar response and distortion are shown in the composite curve in Fig. 10. Unfortunately the author had insufficient time to secure facilities for transient testing but the performance in this respect can be demonstrated by white noise tests.

The question of Doppler distortion is often raised in reference to small full-range loudspeakers. There has recently been some dispute about the significance of this type of distortion, but accepting for the moment that its significance is proved, it is normally applied to small loudspeakers on the assumption that very large cone displacements are necessary to produce adequate radiated power at low frequencies. In our case this is not so since, owing to the efficiency of the type of reflex loading employed, the cone displacement of the loudspeaker described is no more than that encountered in the cone of a conventional 12in loudspeaker.

Final thoughts.—The most significant subjective advantages gained by the use of titanium as a cone material have been in the high frequency and transient responses. The author feels that at the moment there is no entirely adequate explanation for these subjective advantages in terms of the performance parameters normally discussed but that further light may be thrown upon the matter by an examination of the property of mechanical hysteresis within the cone. It is reasonably obvious that titanium will have a lower hysteresis loss when subjected to alternating flexure than any other diaphragm material hitherto used, and in the not too distant future it is hoped to make a complete examination of the relationship between mechanical hysteresis and subjective and objective transient performance.

My thanks are due to Imperial Metal Industries Ltd. for their very considerable help and advice on tooling and their extensive tests to determine the optimum material characteristics for our purpose; to John Martin of Martin Watch Laboratories, Bracknell, for his development of the cone tooling described; and to my assistant Margaret Collett for her work on the experimental and production prototypes.

REFERENCES

1. " Loudspeakers " by E. J. Jordan, Page 49. Focal Press, London (1963).
2. As above, p. 154, eqns. 10.19 to 10.23.

APPENDIX 1

Acoustic power P_r required to reproduce a full orchestra in a medium room (2,000 cu. ft.) at serious listening level (say 80dB) is 0.002 watts. Assume an l.f. limit of 40 c/s.

$$P_r = v^2 R_{MA} \,.\, 10^{-7} \text{ acoustic watts}$$

where v = r.m.s. velocity of cone

$$\therefore 0.002 = v^2\, 2.18 \times 10^{-6} \times r^4 \times 40^2 \times 10^{-7}$$

$$v^2 r^4 = \frac{0.002 \times 10^{-7}}{2.18 \times 10^{-6} \times 40^2}$$

$$\therefore vr^2 = 2.4 \times 10^3$$

From considerations of h.f. response discussed in text, r was found to be 6 cm.

$$\therefore v = \frac{2.4 \times 10^3}{36} \simeq 67 \text{ cm/sec}$$

$$\therefore v_{peak} = 1.11 \times 67 = 74.5 \text{ cm/sec}$$

From which the peak-to-peak displacement at 40 c/s

$$\frac{74.5}{2 \times 40} = 0.94 \text{ cm} = 0.366 \text{ inch.}$$

(Symbols defined in footnote on p. 555).

APPENDIX 2

Approximate expressions for radiation resistance (R_{MA}) above and below the curve " knee " are:

When $kr \ll 2$

$$R_{MA} \simeq 2.18 \times 10^{-6} f^2 r^4 \text{ mech. ohms.}$$

When $kr \gg 2$

$$R_{MA} \simeq 2.16 \times 10^5 r^2 \text{ mech. ohms.}$$

(Symbols defined in footnote on p. 555).

APPENDIX 3

Assume condition of mass control:—

$$P_r \propto \frac{F^2}{\omega^2 L_M{}^2} \cdot R_{MA}$$

where L_M = cone mass.

When $kr \gg 2$ $R_{MA} \propto r^2 \propto A$

For a given cone thickness:—

$$L_M \propto r^2$$

$$\therefore \quad Pr \propto \frac{1}{f^2\, r^4} \,.\, r^2$$

If the effective cone radius were to remain independent of frequency, P_r would fall at 6 dB/octave. Including losses due to the voice coil inductance, this becomes 12 dB/octave. To compensate the above expression must vary as f^4.

$$\therefore \frac{1}{f^2\, r^4} \,.\, r^2 \propto f^1$$

$$\therefore \frac{1}{r^2} \propto f^6$$

$$\text{or } \frac{1}{r} \propto f^3$$

but r is a function of $\left(\frac{c_c}{f}\right)$

where c_c is the velocity of flexural wave motion in the cone.

Then $\frac{c_c}{f}$ must vary as $\frac{1}{f^3}$

$$\text{or } c_c \propto \frac{1}{f^2}$$

In a straight-sided cone, $c_c \propto 1/f$ approx. Thus the above indicates the need of a flared cone.

Consider now the frequency at which the reduction of radius should start. This is given by

$$f = \frac{c_c}{l_c}$$

where l_c is length of cone side.

The frequency corresponding to $kr = 2$ is

$$f = \frac{c}{\pi r}$$

where $_c$ is the velocity of sound in air.

These two frequencies should be coincidental

$$\therefore \frac{c_c}{l_c} = \frac{c}{\pi r}$$

$$\therefore \frac{c_c \,.\, r}{l_c} = \frac{c}{\pi}$$

$$\therefore c_c \sin \theta = \frac{c}{\pi} = \text{const.}$$

where θ is the angle between the cone side and the axis.

While we are unable to calculate absolute values from the expressions, they do give a very good guide in experimental determination.

(Symbols defined in footnote on p. 555).

Thin Films in Electronics

SOME NOTES ON THE I.E.R.E.-I.E.E. CONFERENCE HELD EARLIER THIS YEAR

THE conference on thin film applications was organized because it was felt there was a need for us to take stock of the place of thin films in electronic engineering, the subject having generally taken a back seat compared to solid circuits.

One point that emerged from the conference was that the delegates were by no means all devotees of the thin film approach. Indeed, a speaker questioned the future of thin films since diffused integrated circuits were usable up to 300 Mc/s and above—apart from the obvious use of thin films as stable *R*s and *C*s in hybrid circuits. Perhaps this is the limited extent to which thin film circuits will be used, but much depends on the development of a usable and reliable thin film transistor. Another summed up the position by maintaining that thin film circuitry was not, as is often thought, competitive to diffused integrated circuits, but that the techniques were complementary.

COMPONENTS

Resistors.—A paper by Naylor and Fairbank (Ferranti) described results obtained from tantalum resistors and capacitors made by spluttering. It was stated that the use of the sputtering technique (in which tantalum atoms are "knocked" from a source to a substrate by bombardment with ions of an inert gas), rather than by thermal exaporation by heating or electron beams, resulted in better uniformity of film thickness.

Capacitors.—The two main advantages of thin film capacitors is that capacitance can be up to 1 pF for 0·001 in^2 with a high breakdown voltage and can remain voltage-independent. Tantalum pentoxide is attractive since for one thing its dielectric constant is 21 compared to 2-4 for the more usual silicon oxides. Capacitors with good h.f. performance can be made with tantalum pentoxide (Naylor & Fairbank) by making electrode resistivity low (rather than dielectric losses).

Inductors.—Little, relatively, was said on the subject of inductors, presumably because these are more difficult to adapt to thin film circuits than *R*s or *C*s. (For one thing, a conducting substrate near to the coil reduces inductance and increases losses.) But within limits inductors with values around 1 μH are quite feasible, and a paper by Manfield and Windle (R.R.E.) indicated that inductances can be made up to 12 μH with a tolerance spread of 0.05% and high *Q* values. (Desired *Q* values can be achieved by adjustment of the plating thickness.)

Active devices.—Much work in the field of thin film transistors using evaporated layers of CdS or CdSe (field effect types) has been done by P. K. Weimer, who is well known for his work. Unfortunately, erratic variations in device characteristics have held back progress. Tickle, Swystun and Treleaven (Saskatchewan University) showed that device characteristics were strongly dependent on film thickness. Batch fabrication was thus used to reduce effects of random variations in deposition.

D. J. Page (Westinghouse, U.S.A.) described a heterojunction transistor (or dielectric transistor) which was produced by preparing a dielectric diode on a silicon p-n junction. Most of such CdS-Si devices showed an exponential emitter characteristics. It was felt that if base recombination could be reduced then useful devices may be evolved.

APPLICATIONS

Many examples of the use of thin film techniques were given, including magnetic film memories, cryoelectric or superconducting memories, galvanometric devices, ultrasonic transducers, strain gauges and microelectric circuits. A number of complete equipments have been produced besides many circuit building blocks which use hybrid microelectronic techniques. Holland and Chapman reported on the thin film modules used in Marconi **television equipment** (see p.58 February issue) and W. S. Whitlock (A.S.W.E.) discussed their use in **radar receivers,** using thin film inductors and capacitors in resonant circuits. According to the author, the thin film capacitor is something of an obstacle for narrow band receivers. The main difficulty appears to be the realization of high-*Q* *LC* circuits (>100) at frequencies around 30 Mc/s. Series resistance of leads and electrodes was felt to be a contributory factor to low *Q*, and to minimize this, changes in geometry and material were suggested.

Active filters.—Avoidance of large-value inductors for l.f. work is given by the use of active filters (see p. 129 March issue). Adjustment of component values was necessary, as tolerances were too wide—scribing resistors with diamond gave adjustment to ±0.1%. Capacitor adjustment was provided by cutting the leads to small capacitors giving adjustment to about ±2 pF. The authors concluded that hybrid microelecronics could be used for active filters in many applications.

Ultrasonic transducers.—A technique which has become well known in the last two or three years is that of vacuum deposition of CdS films for use as piezoelectric ultrasonic transducers and is due to the work of N. F. Foster (Bell Telephone). In the past, quartz has been used as the principal transducer material, but for frequencies above 100 Mc/s, the material thinness required is not practical for bonding.

To overcome this and other problems the evaporated layer or thin film transducer was developed. In essence, an electrode is evaporated onto the propagation medium, covered with evaporated CdS and finally a further electrode is deposited. With this method losses can be as low as 4 dB at 200 Mc/s and 12.5 dB at 1.5 Gc/s. Usually CdS is the material used for such transducers, but others have been tried, such as ZnS, CdSe and ZnO. Zinc oxide is the most attractive due to its greater electromechanical coupling coefficients and higher sound velocity. This last factor would mean that films would be thicker than those of CdS for the same λ. CdS films have been deposited by sputtering and efficiencies are similar to evaporated types, but the orientation is such that only longitudinal propagation is possible. Sputtered ZnO films have shown high efficiencies but the full potential has not been realized yet, partly due to lack of control of film orientation.

WORLD OF WIRELESS

Colour TV Service and Servicing

TO keep television dealers and their servicing staffs abreast of the latest developments associated with the proposed start of a colour television service next year Mullard arranged a discussion meeting at the end of September for a small cross-section of the trade. They were addressed by F. C. McLean, B.B.C. director of engineering; David Attenborough, head of BBC-2; A. J. Kenward, secretary of S.E.R.T. and R.T.E.B.; and S. E. Allchurch, director of B.R.E.M.A.

Mr. McLean, dealing with the technical aspects of the colour TV service, stressed that the public is likely to be more critical of quality in colour than in monochrome. He cited experience in the U.S.A. and gave it as his opinion that the slow start of colour there was not only that receivers were expensive but that the colour picture seen on an average receiver was so very variable.

Of the programme side Mr. Attenborough made the point that as 99% of viewers will be receiving the colour programmes on monochrome receivers for some time to come it is essential that the addition of colour should be "an enrichment of a good monochrome picture."

For the benefit of service technicians desirous of taking a course in colour TV servicing the Radio Trades Examination Board has prepared a list of nearly 60 colleges which are offering part-time courses. In answer to a questioner Mr. Kenward stated that the minimum equipment required for servicing colour receivers (additional to that on a well-equipped monochrome bench) is a pattern generator. Useful additions would be a sweep generator, PAL signal generator, degaussing equipment and e.h.t. measuring equipment.

There was the inevitable question regarding the introduction of colour on 405 lines in the v.h.f. band, but both Mr. McLean and Mr. Allchurch stressed that it would be a retrograde step, delay the start of a colour service and complicate receivers.

R.A.F. Engineer Branch

WITH the object of bringing before educationists the need of the Royal Air Force for young men of high calibre who are qualified in the applied sciences—particularly electrical, electronic and mechanical engineers—and the opportunities afforded in the Service, a two-day symposium was recently held at the R.A.F. College, Cranwell. Some 120 guests from the academic world attended.

During the symposium it was announced by the Minister of Defence for the R.A.F. (Lord Shackleton) that the Technical Branch will in future be known as the Engineer Branch. Within the Branch there will be a division between mechanical engineering and electrical engineering duties. The latter will cover communications, ground and airborne electrical and electronic equipment, instruments and surface-launched missiles.

The papers presented at the symposium and the tour of the college stressed the standard of technical training provided for cadets and specially for young post-graduates who enter the Service. The courses at the College vary from the 4½-year engineer cadet course to the engineer officer (graduate) course of eight months and the age of entries varies from 17½ to 45 years.

Correspondence Courses

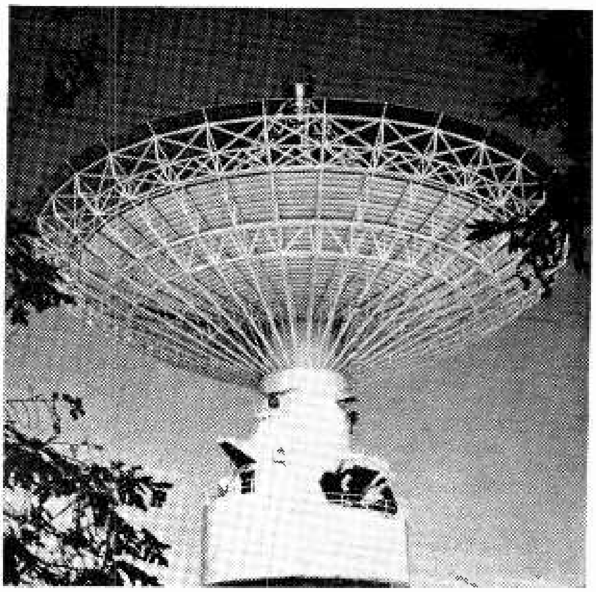
FOR several months the Cleaver-Hume Group of Correspondence Colleges has been operating from its new headquarters at Aldermaston Court, Berks, but it was not officially opened until September 23rd when the ceremony was performed by Sir Arnold Lindley, chairman of the Government's Engineering Training Board.

The new centre, from which are regularly distributed the "lessons" for some 600 different subjects to over 100,000 students in the U.K., is also to be used at week-ends for seminars for selected students. Professor H. F. Trewman, for many years principal of the E.M.I. College of Electronics, is advisory principal at Aldermaston.

Among the members of the Cleaver-Hume Group is the British Institute of Engineering Technology which was founded in 1927. The B.I.E.T. brochure on the electronic engineering correspondence courses gives brief details of a radio and electronics construction course (the £20 fee covers the cost of a Radionic constructional kit and multimeter), several electronic engineering courses and a course on transistor circuitry.

H.R.H. The Duke of Edinburgh will officially open the Radio Communications Exhibition at Seymour Hall, London, W.1, at 12 noon on October 26th. The four-day exhibition, sponsored by the Radio Society of Great Britain, will be open daily from 1000-2100. Admission costs 3s. There will be some 30 exhibitors and there will be displays and demonstrations by Royal Signals, Royal Navy and the Post Office.

Experimental colour television transmissions using the PAL system are radiated daily from Monday to Friday at set times during the normal BBC-2 trade tests from Crystal Palace (channel 33), and the relay stations at Hertford and Tunbridge Wells (channels 64 and 44). The daily schedule is:—1400-1415 test card in black & white, 1415-1425 colour bars, 1425-1500 colour slides; this sequence is repeated from 1500-1700. On Wednesdays, Thursdays and Fridays there is a further series of tests from 1810-1900. Users of 625-line u.h.f. monochrome receivers may find it interesting to see these transmissions to assess the compatibility.



150 ft radio telescope of the National Research Council of Canada at Algonquin Radio Observatory, Lake Traverse, Ontario. The electronics system for controlling the steerable paraboloid was supplied by A.E.I. Electronics. The company's film "The Radio Sky", telling the story of radio astronomy, can be borrowed from A.E.I., 35 Grosvenor Place, London, S.W.1.

B.B.C. Research Scholarships.—The Engineering Division of the B.B.C. maintains six research scholars at United Kingdom Universities and is awarding one scholarship this year. The scholarships are intended to provide the opportunity to work for a higher degree, the subject chosen for post-graduate study being within those fields of physics or engineering which have an application to sound and television broadcasting. This year's scholar is G. C. Goddard, who graduated with an upper second class honours degree in electronic and electrical engineering from Birmingham University this year. He has been awarded a three-year scholarship to undertake research on "A method of increasing the data-handling capacity of underwater telemetry links" at Birmingham University, Department of Electronic and Electrical Engineering.

Philips' 75th anniversary is commemorated in the postmark on the first issue of a new Dutch airmail stamp.

BBC-2 in the North East:— The BBC-2 service from Pontop Pike will start on November 5th, on Channel 64 (sound 821.25 Mc/s, vision 815.25 Mc/s) with horizontal polarization. Test transmissions will begin on October 22nd and will normally consist of test card from 0900 to 1200 and 1400 to 1915 every day except Sunday. Some 1,700,000 people in the north-east of England will be in the service area of the u.h.f. transmissions.

Some **radio altimeters** which operate in the 420-460 Mc/s band have been causing serious interference to observations made at the Mullard Radio Astronomy Observatory at Cambridge. The interference is caused by the local oscillator in the altimeter receiver (which operates in the radio astronomy band 406-410 Mc/s) when the aircraft concerned is flying within radio line of sight of the Observatory. In a Board of Trade notice pilots of aircraft registered outside the United Kingdom carrying specified types of radio altimeter are requested not to operate them when flying within U.K. airspace.

The experiment kit for the 30-week series of television lectures "**First steps in physics**" is being produced by the Communications Division of S.G. Brown Ltd. The course, which is nationally networked by I.T.A., is produced by ABC Television in collaboration with the National Extension College, Cambridge. The series, which started on September 25th and is presented by Professor James Ring, of Hull University, is intended to prepare viewers, with little prior knowledge of the subject, for the G.C.E. "O" Level examination next June.

E.I.B.A.—Many companies and associations in the radio and electronics industry are listed among the donors in the annual report of the Electrical Industries Benevolent Association which assists "any deserving or necessitous person," excluding manual workers, who are or have been in any branch of the electrical industry. Among the associations listed are R.T.R.A., Radio Industries Club, R.E.C.M.F., VASCA, and B.V.A. During 1965 the Association's income went up by nearly £18,000 to over £123,000.

C.N.A.A. Degree Courses.—The Council for National Academic Awards, confers degrees "comparable in standard with those granted by universities" on students completing approved courses in education establishments which have not the power to award their own degrees. The council has recently issued a list of courses which lead to the award of its B.A. or B.Sc. degrees and the colleges providing them. It is obtainable from the C.N.A.A., 24 Park Crescent, London, W.1. The colleges providing electronics courses, as opposed to electrical courses with an electronic bias, are Staffordshire College of Technology, Northern Polytechnic (London) and Rutherford College of Technology (Newcastle-upon-Tyne).

The African Broadcasting Conference, which was convened by the International Telecommunication Union in Geneva in October 1964 but adjourned after a few days, resumed its work on September 19th, again in Geneva. The purpose of the Conference, attended by some 180 delegates from more than 60 countries was to draw up a medium-wave broadcasting plan for Africa and also examine the position as regards long-wave broadcasting on the African continent.

An information sheet, number 4002(4), detailing the **625-line vision signal waveform,** has been issued by the Engineering Information Dept. of the B.B.C., Broadcasting House, London, W.1. It includes all the characteristics with waveforms showing the line and field synchronizing signals and an r.f. response curve for an ideal receiver.

Stereo Test Transmissions.—In addition to the increased frequency of stereo broadcasts announced a few months ago, the B.B.C. transmits test signals to facilitate channel identification and adjustment of cross-talk. A 250 c/s tone is transmitted in the left-hand channel only from about four minutes after the end of the Third Programme until 2355 every night.

A one-day course on **counter design** with silicon integrated circuits is being held at John Dalton College of Technology, Chester St., Manchester, on October 31st (Fee £3 15s including lunch). The lecturer is K. J. Dean of Letchworth College of Technology.

Because of increased attendance at meetings of the **Surrey Radio Contact Club** they are in future being held at the "Blue Anchor," South End, Croydon. Meetings will now be held on the third Tuesday of each month at 2000. At the meeting on November 15th an illustrated taped lecture on the American station W1BB will be given.

NOVEMBER CONFERENCES AND EXHIBITIONS

LONDON

Nov. 9-11 Savoy Pl., W.C.2
Automatic Operation and Control of Broadcasting Equipment
(I.E.E., Savoy Pl., W.C.2)

Nov. 17-18 Savoy Pl., W.C.2
Small-angle Scattering of Electrons and X-rays
(Inst. Phys. & Phys. Soc., 47 Belgrave Sq., S.W.1)

OVERSEAS

Nov. 14-16 San Francisco
Engineering in Medicine & Biology
(Dr. D. H. Lecroisset, Jet Propulsion Lab., Pasadena, Calif.)

Nov. 15-18 Washington
Magnetism and Magnetic Materials
(I.E.E.E., 345 E. 47th St., New York 10017)

Nov. 19-25 Milan
Automation and Instrumentation Conference & Show
(Federazione delle Assoc. Scientifiche e Techniche, via Ripamonti 115, Milan 15/6)

PERSONALITIES

S. S. Carlisle, M.Sc., F.Inst.P., M.I.E.E., director of the British Scientific Instrument Research Association, is the 1966/67 chairman of the Control and Automation Division of the I.E.E. He graduated with first-class honours in electrical engineering at Queen's University, Belfast, in 1940. After postgraduate study he was awarded an M.Sc. From 1942 to 1946 he served with the Admiralty in the experimental department of H.M.S. *Excellent*, Portsmouth, where he was engaged on gunnery, radar and fire control development. Mr. Carlisle joined the British Iron and Steel Research Association in London in 1946 as the head of the instrument section of the Physics Department. From 1953 to 1958 he was head of the South Wales laboratories of B.I.S.R.A., and was head of the Physics Department of B.I.S.R.A. in London from 1958 until 1963 when he was appointed director of the British Scientific Instrument Research Association. Mr. Carlisle is past-president of the Society of Instrument Technology; vice-chairman of the United Kingdom Automation Council, and U.K. delegate on the International Federation of Automatic Control Components Committee.

S. S. Carlisle

Professor A. L. Cullen, O.B.E., Ph.D., D.Sc.(Eng.), who has occupied the chair of electrical engineering at Sheffield University since it was created in 1955, has been appointed to the Pender Chair of Electrical Engineering at University College, London, where for nine years prior to his Sheffield appointment he was successively lecturer and reader in electrical engineering. Prof. Cullen, who was the 1965/66 chairman of the Electronics Division of the I.E.E., graduated at Imperial College, London, in 1940 and was for six years at the R.A.E., Farnborough. The last incumbent of the Pender Chair was **Dr. H. E. M. Barlow,** who is now on the board of directors of Marconi Instruments and W. H. Sanders (Electronics).

Air Marshall Sir Walter Pretty, K.B.E., C.B., Deputy Chief of the Defence Staff (Personnel and Logistics), Ministry of Defence from 1964 until his recent retirement from the R.A.F., has been appointed to the board of directors of Redifon Ltd. Trained at the R.A.F. College, Cranwell, Sir Walter, who was knighted in 1962, became deputy director of radar in the Air Ministry in 1944. The following year he was appointed chief signals officer, Fighter Command, R.A.F., and in 1948 became Director-General of Navigational Services at the Ministry of Civil Aviation. In 1953 he was appointed Director of Electronics Research and Development (Air) in the Ministry of Supply. In 1958 he was appointed Director-General of Organization at the Air Ministry and from 1961-64 held the appointment of Air Officer Commanding-in-Chief, Signals Command.

G. H. Metson, M.C., D.Sc., Ph.D., M.I.E.E., director of research at the Post Office for the past two years, has retired on health grounds and is succeeded by **W J. Bray,** M.Sc.(Eng.), A.C.G.I., D.I.C., M.I.E.E. Dr. Metson, who is being retained as a consultant, joined the Post Office as a youth-in-training in the physics laboratory in 1925. Later he transferred to Northern Ireland, where he carried out research on magnetron oscillations and received his M.Sc. and Ph.D. at Queen's University, Belfast. During the war he served with the Royal Corps of Signals. In 1946 he was back at Dollis Hill in charge of the thermionics group set up to study the causes of valve failure. Dr. Metson became deputy director of research in 1962. His successor, Mr. Bray, who entered the Post Office Engineering Department in 1934 as an assistant engineer in the Radio Experimental Laboratories at Dollis Hill, was chosen in 1961 to lead the newly formed Post Office Space Communication Systems Branch. Since 1963 he has lead a team at Dollis Hill working on research connected with communication satellites and lasers. Prior to his concentration on satellite communications Mr. Bray was concerned primarily with ionospheric- and tropospheric-scatter.

W. J. Bray

Commander Hugh St. A. Malleson has been appointed a director of SGS-Fairchild Ltd. During 16 years naval service he qualified in signals and was experimental officer, H.M. Signal School, Admiralty; and Commander on the staff of the Director of Radio Equipment, Admiralty. From 1950 to 1964 Commander Malleson was head of the Government and Industrial Valve Division at Mullard Ltd.

Cdr. H. St. A. Malleson

R. H. Davies, C.B.E., B.Sc., M.I.E.E., deputy general sales manager, of Ferranti Ltd. for the past nine months has succeeded **O. M. Robson,** M.A., M.I.E.E., as general sales manager. Mr. Robson is retaining his seat on the board as sales director. Mr. Davies joined Ferranti Ltd. in 1946 after spending the later war years with the British Air Commission in Washington, D.C., on joint British/U.S. radar development. In 1947 he returned to the U.S.A. to become vice-president and general manager of Ferranti Electric Inc. (New York), a wholly owned subsidiary of Ferranti Ltd. He rejoined the parent company in 1963 but still remains a director of Ferranti-Packard Electric Ltd. in Toronto and Ferranti Electric Inc. in New York.

J. M. Brunskill was recently appointed plant manager of the Mullard Research Laboratories, Redhill, Surrey, which he joined as administrative assistant in 1952. He previously served for 13 years in the Royal Corps of Signals, reaching the rank of Major.

Maurice Esterson, B.Sc.(Eng.), A.M.I.E.E., is appointed deputy manager of the Microwave Tube Division of English Electric Valve Company. He joined E.E.V. in 1941 as a development engineer in the magnetron section and in 1960 became manager in charge of high-power klystrons. When E.E.V. bought their plant at Lincoln, Mr. Esterson was appointed the managing director's special representative for integrating the Lincoln organization with that at Chelmsford.


M. Esterson

E.A.G. Davis, D.S.O., who joined the Marconi Marine Company in 1959 as marine superintendent in which capacity he acted as the company's adviser on navigational problems as related to electronic aids, has been appointed assistant general manager. In October 1962, he was appointed management executive and in 1964 became assistant to the general manager. During the war he served in the Royal Naval Reserve and was promoted to the rank of Commander. On leaving the service in 1946 Mr. Davis took up a Government appointment.

D. L. Phillips, M.M., B.Sc., A.M.I.E.R.E., has resigned from the managing directorship of Mills & Rockleys (Electronics) Ltd., printed circuit manufacturers of Skelmersdale, Lancs. Mr. Phillips was works manager of Technograph Electronic Products Ltd. before joining the Mills & Rockleys group in 1958 as a consultant to set up an electronics subsidiary. During the war he served in the R.A.F. as a technical signals officer and immediately prior to joining Technograph was with Plessey at their components division at Swindon. He is setting up a consulting service on printed circuits.


D. L. Phillips

L. C. Jesty, who two years ago went to the U.S.A. to join the Westinghouse Corporation, has had the degree of D.Sc. conferred on him by the London University for his work in the field of "The science of visual communication and display." Dr. Jesty was educated at University College, Southampton, and joined the G.E.C. Research Laboratories, Wembley, in 1927, where he spent 18 years. He then went to Cintel as head of the advanced development department. In 1949 he joined Marconi's as chief of the television research group. Seven years later he joined the Sylvania-Thorn colour television laboratories at Enfield, Middx., where until 1962 he was in charge of colour television research.

Roy R. Roper, has joined Racal Instruments Ltd. as sales director. For the past year he has been a director of Weir Electronics and Weir Industrial Controls. For two years prior to that he was general sales manager of Cossor Communications Company, having previously spent seven years with Solartron and five years as a development engineer on submarine communication systems with Standard Telephones & Cables. Mr. Roper, who is 36, started his career as a technician in the Post Office Engineering Department.


R. R. Roper

P. E. Leventhall, B.Sc.(Hons.), M.I.E.R.E., has joined Hudson Electronics Ltd. and International Marine Radio Company Ltd. (both S.T.C. subsidiaries) as technical manager and will be responsible for all development projects. He graduated in physics at Leeds University and has been chief engineer of Cossor Communications Ltd. for the last three years having previously been chief engineer of Murphy's radio-telephone division.

G. S. C. Lucas, O.B.E., F.C.G.I., M.I.E.E., has retired from A.E.I. Electronics of which he was director and group general manager. He started his career with the British Thomson-Houston Company (now part of A.E.I.) in 1915 and after serving his apprenticeship studied at the City & Guilds (Engineering) College. In 1925 he went into the B.T-H. research laboratory and in 1932, as head of the electrical development section, became responsible for electrical measurements and developments in the audio engineering field. Mr. Lucas was appointed an O.B.E. for his contribution to the development of centrimetric fire-control radar during the war. When the B.T-H. Electronics Engineering Dept. was set up in 1945 he was appointed manager. He became chief engineer in 1953, and has been director and general manager of A.E.I. Electronics, Leicester, since 1963.

OBITUARY

Sierd Sint Eriks, K.B.E., managing director of the Mullard Company and chairman of Philips Electronic and Associated Industries until his retirement for health reasons in 1964, died on September 27th, aged 66. Educated at Rotterdam University he came to England in 1929 as general manager of the Mullard Company before becoming responsible for all N.V. Philip's interests in the United Kingdom. He became chairman of Philips Electronic and Associated Industries in 1955 and was personally responsible for starting the Mullard Research Laboratories near Redhill shortly after the war. Mr. Eriks, who in 1961 was appointed an honorary K.B.E. "in recognition of his valuable services to British official interests," felt that the company should play its part in the education of future scientists and technicians and instigated a number of endowments, including the Mullard Radio Astronomy Observatory at Cambridge University, the Mullard Cryomagnetic Laboratory at Oxford University and various readerships in science at a number of other universities.

A. W. Martin, M.B.E., Assoc.I.E.E., technical director of E. K. Cole Ltd., died on September 23rd aged 59. He joined the company in 1926 becoming chief engineer in 1943 and technical director in 1952. During the war he was in charge of the company's radar development unit at Malmesbury, for which he was appointed an M.B.E. With the acquisition of E. K. Cole Ltd. by the Pye group Mr. Martin was appointed to the Pye board and assumed overall responsibility for the domestic sound radio and television engineering activities of the group. He was also chairman of Ekco Electronics Ltd.

Power Sources Symposium

SOME DEVELOPMENTS IN VARIOUS POWER CELLS, BOTH OLD AND NEW

A MEETING held at the same time as the Liberal Party Conference in Brighton, though not so much in the public eye, was the Fifth International Power Sources Symposium. This biennial symposium is organized by the Joint Services Electrical Power Sources Committee and has been previously known as the Battery Symposium. The change of title led one to believe that more prominence would be given to sources of power other than electrochemical batteries, but the number of papers dealing with "unconventional" or non-electrochemical sources was in fact less than in 1964.

The symposium was attended by about 400 delegates from about 20 countries and during the three days 40 papers were read.

As on previous occasions many papers were intended for electro or physical chemists. For example, several of these dealt with the structure and properties of lead compounds present in the positive paste of lead-acid cells, in particular the two modifications of lead dioxide (α and β). These have not yet been fully explored and much work continues using various techniques of analysis. In these notes, however, only those papers which are felt to be of more practical and direct interest to readers are dealt with.

Secondary cells

Lead-acid types.—In both lead-acid and silver-zinc battery systems the plates are usually made by pasting an oxide on to a supporting grid and then, in the case of negative plates, reducing it to a metal. This is obviously a wasteful process as the raw material is metallic lead which is converted to oxide powder and then reduced back to metallic lead at a later stage. This, together with the fact that it is difficult to control the porosity (high porosity is one requirement for high plate efficiency) in a plate made by pasting and reduction (and also the porous material often has a low mechanical strength), has prompted investigation of other methods of manufacture. Work on the use of metal powders was reported by Morrell and Smith (Lucas) who considered for various reasons that the most satisfactory method was that of mixing the powder with a soluble removable filler which does not prevent cold welding (e.g. sodium chloride crystals or sodium nitrate). It was concluded that satisfactory zinc plates can be made from strength and electrochemical aspects. Preliminary results on lead plates are also promising. However, much more work on the subject is needed since little is known about factors which control plate capacity and the processes taking place during plate discharge. The effect of filler size has yet to be investigated.

Sealed Ni-Cd types.—For many years interest and activity in the field of high performance power sources has been growing due, in part, to the advent of the transistor and also to the space effort. At the same time, though, the more well-known electrochemical storage batteries are steadily being improved. Turner, Howden, Ovinaka and McHenry (Bell Telephone) described developments leading to an improved battery design, and new techniques in electrode and separator fabrication. A new separator material developed consists of Teflon and zirconium oxide particles. High porosity (60-80%) is obtainable—necessary for sufficient passage of oxygen from the positive to the negative plate. Dr. Turner considered that the inherent capability of Ni-Cd cells outmatched that of all other sealed rechargeable cells in terms of overall performance and cycle life (which can be >10 years). One paper, by Azulay and Kirkman (Alkaline Batteries Ltd.), contained many useful notes for the user, mainly on charging conditions and an interesting point was made concerning constant potential charging. Here, in a sealed cell, overcharge energy is dissipated as heat (as opposed to gas in an open cell). A rise in the battery temperature, consequently lowering the back e.m.f., would result in a higher end current for a fixed applied potential. This effect could result in a progressively rising overcharge current—or thermal runaway. Thus if the charging period is likely to be prolonged indefinitely the constant potential method should be avoided.

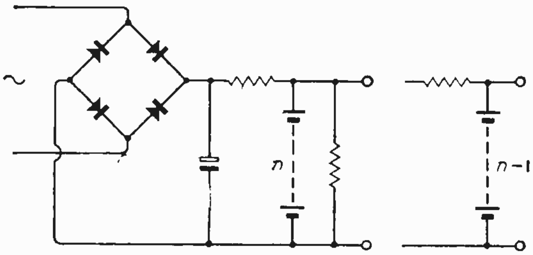


Fig. 1. Use of Ni-Cd cells as stabilizers.

Another piece of advice was that storage of sealed cells should be done in the fully discharged state since, under certain circumstances, gassing could occur when subsequently placed on charge.

If the eletrode pair in Ni-Cd cells is replaced by a pair containing the same active material in both electrodes [e.g. Cd(OH)$_2$] or if the positive electrode is replaced by an electrode free from active material, a type of cell is obtained in which an equilibrium is reached between oxygen evolution and reduction, and only little energy can be stored in such cells. These can be used as stabilizer cells since the cell voltage changes by only a small amount within a certain range of current. These cells are, incidentally, reversible—i.e. current can flow in either direction. An example of their use was given by F. Peters (Varta, Germany)—see Fig. 1. Apart from stabilizing the output voltage against mains variations the cells also act as a capacitor (10,000-20,000 μF) giving a low a.c. resistance practically independent of frequency. Further stabilization can be obtained by adding $n-1$ cells giving virtual independence of mains variations. Temperature coefficient of voltage is about 1 mV deg C^{-1}.

Primary cells

Leclanché type.—In almost all chemical and electrochemical reactions the reaction rate decreases with temperature. The Leclanché cell is no exception to this, the resistance and viscosity of the electrolyte becoming so high that cells are unfit for use at −23° C. Erämetsä and Karsila (Finland) reported on investigations of electrolytes which will operate down to −42° C (at this temperature output is down to 15% of that at +25° C). It was shown that cells using electrolytes based on lanthium chloride (with $MgCl_2$, NH_4Cl and H_2O) gave a slightly greater capacity than standard commercial cells and a considerably better capacity than cells based on lithium chloride and bromide. At −42°C the cell capacity compared with a lithium chloride cell.

Air Cells.—These are primary cells in which the oxygen of air is the active material (serving as the cathode depolarizer) consumed by the positive electrode of the cell. These have been known for a long time, a typical cell having zinc anodes, a KOH electrolyte and a porous carbon cathode depolarized by oxygen diffusing through it to the electrode surface. Interest in these is due to the high energy density and the relative low cost. They are. however, only suitable for low discharge rates (e.g., *C*/700).*

A new magnesium-air cell was described by Carson and Kent of the G.E. Company (U.S.A.), and is known as the Magair cell. It is capable of a much higher power operation than present air cells. The electrolyte used is common salt. The air cathodes in these cells are derived from those used in fuel cells and a catalyst (platinum black) is used. It is interesting to note that in the absence of oxygen the cell still produces power because the air electrode can still operate as a cathode, hydrogen now being evolved from the water in the electrolyte. In this condition a cell voltage of 0.3 to 0.6 V is obtained. Normally though, open circuit voltage is 1.6 V, dropping to 1 V at 60 mA cm^{-2}. At "moderate" production rates, the cost of such cells is expected to fall to about £3 per watt, which for a service life of 1,000 hours would provide electricity at a cost of nearly 1d per watt-hour—much cheaper than dry cells. Costs would be reduced further by using air electrodes without a platinum catalyst.

Solar cells

Further details of the UK3 satellite power system were presented in a paper by F. C. Tremble (R.A.E.). This satellite is the first to be built in the U.K. (by B.A.C.). The "solar" cells (made by Ferranti) are connected in two arrays, one supplying the load directly and the other charging the battery (Ni-Cd) for operation in dark periods. Battery charge is at constant current and then at constant voltage and at 40°C the charge is reduced to prevent overheating. Should battery voltage fall below 14 V it is disconnected from the load and put on trickle charge; should the voltage fall below 9 V, the battery is then assumed to be beyond revival and permanently disconnected. The load requirement is 5 W mean with a maximum of 15 W and this is supplied *via* ±6 and ±12 V rails regulated to 1%.

Each of the load panels comprises six sets of 40 cells in series and each of the 14 battery panels consists of six sets of 48 cells in series. These panels are connected in parallel *via* protective silicon diodes. In all there are about 7,400 cells. (Originally, it was thought that due to the Starfish high-altitude nuclear bomb the flux, integrated over one year, would be equivalent to 10^{14} electron cm^{-2} at 4 MeV. But, the trapped radiation has decayed more rapidly than expected and is now thought that it will not exceed 10^{13} electron cm^{-2}. This would result in a cell current of 60 mA at 400 mV rather than nearer 52 mA.) Efficiency of the arrays, measured at 100 mW cm^{-2} with a tungsten lamp, is about 8.9%.

Thermoelectric sources

A material becoming more popular for thermoelectric use is a Si-Ge alloy, and the design of sources using such was discussed by W. Thorpe (Ferranti). (Si-Ge has the advantage, among others, of high relative efficiency at high temperatures.) Methods of preparation were described and a typical output was 0.2 V at 11 A for a sample 0.44 cm^2 cross-sectional area and a temperature difference of 850 deg C. For higher current the area is increased and for higher voltages, units are placed in series. The number of alloyed connections can affect reliability and it was pointed out that by using an alloy with a higher Seeback voltage—achieved by decreasing the impurity (phosphorous *n* type and boron for *p* type)—the number can be reduced, but a reduced efficiency must be accepted.

Fuel cells

A low temperature hydrogen-oxygen fuel battery was described by Gillibrand and Gray (Electric Power Storage Ltd.). The 30-cell battery provided an output of 1 kW at room temperature and was on load for 2,000 hours. Before such a battery would be commercially acceptable, however, the reliability of the cells and auxiliary equipment (electrolyte pump, cooling fan, valves and so on) would have to be improved. Faults in the experiment were found to be mainly due to mechanical failures—seals and joints usually.

Low temperature cells usually use hydrogen as fuel but often this can be undesirable. An alternative is to use a methanol-water mixture, and at 200°C with a catalyst this produces hydrogen and carbon dioxide. A battery using such methanol-air cells was reported on by Clow, Bannochie and Pettinger (Energy Conversion Ltd.). The cell design provided an output of 55 W at 0.675 V. A battery of cells was proposed to give an output of 6 kW.

Economics.—Fuel cell costs were compared with costs of other power sources in a paper by Harrison & Lomax (Electric Power Storage), although it was difficult to estimate future production costs. It is interesting to note that for a hydrogen fuel cell, as with a motor-generator, little cost reduction is obtained for efficiencies greater than 40%.

It was stated that for electric cars, although fuel cells could provide attractive power densities, it was unlikely that they ever will be economically suitable, unless for instance, the price of hydrazine could be reduced drastically. Capital costs of £100 per kW would increase the cost of the power source in the A.E.I. Mini-car to £1,000. For other applications, such as remote radio repeaters, fuel cells can be attractive, where convenience is of prime importance. A typical example of the high price paid for convenience is the dry battery as used in torches, where costs are given as about £9 per kWh!

**C/700 signifies a rate that will discharge the cell in 700 hours.*

WHY THEY ARE NEEDED AND
HOW THEY WORK

HYBRID COMPUTERS
analogue + digital

2.—HARDWARE OF PARALLEL HYBRID MACHINES

By P. W. J. VAN EETVELT,* Dip.Tech.(Eng),Grad.I.E.E.

IN the previous article, by C. D. Dwyer, reference was made to the limitations of pure analogue computation systems and to the historical development of, and need for, hybrid techniques. It will thus be appreciated that the concepts of hybrid computation have been evolved over the past decade to a state where the commercial production of general-purpose hybrid computing systems is now technologically feasible. In the light of the applications experience gained on early systems it was realized that full emphasis must be placed on the needs of the computer user in the design of these general-purpose hybrid systems.

The object of the present article is to introduce what is known as parallel hybrid hardware. A parallel hybrid computer may be defined in its broadest sense as an equipment in which a pure analogue computer is linked via suitable interface equipment to pure digital logic elements that operate in parallel (see Fig. 1). In a subsequent article illustration will be provided by short descriptions of two commercial hybrid computation systems, and the use of such systems will be shown by their application to two specific problems.

In order to appreciate the capabilities of a parallel hybrid computer it is necessary to understand the operation and field of application of the elements from which it is constructed. These elements may be divided into four distinct groups as follows:—

1. Pure analogue elements.
2. Analogue elements incorporating digital control.
3. Analogue elements providing digital outputs.
4. Pure digital elements.

Let us now consider these groups of elements in more detail.

PURE ANALOGUE ELEMENTS

Present-day electronic analogue computers simulate systems by representing system variables in terms of voltages. In order to solve the equations describing the system, it is necessary to implement basic mathematical relationships between these voltages or machine variables. The basic mathematical operations which can be carried out on a pure analogue computer are as follows: multiplication by a constant; inversion; summation, i.e. generalized addition and subtraction; integration†; multiplication, division, etc.; nonlinear function generation; and variable comparison.

All these operations may be implemented in terms of machine variables by passive elements in association with operational amplifiers. In fact, electronic analogue computers are built around a complement of d.c. operational amplifiers.

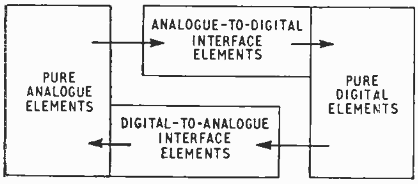


Fig. 1. Block schematic of a parallel hybrid computing system.

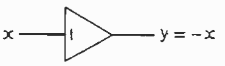
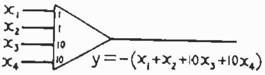
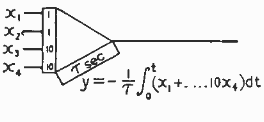
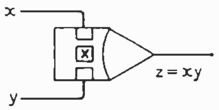
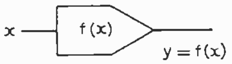
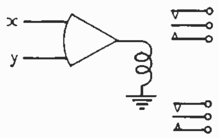
Analogue Element	Symbol	Function
Multiturn high resolution potentiometer		Multiplication by a constant less than unity
Inverter		Inversion of input sign
Summing amplifier		Summation of several inputs
Relay mode controlled summing integrator		Integration of the summation of several inputs
Bipolar quarter square multiplier		Multiplication, division, etc., of inputs
Diode function generator		Generation of arbitrary functions
Relay comparator		Comparison of two inputs to energize relay contacts

Fig. 2. Table of analogue computing elements.

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*Electronic Associates Ltd.

†Differentiation can be implemented directly but is purposely avoided since the signal-to-noise ratio in the circuits can be unacceptable.

I will assume that readers are familiar with pure analogue computing equipment, but for reference purposes a table of analogue elements, symbols and their functional operation is given in Fig. 2. Logic graphical symbols used will correspond to those recommended by B.S. 530:1948, Supplement No. 5, as exemplified by previous articles on logic in *Wireless World*.

Referring to the bipolar quarter-square multiplier in Fig. 2, other types of multipliers do exist and have been used successfully in the field of analogue computers. The most notable is the servo multiplier, which has the advantage of enabling several inputs to be multiplied by a common single input. However, the servo multiplier is restricted by nature for low frequency applications, and is not usually found on hybrid computers, where the object is to solve problems at high speed.

The Fig. 2 table does not, of course, exhaust pure analogue elements nor indeed analogue techniques. It does, however, illustrate the basic capabilities of an analogue computer.

Modern general purpose analogue computers are built as an integrated unit comprising modular units mounted in a single, purpose-built console. These modular units are mounted directly behind the "patch bay" to avoid trunking, thus minimizing cross-talk, etc. The inputs and outputs to the modular units occupy a frontal position, allowing the use of patch panels. The patch panel usually occupies a central position on the computer console, and conveniently placed either side and below this are the computer mode control and readout facilities.

Mode control.—The modes of operation necessary on either analogue or hybrid computation systems are given in the table below.

Mode	State of Computer	Function
Pot-set	Computer reference voltage off	Setting of potentiometers representing input data
Initial-condition	Computer reference voltage on	Setting of integrator initial conditions etc.
Hold	All machine variables held at previously achieved value	Inputs to integrators isolated
Operate	Computing	Solution of problems
Static test	Special reference available at patch panel	Checking out of computer set up
Rate test	Fixed voltage applied to all integrator inputs	Checking out of integrator time constants
Slave	Mode control slaved by external console	Slaving of several computers

In past analogue computer systems all mode control was achieved by the use of relays. This, however, produces problems in high speed computation, since relays are subject to three limitations which become increasingly important at high speeds of operation:

1. Relays are electromechanical devices and the inherent electrical inductance and mechanical inertia produce time delays and limit speed of operation.
2. When several relay contacts throw in parallel the degree of simultaneity of contact is limited, and this causes "initialization" problems that increase with the size of computer installation.
3. Relay contact bounce introduces errors into a simulation which become increasingly important at high speeds of operation.

Thus a limitation is imposed on the speed of operation of relay mode controlled computation equipment, which limits the use of high speed subroutines, high speed iteration and other such techniques being used in current simulation problems.

All modern general purpose hybrid computing equipment utilizes the solid-state switch wherever possible to eliminate the above-mentioned limitations imposed by relays. The solid-state switch is not yet fully developed to the state where it completely replaces the relay, but it is sufficiently developed to enable it to perform important tasks in the field of hybrid computation.

Solid state switching implies the use of digital control which will now be described in the following section.

ANALOGUE ELEMENTS INCORPORATING DIGITAL CONTROL

The digital-analogue switch.—One of the requirements of hybrid computation is the necessity for high speed switching with switching times of the order of 1 μsec or less. Since the fastest switching time which can be realized with electromechanical devices is several milliseconds, it is clear that electronic switching is essential. The d/a (digital-analogue) solid-state switch is a diode bridge assisted by bottoming transistors. The switching action is controlled by a binary logic signal such that a "1" causes conduction and "0" the non-conducting state. The d/a switch is connected directly to the summing junction of an operational amplifier at virtual earth. When the switch is non-conducting its input is switched to earth; thus the input impedance is independent of its state. When used to switch analogue input signals the switch is padded with a resistance which swamps that of the diode bridge itself. Thus transient variations of input impedance during switching are eliminated and also the summing accuracy is made compatible with the resistors commonly used as inputs.

The symbol adopted for the d/a switch does not indicate whether it is a straightforward solid-state switch

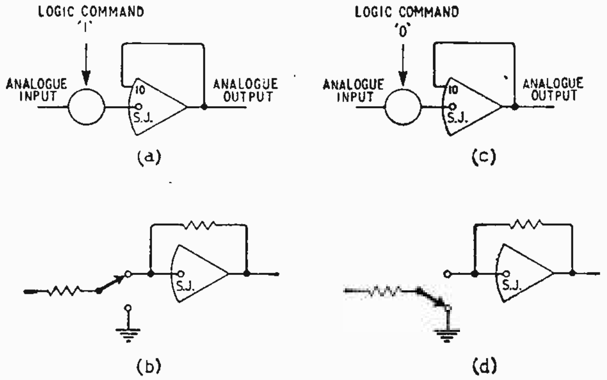
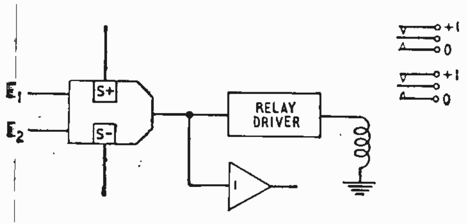


Fig. 3. Digital-analogue switch: (a) conducting state with (b) equivalent circuit; (c) non-conducting state with (d) equivalent circuit.



Left:— Fig. 4. Digital-analogue relay, driven by electronic comparator.

or whether it is padded as mentioned; this ambiguity is however clearly resolved, since when used as a computational element the d/a switch is always of the latter type and is best illustrated in association with an operational amplifier as shown in Fig. 3, which also illustrates the equivalent circuits for the conducting and non-conducting states.

The digital-analogue relay.—Where low-speed switching can be implemented the reed relay can be used to advantage, e.g. initialization subroutines. Modern hybrid computation systems make provision for this facility in the form of a d/a relay. This is a reed relay driven by a relay driver stage, the input of the relay driver stage being controlled by a logic command. This logic command may be derived from a logic comparator to be described later. Thus analogue signals may be compared and a decision based on this comparison made via the relay contacts. This is shown symbolically in Fig. 4.

Digital-analogue relay driven by comparator.—In Fig. 4, when $E_1+E_2 \geqslant 0$, contact is made from the arm via the "+1" contact and when $E_1+E_2 < 0$ via the "0" contact. This convention is consistent with the logic output of the comparator. The d/a relay is used where switching times of the order of 1 msec are sufficient.

Electronic mode controlled integrator.—The relay mode controlled integrator commonly used in analogue computation systems is totally unsuited to the needs of hybrid computation. The electronic mode controlled integrator was developed when the concept of high speed subroutines was utilized to solve complex problems in an efficient manner.

The operation of this type of integrator can be seen from Fig. 5. When the voltage at B is low, i.e. logic state "0," the outputs of the two "AND" gates which it feeds, P and Q, are both logic "0." Thus the base of the operational amplifier is isolated from the initial condition network and summing junction network, since their associated gates (solid-state switches) are non-conducting. The output of the d.c. operational amplifier thus remains at the value it achieved before B became low. Therefore when B is low the integrator assumes the "hold" mode. When B is high, i.e. logic "1," the mode is determined by the logic input A. When this is high the initial condition gate is conducting and the "operate" gate non-conducting. A first order lag circuit is formed. The output of the amplifier thus achieves the initial condition value applied at the initial condition input as the limit or asymptote of an exponential rise. The time-constant *CR* is made as small as possible by making R small while not causing excessive base current to flow. Therefore when A and B are high the integrator assumes the initial condition mode. When A is made low and B remains high the initial condition gate ceases to conduct and simultaneously the operate gate conducts; thus an integrator is formed and the output of the amplifier is dependent on the time integral of the inputs. Therefore with A low and B high the integrator assumes the "operate" mode. A summary of these statements and the programming symbol are given in Fig. 6.

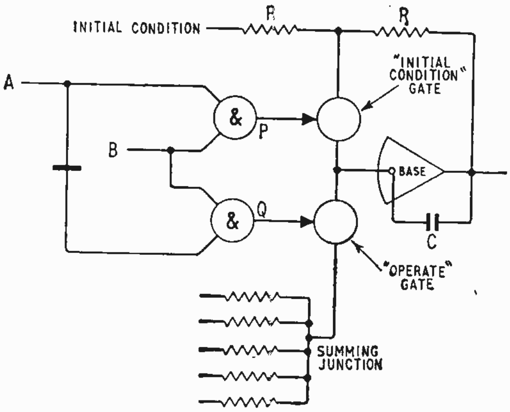
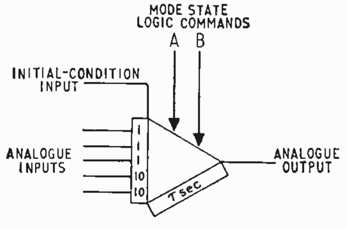


Fig. 5. Simplified schematic of electronic mode controlled integrator.

Track/store unit.—The implementation of high speed subroutines on hybrid computation systems leads to a requirement for storage of analogue sample values. This was originally achieved by utilizing an integrator and restricting it to the initial condition and "hold" modes. Thus in the initial condition mode the input signal is tracked and in the "hold" mode the finally achieved output is stored or held. The two main disadvantages of this method are that the inherent time-constant of the initial-condition network limits the rate at which an analogue signal may be tracked. This may be improved upon by using smaller capacitor values in association with the integrator. However, this leads to a second disadvantage in the "hold" mode since the drift rate of the integrator output is enhanced by the smaller capacitor value used. These disadvantages have now been overcome in an extremely efficient manner in the track/store unit.

The method of operation can be seen from Fig 7. When the voltage at A becomes high the solid-state switch S_0 conducts and an inverter is formed. Since the logic signals A and P are both low the two CR networks C_1 r_1 and C_2 r_2 are both earthed and thus are charged by the amplifier output. When A becomes low the switch S_0 ceases to conduct and the monostable element output M becomes "1" for a predetermined duration (τ msec). Switch S_1 conducts simultaneously and thus the output is stored by C_1. When the monostable returns to logic "0" after τ msec state P becomes high and thus the output is stored by both C_1 and C_2. Resistances r_1 and r_2 are small values purely



A	B	MODE
0	0	HOLD
1	0	HOLD
0	1	OPERATE
1	1	INITIAL CONDITION

Fig. 6. Programming symbol and mode state table for electronic mode controlled integrator.

to limit the charging current derived from the amplifier output. C_1 is very much smaller than C_2 so that C_1 assumes the output value at a rate very much faster than C_2. The monostable is used to allow the charge on C_2 to reach the output value on C_1 before closing the switch S_2 in the store mode. The objective of the circuit may be clarified as follows. In the track mode the amplifier circuit tracks the input virtually instantaneously. In the store mode a CR circuit with a low time-constant, which has been able to achieve the final output, is used initially to store the amplifier output. After a predetermined time has elapsed say $\tau = 10\ C_2\ r_2$, the voltage on C_2 will have reached 99.99% of this value and thus may be used to store the finally achieved output value. Since C_2 is very much larger than C_1 the drift rate in the store mode is rendered almost negligible. Typical figures which refer to a system to be described later are a 300 nsec track time-constant and a 100 μV per second drift rate in the store mode.

The programming symbol for a track store unit is shown in Fig. 8.

ANALOGUE ELEMENTS PROVIDING DIGITAL OUTPUTS

These elements are extremely important since they provide lines of analogue feedback which may be used to effect control decisions of the digital field of operations. Since the digital logic signals are in fact voltage levels, the simplest possible element in this group is the voltage limited trunk in which an analogue voltage is either hard- or soft-limited to produce the voltage levels required for the digital system. This is usually lower than used in analogue systems. Here, for example, if the digital logic signals are such that logic "0"=0V and logic "1"=+5V we may arrange that an analogue signal which is negative produces a logic "0" and one which is positive produces a logic "1" via a voltage limited trunk. This element is only used when a crude form of comparator is needed and on most modern hybrid computation systems the electronic comparator has further useful features such as logic controlled latch facilities. Basically the electronic comparator is an operational amplifier in the high gain mode whose output is voltage limited to provide a logic signal of the right amplitude. The logical complement of this is derived using a single transistor inverter stage. These outputs are arranged to drive an asynchronous bistable multivibrator commonly referred to as a flip-flop, the output of which is the logical output. The drive circuit is arranged with OR-gate logic so that it is possible to override the analogue inputs to the comparator using logic inputs. The logic output may therefore be overridden or latched. Logic comparators are also produced so that the logic output may be used to drive a double-pole double-throw reed relay externally.

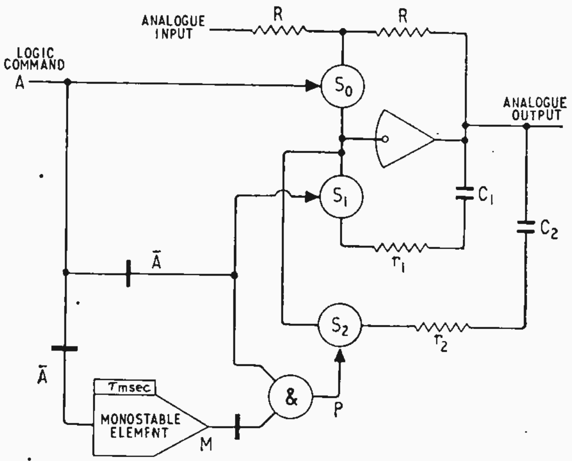
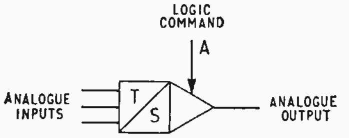


Fig. 7. Simplified schematic of track/store unit.



A	MODE
0	STORE
1	TRACK

Fig. 8. Programming symbol for track/store unit.

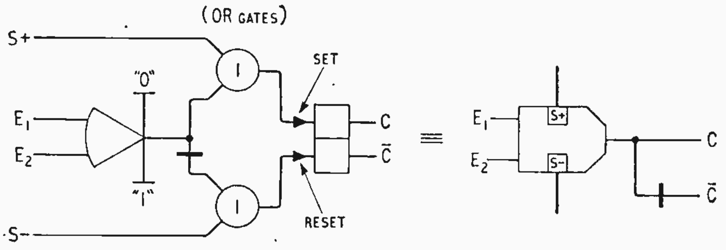
Logic comparators, as in Fig. 9, produce logic "0" when the sum of the inputs is negative and logic "1" when the sum of the inputs is positive. The analogue inputs may be overriden by the application of a logic "1" to logic inputs labelled S+ and S−. The output C can be made independent of the analogue inputs and can be forced to logic "1" or "0" by the application to logic "1" to S+ or S− respectively. The full programmer's symbol is shown in Fig. 9.

The table below represents the state of the logic output C with respect to the sum of analogue inputs and S+ and S−.

E_1+E_2	S+≡'0'	S+≡'1'	S−≡'0'	S−≡'1'
⩾ 0	1	1	1	0
< 0	0	1	0	0

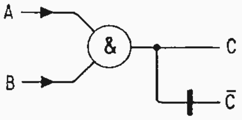
The S+ and S− should not be made high simultaneously otherwise the output C is not clearly defined.

Finally, it is worthwhile mentioning the analogue-to-digital (a/d) converter. A/D converter equipment may be used to convert analogue signals to either parallel or serial digital signals. They are only usually incorporated in fully integrated hybrid systems when the



Left:- Fig. 9. High-speed electronic comparator.

Below:- Fig. 10. Two-input AND gate and truth table.



A	B	C
0	0	0
1	0	0
0	1	0
1	1	1

complexity of the problems justifies their economic inclusion.

PURE DIGITAL ELEMENTS

Before discussing the hardware involved in this section, it is important to appreciate the advantages of synchronous digital elements over asynchronous ones. Early attempts at the development of hybrid computation systems brought out the main deficiencies of individual computing elements.

One of the major problems experienced was due to the use of asynchronous digital elements which had three main deficiencies:—

1. Since asynchronous elements cannot be sequentially controlled by manual step pulses, rigorous check-out procedures were made difficult if not impossible.
2. Inherent noise caused digital element outputs to change state randomly, introducing non-predictable errors into the final solutions.
3. Lack of sequential control causes the outputs of digital elements to become misaligned or out of phase with respect to each other, and can result in asynchronism with the main simulation.
4. A time-event or timing diagram could not be drawn up to establish correct operating sequence.

These problems may be eliminated by the use of parallel digital elements which are controlled in time sequence by synchronizing pulses. This type of digital element is referred to as synchronous logic. The synchronizing pulses are derived from a master clock, which generates a high frequency periodic pulse train. The higher the frequency, in fact, the more closely synchronous operation approaches that of asynchronous elements. The bandwidth of the individual elements dictates the maximum clock frequency permissible and in modern hybrid systems this is of the order of 1-10 Mc/s.

All present day hybrid computation systems incorporate synchronous digital elements, eliminating the problems posed by asynchronous equipment.

Let us now look at the digital elements used in parallel hybrid computation systems.

The AND gate.—This is the simplest element to be considered and its symbol and associated truth table are shown in Fig. 10.

As a basic element the AND gate may be used to build up OR, NOR and NAND gates, parallel half-adders, full-adders, etc., provided its complementary output is made available.* Thus general purpose AND gates are always provided with their complementary output as shown by the programming symbol in Fig. 10.

The AND gate does not require synchronization, its output being almost simultaneously determined by its inputs.

The flip-flop is the other basic element required in parallel hybrid computation systems. It is, in fact, a bistable multivibrator.

General-purpose flip-flops are provided with a logic output and its complement. The output is controlled by three inputs, these being "set," "reset" and "enable." With the "enable" input high, i.e., logic "1," raising the "set" line high causes the output to go high on the next clock pulse, whereas raising the "reset" line high causes the output to go low on the next clock pulse. If the "enable" line is low, the "set" and "reset" inputs are rendered inoperative.

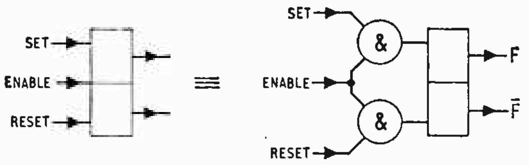


Fig. 11. Flip-flop with set/reset control. (F=1 when set=1; F=0 when reset=1. F does not change state if set and reset=0.)

All other pure digital elements are built up from these two basic elements. The units commonly incorporated in modern hybrid computation systems are as follows:—

General purpose shift-register.—A general purpose shift-register comprises a number of flip-flops arranged so that the set line of each flip-flop is connected to the output of the preceding stage. If a bit is loaded into one flip-flop stage, then enabling the shift-register and raising the shift line high causes the bit to be propagated from one flip-flop to the next at clock rate. The flip-flops may, however, be used separately or may be loaded in parallel when set connected as a shift register.

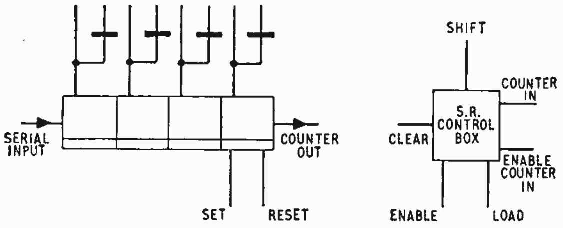
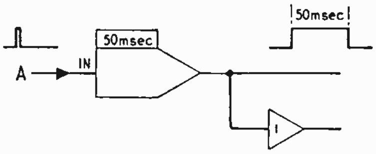


Fig. 12. General-purpose shift register with control box, usable as four independent flip-flops, 4-bit shift register or binary up-counter.

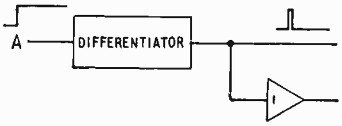
Monostable multivibrator with variable "period."—This unit functions as follows. When the input A is raised high the output becomes high simultaneously and remains high for a preset period capable of adjustment from 1 μsec up to 100 sec with thumbwheel switches and vernier adjustment.

Fig. 13. Monostable multivibrator set up to give an "on" time of 50ms for a short input pulse at A.



Logic level differentiators.—These may be of two types, i.e., leading-edge differentiators or trailing-edge differentiators. The output of these elements produces a momentary blip, one clock pulse wide when the input goes from low to high or high to low depending on which type it is. In practice differentiators are of the leading-edge type. When fed with a complementary output they function as trailing-edge differentiators.

Fig. 14. Differentiator, producing a blip as a result of a level change at point A.



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*See, for example, "Logic Without Tears," by H. R. Henly, *Wireless World*, January 1965, pp. 44-49, and "Economical Logic," by the same author, October 1965, pp. 518-523.

"Microwaves à la Mode"

CAMBRIDGE CONFERENCE HIGHLIGHTS SOLID-STATE MICROWAVE OSCILLATORS AND AMPLIFIERS

DISCOVERER of the Gunn effect J. B. Gunn provided the keynote of the Sixth International Conference on Microwave and Optical Generation and Amplification, held in Cambridge in September, by the title of his paper "Microwaves à la Mode." Although this paper was in fact a "guided tour" of oscillation mechanisms in bulk gallium arsenide (including, incidentally, an excellent cine film showing travelling electric-field domains), the title could well have stood for the whole field of solid-state microwave amplifying and oscillating devices, in which there has been such rapid development recently. At the last MOGA conference, in Paris in 1964, the subject was not included, but at the Cambridge conference about 25% of the papers were devoted to semiconductor devices. The remaining papers were divided between vacuum tubes such as klystrons, magnetrons and travelling-wave tubes and quantum devices such as masers and lasers.

Besides Gunn-effect (travelling-domain) devices, which have already been discussed in *Wireless World*[1], there are gallium arsenide (GaAs) devices in which travelling domains do not appear but transit-time and negative resistance effects are significant; junction devices such as avalanche, tunnel and varactor diodes; devices producing oscillation and amplification by means of magnetoresistive elements made of indium antimonide; and "acoustic" amplifiers based on a t.w.t. type of interaction between microwave mechanical waves and current carriers in piezo-electric materials such as cadmium sulphide[2]. All these were represented at the conference.

Variety of oscillation modes

There seems to be some confusion about the use of the term "Gunn effect" in describing one group of devices. It is certainly confined to bulk-material, usually GaAs, (as distinct from junction) devices, but whether the term should be restricted to the exact phenomenon originally observed by Gunn, in which the applied potential was pulsed, or whether it may be extended to other oscillation modes in bulk materials subsequently discovered by other workers is very much an open question. Mr. Gunn himself, although giving an admirable lecture, only added to the confusion in the minds of the uninitiated by identifying *seven* different modes of operation in which travelling electric-field domains occur (quite apart from *three* non-domain modes!). These seven modes were divided into two classes: (a) modes in which the frequency was determined by the transit time of the drifting electrons and therefore by the length of the GaAs bar; and (b) modes in which an associated resonant circuit determined the frequency because the r.f. voltage in this circuit was large enough to control the nucleation, extinction or propagation of the travelling domains.

In this last-mentioned "resonant" class of modes came one of the highest power Gunn-effect microwave oscillators to be reported so far. This was an oscillator giving, in pulsed operation, 220 watts peak power at 1·1Gc/s, and was mentioned by Dr. D. G. Dow (Varian Associates, U.S.A.) in a paper describing a whole range of experimental pulsed GaAs oscillators. Other high peak powers obtained were 64 watts at 2·2Gc/s and 1·5 watts at 7·65 Gc/s—the peak power in watts, P, being given approximately by the law $P = 200/f^2$, where f is the frequency in Gc/s. The outputs measured were all at frequencies lower than the natural (transit-time) frequency of the GaAs bar; tuning ranges of up to 1·5:1 could be obtained; and efficiencies up to about 8% had been achieved. Dr. Dow said that the principal obstacle to successful application of GaAs microwave oscillators was at present the quality of the GaAs raw material and he mentioned that developments were in progress to improve the quality.

Other bulk-material phenomena

Microwave oscillations produced by GaAs bars biased on the positive-resistance region of the static I/V characteristic at a point below the normal voltage for Gunn travelling-domain oscillations were reported by W. K. Kennedy (Cornell University, U.S.A.) in a paper read by L. F. Eastman. The oscillators had been tuned from 7 to 9 Gc/s by means of a waveguide cavity, and the maximum peak power observed had been 500 mW, with an efficiency of 2·2%. GaAs elements had also been operated as reflection type amplifiers, with a power gain of 16dB over the 7-9 Gc/s range, the output power saturating at about 150mW. Eastman described his own experiments on using GaAs Gunn-effect diodes (natural frequencies; 500 to 3,500Mc/s) for noise generation in the microwave spectrum. In general this was done by operating the Gunn diodes into circuits of higher impedance than those of the GaAs elements.

In the field of piezo-electric semiconductor devices, it appears that the one-time high hopes for acoustic microwave amplifiers have not, in the event, been fulfilled. Workers in this field seemed to agree that the conventional transistor amplifier had now overtaken the acoustic amplifier at microwave frequencies, and that the major

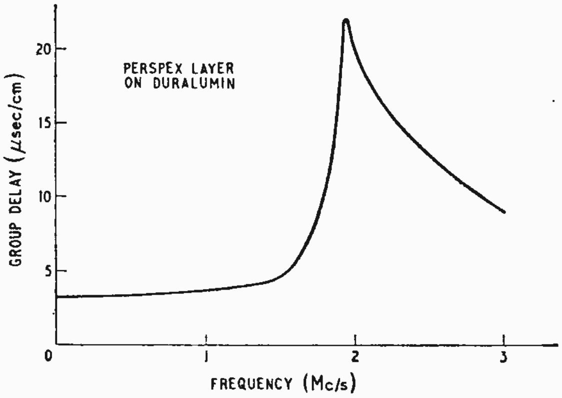

Fig. 1. Delay characteristic of experimental acoustic delay line using Rayleigh surface waves—one possible step towards microwave integrated currents.

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1. "The Gunn Effect," *Wireless World*, August, 1965, p. 416.
2. *loc. cit.* See also "Mechanical Microwaves," *Wireless World*, January, 1965, p. 57.

trouble with cadmium sulphide acoustic amplifiers was the lack of consistency in the performance of CdS samples. (It was suggested that this might be due to a lack of homogeneity in the crystals.) Tests on crystals reported by G. Robertson (University College, London), using a thin light beam as a probe, showed marked variations in conductivity and acousto-electric coupling along the length of the material.

O. Cahen and E. Dieulesaint (Thomson-Houston, France) described a CdS acoustic microwave amplifying equipment in which the acoustic gain was 45dB at 700 Mc/s, but it turned out that, owing to losses in the thick quartz transducers and in the CdS, the overall electrical "gain" was −30dB! However, the authors said they were hoping to achieve net gain eventually by the use of thin-film transducers deposited on the CdS.

Microwave integrated circuits

In the meantime, it seems possible that these piezoelectric elements may prove useful as passive components in microwave systems, and a number of research organizations in the U.K. are studying possible applications very closely, particularly in the field of microwave integrated circuits. E. A. Ash (University College, London), for example, pointed out that whereas complete amplifiers for microwave integrated circuits could be fabricated on small silicon chips, no comparable progress had been made in the construction of the resonators, filters, etc., needed to interconnect the amplifiers. Since microwave integrated circuitry was primarily concerned with surfaces, he felt that the surface or Rayleigh acoustic wave was well adapted to this field of technology, particularly as there were now acoustic materials available with lower loss per wavelength (dB/λ) than that of e.m. waveguide. As a result of using acoustic techniques instead of conventional e.m. waveguide components, considerable size reduction should be possible—as much as 10^5 times, in fact.

By way of illustrating the use of Rayleigh waves, Dr. Ash described an experimental delay line, such as might be used in pulse-compression radar, that had been constructed in his laboratory. This comprised an aluminium substrate, coated with a 0·3mm Perspex layer to allow dispersive waves to be obtained, with a transducer at each end. The delay characteristic is shown in Fig. 1. Similar work on the use of surface waves was reported by F. Mayo and C. P. Wen (R.C.A., Princeton, U.S.A.) and included descriptions of "two-dimensional" transducers evaporated on to the delay-line element.

Magnetoresistive elements

The use of the magnetoresistive properties of indium antimonide to give amplification, oscillation or attenuation at microwave frequencies was discussed by S. Kataoka and H. Naito (Japanese Government Electro-technical Laboratory, Tokyo) in a paper read by a colleague. The principle is that if d.c. is passed through an InSb magnetoresistive element which is subjected to the transverse magnetic field of a microwave signal (plus a constant, biasing magnetic field), a microwave e.m.f. is generated across the element as a result of the multiplying action between the current and the microwave magnetic field. If the element is placed in a cavity in a position where the transverse magnetic field is at maximum and the electric field at zero, the element, in principle, absorbs no signal power. In this way the direct current can be converted into microwave r.f. energy. A description was given of a device based on this principle for operating as an amplifier or an attenuator at 9,840 Mc/s. The cavity contained the InSb element and a tuning piston, and there was a common channel for the d.c. input and the microwave output. Gain or loss was controlled by the direct current or the biasing magnetic field.

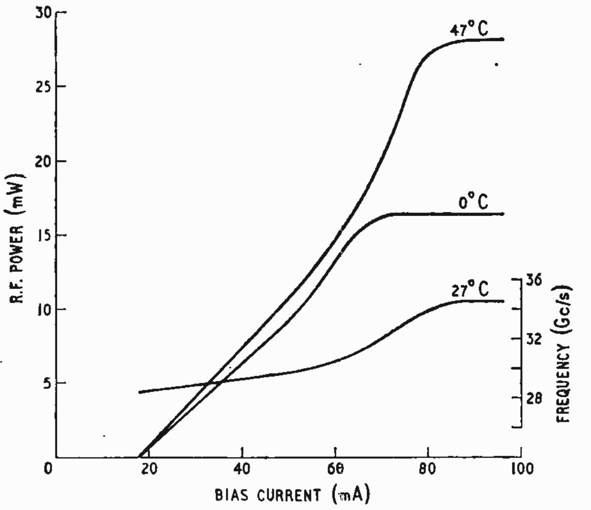


Fig. 2. Power output and frequency performance of a commercial GaAs avalanche diode at different bias currents. (Power measured at 0°C and 47°C; frequency at 27°C.)

In the field of junction-diode, as distinct from bulk material, devices, one of the latest fields of interest is the operation of silicon and gallium arsenide diodes in the avalanche mode, by suitable d.c. biasing, to produce negative resistance effects which can be utilized for oscillation on amplification. In such devices the usable frequency range is related to the transit time of the current carriers through the space charge depletion layer of the diode, which, for example, would be a few microns thick for operation at 10 Gc/s. C. C. Shen and L. A. MacKenzie (Cornell University, U.S.A.) described some experiments using commercial gallium arsenide diodes with different doping levels in oscillation circuits. They stated that very wide operating frequency ranges had been achieved. One diode, for example, produced oscillations in the 2-4 Gc/s band in a coaxial system, in the 7-12 Mc/s band in X-band waveguide and at 50 Gc/s in millimetre waveguide. Results obtained with one diode, in terms of r.f. power output and frequency with varying d.c. bias current, are shown in Fig. 2. The authors had also examined the effects of temperature variation and had found that increasing temperature resulted in increasing power output (as shown in Fig. 2) but decreasing oscillation frequency.

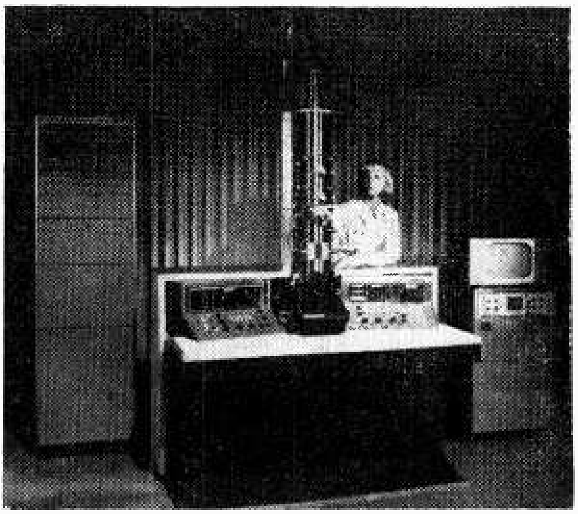
Many of the devices described at the conference were very experimental, and it is hard to say at present which of them will prove successful in the microwave applications of the future and which will turn out to be little more than laboratory curiosities. It has been rightly observed, however, that this whole new field of bulk-material and transit-time phenomena is reminiscent of the arrival of velocity-modulated and crossed-field devices in the valve field several decades ago, and that the coming era of development, as then, will result in important new commercial devices with substantial frequency ranges and power outputs.

The MOGA conference was sponsored jointly by the I.E.E. and the I.E.R.E., and the proceedings are expected to be available in two or three months' time.

NEWS FROM INDUSTRY

COMPACT COMPUTER

OVER 20 million orders per minute can be processed by Myriad II, a new Marconi microelectronic parallel computer. A simpler version of Myriad I, it is a basic intrument using the techniques of modular construction, permitting extra units to be added to the computer with any or all of Myriad I facilities. Myriad II is also designed to be compatible with Myriad I in order that programmes may be interchangeable. This computer is contained in a desk and two cabinets. The control unit is mounted on top of the desk with additional equipment such as tape recorders, tape punches, magnetic drums and disc stores. It uses a 24-bit word, and an order code in simple single address form, the orders being obeyed sequentially. Two sizes of store unit are available with either 4,096 or 16,384 (24-bit) words, providing storage capacity up to a maximum of 32,768 words. The stores are coincident current, ferrite core types with a cycle time of 1·5 μs, and access time of 0·5 μs. If required, magnetic disc or drum stores with average access times of 85 and 10 ms respectively can be added, and a maximum capacity of 2 million words is then available. It has been designed to form the centre of complex data handling systems, such as industrial process controls, and all types of traffic control, and systems can be provided for small control centres which can be built up as the degree of automation is increased. Myriad I remains more suitable for high-speed applications.



The EMU-4 electron microscope *by the RCA International Division, 30 Rockefeller Plaza, New York 20, N.Y., has automatic pumping operation for its vacuum system and an optional image intensifier device that "sees" the image via television and a light intensifier image tube, and displays it on a television picture monitor. Magnification is 200,000x with a resolution of 8Å. For spot size control down to 2 µm there is double condenser operation.*

An independent company has been formed to manufacture quartz crystal units and is known as **Crystal Electronics Ltd.** of 1 Shore Road, Hythe, Southampton. All U.K. military crystal holder styles are available within the frequency ranges 50 to 150 kc/s, and 1 to 20 Mc/s. Additional types include the U.S. military crystal holder styles, and flying lead alternatives to the plug-in pin types. Quartz crystal for high grade filter applications will be supplied to customers' specifications. One of the company's principals, Mr. T. C. McKnight, who will supervise the technical process, has sixteen years' experience in the quartz crystal development industry.

The new 22,500 sq ft Hertfordshire factory for **Kerry's (Ultrasonics) Ltd.** and **P. G. Day (Electronics) Ltd.**, both subsidiaries of Kerry's Engineering & Electronics Ltd., was officially opened on the 26th September. This new headquarters of the two companies is at Hunting Gate, Wilbury Way, Hitchin, Herts. With full production, and integration of the Stratford, E.15, and the Basildon, Essex, departments, it is estimated that about 100 staff will be employed. Ultrasonic equipment developed and produced by Kerry is used in industrial cleaning, the machining of hard and brittle materials, spot, seam, and ring welding of metals, the welding of thermoplastics, and biochemical research. In the field of microcircuit, semi-conductor, and integrated circuit production, ultrasonic welding equipment is available for welding aluminium conductors to gold film deposits on glass, and with the same equipment, copper, nickel and gold wires can be ultrasonically welded to rare and precious metal films deposited on glass or ceramic substrates.

The development of a new system for the **disc recording of video signals** is the objective of a newly formed company, Video Records of Wolverhampton. The video information is recorded on the photosensitized area of a 10 in disc.

A. N. Clark (Engineers) Ltd. of Binstead, Isle of Wight, manufacturers of telescopic masts, and **Precision Metal Spinnings (Stratford on Avon) Ltd.**, specialists in the design and manufacture of microwave aerial dishes, have now joined the Coubro & Scrutton group of companies. With other members of this group, who are Associated Aerials Ltd., and R. T. Masts Ltd., Coubro & Scrutton can offer a comprehensive aerial service from l.f. to microwave frequencies, including masts, supporting structures, and installation facilities.

Three u.h.f. transmitters have been ordered by the B.B.C. from the **Marconi Company** for installation in 1968 at a cost of £300,000. They have been designed for completely automatic unattended operation except for occasional routine visits. From Caradon Hill in Cornwall, Sandy Heath, Beds, and North Yorks they will broadcast BBC-2 programmes and will be capable of handling colour. The 40kW vision transmitter employs an English Electric 4-cavity klystron valve and this section and its associated 8 kW sound section transmit separately. Breakdown precautions take the form of multiplex facilities which provide automatic changeover to a combined sound and vision signal at reduced power on one section, should the other section fail.

A contract for a **computer-controlled traffic regulation system** for the City of Liverpool has been placed with the Plessey Company. The system, which covers the Mersey Tunnel approaches in the city centre, provides for the control of tunnel-bound traffic in such a manner that when there is a hold-up in the tunnel, the queues of vehicles in the approach roads are kept clear of main intersections to minimize interference with cross traffic. The system, employing an XL9 computer, utilizes buried inductive loop "presence detectors" at strategic intersections. It also provides for automatic emergency routing of appliances on the receipt of a warning of fire in any given sector of the city.

Texas Instruments Inc., Fairchild Camera and **Instrument Corporation,** and **SGS Fairchild** (Fairchild's European affiliate) have entered into a cross licensing agreement for patents held by each company in the field of semiconductor manufacture. The ten-year agreement covers world patents except those in Japan.

LETTERS TO THE EDITOR

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

Organ Tuning

IN spite of Mr. Daniel's protestations (September issue), I still maintain that an average good tuner will avoid a too quick beat which would take place if the "temperament" was truly equal (i.e. $^{12}\sqrt{2}$). We are of course talking about beats, where, in the case of a fourth they occur at exactly twice the rate of those caused in a fifth for each cycle of discrepancy from the pure (untempered) interval, and therefore a cycle here or there makes all the difference.

About eighteen years ago I tuned an electrophonic instrument to what I then called "mean beat tuning" (for want of a better name). It was an attempt to create a scale which is in my opinion the sort of scale a tuner would produce—which is very nearly a true progression, but not quite. The instrument when first tried in a shop containing a dozen or more organ builders of the old school, produced the unanimous exclamation "What have you done—this is the first time we have heard one of your machines sound something like a pipe organ."

I cannot quite see the relevance of $A=440$ c/s when middle $C=261$ c/s. If $A=440$, the C is 261.6256 c/s. However, I have performed the mathematical task of $261\times(^{12}\sqrt{2})^9$ and this works out to 438.9479. Oh yes, only a cycle or so, but several beats nevertheless, and these are the subtle differences I intended to convey in my letter. Helmholtz is alleged to have described equal temperament as a "hellish din" anyway, and added "give me my justly tuned harmonium." It is instructive to tune an organ to a pure scale. It makes one realise to what dissonancies our ears have become accustomed.

Regarding Mr. Douglas's comment upon the Compton Rotofon speaker, I would say that Doppler effects plus certain phase reversals are exploited, whereas the rotating speakers of some organs which I have seen, do not, at least to the same extent.

LESLIE E. A. BOURN,
Technical Director.
The John Compton Organ Co., Ltd.,
London, N.W.10.

The Engineer Shortage

MR. SCROGGIE'S thoughtful letter in your September issue is timely. Well may engineers puzzle over why engineering does not appear an attractive career to boys. The trouble is that all too few engineers do puzzle over it and even fewer attempt to put matters right.

The plain fact is that the public does not understand how vital engineering is to the country's future and consequently is not prepared to accord due recognition (including money) to engineers. The first difficulty for the public is the confusion about the term "engineer," for not only do professionals and artisans alike use the same name but there are so many divisions in engineering.

It was an awareness of the difficulties made by fragmentation that caused the Institutions to create the Council of Engineering Institutions so that they could, where necessary, speak with one voice. The Council, with the valuable support of the Ministry of Technology, is doing much to enlighten people, especially young people, about the work of engineers and its vital contribution to our way of life.

As to "prospects," action in the field of individual salaries, pensions and conditions of service is not the concern of the C.E.I., but of the Engineers' Guild Ltd. Roughly speaking the relationship of the Guild to the C.E.I. is comparable with that of the British Medical Association to the General Medical Council. If more engineers of Mr. Scroggie's persuasion would join us, the Engineers' Guild would be in a stronger position to introduce reason and logic into the assessment of engineering salaries.

Engineers' Guild,
London, W.1

J. K. RICKARD
(Hon. Sec.)

TV Research Today

"RADIOPHARE" asks why we have no one like Shoenberg to make dramatic innovations in television today. But is this the right question? A classical investigation of the theory of picture scanning[1] was published *in U.S.A.* in 1934, and the existence of a body of telecommunication research workers in the Bell Telephone Laboratories must surely be an important factor. After the British invention of interlaced scanning, the next big step was colour on a sub-carrier frequency-interlaced with the main video signal: first R. B. Dome, then the N.T.S.C. system, and finally the present European wrangle over SECAM, PAL, SEQUAM and so on.

The French went ahead with 819 lines (on which I have commented favourably: see "More Lines Instead of Colour?", *Wireless World*, May 1956, p. 239), but it appears that 819 lines is being squeezed out by 625. As there have been so few major television developments, should we really be distressed that Britain has not pulled another golden rabbit out of the hat?

For some years research workers in U.S.A., Britain, France, Russia and Australia (and possibly elsewhere) have been seeking means of reducing bandwidth, but the statistical structure of the typical picture is against us: it has such infinite variety. Some of the more promising schemes have been set up and tested by the B.B.C.[2]. Too much is now known about picture-forming processes and about radio propagation for it to be easy to innovate. Turning to "Radiophare's" list of questions, I make the following comments:—

(1) Transmitters and receivers for quasi-optical frequencies. This in practice means laser technology, which is by no means neglected. Propagation is a very major question: is it worth pursuing a television system which would be available only on a piped basis and, therefore, only in densely populated districts? The natural field for the initial development of these techniques is in point-to-point telecommunication.

(2) Efficient wideband modulation methods. What does this mean if not "more efficient methods of packing information into the sideband?"

(3) More efficient methods of packing information into the sideband. This is the obverse of "bandwidth reduction," and the various schemes of colour television are

more or less successful examples of putting three pints in a one-pint pot without losing too much.

(4) Multiple interlace and bandwidth reduction. I have myself instigated a trial of frequency interlace[3] and there is an extensive literature on bandwidth reduction. It is dangerous to say that anything is scientifically impossible, but equally dangerous to find oneself seeking to overcome some fundamental principle of nature such as the second law of thermodynamics. (Remember the Stenode receiver based on a denial of the existence of sidebands?) "Shannon theory" may be relevant, as was recently suggested in *Wireless World*[4].

(5) Simple high-stability oscillators. I suspect that "Radiophare" means *cheap* high-stability oscillators, for use in receivers. Then I must ask two questions. (1) How much should a receiver manufacturer spend on how good an oscillator? (2) Are all present-day receivers equally unsatisfactory, or have some manufacturers already solved the problem?

(6) Local distribution of wideband video. What about Professor Barlow's work on waveguides? Again I assume that receiver cost is important, so p.c.m. is not likely to be practicable and there would be objections even to f.m.

(7) Improved resolution in camera pick-up tubes. I suspect that this could be provided if needed. What did the French do for 819 lines?

(8) & (9) Improved c.r.ts and alternative forms of display. This is an interesting field because it does not appear to come into immediate collision with fundamental laws of nature. There are, however, some fairly basic limitations on c.r.t. brightness and focus because (a) the current-density in the spot is related to the current-density at the cathode and (b) the sharpness of definition of the spot is ultimately limited by the random (thermal-agitation) electron velocities transverse to the beam. I suspect that we could have a lot more if we paid for it, just as the performance and comfort of some expensive cars is a long way beyond that of the family car.

"If we paid for it" is the problem. It appears that since 1945 television has been regarded largely as a means of keeping afloat the domestic radio side of the industry. The *laissez-faire* economist would say simply that if the companies in the radio and television receiver industry cannot make a profit, they must either close down or make something else. The planning economist would say that if television is to be subsidized, we must know why. B.B.C. money comes from viewers and N.R.D.C. money from taxpayers, so does "Radiophare" honestly want to vote 10s worth of TV licence or a pennyworth of income tax to television research? Even if he does, is he right? Machine tools, computers, nuclear reactors, and space vehicles are other applicants for our research money and manpower, and all would claim to have export potential. So the decision is really a politico-economic one.

The worst thing would be to pour out money in the vague hope that it would somehow generate ideas. But on the other hand I suggested in my first paragraph that the presence of an active body of research workers could contribute to the generation of information and ideas. The way out of the dilemma is to be reasonably generous with money whenever there is any sign of long-range ideas. Unfortunately the Science Research Council appears at present to be limiting the amount of money available for long-range and fundamental research, perhaps on the ground that Britain's present economic situation demands urgent rectification of our alleged weakness in technological development in spite of brilliance in fundamental research. None the less I believe that if anyone has an outstanding idea it is still just possible for him to get sufficient support to develop it.

D. A. BELL

The University of Hull.

[1] Pierre Mertz and Frank Gray, "A Theory of Scanning and its Relation to the Transmitted Signal in Telegraphy and Television," *Bell S.T.J.*, Vol. 13 (1934), p. 464.

[2] G. F. Newell and W. K. Geddes, "Tests of Three Systems of Bandwidth Compression of Television Signals," *Proc. I.E.E.*, Vol. 109B (1962), p. 311.

[3] E. A. Howson and D. A. Bell, "Reduction of Television Bandwidth by Frequency Interlace," *J. Brit. I.R.E.*, Vol. 20, No. 2 (Feb. 1960), p. 127.

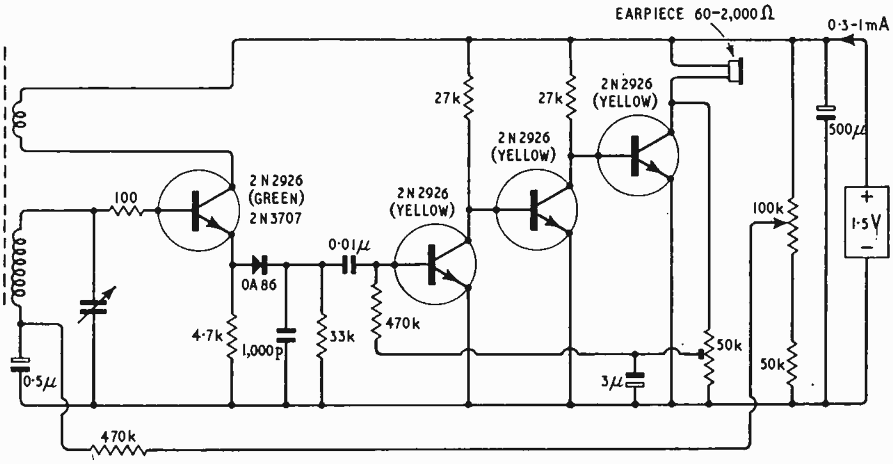
[4] H. O. Codon, "Communication Theory and Colour Television," *Wireless World*, May 1966, p. 243.

Simple Receiver for Low-voltage Operation

THE receiver described in the October issue utilises three r.f. stages and one a.f. stage. While this is the best strategy from the point of view of sensitivity, it is not the approach that leads to the lowest current consumption, since most transistors only work well as r.f. stages when they pass about 1 mA collector current.

The diagram below shows a circuit which works well with as little as 300 μA total battery current. Here the gain is concentrated in three a.f. stages. At the r.f. end, one high-beta transistor is used as a buffer between the tuned circuit and the detector diode. The tuned circuit may be connected directly to the base without appreciable loss of selectivity because of the high input impedance of the emitter follower. This arrangement provides an effective gain of around ten by dispensing with the usual step-down transformer to match the tuned circuit to the transistor. By itself, this is hardly enough, but the addition of a reaction winding of about three turns enables sufficient r.f. signal to be presented to the detector for reception of the Home, Light and Third programmes in the London area, using a ferrite rod aerial three inches long. The 100-Ω resistor in the base circuit of the first transistor was put there to reduce interference from the local television station. It could probably be omitted in most areas.

The receiver is quite simple to operate, the only irri-



tating feature being that, if reaction is pressed to the limit, there is some backlash, and retuning is necessary after adjusting the reaction control. Earpieces with resistances between 60 and 2,000 Ω may be used; the current taken rises to about 1mA with a 60-Ω earpiece.

Croydon. G. WAREHAM

Receiving Stereo Broadcasts

YOUR article under the above title in the September issue seems to paint a somewhat gloomy picture of the possibilities of stereo reception and, at the same time, appears to contain certain inaccuracies and a lack of appreciation of practical and operational requirements.

In the brief outline of the pilot-tone system, your author claims that, in a monophonic receiver, use is made of 90% of the available modulation. This is correct but surely results in a signal-to-noise deterioration of approximately 1 dB and not 4 dB as stated. It may well be that statistically the $L+R$ content of a typical stereo broadcast is some 3 to 4 dB down on the level of a comparable monophonic programme but this does not derive directly from a consideration of system limits. He goes on to say that for stereo reception the signal-to-noise ratio is worsened by about 22 dB but appears to accept the situation, without question, as a price to be paid. A simple qualitative explanation then, may not be out of place here. In a basic f.m. system the noise associated with the sidebands inherently increases rapidly as these sidebands become remoter from the carrier. (Hence the use of pre-emphasis in a monophonic broadcast.) The noise associated with modulation frequencies centred on 38 kc/s is thus relatively large. Although this is not heard directly because of its frequency range, it is translated down into the audio band by heterodyne action with the locally re-inserted 38 kc/s sub-carrier and at once becomes audible. It is, in fact, this latter noise, after normal de-emphasis, which accounts for the deterioration of signal-to-noise performance under stereo conditions.

It is not intended in this note to discuss decoders in detail, but concerning those employing a switching process it must be said that there is no need to use a 1:1 mark-to-space ratio rectangular waveform which, admittedly, does not yield adequate separation of the channels. On the contrary, sine wave switching with the angle of flow limited to less than 180° does, however, give excellent results.

Regarding the presence of a basic 38 kc/s signal in the audio outputs it will be appreciated that harmonics of this frequency are also present and thus twin-T filters may not of themselves provide adequate suppression. However, the 50 μs de-emphasis network will attenuate the 38 kc/s component by over 20 dB and its harmonics even more, probably making the inclusion of any additional filter unnecessary.

Finally, let it be said that the writer is not unaware of the theoretical considerations in the general field of stereo broadcasting but feels that in certain circumstances their importance can be exaggerated when applied to domestic entertainment.

Let your would-be stereo listeners take heart. Let them provide themselves with decent aerials, good average receivers and decoders and enjoy this new facility.

London, S.E.19. G. D. BROWNE

IT is true that, by itself, a 10% reduction in deviation would result in a 0.9 dB reduction in s/n ratio. But in the pilot-tone system, since the $L-R$ signal contributes to the deviation as well as the $L+R$ signal, the $L+R$ or mono output will generally be less than it would be were the sub-carrier absent, by an amount depending on the lack of correlation between L and R channels. (Typically, the total loss would be about 4 dB[*].) Thus it is fair to say that as a result of using the pilot-tone system, in which the main channel deviation is limited to 90% of 75 kc/s, the reduction in s/n ratio is 4 dB.

We are pleased that Mr. Browne raised a point on which we did not go into detail. However, it should be said that reducing conduction usually means reducing output also. For instance, reducing conduction from 180° to 40° would reduce output by 13 dB and reduce the post-detection correction from 4 dB to less than 1 dB[†]. Mr. Browne's "good average receivers" calls for comment. According to one company who adapt receivers for stereo reception, nearly all the latest British tuners are "quite incapable" of producing the necessary bandwidth and detector linearity!—ED.

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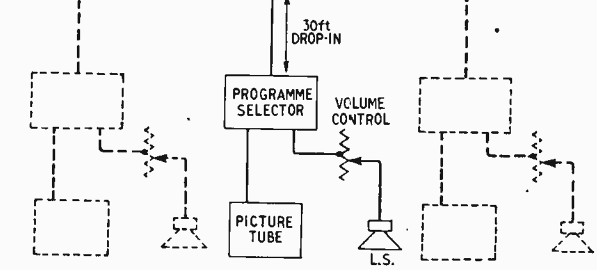
[*] See "Stereo Broadcasting and Reception" J. G. Spencer and G. J. Phillips, *Radio and Electronic Engineer*, June 1964 (Appendix 1), and "Determination of the effective depth of monophonic programme transmitted on the pilot-tone system" D. E. L. Shorter, *E.B.U. Review* Part A Feb. 1963.

[†] see "Stereophonic FM-Receivers and Adaptors" D. R. von Recklinghausen, *I.R.E. Trans.* vol. BTR-7, Nov. 1961, p. 67.

Television Distribution

YOUR contributor, "Radiophare," seems to live in a strange world. It is as though each home was on a separate satellite with no possibility of physical contact between them. Reality is different: most of us live in towns and cities where the distance between one home and the next is but 15 yards. Having got sound and vision signals to the first home in a city the problem is how to extend it to the next. Any of your readers, if faced with this problem in the course of an ordinary day's work, would, I am sure, do the obvious thing and run a bit of cable to it. If they were then asked to extend the signal to the next home they would repeat the process and so on to the boundaries. Given a little time for reflection they would realise that their problem was to design for the maximum efficiency and lowest cost of the unit shown in the diagram. I have no doubt that they would soon conceive an h.f. wired network.

Once the problem is seen in this light the idea of equipping every home as a satellite reception station appears as the absurdity which it is; being, indeed, only one degree less absurd than enabling every home to accept from a distance of 15 yards picture signals containing no redundancy. "Cathode Ray" has already put the suggestion for 1,000 or 2,000 lines into its proper perspective and I will only add that if "Radiophare" should ever find himself in a position to decree this



marvellous thing, he could do it most easily and cheaply with a wired distribution system.

I hope that he may learn to see the problem of broadcasting in this light as it will restore his pride in his own country which leads the world in wired distribution. In contrast to the elaborate demonstrations of electronic expertise which "Radiophare" would inflict on the long-suffering public, high-frequency wired systems bear the true hallmarks of good engineering; they are simple, reliable and cheap.

Rediffusion Ltd.,
London, S.W.1.

R. P. GABRIEL

The Diode-transistor Pump

I AM sorry about the misprint in the opening paragraph of Mr. Waddington's article in the July issue but even the corrected version ("Letters" p. 458, September) does not help me to understand why one should be so concerned about the slope sensitivity of the simple pulse-rate discriminator. At an input-to-output ratio of 10:1 the basic differentiator and clamp will depart from linearity by about 0.7%. If this point is arranged to correspond with an input frequency of 300 kc/s (for a nominal centre frequency of 150 kc/s) a 10 V step at the input will give an output of ± 0.25 V at very low distortion for a deviation of ± 75 kc/s. Since this level is some 40 dB above the maximum input sensitivity of most pre-amplifiers, the programme signal at the discriminator is not likely to be degraded by the audio circuits.

The performance of the basic circuit is, of course, ruined by adding an integrating capacitor and this component must either be isolated in the way Mr. Waddington has done or dispensed with altogether. A moving-coil meter placed in series with the differentiator will sense the mean level of the output current pulses without the aid of a capacitor and for f.m. receiver application the 50 μs de-emphasis function can be combined with the first stage of the pre-amplifier along with the equalizing networks for gramophone, tape and other inputs. The only point to watch here is the possibility of overloading the audio stages by the relatively large discriminator pulses.

Mention should be made of the f.m. receiver design by E. D. Frost[1] which includes an inherently linear pulse-rate discriminator of a centre frequency of 300 kc/s for stereo operation. This receiver appears to combine the best of all worlds and probably represents the proper basis from which future developments should proceed. There still remain many points of detail to interest the circuit designer but the case for high discriminator output is, I suggest, not one of them.

Lee-on-the-Solent,
Hants.

A. S. CHESTER

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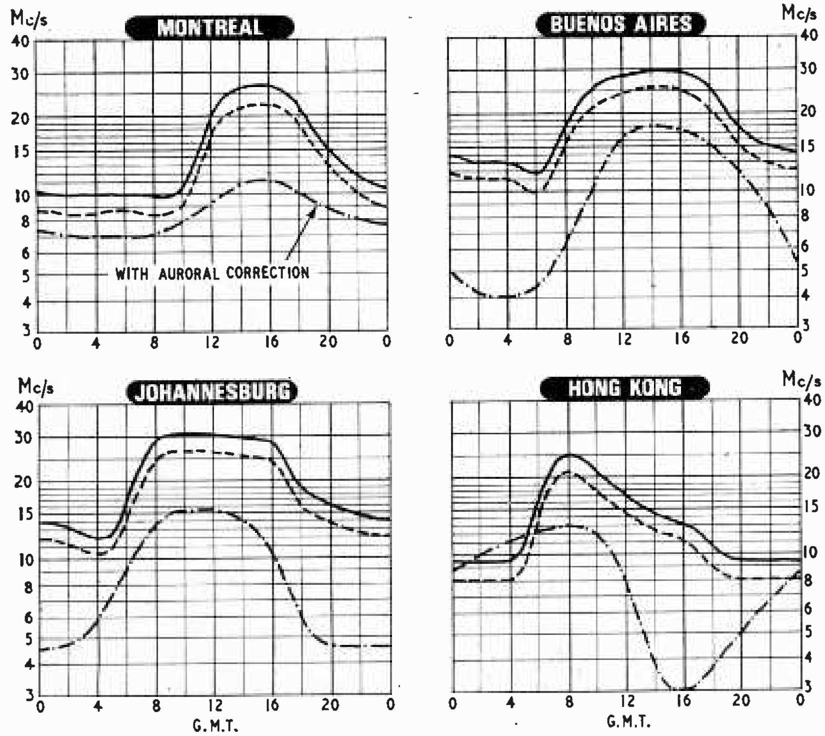
[1] Frost, E. D., 'Pulse-counting F.M. Tuner'—*W.W.* Dec. 65

The author replies:—

From Mr. Chester's comments, it is obvious that he only visualizes one use for a frequency/voltage converter, namely that of discriminator for an f.m. tuner. While I concede that only a few millivolts of input are required for the "general purpose pre-amplifier," the discriminator may, and most probably will in the future, be called upon to drive a stereo decoder. These in general require a higher input. The discriminator may also be used for a.f.c. and for this a large d.c. output is desirable. However, as I tried to show in my article, there are also many other applications of frequency/voltage converters where a large output voltage, coupled with good linearity, is an essential.



H. F. PREDICTIONS NOVEMBER

The higher daytime MUFs, characteristic of the winter months, are now becoming apparent for circuits predominantly in the Northern hemisphere. The Northern Auroral Zone passes roughly through Alaska, Hudson Bay, Iceland and Northern Norway. Radio paths passing through this zone are subject to additional absorption, and a correction is made for this in the calculation of the lowest usable frequency (LUF).

The prediction curves show the median standard MUF, optimum traffic frequency and 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 shown were drawn by Cable and Wireless Ltd. for commercial telegraphy and assume the use of transmitters of several kilowatts and aerials of the rhombic type.

More about Farnborough

NEW NAVIGATION AND GUIDANCE SYSTEMS AT 1966 S.B.A.C. EXHIBITION

LAST month we were able to do little more than mention a few of the interesting items seen at the Society of British Aerospace Companies' exhibition ("Avionics at Farnborough," October issue, p. 487). The following is a continuation of the report, in itemized form, and contains photographs of the new Cossor secondary radar transponder, the S.T.C. improved I.L.S. and the Marconi mobile ground radar outlined last month.

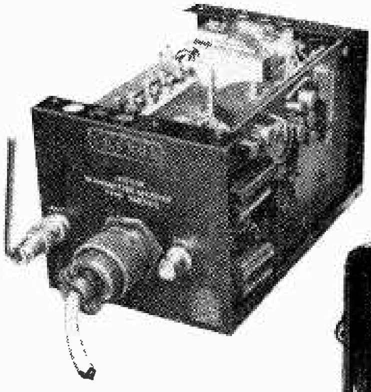
Television target simulator.—As part of a general programme of work on visual factors in flying aircraft, the Royal Aircraft Establishment were demonstrating a simulator using television technique for studying problems in low level flying—in particular the task of looking for objects on the ground. A background scene, which can be a photograph of natural countryside taken from the air or a highly complex artificial scene specially constructed for the job, is televised and displayed on a television monitor. A small square target is superimposed on the background, and this target may be varied in contrast and size either in steps or continuously in accordance with an exponential law. The contrasts in the background may also be varied, from a zero-contrast plain grey display, in conjunction with the exponential change of the target contrast. One recent study was on the contrast threshold of the eye. This, the minimum contrast at which the eye can see the target, is necessary for producing theoretical predictions of visual ability and has been investigated by many experimenters. In the past, plain backgrounds to the target have been used and the results have tended to prove optimistic when applied to the real-life situation. A demonstration on the simulator showed that much of this discrepancy could be explained by the existence of a textured background.

A further demonstration was concerned with the effect of noise on the television display. R.A.E. are interested in the levels of noise which affect a person's performance in a specific task. Again it has been found that the complexity of the background used in the experiment has a direct bearing on the effect of noise, and also that quite obtrusive levels of noise may be tolerated by the observer in his task of searching for a small square target of near threshold contrast.

Television-aided missile guidance.—Components of an Anglo-French air-to-ground missile system called MARTEL, using television for observing the target area, were shown by Marconi, the developers of the television equipment. A sensitive television camera is fitted into the nose of a missile carried by a supersonic aircraft and, after the missile has been launched, the picture from this camera is transmitted back to the aircraft, where the pilot views the target area on a c.r.t. monitor. A joystick enables the pilot to control the field of view of the camera. Once the target has been selected, control signals within the missile adjust the flight path to bring the major axis of the missile into alignment with that of the television camera. The missile itself is being developed by Hawker Siddeley Dynamics in conjunction with Engins Matra of France, and flight trials using the television system have already taken place.

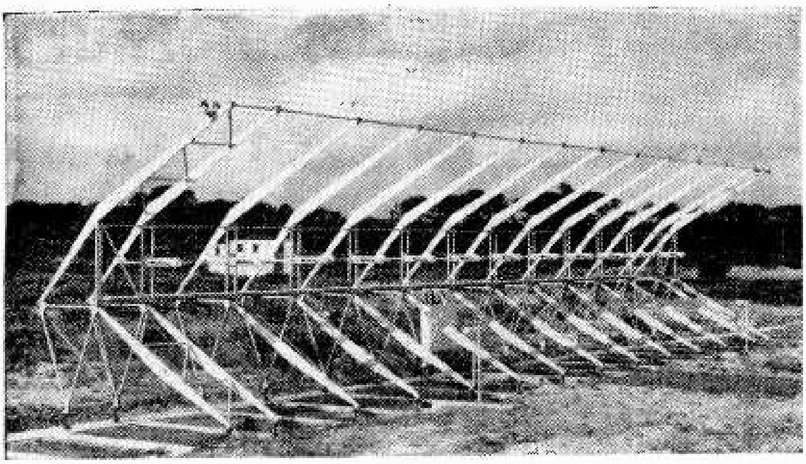
Missile "miss-distance" indication.—Parts of two electronic systems for indicating the "miss-distance" of a guided missile relative to a practice target were displayed by Ekco Electronics. One system uses a radioactive source fitted to the missile, and the miss-distance is determined by a gamma-ray monitor carried in the target. Another system operates on an acoustic principle in which the peak amplitude of the shock wave generated by the missile is measured in the target. With both systems the information obtained in the target is telemetered to the towing aircraft, or to the ground, where it is processed to give miss-distance in digital form.

U.H.F. homer and transponder beacon.—The latest version of the MR343 tactical radar transponder beacon made by Rank Bush Murphy is fitted with a u.h.f. homer. The beacon is designed for parachuting to the ground with airborne assault forces, and as a secondary radar transponder operating in conjunction with Rebecca airborne interrogators it provides distance and homing signals for support aircraft. In the u.h.f. homer application, it provides a homing signal for aircraft fitted with homer equipment operating in the 225-240Mc/s range. The homer uses a crystal-controlled m.c.w. transmitter giving a 150 mW peak power output. This is modulated at 3.5 kc/s and 1.7 kc/s by an electromechanical encoder, using a photo-



Left, Integrated-circuit airborne transponder of the Cossor SSR 2100 secondary radar and I.F.F. equipment (see October issue p.487).

Below, Tactical navigation beacon MR 343 made by Rank Bush Murphy, incorporating a u.h.f. homer facility.

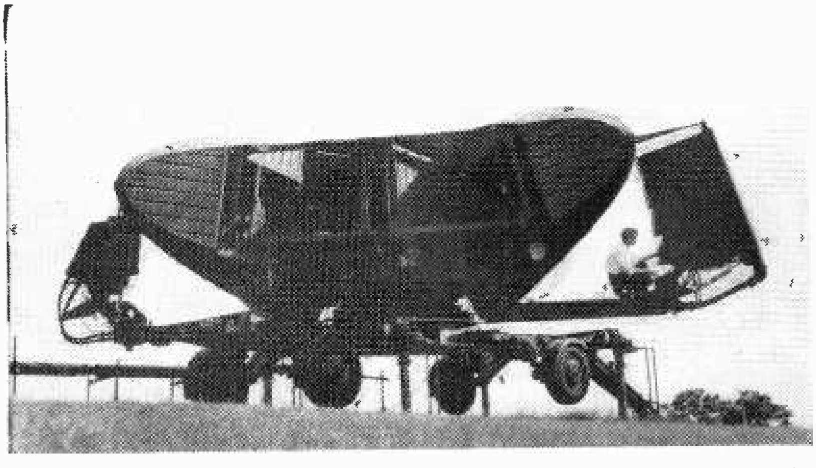


The 85ft localizer aerial array of the S.T.C. improved I.L.S. equipment STAN.7/8/9 which meets ICAO's accuracy and reliability requirements for Category III operational performance (see October issue, p.487).

transistor, which can generate morse identification signals. Power is provided by a 12 V nickel-cadmium battery.

Loran C (and A) receiver.—The Decca Navigator Company were showing a compact airborne receiver, using solid-state circuitry, designed to make available to an aircraft navigator the full position-fixing facilities of both the Loran C and the Loran A navigation systems. Loran C (on which Decca have patents) has not yet been widely used for aircraft navigation, but it is stated that flight trials have shown it to be a promising system. Like Loran A it is a hyperbolic pulse system giving a pair of time-difference measurements in the aircraft, but instead of operating on a radio frequency of 2 Mc/s it works on 100 kc/s. This low frequency virtually eliminates aircraft altitude as a factor of range, and provides a greater ground wave range—which can extend to 1,200 nautical miles over water. Sky waves can be received at ranges up to 2,000 n.m.

Because of the difficulty of transmitting sufficiently short pulses for accurate position fixing, the time difference measurement is based on phase comparison of selected r.f. cycles within the pulses. For this reason the Loran C receiver includes an "indexing" system to ensure correct selection of identical r.f. cycles in all received pulses. Once the master and both slave stations have been acquired, tracking is automatic on both slaves, and either of the two readings can be displayed on demand. Digital outputs are provided to allow the use of an airborne digital computer for converting the hyberbolic information into latitude and longitude readings or for operating an orthogonal map display. Two versions of the receiver are available, one in a single package, and another comprising three units.



Surveillance radar unit of the Marconi mobile radar for air traffic control or ground controlled interception (see October issue, p.487).

Microminiature airborne computers constructed from integrated circuits were displayed by Elliott and Ferranti. Such computers are designed to reduce the workload on the crew of modern high-speed aircraft by performing on-line routine tasks of data assimilation. Using time-sharing techniques, they accept inputs from navigation and other equipments, perform co-ordinate transformation and other data processing operations and feed information needed for navigation and aircraft monitoring to display units.

The Elliott computer, MCS 920M, is a general-purpose, parallel mode computer with a word length of 18 bits and a core storage capacity of 8,192 words, expandable to 65,536 words. For such on-line working it has four levels of interruption and order modification. The machine occupies a three-quarters short ATR case, weighs 27.5 lb and operates without forced-air cooling at ambient temperatures up to 70°C. Mean time between failures is said to be at least 2,000 hours in an airborne environment. Servicing is a matter of replacing disposable integrated circuit modules, of which there are only 38 types in the whole computer. Techniques adapted from this computer are to be used in an advanced "head up" display system, incorporating Elliott's ceramic c.r. tubes in the display unit, which the company are supplying to the U.S. Navy.

Ferranti's microminiature computers on show were the types FM 1600A and FM 1600B, both derived from the company's Poseidon naval-action data automation computer used in H.M.S. Eagle. The FM 1600A, the smaller of the two, is a 24-bit parallel machine with a 1 μsec core store. The central processor, the 4,096 words of core storage, the input/output logic and the power supplies are contained in a long three-quarters ATR case with a volume of 0.7 cu ft. The FM 1600B is also a 24-bit parallel machine, designed with a philosophy of extensive "software" making up for minimum "hardware." NOR logic elements are used. The add/subtract time is 12 μs and the multiplication time is 38-46 μs. A three-address programming system is used.

NOVEMBER MEETINGS

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

LONDON

2nd. B.K.S.T.S.—"Baird and television" by T. H. Bridgewater at 7.30 at Central Office of Information, Hercules Rd., S.E.1.

3rd. I.E.E.—Appleton Lecture "The Cambridge one-mile radio telescope" by Prof. Sir Martin Ryle at 5.30 at Savoy Pl., W.C.2.

4th. I.E.E. & I.E.R.E.—Colloquium on "Character recognition" at 2.30 at Savoy Pl., W.C.2.

9th. I.E.R.E.—"Radio and radar aspects of meteorology" by C. E. Goodison at 6.0 at 9 Bedford Sq., W.C.1.

14th. I.E.E.—Discussion on "Market research in relation to electronics design" at 5.30 at Savoy Pl., W.C.2.

16th. I.E.E.—"Reflections from thin layers" by G. Millington at 5.30 at Savoy Pl., W.C.2.

16th. I.E.R.E. & I.E.E.—Colloquium on "Closed circuit television in medicine and biology" at 6.0 at Middlesex Hospital Medical School, Cleveland St., W.1.

16th. B.K.S.T.S.—"Titanium cone loudspeakers" by E. J. Jordan at 7.30 at Central Office of Information, Hercules Rd., S.E.1.

22nd. I.E.E., Television Soc., & B.K.S.T.S.—Colloquium on "Sound on film" at 9.30 at Savoy Pl., W.C.2.

23rd. I.E.E.—"Electronically assisted acoustics in concert halls" by J. Moir at 6.0 at Savoy Pl., W.C.2.

23rd. I.E.R.E.—"Psychological aspects of acoustics" by Prof. J. T. Allanson at 6.0 at 9 Bedford Sq., W.C.1.

23rd. I.E.E. Grads.—"Travelling wave masers" by J. C. Williams at 6.30 at Savoy Pl., W.C.2

23rd. B.K.S.T.S.—"Special effects" by Bernard Marsden at 7.30 at Central Office of Information, Hercules Rd., S.E.1.

24th. Television Soc.—"Interference to television in the u.h.f. bands" by A. S. McLachlan at 7.0 at I.T.A., 70 Brompton Rd., S.W.3.

28th. I.E.E.—Colloquium on "The use of electromagnetic waves in distance measuring" at 2.30 at Savoy Pl., W.C.2.

28th. I.E.E.—"Elementary particles and resonances" by Dr. F. Heymann at 5.30 at Savoy Pl., W.C.2.

30th. I.E.E.—Discussion on "Transfer-function measuring instruments" at 5.30 at Savoy Pl., W.C.2.

30th. I.E.R.E.—"The development of a pay-television system" by Dr. G. L. Hamburger at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel St., W.C.1.

ARBORFIELD

24th. I.E.R.E.—"Digital radar simulator for air traffic control" by D. Stoddart at 5.0 at Lecture Theatre, School of Electronic Engineering, R.E.M.E.

BASILDON

16th. I.E.R.E.—"Gas lasers" by H. Foster at 6.30 at Barstable Grammar and Technical School, Timber Log Lane.

BEDFORD

7th. I.E.E.—"The education and training of technician engineers" at 7.0 at Bridge Hotel.

BIRMINGHAM

28th. I.E.E. & I.P.O.E.E.—Forum on "Connections in electronic circuits" at 6.0 at M.E.B. Offices, Summer Lane.

BOURNEMOUTH

15th. I.E.R.E.—"Transistor, sinusoidal, stabilized inverters" by C. E. S. Ridgers at 7.0 at the College of Technology.

30th. I.E.E.—"Introducing integrated circuits" by P. Cooke at 6.30 at College of Technology, Lansdowne.

BRIGHTON

8th. I.E.R.E.—"Thin film microelectronics" by T. Cummins at 6.30 at College of Technology.

BRISTOL

3rd. I.E.R.E., I.E.E. & Inst. Prod. Eng.—"Recent developments in satellite telecommunications" by Dr. H. C. Husband at 7.0 at Victoria Rooms, Clifton, Bristol 8.

7th. I.E.R.E. & I.E.E.—"Television recording" by P. Leggat at 6.0 at Large Lecture Theatre, The University.

16th. Inst. Prod. Eng.—Viscount Nuffield Memorial Paper "A survey of microelectronics, including future developments" by Dr. I. M. Mackintosh at 7.0 at The University.

CAMBRIDGE

10th. I.E.R.E. & I.E.E.—"Some problems in the design of electrical filters" by J. K. Skwirzynski at 8.0 at University Eng. Dept., Trumpington St.

24th. I.E.E.—"Speech compression" by Dr. J. Swaffield at 8.0 at University Eng. Dept., Trumpington St.

CARDIFF

4th. Television Soc.—"Microelectronics" by Dr. S. Forte at 7.30 at Angel Hotel.

9th. I.E.R.E.—"Latest developments in radio astronomy" by Dr. P. Williams at 6.30 at Welsh College of Advanced Technology.

CHELMSFORD

28th. I.E.R.E.—"The Watkins-Gunn effect: negative resistance in semiconductors" by B. K. Ridley at 7.0 at the Technical High School, Patching Hall Lane, Broomfield.

COVENTRY

28th. I.E.R.E.—"Electronic exchanges" by E. S. Grundy at 7.15 at Lanchester College of Technology, Priory Street.

CRANFIELD

22nd. I.E.E.—"Lasers & associate devices" by Dr. McFarlane at 7.0 at the College of Aeronautics.

DAGENHAM

16th. I.E.E. Grads.—"Electronic telephone exchanges" by L. R. F. Harris at 6.45 at South-East Essex Technical College.

EDINBURGH

8th. I.E.E. & I.E.R.E.—"Scanning electron microscope and other electron probe instruments" by Prof. C. W. Oatley at 6.0 at Carlton Hotel, North Bridge.

24th. I.E.R.E. & I.E.E.—"Transducers in medical research" by Dr. D. C. Thomas at 6.0 at Carlton Hotel, North Bridge.

GLASGOW

7th. I.E.E. & I.E.R.E.—"Scanning electron microscope and other electron probe instruments" by Prof. C. W. Oatley at 6.0 at the University of Strathclyde, C.1.

KINGSTON, SURREY

2nd. I.E.E. Grads.—"Technical plans for starting colour on BBC-2 by J. Redmond at 7.0 at the College of Technology, Penrhyn Rd.

LEICESTER

9th. Television Soc.—"Steam radio—the birth of broadcasting" by The Hon. Rowland Wynn at 7.15 at Vaughan College, St. Nicholas Street.

LIVERPOOL

14th. I.E.E.—"Variable speed drives using semiconductor adjustable frequency inverters" by D. A Jones at 6.30 at Electrical Engineering Labs., The University.

16th. I.E.R.E.—"Stereophonic broadcasting" by Dr. G. J. Phillips at 7.0 at the College of Technology, Byrom Street.

21st. I.E.E.—"Lasers" by J. C. North at 6.30 at Electrical Engineering Labs., The University.

LOUGHBOROUGH

15th. I.E.E.—"Field effect devices" by Dr. R. E. Hayes at 6.30 at Edward Herbert Building, University of Technology.

MALVERN

14th. I.E.R.E.—"There is more to colour than wavelength" by R. W. Brocklebank at 7.0 at the Abbey Ballroom.

NEWCASTLE-UPON-TYNE

9th. I.E.R.E.—"Lasers and their applications" by Dr. G. W. Wilson at 6.0 at the Inst. of Mining and Mech. Engrs., Neville Hall, Westgate Road.

OXFORD

8th. I.E.R.E.—"Circuit design using digital computers" by E. Wolfendale at 7.30 at Clarendon Laboratory, Parks Road.

9th. I.E.E.—"Micro-miniaturization" by R. G. Dixen at 7.0 at S.E.B., 37 George Street.

PLYMOUTH

15th. I.E.E. & I.E.R.E.—"Automatic driving of trains" by R. Dell at 7.0 at the College of Technology.

PORTSMOUTH

16th. I.E.E.—"U.K.3 satellite electronics" by W. M. Lovell at 6.30 at the College of Technology, Anglesea Road.

SHEFFIELD

2nd. I.E.E.—"Hybrid computers" by Dr. H. B. Williams at 6.30 at Sheffield Industries Exhibition Centre.

SOUTHAMPTON

8th. I.E.E.—Colloquium on "What's new in integrated circuits" at 2.30 at the Lanchester Theatre, The University.

23rd. I.E.E.—"Satellite control" by E. G. C. Burt at 6.30 at the Lanchester Theatre, The University.

SWINDON

9th. I.E.R.E. & I.E.E.—"Ballistic missile early warning system" by B. S. Batt at 7.0 at the College.

WHITBY

7th. I.E.E.—"Semiconductor integrated circuits" by C. S. den Brinker at 7.0 at Botham's Cafe, Skinner Street.

NEW PRODUCTS

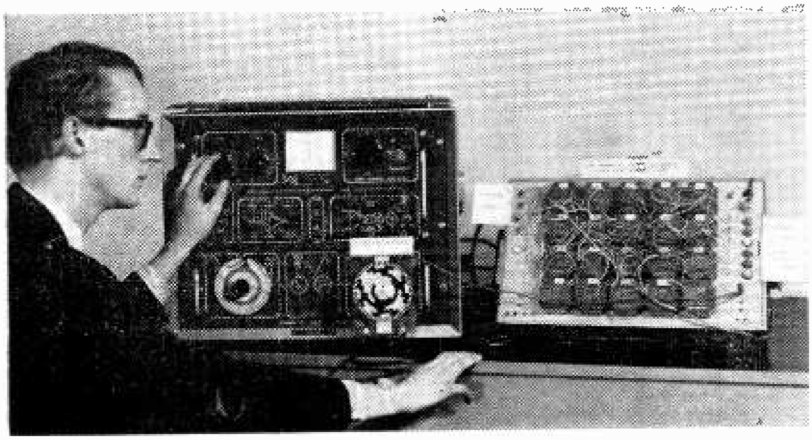
equipment systems components

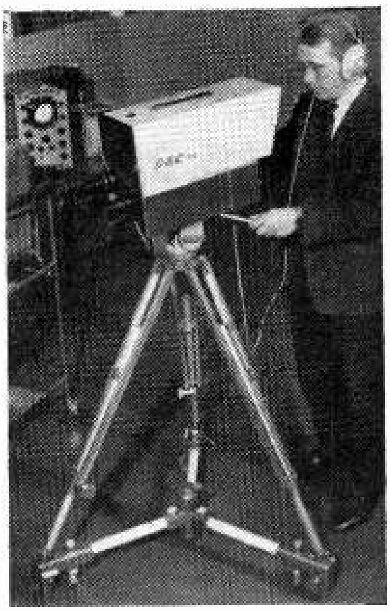
NUMERICAL CONTROL

FEEDBACK Limited who produce both servo and computer logic teaching equipment have now married both systems together to give an assembly which illustrates the principles of numerical control and can be constructed and understood by an average student during a single laboratory period. Described as a logic tutor the Feedback Logikit Primer LK.255 with the additional plug-in elements and the Digital Encoder SE.254 costs £200, and may be expanded to accommodate larger experimental developments for very little extra cost. Both d.c. and carrier servo systems can be controlled from the logic and, for authorities wishing to teach servo plus logic, under £450 will equip a laboratory unit. In the simplest form, a position control system can be constructed which responds to a numerical demand in the form of a 3-bit binary number set on three switches. A digital encoder is coupled to the output shaft, and this produces a Gray code to identify any of eight equal angular segments within a 360° rotation. The logic circuits made up by the constructor from simple plug-in elements convert the Gray code to natural binary and then compare the input demand with the encoder output. The differences (greater or less) in binary form are converted into an error signal suitable for the servo. This drives the encoder in the correct direction to reduce the differences to zero. Input demand, and the natural binary response are monitored continuously by a bank of indicator lamps. The student is thereby in no doubt of the accuracy and speed of the system response. The encoder SE.254, which is covered by a clear Perspex case, carries a mimic replica of the encoding disc, on the front. Its lamps and phototransistors are energized from the logic tutor by means of a long plug-in cable. The encoder can be used with any servo or other suitable mechanism which will respond to the error signal. It is specifically supplied with attachments to couple it directly to any Feedback servo system. Although the experiment illustrated in the photograph involves only a 3-bit number, the encoder will produce up to five bits (32) as well as generating continuous impulses for speed control experiments.

The experimental scope of the Logikit primer includes simple functions of several variables, theorem application, binary addition and subtraction, cyclic binary numbers, a parity chain, decimal to binary-decimal translation, the use of NOR and NAND logic elements for basic operations, binary comparisons, and others, all of which are included in the handbook. Feedback Ltd., Crowborough, Sussex.

WW 301 for further details





Television Studio Camera

A MAINS operated transistor TV studio camera, has been developed by G.E.C. Electronics' Communications Group, of Spon Street, Coventry. Known as the type VCT 2/S, it incorporates a 7 in electronic viewfinder which is easily removed for use separately as a picture monitor. The camera and viewfinder have separate power circuits. The camera can be supplied with a scanning/field standard of either 625/50 or 525/60 and transmits over a bandwidth of 10 Mc/s.

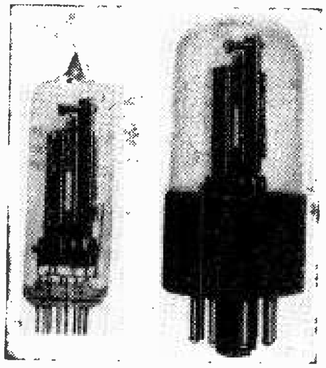
A vidicon tube is used in the camera, and a four-lens turret, which will take "C" mount or broadcast mount lenses, is fitted. A control knob at the side of the camera enables optical focus to be adjusted, or a remote control system can be fitted. The camera has a built-in sync pulse generator and all the principal circuits are contained in replaceable printed circuit modules, thus simplifying maintenance. To minimize the length of the signal cable from the vidicon tube, the video head amplifier module is mounted directly above the vidicon focus coil. A high signal/noise ratio of 36dB peak-to-peak with a 0.2 μA signal is obtained from the video head amplifier. The "target voltage," "beam current," "electrical focus" and "black level" camera controls are normally preset but can be linked to a camera terminal unit to permit adjustments to be carried out remotely. The viewfinder's electronic circuits are also contained in printed circuit modules to facilitate easy servicing.

WW 302 for further details

Delay Relays

TIME delays of 3 to 180 seconds can be obtained from series 200 and series 300 time delay relays by Relay Specialties Inc. Style 200 (9-pin miniature socket) and Style 300 (8-pin octal socket) are hermetically sealed in glass, flushed and gas filled, and both series are constructed to assure either on or off operation with single-pole, double-throw contacts. All relay components including ceramics, wire, glass, steel and silver contacts are inorganic, and free from moisture. Standard tolerances on time delays are ±25% with closer tolerances available. These relays, thermally operated by a separate heating circuit, have standard heater voltages of 6·3, 26·5 and 115 V a.c. or d.c. Contact ratings are 115 V a.c. 3A resistive, or 28 V d.c. 3 A resistive. Operating temperature range is 65° to 100°C, and a minimum life of 100,000 operations is claimed for average operating conditions. Relay Specialties, 3 Godwin Avenue, P.O. Box 223, Fair Lawn, N.J., U.S.A.

WW 303 for further details

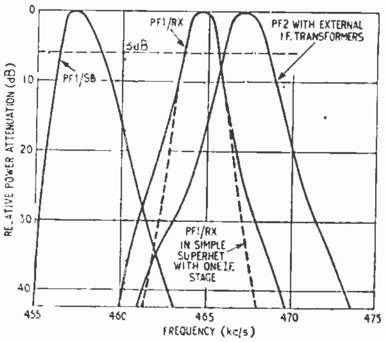


Dual Transistor

THE 2C444, a silicon planar dual transistor is available from SGS-Fairchild Ltd., Stonefield Way, Ruislip, Middlesex. This is a six terminal device giving low drift performance in d.c. amplifiers, and can be used in industrial applications, power supplies, video and cascade amplifiers. The 2C444 replaces two C444 transistors, and it is stated that this is the first industrial transistor to have guaranteed h_{FE} and V_{BE} matching. Planar construction, and low leakage, offer a range of guaranteed hybrid parameters that allows flexibility in designing equipment. Maximum drift 30 μV/° C, f_T is typically 350 Mc/s, and h_{FE} ratio 0.7 minimum.

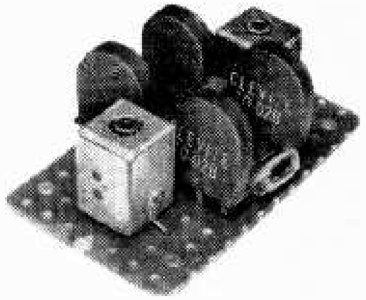
WW 304 for further details

CRYSTAL FILTERS



TWO filter units, the PF1 and PF2, by Elliott Electronics, 3 Sandgate Avenue, Tilehurst, Reading, Berks, have been designed to improve the selectivity of existing receivers with i.fs of 455 to 470 kc/s. They are also intended for incorporating into new receiver assemblies and single-sideband generators. The PF1 is available in two versions, PF1/RX with a symmetrical passband for receiver applications and PFL/SB with an asymmetrical passband, and sharp cut-off on the l.f. or h.f. side for sideband generation. Input and output transformers are tapped to match into valve or transistor circuits with impedances of 1 to 2 kΩ, 10 to 40 kΩ or 100 kΩ upwards. The centre frequency can be 457, 465 or 470 kc/s ±1 kc/s. Price £4 1s. The PF2 is a simplified filter in which there are no matching transformers and it has been designed to couple directly (without centre tappings) to standard i.f. transformers which are tuned to the centre frequency of the filter. The centre frequency can be 459, 467 or 472 kc/s ±1 kc/s. The price is £3 2s.

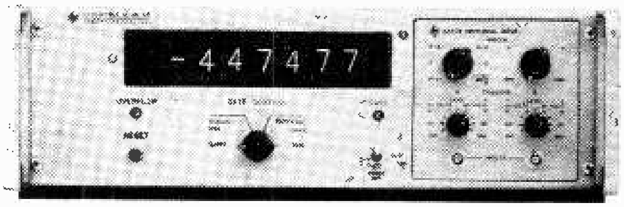
WW 305 for further details



Reversible Counter

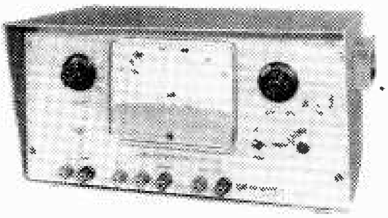
THE Hewlett Packard reversible electronic counter 5280A counts at rates up to 2 Mc/s, reverses in 250 ns and has a reverse counting rate of 1 Mc/s. The instrument is intended for the precise control of automatic processes, where the counter's ability to operate in a temperature range from 0° to 50°C will also be useful. With its accompanying 5285A universal plug-in unit it will count either of two input channels A or B, or count A upwards or downwards, depending on the polarity chosen for B, at the 2 Mc/s rate. It will count A+B and A−B, at rates up to 1 Mc/s. This last-mentioned mode has special value with laser interferometers and other kinds of transducers, to make precise measurements of length, or in X-Y positioning. Model 5280A will maintain accurate count, even if simultaneous signals should arrive at A and B channels in the A+B or A−B modes; an anti-coincidence circuit is built in. This instrument will perform tasks that include reading pulses in remote control or telemetering systems, comparing frequencies, and measuring length, thickness, angular displacement, flow rate, liquid level and weight (with appropriate transducers). The controls include a polarity switch to reverse input signal direction-sensing and trigger level settings with ± 100 volt range. Readout is 6 digits in-line with ± sign; 7th and 8th digits are optional, with no decrease in maximum counting or reversing rate. Overflow is indicated by a front panel neon light. The inputs present 1 megohm in parallel with 80 pF to the external circuit. Sensitivity is 100 millivolts r.m.s. or 1 volt pulse of 0·2 μs minimum width. Either a.c. or d.c. coupling may be selected. For recording or to control other equipment, Model 5280A has four-line binary coded decimal outputs as standard equipment. Model 5280A is priced at £558. The Model 5285A universal input plug-in unit is £172. Hewlett Packard Ltd., Slough, Bucks.

WW 306 for further details



THYRISTOR GATE SENSITIVITY METER

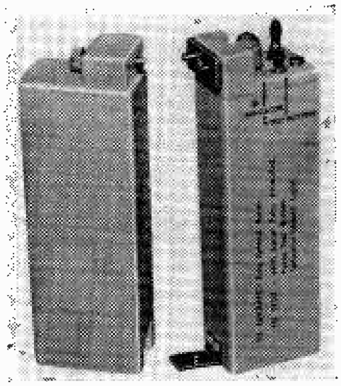
A GATE sensitivity meter is now available from Caltronics Limited of Hunting Gate, Hitchin, Herts. This thyristor gate sensitivity meter provides accurate and rapid measurement of the gate current-to-fire for a wide variety of thyristors. A Zener diode provides a stabilized anode-to-cathode voltage of 6 volts to the thyristor under test. The gating characteristics of the device under test are measured by applying half-wave rectified 50-60 c/s pulses between the gate lead and cathode of the device. A trigger network in the anode supply lead senses the turn-on point of the thyristor and energizes an electronic switch that removes the gating signal. A peak reading voltmeter circuit is utilized to give a direct indication of the current or voltage level at which the thyristor fires. The gate current-to-fire reading is obtained by driving the gate circuit through a set of precision resistors which form an adjustable 10-step current source. The gate voltage-to-fire reading is obtained by driving the gate circuit from an adjustable 3-step voltage source. Calibration potentiometers allow the sensitivity meter to be calibrated on both current and voltage. Terminals are provided for parallel remote operation of the instrument. Remote indication of the meter reading may be obtained from a pair of panel terminals which provide a 1 volt signal for full scale indication on the front panel meter. The full scale gate current ranges start at 0·010 mA, rising to 300 mA. The gate current accuracy is ± 3% of full scale, and the full scale gate voltage ranges are 1, 3 and 10 volts with a gate voltage accuracy of ± 5% of full scale. The analogue output is 0 to 1 V d.c. into a 1 MΩ load. The input power requirements are 220-240 V, 50-60 c/s single phase. The price is £195.



WW 307 for further details

Distress Beacon

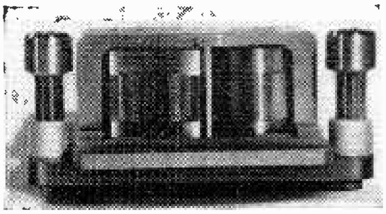
BASED on the SARBE range of military beacons, the compact beacon BE355 is manufactured by Burndept Electronics Ltd., Erith, Kent. It will be of special value to yachtsmen and to business/private aircraft flying over the sea, or thinly populated areas. It will transmit on the v.h.f./u.h.f. distress frequencies 121.5 and 234 Mc/s. Power output is 100 mW mean and 200 mW peak. It will operate for 24 hours over the temperature range 0°C to 55°C with a 13.4 V mercury battery, which is butt mounted to the radio. A larger battery is available for 48 hours transmission. Both beacon and battery are encased in cans of drawn aluminium and they weigh 25 ounces complete. A sealed retractable telescopic aerial is also contained within the beacon housing when not in use. A function check is carried out by button and indicator lamp. When the beacon is required, extending the aerial initiates the transmission of a wobbulated signal two or three times per second. When not in use the BE355 is 5¾ in high, 3¾ in wide and 1¼ in deep. The price is expected to be about £33 to £40.



WW 309 for further details

Recording Tape Tester

TAPE testing assemblies which will test the full width of magnetic tape for "drop out" and other defects have been developed by Gresham Lion Electronics. Already available to tape manufacturers, it is now available to users of tape. A wide choice of tracking arrangements is offered, and a version for computer work provides a full width record head for ½in tape followed by a dual replay head stack with 7 and 9 tracks (type P.S. 79). Top or bottom edge tape guidance is provided by spring loaded ceramic guides, and head blocks are protected by an enclosed cover. Electrical and mechanical specifications can be drawn up to meet particular applications. The specification of one assembly—the seven and nine track replay head assembly for ½in tape—is as follows: the record head has a track width of 0.505 ±0.001 in., a gap length of 0.0005 in (nominal). The resistance is 25Ω, inductance 7 mH, and saturation current 33 mA p-p. The replay head with 7 tracks has a track width of 0.030 ± 0.001 in (9 tracks 0.040±0.001 in) and a gap length of 0.00025 in (9 track 0.00025 in); the resistance is 11.4 Ω (9 tracks 12.5 Ω) and the inductance is 5.6 mH (9 tracks 5.3 mH). Also being developed is a nine track assembly (T.S. 45) which will provide total surface checking of half an inch, high density tape (9 track, 3,200 flux reversals per inch). Gresham Lion Electronics Ltd., Lion Works, Hanworth Trading Estate, Feltham, Middx.

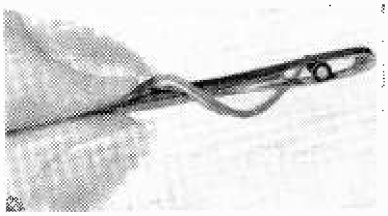


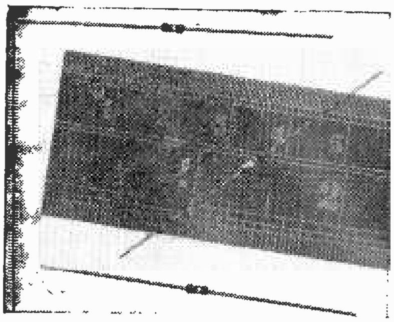
WW 308 for further details

Inductive Transducer

THE P/12/150 non-contact subminiature inductive transducer is 0·1 in diameter and 0·15 in long. Designed to be fully compatible with the range of Associated Engineering electronic units for measuring displacement and vibration, it can be used in temperatures from ambient up to 150°C, and in acceleration fields up to 2000g. It has a working range of 0·005 in, a resolution of 10μin and a frequency response from d.c. up to 10 kc/s, with extension to 60 kc/s for special applications. Associated Engineering Ltd., Group Research and Development, Cawston, Nr. Rugby, Warwickshire.

WW 310 for further details





SUBMINIATURE RESISTORS

ERG Industrial Corporation has produced a range of subminiature precision metal film resistors with dimensions from 0·145 in×0·045 in upwards. Style RE-0·125 (illustrated) is rated for $\frac{1}{8}$W at 100°C. Temperature coefficients are from ± 0·0025%/°C upwards and initial resistance tolerances of ± 0·1% are available. The operating temperature range is − 55°C to + 165°C, and values between 2 Ω and 2 mΩ can be specified. Other styles with ratings from 1/20 W up to $\frac{1}{2}$W at 100°C are available. Erg Industrial Corporation Ltd., Luton Road, Dunstable, Beds.

WW 311 for further details

A.F./R.F. Test Set

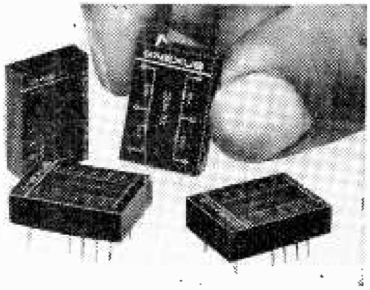
MODEL A 220 a.f./r.f. test set is an instrument manufactured by Amalgamated Wireless (Australasia) Ltd., and marketed in the U.K. by Livingston Laboratories. This receiver functions as a variable frequency generator, wideband receiver, high impedance volmeter, and modulation meter and it can be mains or battery powered for station or field operation. The generator provides frequencies from 100 c/s to 650 kc/s with a maximum output level of +13dBm at switch selected output impedances from 75 Ω to 1.2 kΩ. The generator output can be amplitude modulated up to 80% by an internal 820 c/s oscillator, or from an external source between 200 c/s and 3.4 kc/s. The wideband receiver function measures signal levels down to −80dBm over the frequency range 50 c/s to 250 kc/s with selectable balanced input impedances of 75, 150, 600, and 1,200 ohms. Provision is made for monitoring by headphones or a.c. recorder, measuring distortion, intermodulation products, and filter bandpass characteristics. The generator will withstand a short circuit across the output terminals for up to one hour without damaging the instrument. Instrument Division, Livingston Laboratories Ltd., Livingston House, Greycaine Road, North Watford, Herts.

WW 312 for further details

Film Resistor Networks

ENCAPSULATED cermet resistance networks made by Nexus Research Laboratory Inc. (U.S.A.) are available in a wide range of values, with standard tolerances of 1% and 0·5% and specially ordered resistance tolerances of 0·25% and 0·1%. They are intended particularly for users of operational amplifiers. Claimed advantages of these networks are small size, inherent reliability, and close thermal tracking of similar resistors fired on a common substrate. These networks are available to order, in special configurations including binary and b.c.d. related resistance ratios for use in digital/analogue interface converters. The thermal tracking (ratio between units on a common substrate) is ± 20 p.p.m./°C. Power dissipation per substrate is 0·5 W. From Livingston Components Ltd., Livingston House, Greycaine Road, North Watford, Herts.

WW 313 for further details



A.C.-D.C. Converter

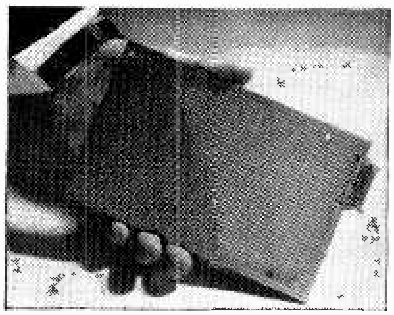
IN modern data processing systems, a frequent requirement is the conversion of a.c. data signals to d.c. signals that will drive suitable indicating devices and recording equipment. The TP-663 a.c. to d.c. converter made in the U.S.A. by Technical Products Company, is such an instrument complete with self-contained regulated power supplies. Operator controls are not required, since the a.c. input voltage is converted directly to an average d.c. output. This instrument may be equipped with from one to eight channels. Two connectors are provided on the rear of the chassis for each channel. The two detectors (used in the conversion process) that are available with the converter are TP-663A and TP663B. The TP-663A provides a 70 dB dynamic range over a frequency range from 5 c/s to 20 kc/s, and a 60 dB dynamic range over the frequency range 4 c/s to 40 kc/s. The RP-663B provides a 70 dB dynamic range over the frequencies 4 c/s to 40 kc/s and 60 dB from 2 c/s to 200 kc/s. The TP-663A provides a response time of 0.5 s for 63% of final reading, while the TP-663B normally supplied with damping has a response time that is 0.2 s for 63% of the final reading. There is the option of faster response time with less damping. Marketed in the U.K. by Environmental Equipments Ltd., Denton Road, Wokingham, Berks.

WW 314 for further details

WIRING BOARDS

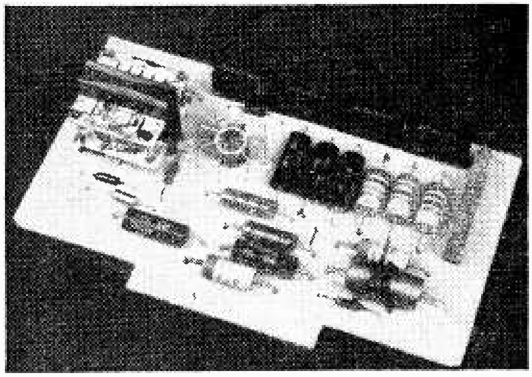
PRECISION printed-circuit boards known as ISEP-Veroboards are being made in eight sizes to fit the various sizes of 19 in ISEP sub-racks. Available from Electronic Services, S.T.C., Edinburgh Way, Harlow, Essex, the boards are supplied plain, or clad with narrow copper strips that connect entire rows of holes together horizontally to simplify component connection. Insulation between strips is at least 100 M Ω. Strips can be interlinked or severed between holes to provide many variations of component interconnections. Boards are protected by a flux preservative, and are suitable for cutting out, and punching at room temperature. Claimed advantages of ISEP-Veroboards include ease of access to components, and ease of adaptability to suit changing requirements. Specially designed terminal pins to fit the board holes (which are spaced out on a 0.1 in matrix) are available, as well as a tool for inserting pins at the rate of 1,000 an hour, and a cutter for making breaks in the copper strip.

WW 315 for further details



Vibration Monitor

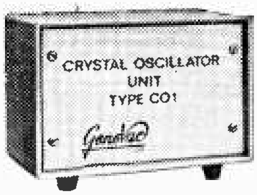
ALTHOUGH primarily designed to measure vibration levels at the engine bearings of jet airliners, the Vibration Monitor developed by the Plessey Dynamics Group will find many applications in marine and other industrial fields, where vibration can lead to fatigue of basic materials, or where vibration levels are excessive and therefore unacceptable for reasons of safety, reliability or accuracy. The equipment consists of two units, a display unit containing a bank of up to 12 vertical scale indicating meters, and a remotely located amplifier unit containing an amplifier for each transducer channel. The amplifiers, completely interchangeable and identical with each other, are of the integral subminiature type housed in a single semiconductor can. The voltage gain is 100dB up to 1 Mc/s, and response is flat to 2dB over the range 80 c/s to 200 c/s, falling to −23dB at 25 c/s to meet specified requirements. The gain of each amplifier can be varied by means of a preset adjustment. Maximum operating temperature rating is 75°C. The equipment is provided with a built-in self-checking function: a two position switch spring-loaded to the "normal" position, tests all channels simultaneously when held in the "test" position. Normal "no faults" operating gives a mid-scale reading on the indicator, whereas a short-circuited transducer gives no reading and an open circuit a full scale reading. Transducers, not included in the equipment, should be of a type conforming to ARINC 554 characteristics. Plessey Electrical Equipment Division, Eastern Avenue, Romford, Essex.

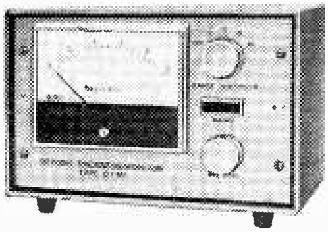


WW 316 for further details

Thin-Film Monitor

A NEW film thickness monitor from Genevac Limited, Pioneer Mill, Radcliffe, Manchester, is designed for measuring the total thickness and also the rate of deposition of vacuum-deposited thin films. This is achieved by collecting a portion of the evaporant stream on a quartz crystal mounted in a suitable position within the evaporator. Using the principle of the linear change of resonant frequency with increasing mass of the monitor crystal, the device indicates the change as a displayed d.c. voltage and likewise indicates the rate of change of this voltage. Feedback can be taken from the instrument and used to control the heat input to an evaporation source and hence the rate of deposition; also the end point of the evaporation can be preset by using the instrument to operate an electro-mechanical shutter. The instrument can be used to control both laboratory and production depositions with a high degree of repeatability. The total mass deposited is indicated over four ranges of 1, 5, 10, 50 kc/s full-scale deflection. Provision is made for backing off to zero between consecutive depositions; the crystal requires cleaning at intervals of approximately 60 kc/s shift. The control unit is housed in two cases both 9in wide, 6in high and 6in deep; one case contains all the necessary power supplies and displays the mass deposited; the second case displays the rate of deposition. The electronic circuitry of the oscillator, which is in a separate unit, is placed close to the evaporator and connected to the monitor's quartz crystal through a coaxial vacuum seal.





WW 317 for further details

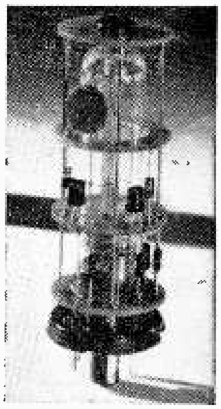
INSTRUMENT CASE

MODERN style instrument cases are being manufactured by Vero Electronics Ltd., of Chandler's Ford, Hampshire. Plastic side frames incorporating handles are injection moulded in dove grey "Cycolac" polymer, which, with four substantial aluminium extrusions offer a strong, rigid frame. The cover panels are aluminium, coated with p.v.c. (charcoal grey or green). Parts can be packed flat in kit form, and assembly takes about 15 minutes using a screwdriver. One size only is available at the moment to accommodate a unit 19 in wide × 7 in high, and 15 in deep.

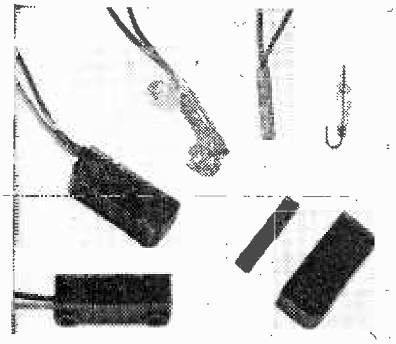
WW 318 for further details

Crystal Oscillator

PLUG-IN crystal oscillators intended as medium stability frequency sources, are now available from the Marconi Co. Ltd. Each of the oscillators in this range possess a glass encapsulated quartz crystal, with the buffer output stage (solid-state) circuitry accommodated around it. Housed in aluminium tubes 1.125 in in diameter and mounted on international octal valve bases, type F3170 units cover the frequency range 1 to 115 kc/s. The seated height will vary between 3.125 in to 5 in, depending on the frequency of the unit. Type F 3171 units, mounted on B7G valve bases, cover the frequency range 115 kc/s to 100 Mc/s, and they can be housed in standard F3006 crystal ovens for enhanced frequency stability. With a seated height of 3.125 in, these units are provided with ¾ in diameter cylindrical aluminium covers. Frequency stability of both types is better than 1 part in 10^{4} within the temperature range −20° to +70° C. The frequency of the units can be trimmed by an external capacitor located between a base pin and earth. The buffer output stage will maintain a frequency stability of 1 part in 10^{6} for a 10% variation in load impedance. The output impedance is 5 kΩ ± 10% with an output of 2 V peak to peak. A 6 V supply is required. Marconi Co. Ltd., Chelmsford, Essex.



WW 319 for further details



REED SWITCH

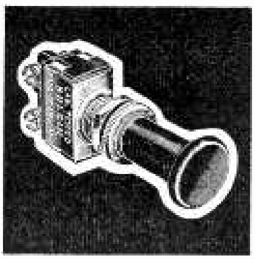
MOULDED reed switches of a new design are available from West Hyde Developments Ltd. The glass envelope is shielded by a brass sleeve, which in turn is completely encapsulated in a polypropylene moulding; it is thus claimed that the attendant risks to the normal fragile housing of such reeds are considerably reduced. It is stated that test switches have been working continuously for 5×10^{10} operations, at a rate of 100 operations/s. Applications for this moulded reed switch with hermetically sealed contacts include over and under speed monitors, flow and conveyor monitoring, routing control, counting, press tool protection and guards, position detection, timing, and proximity detectors. The switches will give operations either directly, or through plug-in diode-transistor-logic modules on B9A bases including relay drivers, monostable Schmitt triggers, and AND gates. West Hyde Developments Ltd., 30 High St., Northwood, Middlesex.

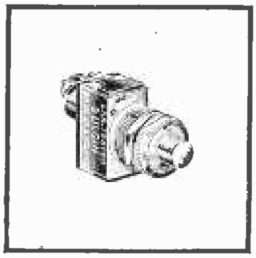
WW 320 for further details

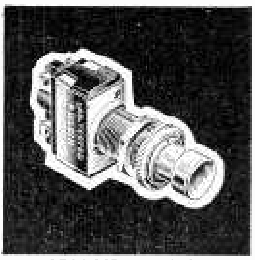
2-Way CdS/CdSe Cell

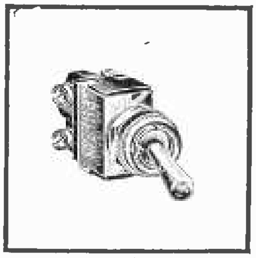
THE photoconductive cell PH50 made by Photain Controls Ltd. has an element consisting of a mixture of cadmium sulphide and cadmium selenide, with resistance variations from 2 MΩ in the dark to 3 kΩ at 100 lux. It will operate in the range 6 to 200 V d.c. with a permissible continuous power dissipation of 200 mW. The glass encapsulation allows it to operate over the temperature range −30°C to +60°C. Since it is sensitive to both side and end illumination, it can be used in oil burner and flame failure controls, where a standard housing is required for mounting into the blast tube of a burner, whilst at the same time being suitable for end-on mounting on to the front plate of the boiler. Photain Controls Ltd., Randalls Road, Leatherhead, Surrey.

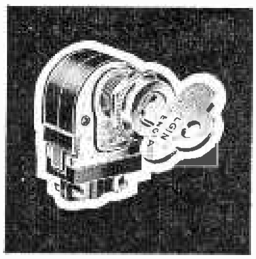
WW 321 for further details

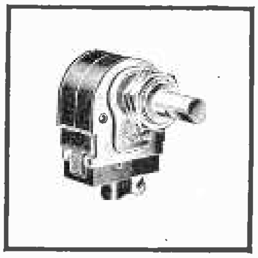


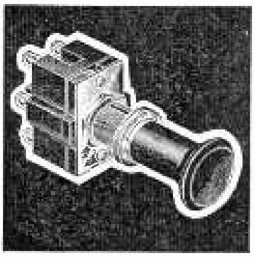


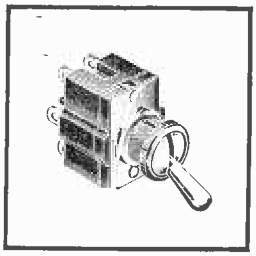


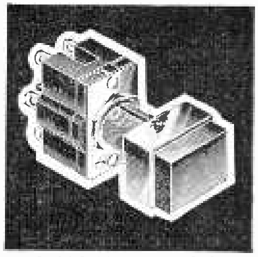


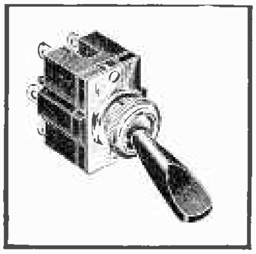


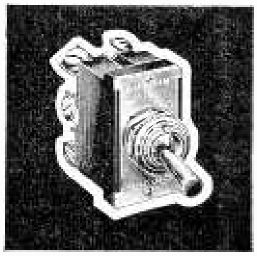


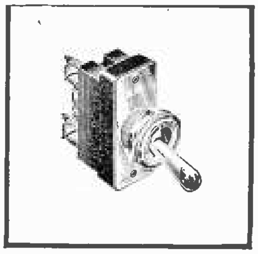












Real and Imaginary

By "Vector"

"Something Nasty in the Woodshed"

IT cannot have escaped your notice that just about everybody has been having a go at the great television controversy and getting all hot under the colour in the process. You will be relieved to learn, I intend to stand aloof from the hurly-burly (largely because nobody would take the slightest notice anyway). Instead, I would like to take the opportunity of reminding my One Regular Reader of the root cause of all this 405-625-colour wrangle.

Knowing that television broadcasting is allegedly dedicated to serving the best interests of the viewer, the otherwise uninformed foreign visitor might reasonably suppose that the ruckus has been brought about by a revolt on the part of the proletariat. But if inflamed mobs are storming Pearlcasting House bearing banners inscribed "We demand the Black & White Minstrels in colour!" or "Give us 200 extra lines!" all I can say is that the newspapers are keeping awfully quiet about it.

Drawing blank in this quarter, our visitor might then turn his attention to our various national Aunt Sallys. The Government, perhaps? Well, certainly the Conservatives gave us some action. They very kindly pledged about £150M of our money to support a third service which the viewers didn't particularly want and most certainly couldn't afford. The Labour Government condoned this project, but in view of the national economic situation have taken the most rigorous steps to ensure that nobody can buy a new receiver to make use of the service. But, as everyone knows, no government has ever been known to act of its own volition, but only when someone is kicking it in the rear, so our hypothetical foreign visitor must look elsewhere for the culprit.

This brings the B.B.C., the I.T.A. and the programme companies under the bright lights for grilling. Here we have some circumstantial evidence, for the B.B.C. is already going ahead with the third service and promising colour, while the I.T.A. is going R G B with rage, envy and frustration. But stay. A moment's thought will produce the paradox that neither they nor the programme contractors really wanted another service or colour any more than elephants want wings. The B.B.C. took it on because it was told to, and because if it hadn't the opposition soon would have. If the roles had been reversed, the situation would have been a mirror image of the present one, in which the I.T.A. has to agitate for parity in the cause of preserving its programme ratings. Similarly, deep down in their cheque-books, the programme contractors and advertisers wish colour TV had never been invented, because it will undoubtedly cost much more but will sell no more soap powder or what have you. But if they don't go into colour they won't sell as much as they do now, so although they don't want it they must have it.

Personally, I don't think the commercial boys need get so het up as all that. It will be a long time before colour sets are in anything but a minority and they could well leave it to the B.B.C. to get the gremlins out before chipping in—after all, this worked on the black-and-white service. But that's a digression. The point to note is that neither the B.B.C., the I.T.A. nor the programme contractors started the agitation.

This leaves only one more suspect, namely the domestic radio industry itself. But what was the motivation?

The answer lies back in the early 1920's when sound broadcasting was born. The boom in domestic receivers and components which followed was completely unexpected. It happened because conditions were exactly right; there was the magic of conjuring voices from thin air; the fact that the cost of a crystal set did not overstrain even a modest pocket, and the circumstance that the home construction of simple receivers could bring a local kudos which was out of all proportion to the skill demanded. The situation was equivalent to the winning of a first dividend on the football pools.

Fair enough. But with the growth of the boom emerged the dangerous philosophy that it, like Tennyson's brook, would go on for ever, or even if it didn't, another first dividend would materialize in its place. The domestic receiver industry became addicted to pulling down its barns and building greater, regardless of the biblical warning concerning such conduct. Came the dawn, when, with overseas markets neglected and saturation point looming at home, the rosy dreams of yesteryear were ousted by nightmares about over-production.

Television was hailed as the saviour of the situation, but first dividends, like lightning, rarely strike twice in the same spot. This time the conditions were not precisely right. The price tag on the television receiver was too high, there was no crystal set equivalent and no home construction on a massive scale. The sales curve took a long time to get off the ground and when it did no vast fortunes were made in the domestic receiver industry. Nevertheless for some years television served to prevent the wolf from shouldering open the doors of many a factory.

But instead of using this period as a breathing space in which to rationalize the size of the industry to an off-peak demand, the receiver manufacturers have constantly attempted suicide, using the weapons of price-cutting and gimmickry. The public, too, has suffered; for example, the high-quality potential of the v.h.f./f.m. sound service has been nullified by cut-to-the-bone circuits and tinny 6in loudspeakers; in the television field, very few have ever seen a 405-line picture as it could be and should be and the accompanying sound reproduction leaves much to be desired.

The present appalling muddle has largely been brought about by the industry's frenzied lobbying to sustain an artificial level of demand. The u.h.f. television service has boomeranged to clonk the manufacturers on the side of the head with a dual-standard design requirement and Nature has very unsportingly refused to modify her laws of electromagnetic wave propagation to suit their desires. As for sales, there is patently no first dividend here even if there had been no credit squeeze. Colour? I don't think anyone is so wildly optimistic as to visualize an avalanche of colour receiver sales in the foreseeable future (and if the Earls Court Radio Show demonstrations were anything to go by, the hand of Providence is in that).

So, to end on a cliff-hanger note, we leave the villain of the piece, the receiver industry, still struggling wildly to get out of a pit of his own digging, while the American takeover tiger purrs smilingly down over the rim. Will he perish miserably at the bottom or will he find the foothold of rationalization in the nick of time? If so, will he be devoured by the tiger?