WW—001 FOR FURTHER DETAILS

Wireless World

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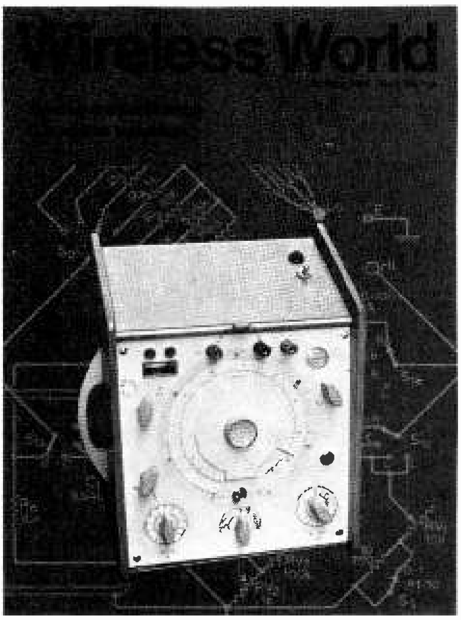

This month's cover features the universal components bridge for which constructional details are given in this issue.

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Wireless World

Our New Master

When the Post Office Bill becomes law (albeit, we hope, in modified form in some respects) we in the United Kingdom will have a new master. No longer will the master of the Post Office (or to give him his more common title the Postmaster-General) be the overlord of radio communication. All telecommunications—and it would appear a great deal more in the field of communications—will come under the jurisdiction of the Minister of Posts and Telecommunications. The new Post Office, which is to become a public authority, will no longer be the controlling body in radio matters. The new "P.T.T." Ministry will "license radio stations, control frequency usage and regulate and co-ordinate the use of apparatus for transmitting and receiving". The Minister of Posts and Telecoms will also be responsible for the oversight of the new Post Office and will assume the present responsibilities of the P.M.G. for the broadcasting authorities.

It has frequently been suggested that the regulatory powers regarding frequency allocation should be withdrawn from the Post Office (because it is both user and arbiter) and that a British counterpart of the American Federal Communications Commission should be set up. The changes planned in the Bill, are, therefore, seen as a move in the right direction. But....

Under the Wireless Telegraphy Act 1949 the Postmaster General has regulatory control of "apparatus generating, or designed to generate, or liable to generate fortuitously, electro-magnetic energy at frequencies of not more than three million megacycles per second". This upper frequency limit has been seized upon by the people who are organizing Radio Love (referred to in our "news" pages this month) who undoubtedly and justifiably considered that laser beams did not come under the control of the P.M.G. It was obvious, of course, that because of the gradual disappearance of the "generator gap" between radio and light waves (as pointed out in our review last month) sooner or later the upper limit of that part of the radio spectrum coming under the P.M.G's jurisdiction would be raised. It would appear, however, from Part IV of the new Bill that our new overlord is going to be a harder task master than his predecessor.

As the Bill stands at present the Minister will control without specifying frequency limits the use of "electric, magnetic, electro-magnetic, electro-chemical and electro-mechanical" energy for the distribution of sound and vision programmes "to inform persons of anything or to educate or entertain them". The mind bogles at the measure of control which could be imposed under such sweeping powers. Will the overlord try to license magnetic recording? One could, of course, say that our car trafficators and indeed traffic lights, railway signals and a thousand and one other visual indicating devices (all using electro-magnetic energy in the optical part of the spectrum) are "to inform persons"! But, to be serious, it now seems that those who drew up the Bill are absolutely determined to make sure that no loop hole has been left in the regulations governing the Minister's monopoly of telecommunications. While such a monopoly is probably necessary in order to ensure that our telecommunications are controlled fairly, for the benefit of the whole community, one hopes that it will be used in a charitable manner and that the new Minister will not become a telecommunications dictator. (Never mind—there's always telepathy!)

Universal Component Bridge

R, L, C measurement to 1% accuracy with out-of-balance amplitude and phase indicated on a cathode-ray tube

by L. Nelson-Jones, M.I.E.R.E.

The component measuring bridge described here was designed with the emphasis on ease of use, and to this end it uses a miniature cathode-ray tube to display the balance state of the bridge on the capacitance and inductance ranges. This type of indicator enables both the amplitude and phase of the out-of-balance quantity to be displayed, and also indicates if the component has non-linear tendencies, as shown in the illustrations later in the article. The ability to see both the magnitude and phase of the out-of-balance enables the null to be found with much greater speed and ease than with an indication of amplitude alone. This is especially true with inductors of low Q value.

The instrument covers a wide range of values, as can be seen from the specification, and is generally in line with the performance and coverage of the majority of similar commercial instruments. Its accuracy depends on the resistor and capacitor standards used. With the values specified it is better than 1% on resistance, except at the extremes of the coverage, where indicator sensitivity limits the accuracy (see later). On the capacitance ranges the accuracy is also better than 1%, and the zero value of capacitance of the bridge may be reduced to a true zero as described later. On the inductance ranges the accuracy is in general better than 1%, but at the extremes of the coverage it falls to about 2%, since the bridge is optimised for the capacitance ranges. Very low-Q inductors, especially ones of low inductance, also give a lower accuracy than the basic 1%.

The completed component bridge, with a capacitor connected for measurement. (See front cover for details.)

Basic bridge circuits

The basic bridge circuits used in the instrument are shown in Fig. 1 (a), (b), (c) and (d). On the resistance ranges the basic circuit used is the Wheatstone bridge, (a). Energization is provided from the h.t. supply via a potentiometer (shown here as a battery of 75 volts maximum with a series resistance). The arm R_A is the ratio arm, having values of 1 Ω to 1 MΩ, and this same ratio arm is used for all other ranges, both capacitive and inductive. The arm R_S is the standard arm, which is of 10 kΩ, while RV_1 is the calibrated balance arm. This balance arm is in fact a 10 kΩ potentiometer in series with a 750 Ω fixed resistor, so that the values 1 kΩ to 10 kΩ are covered fully, despite the 5% tolerance on the overall value of the potentiometer. Provision is made to switch out the 750 Ω resistor, and the dial of the balance arm is calibrated with an additional 0–1 scale at the lower end of the range only.

In practice it will be found that the lowest resistance range of the instrument, covering up to 1 Ω, is of so low a sensitivity that it cannot usefully be used except with an external indicator of much higher sensitivity, and this is the reason for the resistance ranges being quoted as 1 Ω to 1 MΩ, and not 0·1 Ω to 1 MΩ as would seem correct from the spread of the inductance and capacitance ranges. External galvo terminals are provided so that greater sensitivity can be obtained on the extreme ranges if required. Additional sensitivity could have been obtained by the application of the full h.t. supply to the bridge, but for reasons of personal safety this could not be justified, and in addition there would have been trouble with excessive dissipation on some ranges. The use of a push-button for the two levels of energization supplied to the bridge (see Fig. 2) enables a much higher sensitivity to be obtained from the instrument than the meter sensitivity of 100–0–100 μA might indicate. This is achieved by using the push-button as a tapping key and watching the meter pointer until it stops pulsating while adjusting the balance arm. Out-of-balance currents of less than 1 μA may easily be seen in this way, and in addition any out-of-balance inherent in the meter movement is of no importance with the method. 1% discrimination is possible (with the internal indicator) between 10 Ω and 100 kΩ.

Specification

Resistance	1 Ω–1 MΩ
Capacitance	10 pF–100 μF
Inductance	10 μH–100 H
Loss (capacitance)	Q values from 10 upwards
Loss (inductance)	Q of any value: 0–10 Maxwell (series loss) 10–∞ Hay (parallel loss)
Accuracy	better than 1% (see text)

On the capacitance ranges (Fig. 1(b)) the ratio arm is as in the resistance measuring circuit, and so is the balance arm RV_1. The standard arm consists of a standard capacitance C_1 of 10,000 pF nominal value, together with the variable series-loss resistor RV_2 of 1 kΩ. Use of this standard value of variable resistor is made possible by arranging the energization frequency to be 1,592 Hz (for which $\omega = 2\pi f = 10^4$). Had the bridge used the usual frequency of 1 kHz the variable resistor would have had to be 1·592 kΩ for $Q = 10$, the lowest value covered—a Q value chosen so that the error in the Hay inductance bridge configuration (Fig. 1(d)) will not exceed 1%. The instrument is not intended for the measurement of electrolytic capacitors, and therefore Q values of less than 10 are not allowed for on the capacitance ranges. There is no reason why the lower values of Q should not be catered for, if required, by switching in the parallel 100 kΩ used in the Maxwell inductance configuration for Qs of 0–10.

The main problem with the capacitance bridge comes from stray capacitances, especially across the balance arm B–D of Fig. 1(b). Stray capacitance to ground across this arm has the effect of making the standard capacitor C_1 "look" as if it is lossy, so that the effective minimum value of the series-loss resistor is not zero. In the case of the present design a minimum value of about 20 Ω was at first achieved, despite the use of a special low-capacitance screened coupling transformer for the bridge energization and the exercise of great care with the wiring layout. In many commercial bridges this problem is overcome by the use of a lower impedance for the balance and standard capacitance arms (usually 1 kΩ and 0·1 μF), so that the effect of stray capacitance is greatly reduced and may be safely ignored. This solution was rejected because of the difficulty of obtaining capacitors of suitable type (silvered mica) having values above 10,000 pF, and also because it was felt that the resolution of the balance arm would be inadequate if it were of 1 kΩ value. The solution eventually found to be fully successful was to inject into point *B* of the Fig. 1(b) circuit a voltage which is in anti-phase with that normally present at point *C*, and to inject that voltage through a capacitor nominally equal to the stray capacitance present. This capacitor is VC_3 of Fig. 2.

The use of this balancing voltage has the additional effect of largely eliminating the small zero error in the readings of the lowest capacitance range. A fixed setting of the capacitor VC_3 can be used since the stray capacitance does not vary appreciably with the value of the ratio arm R_A. The only side effect caused by this correction technique, and also by the stray capacitance across arm *C–D* is to make the optimum value of the standard capacitance C_1 less than the nominal value of 10,000 pF by about 60 pF, a value of 9,940 pF being used in the prototype. The value needed is within the 1% tolerance of standard types of silvered mica capacitors, so that no difficulty should be experienced in finding the required value by selection on an accurate bridge. If this cannot be done an additional small error will be present on the capacitance and inductance ranges so that the basic accuracy will only be about 1·5% overall.

On the inductance ranges (Figs. 1(c) and 1(d)), the Hay configuration is used for high-*Q* inductors (*Q* above 10) and the Maxwell configuration for low-*Q* inductors (*Q* below 10). The Hay arrangement uses the same components as the capacitance range with the balance and standard capacitance arms inter-changed. In the Maxwell arrangement the series loss resistor RV_2 is replaced by a parallel variable loss resistor of 100 kΩ with the addition of a 1 kΩ fine control to make balancing easier with inductors of very low *Q*. In all other respects the two inductance bridge configurations are identical. The balancing voltage via VC_3 remains connected in the inductance bridges, across the balance arm RV_1. The value for VC_3 will not, of course, be identical for all the bridge configurations but the difference is not great. However, since the *Q* values of capacitors are in general much higher at 1592 Hz than the *Q* values of typical inductors, it is more important that the errors in the reading of the loss balance control are corrected on the capacitance ranges than on the inductance ranges, where, with lower *Q*s, the percentage error will be much less.

Power dissipation in R bridge

Maximum dissipation in a resistance under measurement depends on the value of the resistance, and on the range, and setting of the balance control at the time. Worst conditions are with the balance arm at zero,

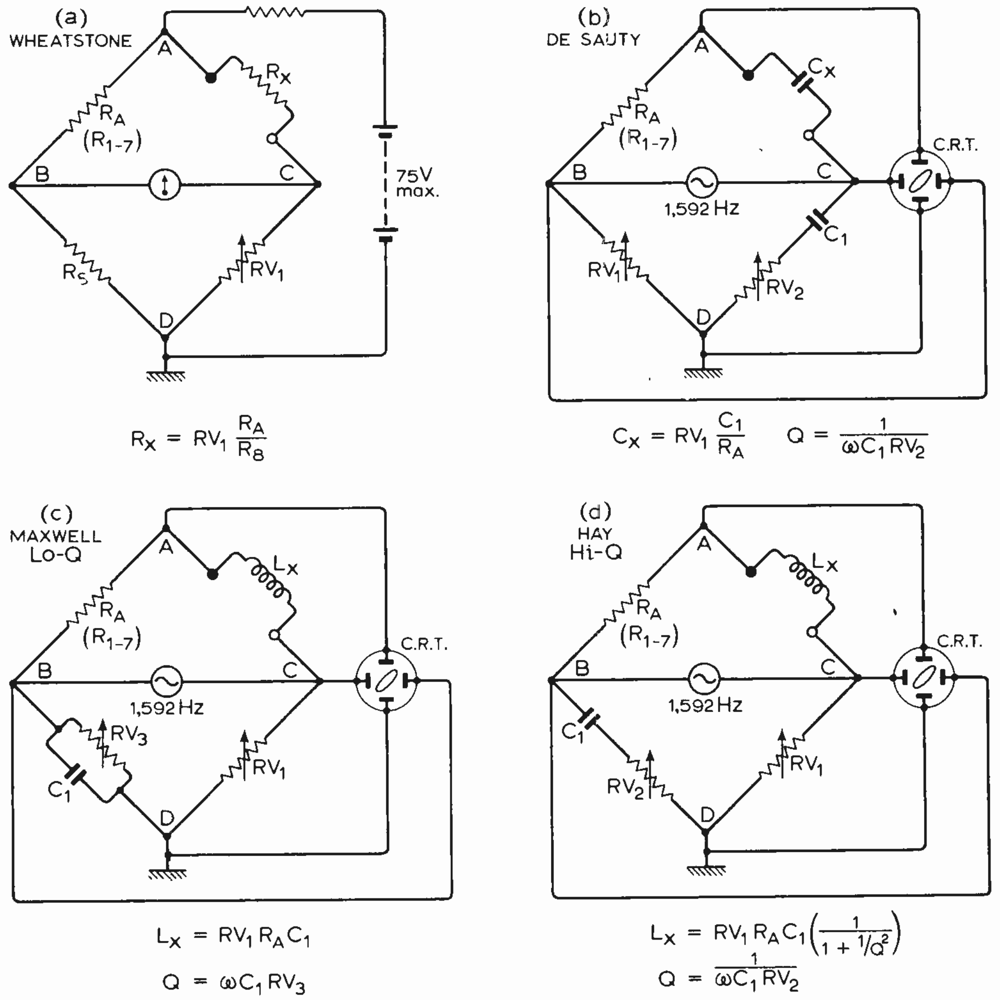
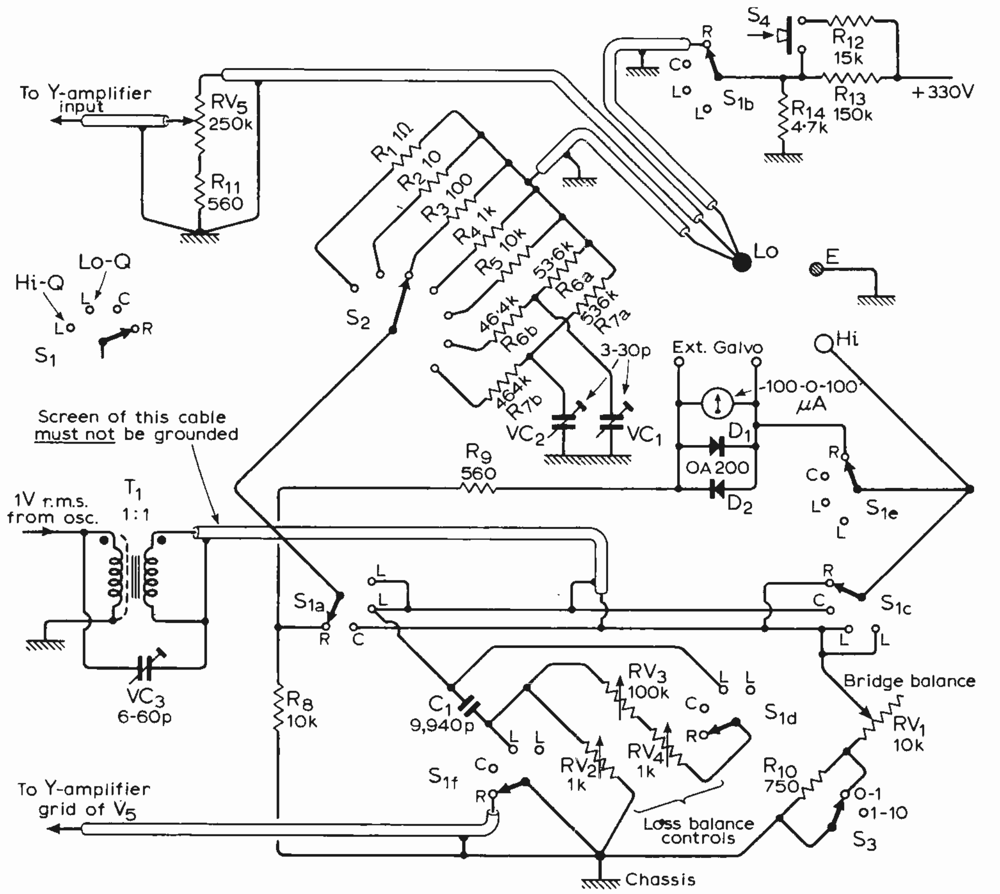


Fig. 1. Basic circuits used: (a) resistance bridge (Wheatstone); (b) capacitance bridge (De Sauty); (c) low-Q inductance bridge (Maxwell); (d) high-Q inductance bridge (Hay)

Fig. 2. Full circuit of the R, L, C component bridge. (Press-button S_4 *at top right.)*



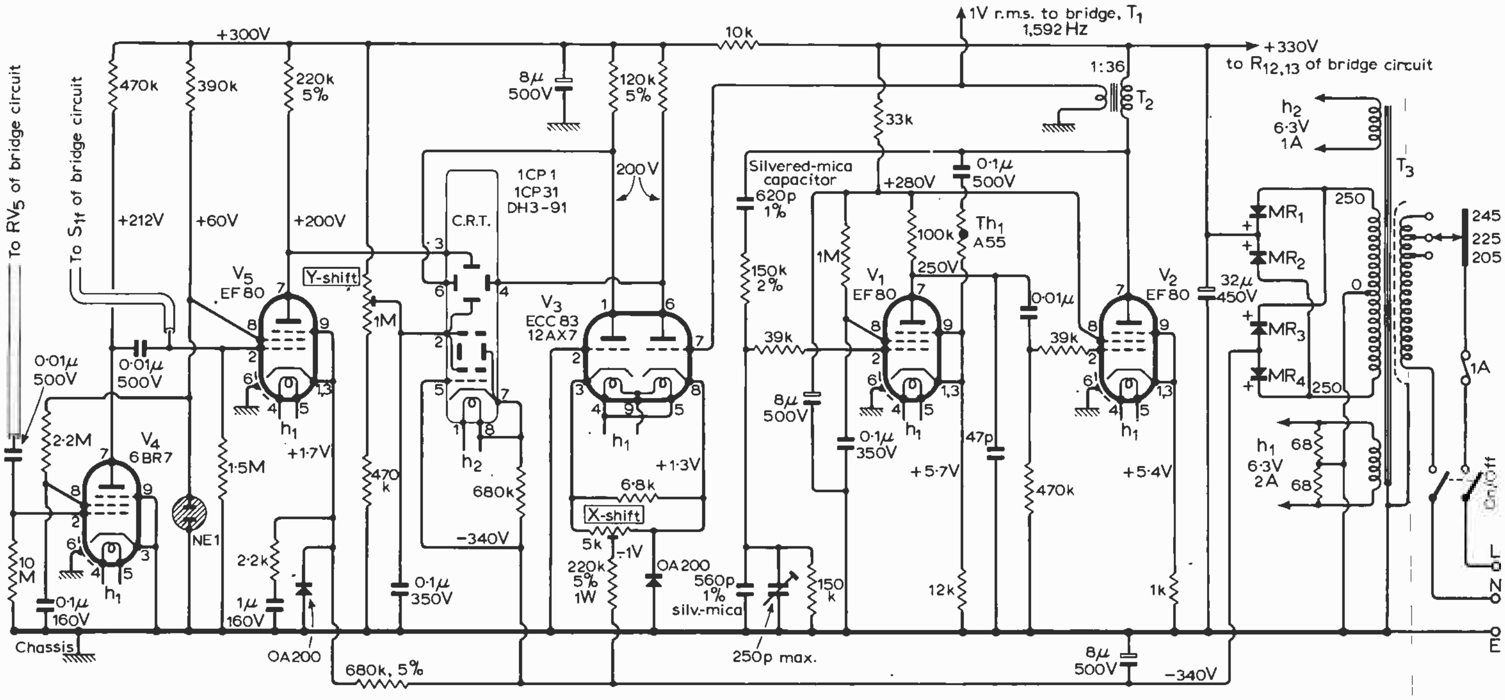


Fig. 3. Circuit of the cathode-ray tube display, the Y and X amplifiers, the bridge energization oscillator, and the power supply

the range switch at the 100 kΩ–1 MΩ range, and the sensitivity press-switch closed. Under these conditions maximum dissipation reaches a fairly flat maximum between 3 and 3·5 kΩ of 440 mW, but this is a condition unlikely to be met in practice. Assuming that normal balance has been established before the press-switch is closed, the maximum dissipation is at about 1·5 kΩ and reaches 180 mW, but this can be limited by keeping the press-switch closed for short periods only. Indeed it is for this purpose, as well as to allow for its use as a "tapping key", that such a biased switch is fitted. With the press-switch open, maximum dissipation is limited to less than 6 mW at a value of about 4 kΩ.

As has been said above the voltage available at the terminals of the bridge is limited to 75 volts maximum by the use of a potentiometer across the h.t. supply, the values for which are also chosen to limit the current to a safe value. The guiding values used to determine these limits were the normal maxima allowed on Post Office line equipment—where 75 volts with respect to ground and a maximum current of 50 mA are the accepted safe limits. The voltage is limited to 75 volts, but the current is restricted to 22·5 mA to limit dissipation in the resistor under test. This point was felt to be of importance in the design of the bridge, and is a matter that has not always received sufficient attention, especially in the earlier models of some commercial equipments—as the author has had painful cause to remember. In practice it is difficult to get a shock as it is not normal to both press the switch S_4 and touch the insulated terminals or the component leads at the same time, and with S_4 open the maximum voltage is only a few volts and the current does not exceed 2·2 mA.

Oscillator design

The oscillator used (Fig. 3) is a Wien bridge circuit with thermistor stabilisation, and there is no separate output stage. The output from the secondary of the output transformer is 1 volt r.m.s., and the frequency, as has been said, is nominally 1,592 Hz. In practice it is easier to set this to 1,600 Hz by forming a Lissajou figure against the 50 Hz mains, and the error in Q measurement is very small compared to the accuracy of the basic Q measurement, of about 5%.

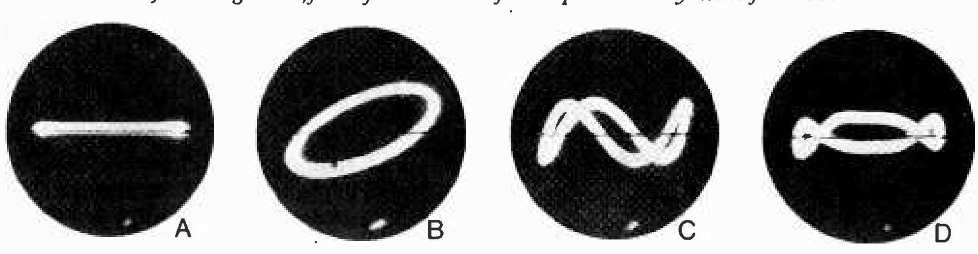
The frequency is adjusted by means of a variable capacitor in the Wien bridge, but a variable resistor would serve equally if preferred. When using the Lissajou method it is preferable to use the 50 Hz for the X deflection, with a small amount of 50 Hz (in quadrature) applied to the Y axis together with the 1,592 Hz from the oscillator, so that the forward and return traces are separated.

The design of the oscillator follows normal lines for a Wien bridge, and the only point which must be emphasised is that since an output transformer forms the load it is necessary to reduce loop gain at the high frequency end of the pass band of the amplifier to maintain freedom from spurious oscillation. This is achieved by the inclusion of a 47 pF capacitor from the anode of V_1 to ground, and grid stoppers are also fitted to V_1 and V_2. The screen of V_2 and the supplies to V_1 are decoupled and smoothed by an 8 μF electrolytic and a 33 kΩ resistor to reduce the hum content of the oscillator output, and to improve low frequency stability.

Y amplifier design

The first stage of the Y amplifier is a low-noise pentode, operated with "grid current" biasing, so that the cathode may be directly earthed to avoid heater-cathode hum troubles. For satisfactory operation in this mode a very low screen potential must be used (in this design around 12 V) and this is derived from a 60-volt line stabilized by a miniature neon tube NE1. This use of a stabilized supply ensures additional stability of the output stage anode voltage since the screen potential of the output stage is also stabilized by the neon tube. However, the main factor contributing to the high stability of the current in the output stage is the fact that the cathode bias resistor of the stage is returned to the −330 V line so that this resistor rather than the valve characteristic determines the anode current. To ensure freedom from heater cathode breakdown on

Fig. 4. Examples of displays on the c.r.t. balance indicator: A display for balance condition; B out-of-balance on both L and C ranges; C at balance when measuring a barrier layer Hi-K ceramic capacitor, 0·22 μF 20 V; D at balance with iron or ferrite cored inductor, showing the effect of variation of core permeability with flux level



switching on (when the valve is non-conducting) a diode is connected to catch the cathode potential at −0·6 volts. The gain of this stage is increased by a controlled amount by the cathode by-pass path consisting of 2·2 kΩ in series with a 1 μF capacitor. Some degree of cathode degeneration is necessary to linearize the transfer characteristic for the fairly large voltage swing required of this output stage, hence the 2·2 kΩ in this cathode bypass path.

Overall sensitivity of the *Y* amplifier is such that 2·5 mV r.m.s. causes 1 centimetre deflection of the c.r.t. spot. This represents a voltage gain of approximately 8,700 times in the *Y* amplifier.

X amplifier design

This stage is a straightforward long-tailed phase splitter with a degree of cathode degeneration caused by the two halves of the balancing potentiometer. The gain of the stage is set by the resistor by-passing this potentiometer. The long tail is returned to the −330 V line. The input to the stage is the output of the oscillator (1 volt r.m.s.) and the output is connected directly to the balanced *X* deflection plates of the c.r.t. The value of the long tail resistor is chosen to achieve the same anode potential as that of the output stage of the *Y* amplifier, in order to avoid astigmatism of the c.r.t. spot. The balance potentiometer is set to centralize the spot on the c.r.t. screen in the *X* direction, hence the label "*X*-shift".

Cathode ray display

The 1CP31 tube used has asymmetrical *Y* deflection and symmetrical *X* deflection plates, and will operate anywhere between 350 and 1,000 volts anode-cathode potential. The focus is automatic over this range. In the circuit described the tube operates at approximately 500 volts and auto-bias is used since the operating conditions of the tube are known to close limits, i.e., it is only required to operate on an ellipse within the screen diameter.

The only control is a potentiometer controlling the anode potential of the tube, which with an asymmetrical deflection system acts as the *Y* shift control.

Overall bridge circuit design

Selection of the bridge circuit required (Fig. 2) is achieved by S_1 and the range of the bridge by S_2. S_{1a} and S_{1c} select the lower arms of the bridge. S_{1b} connects the h.t. supply on the resistance range only. S_{1d} connects the low-*Q* variable loss control in the Maxwell inductance bridge circuit. S_{1e} connects the d.c. balance meter on the resistance range, and S_{1f} shorts out the high-*Q* variable loss control in the Hay inductance bridge configuration and also serves to cut the gain of the *Y* amplifier to zero on the resistance range, by shorting the grid of V_5 to ground.

In order to keep stray capacitance to a minimum the d.c. balance meter is connected to the standard resistor rather than the rotor of S_2. The *Y* amplifier is permanently coupled to the top of the bridge, and all leads at this point are screened to cut down hum pick up. Stray capacitance at this point is of little consequence since it is across the input of the *Y* amplifier and does not affect the balance of the bridge. It is for this reason that the measurement terminal connected to the top of the bridge is called the "low" terminal, and the terminal connected to the right hand side of the bridge, the "high" terminal.

Energization to the bridge is via a low-capacitance 1 : 1 transformer (fully described in the appendix). The transformer is connected so that the phase of the arm connecting to the standard capacitor is opposite to the phase of the oscillator output on the primary of this transformer. The capacitor VC_3 then connects between these points to provide the correction for stray capacitance as described above. The lead from the transformer to S_{1a} and S_{1c} is an insulated screened lead, with the screen used to connect the secondary of the transformer to the standard capacitor. This method of construction still further reduces the stray capacitance on the balance arm of the bridge.

Further phase correction is required on the two highest impedance ranges of the capacitance bridge. This correction is provided by VC_1 and VC_2. These capacitors are set using an air-spaced capacitor of low loss to give a zero setting of the loss control at balance. If the setting of the capacitor on either range is less than the minimum a small silvered mica capacitor should be placed across the whole centre-tapped range resistor, which will bring the capacitor within the range of adjustment. A capacitor of only a few picofarads will be needed. (A ceramic capacitor may also be used if silvered mica types of low value are not available.)

The range resistors are wire wound on the four lowest ranges, while on the three remaining ranges metal film resistors are used. Metal film resistors may, however, be used on all ranges. The standard resistor of the resistance range is also a metal film resistor. Full details of suitable resistors are contained in the appendix.

The d.c. balance meter is protected from overload by the two diodes D_1 and D_2 together with the 560 Ω resistor.

Using the bridge

Resistance Ranges. Select *R* on the switch S_1 and rotate the balance control (with the 0–1/1–10 switch to 1–10). If a balance is not obtained rotate the switch S_2 in a direction depending on the movement of the out-of-balance with variation of the balance control. If the error increases with increasing balance arm reading, reduce the ohmic value of the range. If the error decreases with increasing balance arm reading, increase the ohmic value of the range. When a balance point is found press the d.c. sensitivity press switch S_4 and using this as a "tapping key" find the exact null.

Capacitance Ranges. Select *C* on the switch S_1 and rotate the balance control (with the 0–1/1–10 switch to 1–10 and the *Y* gain control RV_5 set to a low gain). If a balance is not obtained proceed as with the resistance ranges in finding the correct range. As the balance is found, increase the *Y* gain until (with the use of the high-*Q* control) a horizontal line is obtained as shown in Fig. 4A, with the gain fully up. The 0–1/1–10 switch S_3 may be used on the 10–100 pF range (the lowest) to provide a 0–10 pF range of limited accuracy but nevertheless useful. As has already been said the zero error is negligible (due to the use of VC_3 to compensate for stray capacitance). Since the steps on the potentiometer are visible and represent about 0·1 pF each, this extension of the lowest range is quite sensitive, and useful.

Inductance Ranges. Select either *L* (low-*Q*) or *L* (high-*Q*) as required and proceed as with the capacitance ranges. The 0–1 switch is of little use on the lowest range of the inductance ranges since the secondary of the bridge supply transformer is deliberately wound with resistance wire to prevent the oscillator being shorted out by the very low bridge impedance on the high capacitance and low inductance ranges (where the ratio arm is 1 ohm). The use of the resistive transformer winding reduces the sensitivity of the bridge on these extreme ranges, but the effect only becomes severe on the very low inductance range with a very low *Q* value. Consequently the 0–1 range extension is not usable on this lowest inductance range because of the very broad null.

Calibration. This is best carried out using an accurate decade resistance box (preferably of 10,000 Ω total value) on the 0–10 kΩ range, which is the most sensitive. The capacitance ranges may be checked with standard capacitors, or by measuring a range of capacitors on a known accurate bridge and then checking these on the bridge. The loss balance control may be checked by placing known values of resistance in series with a low-loss capacitor to make it lossy.. A similar method of connecting a resistor in series with an inductor of high-*Q* may be used to check the low-*Q* loss balance control. Some readers may prefer to calibrate the loss controls in terms of "*D*", the loss factor ($D = 1/Q$). This gives a linear scale on the high-*Q* control whereas a *Q* scale gives a linear scale on the low-*Q* control.

Note. Before calibration the bridge must be set up for correct values of VC_1, VC_2 and VC_3. The bridge is set to the 1,000–10,000 pF range and a good quality silvered mica capacitor is connected for measurement. The bridge is balanced with the high-*Q* loss control set to infinite *Q* ($D = 0$). The capacitor VC_3 is then adjusted while maintaining balance with the balance control RV_1 until a setting is found where the oscilloscope display is a horizontal straight line (at exactly the same angle as that present when the bridge is switched to the resistance ranges). A horizontal line is

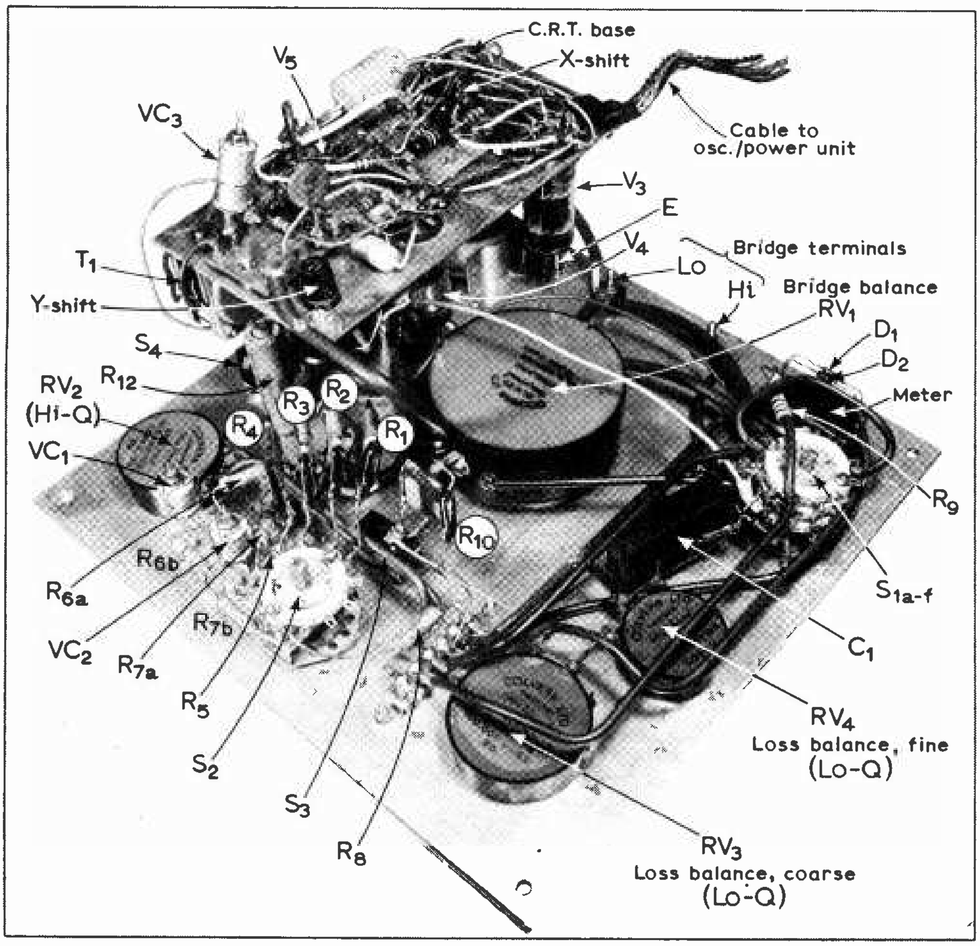


Fig. 5. Rear view of bridge front panel, showing the location of the X and Y amplifiers and the principal bridge components

scribed on the Perspex panel as an X reference line and the trace should be aligned to this using the X and Y shifts and rotating the tube while the bridge is switched to the resistance ranges). The bridge is next switched to the 100–1,000 pF range and an air-spaced variable capacitor connected for measurement (the frame of the capacitor to the low terminal). A twin gang 365 pF or 500 pF is suitable with both gangs paralleled. The loss control is again set to infinite Q ($D = 0$) and capacitor VC_2 adjusted as above until a horizontal line is obtained at balance. This method is repeated using a smaller variable capacitor on the 10–100 pF range and adjusting VC_1. Leads should be kept short, especially to the low terminal, in order to avoid hum pick up, which causes the trace on the tube to break up into a complex pattern, making balancing difficult. It is assumed in the above that the bridge frequency has already been set to the correct value of 1,592 Hz (or 1,600 Hz as described above).

Finally the calibration of the loss controls is part of the setting up procedure. This is carried out using either an accurate ohm-meter or bridge. The low-Q control is calibrated linearly from $Q = 0$, $R = 0$ to $Q = 10$, $R = 100$ kΩ. The high-Q control is calibrated to an inverse law $Q = \infty$, $R = 0$, to $Q = 10$, $R = 1$ kΩ. The law being $R = 10^4/Q$, or if calibrating in terms of "D", $R = 10^4 D$ (since $D = 1/Q$).

The remainder of the article deals with constructional matters.

CONSTRUCTIONAL APPENDIX

Bridge components

R_1	1 Ω 0·5% wirewound or metal film Welwyn 4015D
R_2	10 Ω 0·5% wirewound or metal film. Welwyn 4015D
R_3	100 Ω 0·5% wirewound or metal film. Welwyn 4015D
R_4	1k Ω 0·5% wirewound or metal film. Welwyn 4015D
R_5	10k Ω 0·5% metal film. Welwyn 4015D
R_6	53·6k Ω 0·5% metal film. Welwyn 4015D
R_{6b}	46·4k Ω 0·5% metal film. Welwyn 4015D
R_{7a}	536k Ω 0·5% metal film. Welwyn 4015D
R_{7b}	464k Ω 0·5% metal film. Welwyn 4015D
R_8	10k Ω 0·5% metal film. Welwyn 4015D
R_9	560 Ω ½ W 10% carbon
R_{10}	750 Ω 1% wirewound or metal film. Welwyn 4015D
R_{11}	560 Ω ¼W 10% carbon
R_{12}	15k Ω 10W wirewound
R_{13}	150k Ω 1W 10% carbon
R_{14}	4·7k Ω 1W 10% carbon
RV_1	10 k Ω 5% Colvern C.L.R. 7001/15S
RV_2	1 k Ω 5% Colvern C.L.R. 4001/15S
RV_3	100 k Ω 5% Colvern C.L.R. 5001/15S
RV_4	1 k Ω 10% Colvern C.L.R. 3001/15S
RV_5	250 k Ω log. carbon
C_1	0·01μF nominal 0·5% silvered mica (selected preferably to 9940 pF)
VC_1	3–30 pF airspaced trimmer. Mullard E7876 (or 7864/01)
VC_2	3–30 pF airspaced trimmer. Mullard E7876 (or 7864/01)
VC_3	6–60 pF airspaced trimmer. Mullard E7881 (or E7879)
D_1	OA200, 1S120, HS1010, etc.
D_2	OA200, 1S120, HS1010, etc.
Meter	100–0–100 μA. (Prototype uses Type SB.305 from Henry's Radio Ltd.)
S_1	Prototype uses three 6-way 2-pole Radiospares Maka-Switch Wafers with the index mechanism set to 4-way, in order not to crowd the connections too much. (Similar switch available from Electroniques.)
S_2	Radiospares Maka-Switch 12-way 1-pole with index set to 7-way. (Similar switch available from Electroniques.)
S_3	S.p.s.t. toggle switch
S_4	S.p.s.t. press to make
T_1	35 mm ungapped ferrite pot core, Mullard FX 2240. *Primary:* (wound on first) 42 turns 24 s.w.g. enamelled copper wire followed by copper foil screen. Low capacity filler then added to fill most of the remaining bobbin space (polyurethane foam was used in the prototype). *Secondary:* wound with 42 turns of 32 s.w.g. eureka, cotton covered or enamelled.
T_2	See "Oscillator" section following

Making the wirewound resistors. The 1, 10, 100, 750 and 1 kΩ resistors may be wound by hand if desired, as in the prototype, or metal film resistors may be used throughout. The wirewound resistors are wound on cards of $\frac{1}{16}$-inch thick paper base phenolic sheet, 1 inch square. Clearance holes are drilled near each corner for 18 s.w.g. tinned copper wires which are threaded as shown in Fig. 7 to form terminations. The three lowest values are wound non-inductively, by winding on a first layer equal to twice the required resistance and then winding on an equal length of wire

Fig. 6. Layout of oscillator and power unit chassis. (Connections to the X and Y amplifiers and the bridge circuit are made via a multi-way connection block on top of the chassis)

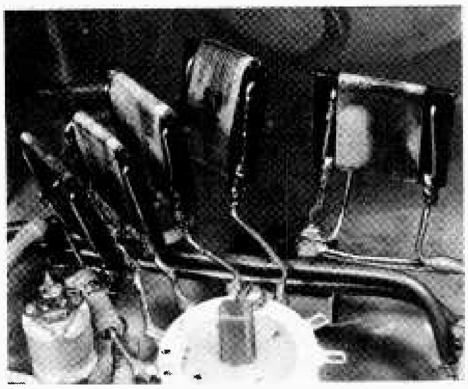


Fig. 7. The specially made wire-wound resistors R_1, R_2, R_3, R_4 and R_{10}, showing the form of construction. Also in the picture are some of the metal film resistors forming the ratio arm. The common end of these resistors connects to a ceramic insulated terminal strip. R_{10} is mounted on S_3

in a second layer, but in the reverse direction, the two windings being placed closely over one another. The upper layer is then trimmed on an accurate bridge to the required overall value. These three lowest values (1, 10, 100 Ω) are wound with 24, 32, and 42 s.w.g. cotton covered eureka (cupro-nickel) wire. The two upper-value resistors are wound with a similar wire of 47 s.w.g. (enamelled) in a single layer. The reason for the non-inductive winding of the lower values is that, owing to the use of thicker wires for the lower values, the number of turns does not go down in relation to the resistance, so that the inductive component becomes of greater importance on the lowest values. The use of a flat winding also helps to reduce inductance by minimising the area of the winding. The prototype resistors were finally given paper labels and then several coats of a polyurethane varnish.

Oscillator. The capacitors of the Wien bridge are silvered mica of 1% tolerance. (Capacitors may be paralleled to obtain the required values.) The resistors are metal-oxide in the prototype but carbon film would be an alternative. The thermistor is an S.T.C. Type A55, obtainable from Electroniques Ltd. The transformer, T_2, may be any good output transformer having a primary inductance of around 5 henrys (with up to 5 mA d.c.) and of 36:1 ratio. In the prototype the transformer was hand-wound using a ¾ in. stack of No. 74 laminations (Linton & Hirst, Magnetic & Electrical Alloys, Telcon, etc.) 0·014 in. silicon-iron fully interleaved. The primary is 1,600 turns of 40 s.w.g. enamelled copper wire. The secondary is 45 turns of 28 s.w.g. enamelled copper wire. Both windings are layer wound with interleaving and the primary is wound on first. Inductance of prototype 5·2 H (zero d.c.).

***X* and *Y* amplifiers.** The construction of these is shown in the illustrations and only a few components need special mention. V_4 is shown as a 6 BR7, but many constructors will have the more common EF86, which may be used for V_4 without any changes in values, but the pin connections must be changed as the EF86 has totally different connections with the exception of the heater pins. Both types were tried in the prototype with equal success. The neon NE1 may be Hivac Type 3L or 34L, American type NE2, Radiospares miniature neon (wire ended), or Thorn L.1161, 1163 or 1165.

Silicon protection diodes fitted to V_5 and V_3 (pin 8) prevent the application of −330 volts to the heater cathode insulation of these two valves when they are first switched on. The diodes have no effect on the operation of the circuit after the valves have warmed-up, as can be seen from the normal d.c. voltage present; the diode at the cathode of V_5 is reverse biased by 2·3 V $(1{\cdot}7 + V_f)$ and the diode at the cathode of V_3 is reverse biased by 1·9 V $(1{\cdot}3 + V_f)$. The diodes may be any of the types quoted for D_1 and D_2 of the bridge circuit; in fact almost any silicon diode is suitable for this application.

C.R.T. display. The 1-inch tube is mounted so that it can be rotated to set the *X*-axis horizontal. The tube is held by its base socket (B8G-Loctal) and by a clamp around the screen end of the tube. (Some soft material must be placed between the clamp and the tube, as the glass of the tube is relatively thin in such a small tube and is easily crushed.) In the prototype the tube base socket was fitted using slotted holes in the chassis plate, so that after rotating the tube the fixing screws could be tightened to hold the tube in the correct position.

Power supply

T_3: Radiospares "Economy Mains 250 V" 250–0–250 V, 75 mA; 6·3 V, 2 A; 0–5–6·3 V, 1 A

MR_{1-4}: Westinghouse FC116 contact cooled 250 V, 60 mA (Henry's Radio), S.T.C. C2D contact cooled 250 V, 60 mA (Electroniques). Also Continental types E250, C50.

The 68-Ω resistors "centre-tapping" the 6·3 V heater supply to ground are mounted on the base of V_3. The heater supply to the c.r.t. is connected to the cathode of the c.r.t. to reduce heater cathode leakage.

Note. The neon NE1 may be used as a panel lamp if required as it is running at its normal brilliance and will therefore provide a suitable lamp. Beware, however, of using a self-contained neon lamp assembly designed for mains use, since this will normally contain a series resistor.

Cabinet construction. This may largely be to the taste of the individual constructor as no special precautions need to be taken. It helps greatly to use a reduction drive to the balance potentiometer, but otherwise the controls are all straightforward. The layout chosen places the controls very conveniently in that the hands do not obscure the main dial or the indicators when the bridge is in use. A left-handed person might prefer to transpose the whole panel left-to-right, however. The panel of the prototype is constructed in much the same way as those of the author's previous articles (see April 1968 *W.W.*) but in this case not all the dial markings are placed on the reverse of the perspex covering the metal front panel. To ease the problem of calibration a layer of stiff white card (of the sort sold by good stationers for artwork use) was placed behind the perspex and the calibrations marked on this in indian ink. The Perspex overlay then has clear panels left over these scales so that they can be read but are protected from dirt by the Perspex. The main balance control scale of the prototype has the Perspex cut away over its scale and a clear, and slightly domed Perspex cover fixed over this, cut out to allow clearance for the slow motion pointer of the drive to this control.

The bridge terminals are placed at the top of the panel so that bulky components may be placed on top of the instrument, and to this end a hard wearing Melamine laminate panel is fixed to the top of the case to prevent damage to the wooden case. (Warerite, Perstorp, Formica, etc.) The mains switch and fuse are also mounted in this Melamine top cover, but a small metal sub-panel is mounted in the cut out of the wooden panel behind this switch and is earthed so that in the unlikely event of an insulation breakdown of the switch or fuse, the switch dolly will not become live. Care should be taken to wire this type of panel-mounting fuse holder so that the live incoming mains connection goes to the tip of the fuseholder and the connection to the transformer goes to the side connection. Thus, on removing the fuse, the carrier disconnects from the mains, before the metal parts of the carrier can be touched. If the side connection goes to the mains this is not so, especially if the fuse is not blown. Of course one shouldn't remove a fuse with the supply on, but people do just the same, and it is better to be safe than sorry.

B.B.C. Sound-in-Vision System

The B.B.C. Research Department has developed an experimental sound-in-vision system for the single-line distribution of 625-line television signals. Within each 4·7μs line synchronizing interval, a period of 3·8μs, symmetrically disposed with respect to the leading and trailing edge of the line synchronizing pulse, is occupied by a p.c.m. sound signal. The leading edges of the synchronizing pulses are preserved during transmission.

The sound signal is sampled at twice the line frequency allowing a bandwidth of 14kHz to be transmitted. The two samples produced during each line period are converted to p.c.m. signals, delayed and compressed, and inserted into the video waveform during the next line synchronizing interval.

In order to provide room for the sound pulses throughout the full blanking interval it is necessary to extend alternate equalizing pulses from 2·35μs to 4·7μs. On reception the sound pulses are extracted and reconverted to normal audio signals and the video waveform restored to standard form.

High-quality Electrostatic Headphones

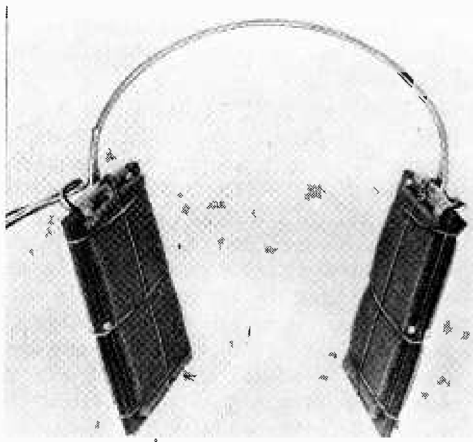
Theoretical and constructional details for simple electrostatic units producing plane wavefronts, and operating from the push-pull anodes of a valve amplifier

by J. P. Wilson, B.Sc., Ph.D.*

The ability to hear sources of sound at their appropriate positions in space depends on several factors. The more familiar of these are the binaural cues; the nearer ear receives its message slightly earlier and, particularly at high frequencies, louder (Fig. 1). Other factors must also be involved because with binaural headphone listening all sounds appear to be within the head on a line between the two ears.

Two possible reasons for hearing sound sources out in space under normal conditions are motion parallax (the changes in the signals at the ears brought about by head and body movements) and the acoustic diffracting properties of the external ear. It was this latter factor which led the author to consider the present design.

The sound wavefront arriving from a source situated at some distance is nearly plane. It should be possible to stimulate this natural condition by providing a large flat radiator in which the signal is in phase all over its surface: in addition the radiator should be a poor acoustic reflector so that it does not re-reflect sound returning from the head and ears, nor form a semi-enclosed resonant cavity with the ear. An electrostatic device has characteristics which can approximate to these requirements.



The finished units with headband.

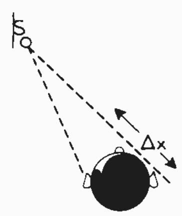


Fig. 1. The left ear hears information from S before the right ear.

Theory of electrostatic transducers

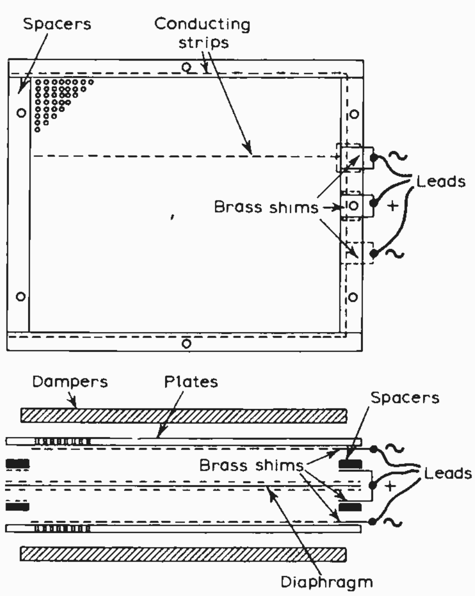
Hunt[1] has shown that for linear operation an electrostatic device should be push-pull, and operate with a constant charge on its diaphragm. If, however, parts of the diaphragm can move independently, the constant charge principle will not hold on a local scale unless the parts are electrically independent. This can be achieved by using a very high resistance coating.[2] The pressure at all points on the diaphragm will then be equal to the product of the field strength between the plates (produced by the signal voltage) multiplied by the charge density (derived from the bias voltage).

The motion of the diaphragm is controlled by the acoustic resistance of air at mid frequencies, by the mass per unit area at high frequencies, and by the tension of the diaphragm at low frequencies.[2] The high frequency roll-off is well above the audible limit for diaphragm materials commonly used in electrostatic speakers. At certain low frequency the entrained mass of air and the tension of the diaphragm form a resonant system.[1] This resonance determines the lower frequency limit of the device. It should not be made lower than required because this would limit the apparent sensitivity.[2]

The limitation on peak output imposed by the breakdown of air can be overcome by coating the plates with insulation.[1] At low frequencies, however, the limit will be set by the diaphragm touching the plates.

Other features considered by Hunt[1] to be desirable in an electrostatic speaker are concerned with altering the polar response and matching the impedance and are not applicable to a headphone design so will not be considered here.

Fig. 2. Constructional details of the units.



A practical headphone design

The practical starting point was an unpublished loudspeaker design by M. K. Taylor which gave many of the constructional details used here. It is proposed to deal with each of the elements in turn in such a way that the reader can modify design according to his own requirements.

The plates

These must be electrically conducting, acoustically transparent, non-resonant, rigid and flat. The first design (7in × 5in) used perforated zinc which has excellent acoustic properties (55% hole area) but is not sufficiently rigid for practical purposes.

Experiments with various hole patterns in hardboard revealed that the holes should constitute at least 20% of the total area and that they should be spaced much closer than the shortest wavelength to be reproduced in order to avoid internal resonance and presumably also diffraction grating effects.

The dimensions of the plates are determined by two considerations. They should be large enough to overlap the ears all round and must be of the appropriate size to give the desired bass resonant frequency to the diaphragm. The present unit used perforated paxolin boards (Lektrokit: Chassis Plate

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No. 4:4¾ in. × 4in.) which provide insulation from the high voltages involved. These are rendered electrically conducting on their smoother sides as follows:

A stripe of high conductivity paint (Acheson Colloids Ltd.) is applied across the plate and brought out to a land for connection to the signal source (Fig. 2). The whole of the perforated area is then given a thick coating of colloidal graphite (Aquadag). In both cases care must be taken not to let any liquid run into the holes.

It is possible to dispense with the high conductivity paint (which is quite expensive) and make direct contact between the brass shims and graphite (Aquadag) lands on the plates.

When dry, the surface is polished with a dry cloth to remove any surface irregularities, or hairs, and blown thoroughly clean. A flame can be applied quickly to the surface just before assembly to remove any remaining dust or lint.

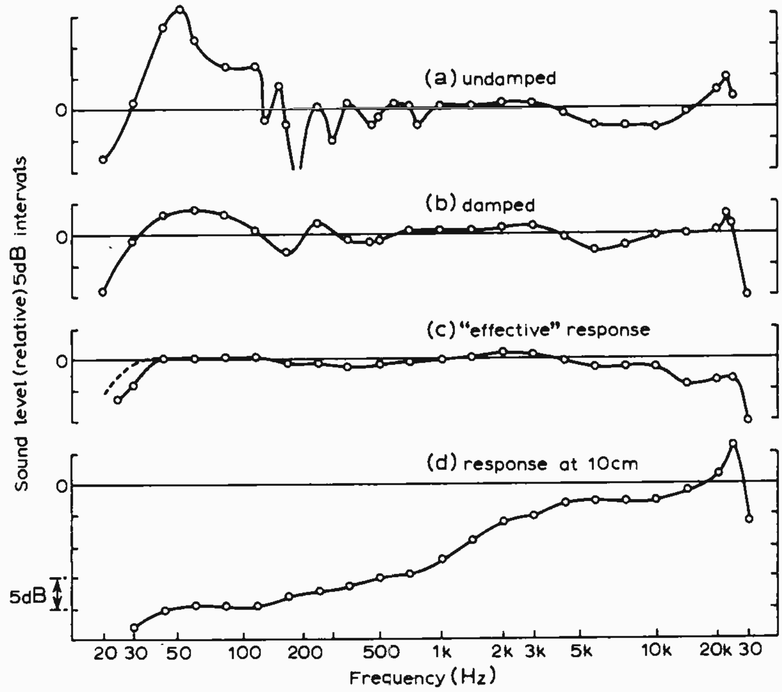


Fig. 3. Graph of frequency response against relative sound levels.

The spacers

These must have excellent insulating properties and be uniform in thickness. The actual thickness is not critical: thicker spacers will allow larger excursions at low frequencies but will require correspondingly greater signal and bias voltages to produce a given sound pressure.

Acetate sheeting of 0.04in. thickness was used for the spacers and stuck to the plates with Evostick. This thickness was chosen partly to ensure uniform response in spite of small deviations from flatness in the plates and might with advantage be reduced to about 0.025in. in less critical applications particularly if less bias and signal voltage is available. The holes required around the edges can be drilled after the spacers are fixed (Fig. 2).

A stripe of high conductivity paint (or Aquadag) is applied near the inner edge of the spacers for connection to the bias supply.

The diaphragm

This consists of a thin resistively coated film of stressed plastic of the type used by supermarkets for wrapping foodstuffs (Goodyear: Vitafilm). It is soft and acoustically dead, readily heat stressed, and is available in 0.0005in. and 0.001in. thicknesses.

The thinner material was chosen because it would be damped more readily by the acoustic loading.

The resonant frequency of the diaphragm will depend on size and shape, mass and tension. Too low a resonant frequency is undesirable because this will also necessitate using a lower bias voltage consequently lowering the sensitivity. It would also render the device more sensitive to any unwanted subsonic signal. The paxolin version has a resonant frequency of about 50Hz in free space which when damped leads to a −3dB point of about 30Hz.

In practice the proximity of the ear and head reduces these frequencies by about half an octave presumably by increasing the effective mass of entrained air.

A conductive coating is needed on the diaphragm to allow it to charge up to the bias potential and to counteract any leakage of charge. But it should not be so conductive that charge can flow around during signal movements or linearity will be lost. A resistance within the range 100-10,000MΩ measured between two parallel electrodes 1in. long and separated by 1in. would be satisfactory (a just detectable deflection on a 50μA meter when fed from 250V).

To prepare this coating the plastic sheet is pressed on to a piece of moistened glass using a rubber roller. When the upper surface is dry a little colloidal graphite is rubbed on with cotton wool. At first it wets the surface in a thick black layer which by further rubbing, using the same piece of cotton wool, is nearly all removed leaving a shiny surface just noticeably darkened.

When the whole surface is within the required resistance range it can be turned over and coated on the other side. (The water will not harm the first coating unless it is rubbed hard.)

The finished diaphragm can then be stuck with Evostick to the spacers on one of the plates and pressed between two flat surfaces to dry. Only the minimum of adhesive must be used so that it does not spread between the diaphragm and the conducting stripes.

Heat tensioning may be performed in several ways. The method of Taylor was to use a fan heater with restricted air flow: the method adopted here was to place the diaphragm assembly under a hot grill for a few seconds. The plastic goes soft and then the wrinkles shrink out: it can then be removed and the tension builds up further as it cools. The process may be repeated if for any reason it appears necessary.

The resonant frequency and therefore the tension appears to be constant for a given size of diaphragm. This ability to obtain a controlled tension is probably the chief advantage this material has over other plastics.

The two halves are next bolted together with 6 BA nylon nuts and bolts. Thin brass shims should be inserted in the appropriate positions to make contact with the conducting stripes.

A single shim may be used for the bias supply if a small nick is made in the edge of the diaphragm allowing contact with the conducting stripes on both sides. Leads may then be soldered onto the shims and well insulated.

It is probably better to bind the three separate leads together at a few points only rather than twist them or use three-core cable, otherwise the capacitive load on the amplifier may be too great.

Acoustic damping

Without extra damping the response below 1kHz is really quite irregular, as shown in Fig. 3. The plates themselves contribute a certain amount of damping as was deduced by comparing a similar diaphragm made on an open frame which had very characteristic drum-like properties.

Whilst it may be possible to obtain the desired damping by using plates with a very large number of minute holes this alternative was not pursued as the method adopted is simple and satisfactory, and in addition produces further electrical insulation. This consists of sandwiching the units between 4mm layers of foam plastic attached with rubber bands, or sewing together the edges of the foam layers to form an envelope. Adhesive was not used because of the danger of filling the perforations and because it was thought desirable to be able to inspect the diaphragm from time to time.

The effectiveness of this treatment can be judged by comparing (a) and (b) in Fig. 3. Doubling the thickness does not lead to any further improvement.

Finally a headband is arranged to hold the units flat against the ears and just in contact. This can be a 12in. × ½in. strip of 16 gauge Duralumin bent to shape and given a slight twist at each end to hold the units flat against the ears. Owing to their light weight, lack of pressure and good ventilation these

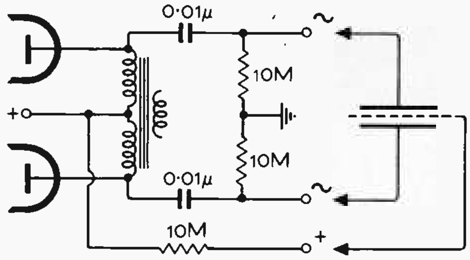


Fig. 4. The electrical circuit for connecting the phones to a push-pull output valve amplifier.

headphones can be worn indefinitely in complete comfort.

Electrical considerations and maximum output

As the impedance of an electrostatic device is predominantly capacitive it presents its lowest impedance at maximum frequency. For optimum performance the source impedance should be sufficiently low to cater for the highest frequency. Below this the output will be constant and limited by the maximum output voltage of the amplifier down to the lowest frequencies where plate spacing further limits the maximum output.

As the capacitance of the headphone unit is only about 80pF including leads it would be possible to utilise a step-up transformer between the anodes of a push-pull amplifier and the unit. However, the high inductance and low capacitance required to cover the whole audio frequency range in such a transformer would be difficult to achieve particularly in view of the high insulation required.

The output voltage available from push-pull anodes (Fig. 4) is adequate for most applications, however, and there would be little point in having much greater available output at medium and high frequencies than at low frequencies.

Besides its simplicity this method has the advantage that internal insulation of the plates is unnecessary unless the spacers are reduced to below 0.025in because the breakdown of air is not reached. A high quality output transformer may be used to step up the output of a transistor amplifier to a comparable voltage but separate provision would be needed for biasing.

Insulation of the plates would be necessary only for very high outputs and it would be practicable to obtain this only over a restricted frequency range.

After preliminary insulation tests to check construction the bias voltage should be applied. By observing the shape of objects such as a window opening or a fluorescent tube by reflection from the diaphragm it is possible to see that it is flat and not plastered against one of the plates.

The bias voltage should be set so that even when the diaphragm is blown towards the plates it will return to the central position by its own tension.

Using a Radford STA 15 (a 15W amplifier with h.t. supply at 375 volts) with no resistive load, the free field r.m.s. sound pressure is limited to 90dB (rel. 0.0002 dynes/cm^2) from 30Hz upwards by the voltage handling capacity of the amplifier. (As some amplifiers become unstable without a resistive load it would be safer to include this and accept the reduced output if stability cannot be checked by the user.) By reducing the spacers to 0.025in the output above 60Hz is increased to nearly 100dB before the amplifier overloads but below 35Hz the maximum output would be limited to less than 90dB by the diaphragm excursion.

The actual sound pressure at the ears is about 10dB greater than the free field pressure due to the reflective and sound gathering properties of the ear and head. This would also apply to loudspeakers, and indeed natural sounds, but not to headphones. The exact magnitude of pressure increase is dependent on frequency and on the direction of the source in space relative to the ear.

Performance tests

The units were tested for frequency response and square wave response using a B & K 4133 microphone in contact with one of the plastic dampers.

This was done in several positions as uniformity cannot be assumed for the following reasons: uneven spacing between the plates causes variations in the signal field strength; tension controlled motion at low frequencies gives a curved deflection profile (with highest sound pressure in the centre) whereas air resistance controlled motion at high frequencies gives a constant displacement (apart from the extreme edges) and a uniform sound pressure; nodes and antinodes may be formed; a leakage path causes reduced sensitivity in this region.

Fig. 3 shows the frequency response under a number of different conditions: (a) shows the performance just off centre without the plastic dampers. There is a resonance at 50Hz and a number of peaks and dips up to 1kHz.

Curves taken in other positions (not illustrated) had the same main resonance but the frequencies of intermediate peaks and dips were quite variable. It is assumed that these were due to the formation of nodes.

Curve (b) taken at the same position illustrates that the effect of the foam plastic was to damp out all these irregularities. Curve (c) is an averaged response over an area of the diaphragm corresponding to the size of the ear.

Taking into account the lowering of resonance when in proximity to the ear (dashed line) the effective bandwidth is 25Hz–25kHz$\pm$3dB without any sharp peaks or dips (all maxima and minima are plotted).

One of the interesting features of a device like this is the polar response pattern. If λ is the wavelength of sound, r, the radius of the generating surface, and x, the perpendicular distance from the centre, then for very low frequencies when $\lambda >> r$, the response pattern is a figure of eight.

Initially when $x << r$ pressure falls off slowly with distance but as x increases and becomes much larger than r, the response tends towards an inverse square law.

For very high frequencies, however, when $\lambda << r$, the device acts as a plane wavefront generator. Sound pressure is uniform across the beam (projected area of the diaphragm) and independent of distance but falls off rapidly outside the beam.

In practice, of course, much of the sound spectrum lies in the intermediate region ($\lambda \sim r$) and the characteristics will lie between the limiting cases outlined above.

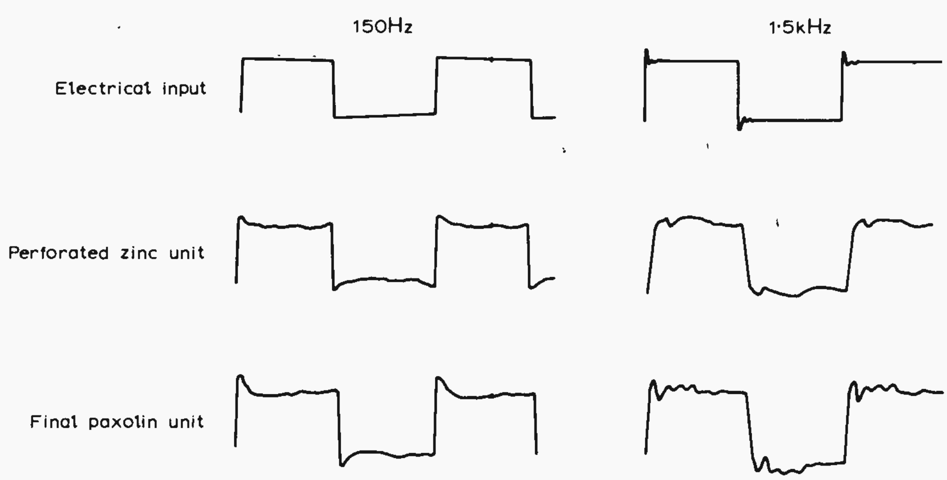
It is obvious from these considerations that this does not form a suitable basis for a loudspeaker as the frequency response would vary greatly with distance and off-axis angle. This variation is reduced in full range electrostatic speakers by dividing up the frequency range and feeding the components into separate sections.

To illustrate the above points the frequency response has been plotted at 10cm from the diaphragm in Fig. 3(d).

In headphones the condition that $x << r$ is easily satisfied and the wavefront should be nearly plane at all frequencies so that small changes of position or distance make little difference to the sound pressure. For reproducibility of psychoacoustic thresholds this represents a distinct advantage over conventional phones.

The square wave response is shown in Fig. 5 for the same microphone placement as Fig. 3 at 150Hz and 1.5kHz. This shows the

Fig. 5. Square wave response at 150Hz and 1.5kHz for the two types of unit mentioned in the text.



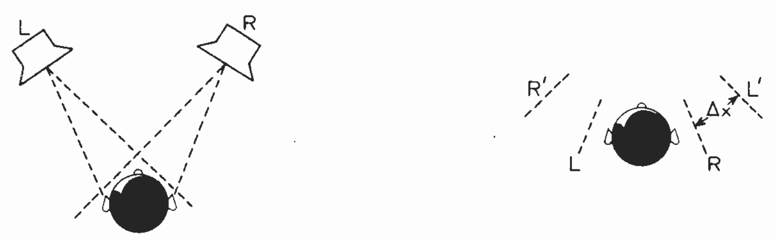


Fig. 6. (left). The effect of crossed soundpaths. Fig. 7 (right). Units put in parallel to simulate crossed soundpaths.

excellent phase characteristics of the units. The "ring" at 25kHz indicates the internal resonance referred to above and is also apparent in the frequency response curves. Obviously at this frequency, so far outside the audible range, it is of no consequence.

Harmonic distortion was measured at a number of frequencies at a sound power level of 80dB. The second harmonic ranged from about 0.5% at low frequencies (50 – 200Hz) down to about 0.2% at higher frequencies. Third and higher harmonics were less than 0.1% at all frequencies.

Different methods of assessing the transmissive and reflective properties of the units did not lead to consistent results. The reflection coefficient may be about 0.1 up to 1kHz rising to about 0.5 at 6kHz and perhaps falling above this.

With a probe microphone situated at the entrance to the ear canal it appears that the difference in response between using the electrostatic earphone and a source of sound at some distance, in a comparable direction, can be represented by a series of peaks and dips of 2—3dB in the region of 2kHz upwards. Although these are less than the fluctuations in response produced by the external ear itself (which in turn are dependent upon the direction from which the sound arrives) it should not necessarily be assumed that they can be neglected.

The author wearing the headphones.

Subjective impressions

Several types of signals have been demonstrated to a number of observers including "hi-fi" enthusiasts, but not professional listeners. All were most favourably impressed by the smoothness and lack of coloration of white noise, the dead sound of clicks, and the naturalness and sense of presence of stereophonic music. They were unanimous in preferring this to any system of reproduction heard previously.

Distortion and other shortcomings in the signal source are of course also heard with greater clarity. Part of the increase in clarity is no doubt due to the absence of room reverberations.

Spatial effects

As the intention of the design was to simulate sound sources at a distance, the spatial effects are of particular interest. Although these effects cannot really be called natural they are far from disappointing.

Sounds appeared to be coming from many different distances as well as many directions, including, surprisingly, some above and below the horizon. Regrettably, however, a few sounds still persisted within the head or in close proximity to the ears. It was thought possible that part of this exaggerated impression could be due to the absence of the crossed soundpaths shown in Fig. 6.

A simulation of these was made by introducing two further units R' and L' connected in parallel with R and L respectively (Fig. 7). This did not effect any improvement, and it must be noted that these "crossed" paths would be deficient in low frequency components because of the distance of the units from the ears—see Fig. 4(d).

Furthermore, it must also be noted that the wavefront produced by a unit represents a single direction of sound only and will be inappropriate for other directions.

This limitation is shared by loudspeaker stereophony in which the illusion of sounds arriving from between the loudspeakers can be dispelled by rotating the head.

The great improvement in the externalization and spatial representation of sounds compared with conventional headphones, however, indicates that it is better to have directional information which is sometimes inappropriate than none at all.

Further experiments using the larger perforated zinc units fixed in space to allow small head movements were also disappointing. It does not appear that motion parallax alone is the final requirement for realism.

Conclusions

The units described obviate some of the difficulties inherent in normal headphones for psychoacoustic work: variations of sound pressure with position on the ears and with efficiency of seal; poor response at low and high frequencies; and poor phase response.

On the debit side electrostatic headphones provide no sound isolation, and methods of overcoming this limitation tend to degrade the performance.

For music reproduction they provide greater fidelity than either conventional headphones or loudspeaker systems. They share with conventional headphones the absence of room reverberations but surpass them for spatial realism. They fall short of loudspeakers in providing spatial realism but provide greater clarity and separation.

Thanks are due to Mr. J. R. Ruscoe for constructing the units.

REFERENCES

1. Hunt, F. V., *Electroacoustics*, Harvard University Press, 1954.
2. Walker, P. J., Wide range electrostatic loudspeakers, *Wireless World*, May, June and August, 1955.

Our Next Issue

Speech Recognition. Part 1 of a two-part article on the automatic recognition of spoken English will investigate the elements of speech that can be differentiated most simply by a machine. These are called phonemes, and are not identical with syllables.

Digital Exposure Timer. A timer designed by a photographer for photographers, and built on digital elements, will be described with full details–theoretical and practical. The design meets the timing accuracy and range required in colour photography, whilst the components are cheap and readily available.

Circuit Ideas. We will be starting a new regular feature—selections of original circuit ideas submitted by readers. These circuits were sent to us in response to the open invitation headed "Circuit Ideas" which appeared in the June and July issues of *Wireless World*. The request was (and still is) for functional 'bricks' which have proved useful to somebody at some time. Performance, originality of realization and economy of components are the most important criteria in selection. Five guineas will be paid for each circuit published.

News of the Month

Pay-TV company to disband

The boards of the Associated British Picture Corporation, British Home Entertainment Ltd and British Relay, all partners in Pay-TV Ltd, have unanimously decided that Pay-TV should cease to exist as an active company and should be run down as quickly as possible. This follows the Government's decision that the number of subscribers to Pay-TV should be limited to 150,000 and that the situation was to be reviewed again in 1976.

Subscription television began in the UK in 1963 and a pilot scheme was started in 1965 under a three-year licence. The directors of Pay-TV are convinced that coin-in-the-slot television experiment has proved to be successful and are willing to back their conviction with large sums of money if it were not for "impossible restrictions imposed by the Government".

Pay-TV have already invested about £1M in the service which was confined to areas in London and Sheffield. To keep it running until 1976 would cost them another £3M. With only 150,000 subscribers there would be no chance of recouping their investment and if in 1976 the Government decided to close them down they would be four times worse off than they are at present.

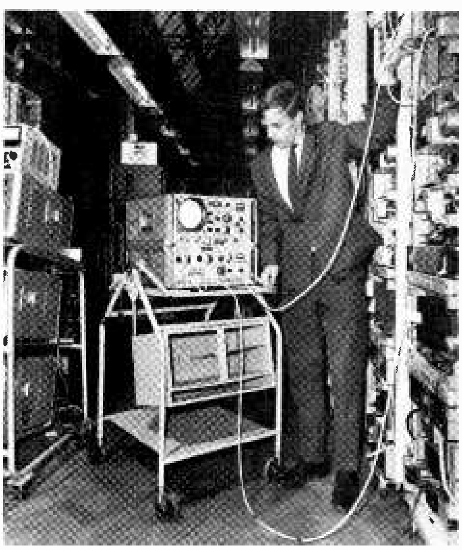
The Government decision was originally conveyed to the company on July 31st, 1968. Pay-TV Ltd replied, saying that the limit placed on the number of subscribers would make it impossible for them to continue to function. Pay-TV Ltd received no reply and the next thing that happened was the October 25th announcement in the House of Commons which stated that the Pay-TV experiment was to be terminated.

Later, at a meeting with the directors of Pay-TV, the Postmaster-General again reversed his decision and agreed that Pay-TV could continue. However, the unacceptable upper limit of 150,000 subscribers was insisted upon and as a result Pay-TV Ltd will now exist in name only in the hope that one day the Government will relax the restrictions.

Pay-TV Ltd have said that if the upper limit was raised to 450,000 subscribers the operation would become viable.

It could be argued that the number of subscribers required to enable the service to continue represents only a tiny percentage of the total viewing population and if these people want a coin-in-the-slot television service why shouldn't they be allowed to have it?

A GEC-AEI test engineer setting up the i.f. amplifier of a 6GHz transmitter-receiver using the microwave link analyser designed by Hewlett Packard. The G.P.O. has just placed a substantial order for this equipment for use by the Network Planning and Programming Department.



S.R.C. annual report

In its third annual report, out last month, the Science Research Council revealed that for the year ended last March £38M of the Council's funds was devoted to basic research. Presenting the report, the chairman of S.R.C., Professor Brian Flowers, stated that almost all this money had gone into universities, either directly or indirectly. The report complains that fewer resources are available than are needed to carry out all the programmes which are desirable on "scientific grounds", and a system of priorities has been established. Most of the Council funds for the next few years will continue to be devoted to basic research; astronomy being given high priority at the expense of nuclear physics, but S.R.C. laboratories and university departments will be encouraged to look for applications resulting from basic research. Support will be given on a selective basis to particular fields of scientific and technological importance. The number of academic and professional staff supported through research grants will be restricted in the hope of attracting trained manpower into industry or teaching. Substantial support for postgraduate training of scientists will continue, with emphasis on training for industry. The falling proportion of the Council's resources to be spent in the nuclear physics field will be put towards participation in the 300GeV accelerator or a similar international project. Despite the Government's decision not to participate in the proposed 300GeV European accelerator laboratory, the Council reaffirms its policy of recommending that U.K. participation in this or a like project will be essential to secure the long term future of elementary particle research in Britain, and the Council will continue to press for a reversal of the decision. Progress is being maintained in both optical and radio astronomy, and plans are prepared for work to be undertaken in the region between these two, infrared astronomy. Most of the radiation from the galaxies occurs at infrared frequencies and it has been agreed to devote increased effort to this field following recent interesting discoveries in America. In engineering research, the report gives examples of progress in the application of computers to engineering in various fields. Report of the Science Research Council for the year 1967-68 is available from H.M.S.O., price 7s 6d.

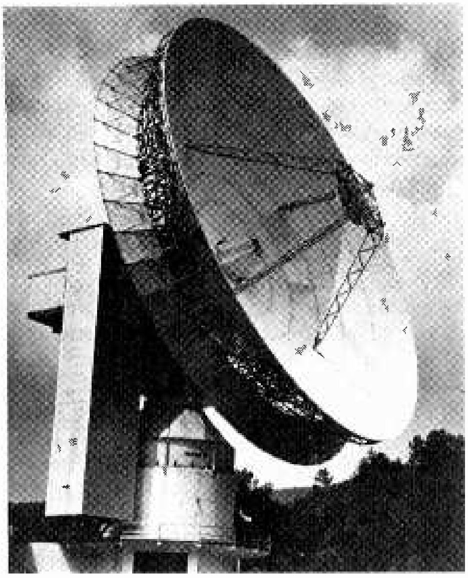
Radio Love

A group of people intend to set up in London their own independent radio service, to be known as Radio Love. To avoid coming under the jurisdiction of the current Post Office licensing regulations (which cover frequencies up to 3,000GHz) they intend to use a laser beam as the means of carrying information. The idea is to use a galium arsenide laser with a beam, shaped by a reflector, in the form of a horizontal disc inclined towards the horizon from a height of about 200ft. The laser will be modulated with an r.f. sub-carrier carrying the audible information. The receivers will be conventional with the addition of a photocell, housed in a small reflector, that will feed directly into the aerial circuits of the receiver. A representative of Radio Love told us that it is their intention to house the transmitter on top of a tall building in London and to have similar repeater stations to cover shadow areas. The service is planned to start next year, Post Office permitting, covering a radius of three or four miles from Charing Cross.

COMSAT earth station

An earth station with a 97-ft diameter rotatable paraboloid was brought into operation in September by the Communication Satellite Corporation. The station, which is situated in a mountain valley 50 miles south of Morgantown, West Virginia, is one of four identical stations being built by Philco-Ford under a $7.6M contract from COMSAT. The other three stations are at Cayey, Puerto Rico; Jamesburg, California; and Paumalu, Hawaii.

The stations which transmit in the 6-GHz band and receive at 4GHz for operating through the Intelsat satellite network, can work orbiting satellites from 5,000 miles to a synchronous altitude of 22,300 statute miles. Up to 5,000 channels in each direction can be handled simultaneously—television



The 470-ton earth station built by Philco-Ford in West Virginia to operate within the Intelsat network.

signals occupy ten channels and telephone and telegraph signals use one channel only. The station is built in a valley to minimize interference from other electromagnetic signals.

One of the first tasks carried out by the station was the transmission of the Apollo splash down pictures, however that is another story which follows.

Satellite terminal designed and built in 16 days

A time limit of 16 days was set for the General Electric Company of America to develop and build a portable satellite terminal capable of transmitting colour television signals for Western Union International Incorporated. The terminal was to be installed on the aircraft carrier *Essex* so that live colour television signals of the Apollo 7 splash-down could be transmitted. The equipment, which was produced on schedule, consisted of a 6-kW television transmitter, video processing equipment, power supplies, two-way audio transmission equipment, a 5m diameter folding parabaloid aerial with associated gyro control and automatic tracking equipment.

The signals from the portable station were transmitted via ATS-3 to the West Virginia station and from there to the TV network pool in New York for distribution to all parts of the world.

Radio communications in tunnels

The use of a tunnel as a sort of waveguide so that reliable communication can be established with moving vehicles in tunnels is being investigated by Bell Telephone Laboratories of America. The problems associated with using v.h.f. communications in tunnels are well known—low signal strength, dead spots, etc. It has been found that by placing a microwave transmitter near the entrance to the tunnel and directing the energy into the mouth of the tunnel good communications can be established with moving vehicles even if the tunnel is a winding one. This is because the microwave energy is not absorbed by the tunnel walls, instead, the walls themselves act as very good reflectors which guide the waves, by reflection, down the length of the tunnel. Only at the open ends of the tunnel does the signal strength fall off as the waves spread out into space.

Tests were made in a tunnel at 11.2GHz. A vehicle equipped with receiving and measuring equipment drove down the tunnel and the following facts were obtained. At 2,000ft from the transmitter signals had dropped only a few dB as against the more than 30dB/1,000ft associated with v.h.f. equipment. In fact for most of the length of the tunnel the received signal was 6dB higher than if the vehicles were the same distance apart in free space! Tests were made over a wide frequency range, from 153MHz to 11.215GHz. For any given distance between the transmitter and receiver the higher the frequency the better the reception. To date, however, no theory exists that will explain the inter-relationship between distance, frequency and loss rate.

T.A.C. report

The case for retaining the existing 405-line television services radiated in the v.h.f. band for at least seven years after the start of their duplication on 625 lines in the u.h.f. bands is set out by the Television Advisory Committee in its 1967 report. In concluding its recommendations on the eventual role to be played by the v.h.f. bands in the general pattern of frequency allocations, the report states that the ultimate objective of six services of national coverage (two on v.h.f. and four on u.h.f.) will be jeopardized unless additional channels for broadcasting can be made available above 216MHz in Band III and above 854MHz in Band V. The committee recommends that the possibility of securing additional channels be re-examined. Report of the Television Advisory Committee 1967 is a record of the background of the study of methods and timing of changing the definition standard (405 to 625 lines), which the Government accepted in February of that year. It is obtainable from H.M.S.O., price 2s 6d.

Computer-aided design centre

The latest development in the establishment of a Centre for Computer-Aided Design at Cambridge by the Ministry of Technology is that negotiations are taking place with International Computers Ltd with a view to placing a contract for managing and running the Centre under Ministry of Technology direction. The contract will also enable I.C.L. to appoint consultancy staff who will be available to assist users of the system. I.C.L. supplied the Atlas 2 computer on which the Centre is based and already has teams on site concerned with commissioning and maintaining the computer.

The Centre is expected to be able to start work on Computer-Aided Design projects approved by the Ministry about mid-1969. The Centre will provide multi-access facilities working largely through the medium of teleprinters but using displays and other devices in some instances. It is intended that at the outset a good deal of the work will probably use the multi-access facilities on site.

The Ministry's plans to set up the centre were first announced in July, 1967. It is expected that about £2½ million will be required to cover the initial costs and running expenses for the first five years of operation.

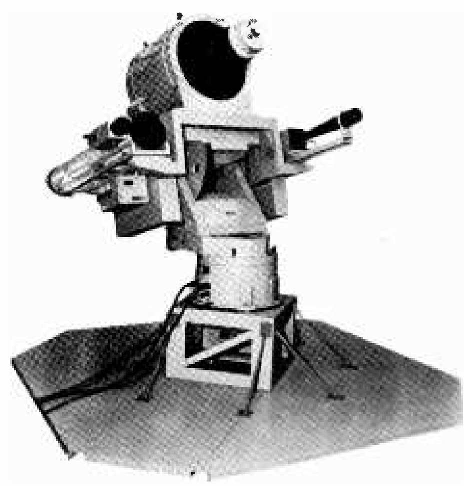
B.A.C. to build two Intelsat IV satellites

The British Aircraft Corporation, as leading sub-contractors to Hughes Aircraft Corporation of America, will assemble two Intelsat IV satellites in the U.K. with the assistance of Compagnie Français Thomson-Houston of France and AEG Telefunken of Germany. In addition B.A.C. and the French and German companies will manufacture a good deal of the sub-system hardware for three of the space-craft.

The first satellite in the Intelsat IV series is planned to be launched in 1970. B.A.C. already have much experience in the technological and scientific satellite field. However, this will be the first task involving communications satellites.

Satellite-tracking laser

An experimental laser system for high precision tracking of artificial satellites has been developed by Hitachi Ltd, with subsidies from the Ministry of International Trade and Industry, Japan. Based on a ruby laser, the experimental tracking system is claimed to be ten times more accurate than conventional radio tracking devices. The artificial satellite is first sighted through a small telescope; the laser is then aimed at the satellite through a second more powerful telescope. A special reflector on the satellite bounces the laser beam back to the tracking system's receiver, which comprises a light collector and photo-multiplier. Very short pulses with peak power of 5 megawatts at an average repetition of one per second for a duration of six minutes are emitted by the ruby laser, providing pulse characteristics which allow highly accurate tracking. In its present de-



sign, the laser system can track satellites in orbit at 300-2,000 km altitudes and it will be put to work within the next six months to track a number of satellites fitted with a laser reflector.

"Nobel" Prize for British Engineers

An annual presentation to be known as the "MacRobert Award", of £25,000 and a gold medal, is to be made to an individual, or team of up to five people, who contribute the most outstanding innovation in the fields of engineering or other physical technologies or in the application of physical sciences. This is a major award, from trusts formed by the late Lady MacRobert, which is intended to provide a balance in the U.K. with the renowned Nobel prizes for contributions to science. The MacRobert trustees intend that their funds should be used to enhance the national prestige and prosperity of Great Britain and entries for the prize will be confined to ideas which originate and grow in this country. Administration of the award will be handled by the Council of Engineering Institutions. When announcing the award scheme at a recent press conference, Sir Leonard Drucquer, chairman of C.E.I., said the award would not be made for an innovation purely on its commercial success but also on its benefit to mankind coupled with the effectiveness with which development problems had been overcome. In selecting prizewinners, MacRobert Trusts will be advised by a committee comprising a chairman and nine members. In the chair will be Lord Hinton of Bankside, and his committee will be made up of three members nominated by the Royal Society and the remaining six nominated by the C.E.I. Applications should be submitted to the Council in the period January to April inclusive each year and will be accepted from firms, organizations, laboratories or individuals. Presentation of awards will take place at the end of each year. Full details can be obtained from the MacRobert Award Office, Council of Engineering Institutions, 2 Little Smith Street, London, S.W.1.

Optical pumping now a Westinghouse patent

A patent that affects all concerned with any type of optically pumped laser was issued on September 24th to the American Westinghouse Electric Corporation by the United States Patent Office. The patent recognizes the fact that optical pumping, which is basic to lasers, was invented by Dr. Irwin Wieder at the Westinghouse Research Laboratories in the late 1950s.

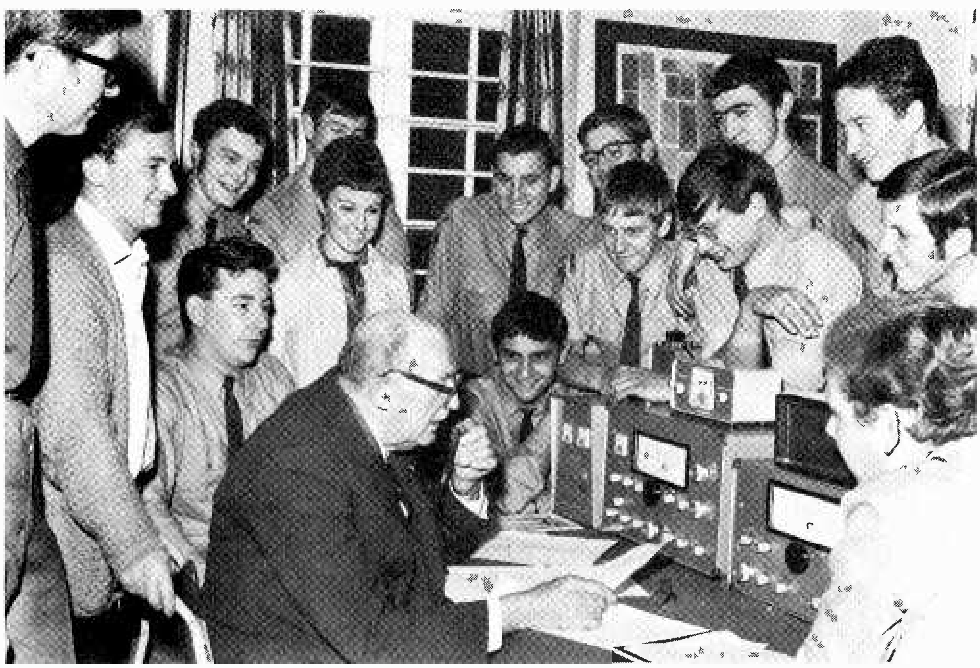
Fact finding tour

Earth stations, either completed or under construction, in Hawaii, Japan, Thailand, Australia and Italy will be visited over a period of about six-weeks by B. A. Lower director of experiments at Goonhilly. The object of the tour is to secure for the Post Office up-to-date technical knowledge about the way other countries are meeting the problems of earth station design, construction and operation.

Electronic surveillance aid

A compact television camera, equipped like a rifle with a telescopic sight and a stock is being tested, as part of a helicopter air surveillance system, by Marconi in co-operation with the British Army. In a recent trial, signals were successfully transmitted from the aircraft to a ground station. Results suggest that the camera, equipped with a zoom lens, provides a magnified bird's-eye view of operations on the ground, making information instantaneously available at a forward command post while a reconnaissance mission is being carried out. Using microwave radio link equipment, signals ser over distances of several miles were dis played on a monitor at the base, where clea steady pictures were obtained. Work is being carried out on a camera and associated equipment for night viewing, which woul further extend the usefulness of the systen for tactical surveillance purposes.

Our contributor of "World of Amateur Radio", besides being a radio amateur with the call sign G6CL, is Alderman John Clarricoats, O.B.E., J.P., Mayor of the London Borough of Enfield. He is seen here in both roles taking an active part in the "Jamboree on the Air 1968" at the Edmonton Venture Scouts' amateur station.



More on Explorer 38

Following our announcements in the tw previous months concerning this satellite w have heard from the National Aeronautic and Space Administration that the aerial have now been extended to their full length The satellite is now five times larger than an object placed in orbit and measures 1,500f in diameter.

The satellite is being used to monitor low frequency signals from space and the earth.

New Crystal Palace aerial

As part of the expansion of television transmissions in the London area, a new u.h.f transmitting aerial was brought into service in August, on the B.B.C's 645ft tower at Crystal Palace. At present radiating BBC-2 programmes, the new aerial, supplied by E.M.I. Electronics, will later transmit the duplicated BBC-1 programme in the u.h.f. band. A similar aerial currently being installed on the same tower is for I.T.A. programmes duplicated in the u.h.f. band which will be brought into service concurrently with the start of the BBC-1 duplicated service. The aerials are mounted colinearly on a 63ft extension to the tower and are enclosed in a 5ft-diameter reinforced plastics cylinder. Each aerial will be able to radiate two programmes with maximum e.r.ps approaching 1000kW.

Valve and semiconductor sales

The British Radio Valve Manufacturers' Association and the Electronic Valve & Semiconductor Manufacturers' Association have announced the following total sterling value of their members' sales in the second quarter of 1968:

Valves and tubes £15.3M.
Semiconductors £10.4M.

R.A.F. reorganization

On January 1st R.A.F. Signals Command will be renamed 90 (Signals) Group and will join Bomber and Fighter Commands as part of the new Strike Command. The responsibilities of 90 Group will be the same as those for Signals Command, the change being purely administrative.

"Codes and Code Converters"

We regret it has been necessary to delay the publication of Part 2 of "Codes and Code Converters" by N. M. Morris.

Tailpiece. Sales talks thinly disguised as technical consortia have been called "Tech-sortium" by the vice-president of Hughes Aircraft speaking at the E.I.A. autumn conference in America.

Direct Broadcasting from Satellites

A single satellite in geo-stationary orbit could replace the 44 television stations and numerous booster stations now in use in this country. This became clear at a recent I.E.E. colloquium called "Direct Broadcasting from Satellites" held in London. In such a system, which, we suggest, could be called DOMSAT, signals would be received and processed directly by a domestic television receiver and aerial installation instead of by an earth station for distribution as is the current practice.

The choice of frequency and modulation method used in such a system will be influenced by the need to keep the equipment at the receiving end as simple and as cheap as possible and at the same time not to place too many stringent requirements on the satellite.

Ideally, the satellite would transmit at u.h.f. using amplitude modulation and provide a signal strength equal to that of existing television transmitters. At u.h.f., and v.h.f., propagation conditions are practically as in "free space" and attenuation is negligible. However, if either horizontal or vertical polarization is used, a complication arises in that in passing through the ionosphere the plane of polarization is twisted due to Faraday effect. So it would appear that circular polarization would be the sensible choice. It has been established that to provide full television coverage, as far as the U.K. is concerned, a beamwidth of 1° is required. A u.h.f. system would require a space-borne aerial with a diameter of about 30m, which is not beyond the bounds of possibility, and a transmitter power of 25kW which would be very difficult, if not impossible, at the current state of the art. Another severe problem with u.h.f., as pointed out by T. Kilvington of the Post Office, is that the area of possible co-channel interference would reach to about half way down Africa.

Most speakers plumbed for the 11.7 to 12.7GHz band allocated internationally to broadcasting as being the best solution as far as the satellite was concerned. At these frequencies the dish diameter is reduced to about 1m. To provide good-quality television signals about 60kW of transmitter power is required if amplitude modulation is employed and only 250W if frequency modulation is used. Although the latter system is not so economical as far as bandwidth is concerned, 25MHz as against 5MHz for a.m., problems of satellite power supply and heat dissipation from the transmitter output stages are not so severe. Most of the figures given here were presented in a paper by G. J. Phillips of the B.B.C.

G. K. C. Pardoe of Hawker-Siddeley Dynamics speaking on the subject of space-craft design did not think that aerial size was a limitation and that very large aerials could be "grown" in space. His paper was intended to spread confidence amongst electronic engineers and stated that once it was known what was required of the satellite and what it had to carry it could almost certainly be done. On doubts expressed by some speakers regarding the satellite's ability to maintain the required pointing accuracy, 0.1° was mentioned, he said that space-craft with pointing accuracies of 1 second of arc had been designed for astronomical use. He urged electronics engineers to produce something concrete as soon as possible so that, as he put it, "space-craft designers would not be reading from another country's script".

Two papers dealing with satellite power supplies were given. A system based on very thin (125 µ) silicon solar cells mounted on polyimide film with a power/weight ratio of about 50W/kg was described by F. C. Treble and R. L. Crabb of R.A.E. The solar cells, during satellite launch, are stacked in a container concertina fashion. They are extended by a telescopic tube containing a gas cylinder which is operated pyrotechnically.

A satellite in a geo-stationary orbit positioned to serve the U.K. would, during certain times of the year, be in eclipse for periods of about 70 minutes around midnight. A continuous television service would require, if solar cells were the source of prime power, some form of power storage system which would be heavy and would incur high launch costs.

A brief review of the principles of thermoelectric and thermionic converters used with solar, radio-isotope and nuclear reactor heat sources was given by J. Myatt of A.E.R.E. Using these methods power/weight ratios of between 24 and 52kg/kW could be achieved. The solar heat source method would require a parabolic reflector that was continuously pointed at the sun and during periods of eclipse and energy could be stored in the form of heat. Safety problems in the event of an abortive launch could provide serious problems with the radioactive heat sources.

If the system is put into operation domestic television receiver designers will be asked to provide a unit that will enable standard television receivers to use the satellite's signals. As the present vision signal is amplitude modulated at u.h.f. and as the satellite's signals will probably be at s.h.f. with frequency modulation the problems are not going to be small.

R. N. Jackson read a paper prepared by himself and P. L. Mothersole and S. J. Robinson (all of Mullard) that pointed out the obvious places for injection of the signal into a television receiver. These were the aerial socket, the i.f. amplifier input and the video amplifier input. These, in turn, require an amplitude modulated u.h.f. signal, an a.m. intermediate frequency at 35MHz, and a video signal. A dish aerial of 1m diameter was thought to be the best for the job with a microwave converter at the aerial. The converter, which would eliminate the need for a waveguide feed to the television receiver, would probably consist of a hot-carrier diode mixer and a Gunn-effect oscillator. In the paper, it was said that either a wide-band fixed-tuned or a tuneable converter could be used. If the fixed-tuned approach was made and the converter output was fed directly into the receiver's aerial socket the oscillator would have to be accurate to within ±100Hz (at microwave frequencies) and the system would possibly be subject to interference from ground stations. Tuning would be carried out at u.h.f. With the tuneable converter, problems and expense would be incurred in remotely tuning the converter at the aerial. With either of the systems it was stated that two mixers would be required to produce an output at i.f. to avoid second channel interference.

It was suggested that the satellite signal could include a pilot to lock the mixer oscillator to provide the necessary frequency stability. However, such a pilot would fall at the vision carrier frequency of the fourth or fifth channel away from the required one.

J. P. Penney of Radio Rentals proposed that the composite signal could consist of a 12GHz carrier frequency modulated by a 35MHz amplitude modulated video carrier. Such a signal would be down-converted at the aerial to about 100MHz so that it could be fed via coaxial cable to an amplifier and discriminator. The output of the discriminator would be in standard form and could be fed straight into a television i.f. strip.

There are numerous problems to be solved if direct broadcasting from a satellite is to be achieved. How can a parabolic aerial, microwave converter and associated electronics be supplied at a cost acceptable to the general public (£60 was mentioned)? On top of this there is the cost of modifying existing television receivers and the cost of maintaining aerial-mounted electronics. The latter problem is alleviated to some extent by the fact that the aerial can be mounted adjacent to a window and need not be on a rooftop. The aerial problem may be solved by a sandwich wire planar array that was described by R. Graham of Elliott Automation if it could be economically manufactured.

The system may be ideal in newly developing countries starting a television service from scratch but not in the U.K. for many years.

Sound and Vision in the Queen Elizabeth 2

Passengers in Cunard's latest transatlantic liner will be served by a six-channel audio system which is part of a comprehensive sound complex embracing entertainment, emergency calls, crew orders and alarms. It is the first time that all these services have been combined with a ship's broadcasting system and the control equipment was specially developed and installed by Tannoy Marine Ltd. The connection of over 1,800 remote loudspeakers to the system and a total available audio power of 4.25kW gives some idea of the scale of the operation.

Audio Equipment

The main control console and distribution equipment are housed in a single operations centre but there are also subsidiary systems for turbine control, machinery control, restaurant service and the ship's theatre. Priority criteria determine when the subsidiary systems are connected into the main complex for emergency calls. The amplifiers are built up to the required output with combinations of two basic modules; one having 60W output and the other 200W output. These two standards of output power were chosen as being conveniently related to the different loudspeaker loads. In their construction, silicon transistors are used throughout.

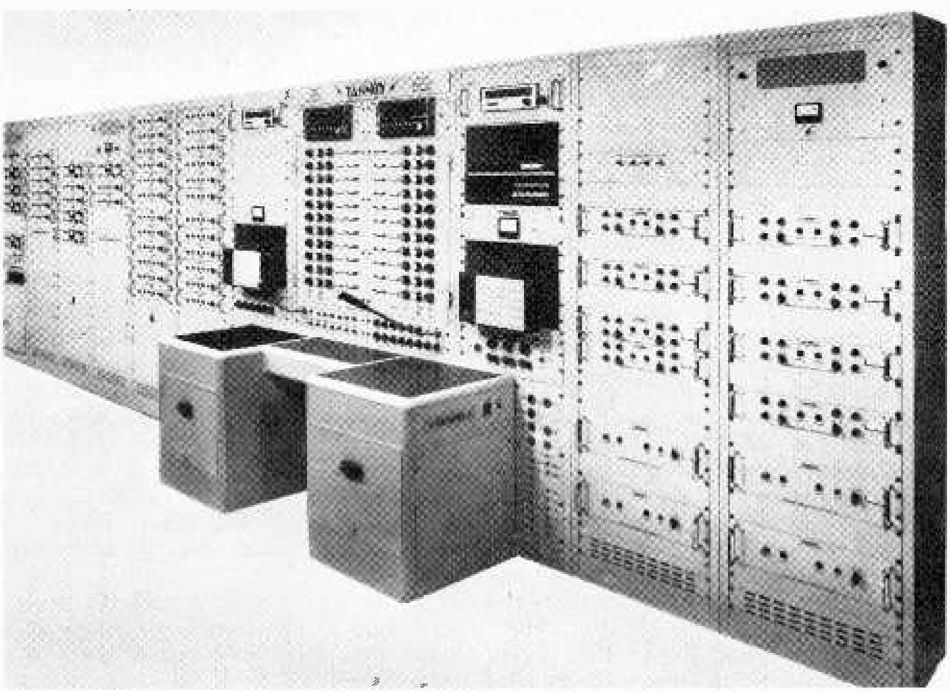
The six-channel cabin entertainment provides for, (1) background music, (2) performance music, (3) an hourly four-language news service and (4, 5 and 6) a selection of either "off air" radio programmes or control room originated material. It is possible for the passenger purser to break into all cabin and public room loudspeakers to make an announcement and, similarly, the crew purser can interrupt crew and officers programmes. Emergency calls from the bridge can override all programmes.

In the photograph of the equipment bank, two tape recorders can be seen just above the control desk, and at the top are just discernible, two f.m. tuners and two a.m. tuners. The left-hand tape recorder plays a continuous recorded tape which has a 23-hour capacity (not 24-hour, to avoid the same music being played at the same time each day) for service (1). The right-hand recorder is used to provide the 15-minute news service every hour in four languages, the translated recordings being made on the spot. The nightclubs have separate discotheque equipment and the theatre its own p.a. system from which the audio can be taken for relaying over the ship's broadcast network.

A final requirement of the system is the provision of "at anchor" fog warning signals. These comprise an electronic gong at the stern and an electronic bell at the bows sounded through Tannoy high-power units (recordings of the bell and gong installed in the original *Queen Elizabeth*).

The only equipment which operates entirely independently from the general sound reinforcement equipment is the induction loop radio interpretation system which is installed in the theatre and which gives a choice of several languages plus one floor language. Again, the circuitry is solid-state and stand-by modules are incorporated in the equipment. All of the systems operate from 240V 60Hz a.c. and in the event of an a.c. failure the emergency call circuits of the system are switched automatically to an independent 50V d.c. stand-by supply which will give 36 hours continuous operation. The main equipment is housed in the 12 metal racks shown in the photograph, installed in the air-conditioned control room.

Audio control desk and equipment racks



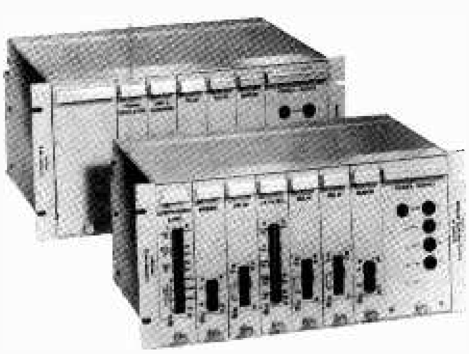
Television System

Provision of television entertainment equipment is being handled by Marconi Marine Ltd. It comprises basically two multi-standard master television receivers feeding over 1,000 terminal units in cabins and public rooms. Although similar in layout to a conventional land-based relay system it differs in one important respect; the parameters of the received signal will vary according to the ship's sailing schedule as she moves out of range of one country's transmitters and into range of the next. Six vision programmes can be provided and these are likely to be picked up from transmissions in any of the television broadcast bands, I, III, IV and V, either vertically or horizontally polarized and on any of the known system standards, except the 405-line.

Starting therefore with the aerials, these are a cross-polarized type designed by Marconi and built by J Beam Aerials. A separate aerial for each band is mounted on a common mast which is rotatable, the rotation being controlled by an operator in the main control room (the same room that houses the Tannoy audio system). Also mounted on the mast is a Band II aerial for part of the radio services. Television signals from the aerial cluster are applied to the Marconi master TV receivers which are adjusted locally to suit the signal parameters e.g. 625-50Hz or 525-60Hz, positive- or negative-going video, a.m. or f.m. sound and appropriate intercarrier spacing. No provision is made for 405-line reception since programmes using this mode of transmission in the U.K. will shortly be duplicated on 625 lines.

Vision output from the master receivers is 1V positive-going and the sound output is at audio frequency. The sound and vision signals are extracted in these forms so that they can be suitably processed for feeding over a Rediffusion h.f. wired relay system which is the system employed for distribution to the remote viewing units. The vision signal is remodulated on to a 5.5-MHz carrier and distributed to the viewing units via individual pairs. The accompanying sound channel is carried on the same cable at audio frequency.

The vision signal retains its original line standard when it is routed to the terminal units and at first it is surprising to learn that the terminal units are not switchable from one line/field standard to the other. They are Rediffusion terminal units designed ostensibly to operate on the 625-line 50-Hz field standard but they are also expected to work on 525 lines at 60-Hz field frequency without adjustment by the viewers. Any distortion of the picture geometry when the standard changes, because of the effect of the increased field scanning speed on the current through the field deflection coils, is put right by electronic adjustment of the picture height by automatic correction circuitry. Channel selection on the terminal units, which are supplied to Marconi Marine on sub-contract by Rediffusion, is by a rotary switch. As well as "off air" programmes, a telecine machine with two projectors in the control room allows films to be shown without a break. Also a small television studio enables "live" interviews or similar programmes to be distributed. It is expected that about seven colour receivers will be ordered by the shipping line for use in public rooms and these will have to be dual-standard-N.T.S.C./PAL receivers.



Lincompex r/t transmit and receive terminals

G.E.C. type RC/410/R. h.f. synthesized communications receiver.

Marconi Marine are also responsible for serving the cabins with a.m. radio signals from 150kHz to 30MHz and v.h.f./f.m. signals, for passengers who may wish to use their personal radio receivers. The a.m. signals are received on a whip aerial and the f.m. signals from the Band II aerial on the television aerial mast. They are distributed through the company's "Pantenna" system and are also fed to the Tannoy system's a.m. and f.m. tuners to provide its "off air" programmes. On the ship's operational side, electronic aids supplied by Marconi's include a recording echo sounder and visual depth meter, a weather facsimile receiver and chart recorder, an automatic direction finder and two lifeboat transceivers.

R/T Communication

Ship-to-shore radiotelephony communication services employed by the *QE2* include the new link compression and expansion techniques (Lincompex) evolved by the G.P.O. The GEC-AEI Lincompex II incorporates these techniques and is used in *QE2* in conjunction with GEC type RC/410/R synthesized receivers and International Marine Radio Company's transmitters.

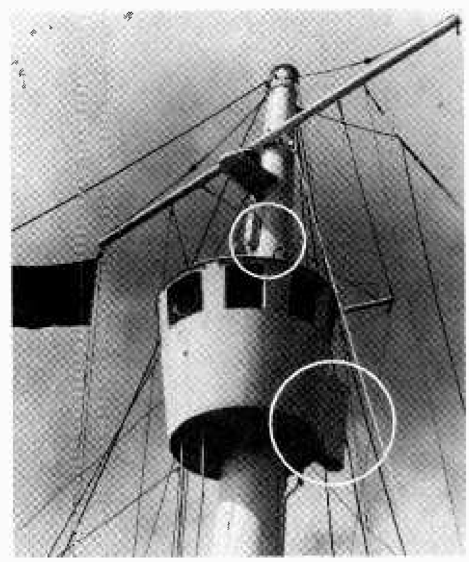
In this system 300Hz of the audio passband accommodates a control signal. Voice signals to be sent are compressed and the 300Hz-wide control signal is impressed with the compression details. At the receiving end the control signal determines the amount of expansion to be applied to the voice signals to restore them to their original form. This process allows full use to be made of the transmitting power and a consequent improvement in the signal/noise ratio. The GEC RC/410/R receiver, which was described in *Wireless World* for February 1968, page 712, covers 2-30MHz and features a built-in frequency synthesizer. Signal frequency is displayed digitally, the display being locked to the frequency synthesizer. A single knob allows the receiver to be tuned in 1kHz or 100Hz steps and frequency stability is said to be 5Hz at 30MHz.

I.M.R.C. has supplied four long-distance communication transmitters, which are stated to be "self-tuning". In reality, the transmitter exciters and remote tuning for the power amplifiers are located in the radio room while the power amplifiers are sited near the funnel, which carries the transmitting aerials. Selection of frequency is carried out on low power using two rotary switches and, on switching to high power, the power amplifiers are brought into tune by a servo-driven system.

Three of the transmitters, type ST1430A, cover the range 1.5-25MHz and have a peak envelope power output of 1kW. The fourth, type ST1400, covers 405-525 kHz, 1.6-3.8MHz and from 4 to 25MHz in seven bands, and has a 1500-W p.e.p. output. Two v.h.f. transmitter/receivers by I.M.R.C., installed on the bridge, will be used for communication with the ship's launches, when in use, and for communication with tugs, harbour masters and other services, when entering and leaving port.

A modern contribution to the liner's communication efficiency makes use of expertise gained in the rival aircraft industry. The h.f. and v.h.f. aerials employed for ship-to-shore communication were supplied by the British Aircraft Corporation and were originally developed as notch aerials for use on high-speed aircraft. Although the aerials fitted to the *QE2* cannot be accurately described as

Notch aerials mounted on the mast of R.M.S. Carmania.



notch aerials they are the products of a novel application of the notch principle and their small size (dimensions of the h.f. version are 150 × 46 × 76cm) enables four transmitter h.f. aerials to be mounted on the funnel structure and one receiving aerial on the wheelhouse adjacent to the radio room. Two v.h.f. notch aerials on the mast are for radio links between the bridge and the ship's launches and tugs. Notch aerials replace the conventional wire aerials with their attendant disadvantages, including fading due to screening and icing-up, when slung on the ship's superstructure, and damage from gale-force winds.

In our photograph of notch aerials on the mast of *R.M.S. Carmania,* which was used as a test bed for the *QE2* equipment, the aerial mounted on the after side of the crow's nest is an h.f. type and the two aerials fixed fore and aft the mast above the crow's nest are v.h.f. type. V.h.f. notch aerials are normally mounted in pairs on opposite sides of the mast to provide 360° coverage and are coupled by an associated phase feeder system.

Personalities

C. D. Hannaford, B.Sc., Ph.D., aged 32, recently joined Ferranti Ltd, Dundee, as head of the Ferrite Group. For six years before joining Ferranti Dr. Hannaford was a lecturer in the Department of Electrical and Electronic Engineering at Leeds University. A specialist in electromagnetic wave propagation, Dr. Hannaford took his degrees in electrical engineering at Leeds University after five years in the Royal Air Force Radar Branch.

The Saarland Government has conferred on **Dr. Walter Bruch,** the inventor of the PAL colour television system, the title of Professor "in recognition of his outstanding scientific merits". The honour was conferred on him at the recent annual conference of the Fernseh-Technische Gesellschaft e.V. (the German Television Society). Professor Bruch, who is 60 and is head of television basic development of AEG-Telefunken, received the Geoffrey Parr award of the Royal Television Society in London in 1967.

Peter Godfrey has been appointed director of automation by Standard Telephones and Cables Ltd. He joins S.T.C. from Plessey where he was manager of the Systems Application Division. Before that he held a number of senior research and engineering positions within Plessey. Mr. Godfrey replaces **John Hill** who has held the post for the past three years and has left to take up an appointment in the United States.

P. Godfrey

Alan C. Palmer has joined the board of the Aircraft Supplies Group of Companies, Bournemouth. Mr. Palmer joins the Group following fifteen years with the Sperry Gyroscope Division, Sperry Rand Ltd. where he was assistant sales manager of the Aero Systems Group. He spent three and a half years at the Woomera Rocket range in Australia in charge of missile firing teams for Sperry, and also spent three years at the Royal Aircraft Establishment, Farnborough, on the development of specialized instrumentation. Aircraft Supplies specialize in the overhaul and supply of flight instruments and also manufacture the MIDAS aircraft accident data recorder.

Philip L. Stride, F.I.E.E., has been appointed director and general manager of Ekco Electronics Ltd. He joined Ekco in 1948 and later became manager of the Malmesbury Division. Since 1960 he has been manager of the Aviation Division at Southend where he is succeeded by **V. J. Cox,** M.B.E., who has been deputy to Mr. Stride for some time.

D. R. Bell has been appointed chief engineer of Alma Components Ltd., of Diss, Norfolk, and its subsidiary companies. He was previously with Painton & Co. Ltd, and is chairman of the Technical Committee of the Radio & Electronic Component Manufacturers' Federation.

Robert Taylor has joined Transitron Electronic Ltd, of Maidenhead, as senior product marketing engineer. After studying at the Northern Polytechnic, London, Mr. Taylor was a graduate apprentice with Pye Ltd and held various positions in the technical publications, sales promotion and technical sales departments. He was latterly with Texas Instruments as a product marketing engineer.

The new manager of the Data Systems Division of Standard Telephones & Cables is **D. R. W. Thomas,** M.B.E., M.I.E.E. After service in the Royal Corps of Signals Mr. Thomas was a general staff officer in the Ministry of Defence. He joined S.T.C. as chief engineer of the Data Systems Division just over a year ago. In his new position Mr. Thomas is responsible for the company's activities at Cockfosters, North London, which covers the supply of a "total systems" service in computer-based communications.

Three research scholarships have been awarded by the B.B.C. under a scheme "to provide the opportunity for selected honours graduates 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 or television broadcasting". **A. M. Chitnis,** who graduated in electrical engineering from the Imperial College of Science and Technology, University of London, in 1963, was subsequently awarded a three-year Science Research Council Scholarship to Undertake research at the College, on "computer simulation of data reduction schemes for the transmission of pictures". He has been awarded a one-year B.B.C. Research Scholarship to enable him to complete his work. **M. J. Hawksford,** an electrical engineering graduate from the University of Aston, Birmingham, has been awarded a three-year B.B.C. Research Scholarship to undertake research in the Department of Electrical Engineering, at the University. His study will be on "delta modulation for television transmission". **G. B. Lockhart,** who graduated in electrical engineering from the University of Aberdeen in 1965 and in the following year was awarded an M.Sc. degree for his research into "the detection of signals in noise by the sequential estimation of channel conditions", has been awarded a one-year B.B.C. Research Scholarship to enable him to complete his Ph.D. studies. He is undertaking research at Imperial College, London, on the subject of "compatible single sideband modulation".

Brian J. Steel, who joined S.E. Laboratories four years ago, has been appointed sales manager of S.E. Laboratories (Engineering), of Feltham, Middx. Prior to joining the company Mr. Steel spent 14 years with British Aircraft Corp. where he was latterly engaged on the design and development of flight test instrumentation, notably for the BAC 1-11 and the VC 10.

J. P. R. West has joined Transitron Electronics Ltd, of Maidenhead, as European Marketing Manager. He will be responsible for co-ordinating the activities of the Transitron plant at Vernon, France, with those of the European engineering headquarters at Maidenhead. Mr. West was 11 years with Mullard, as a development engineer. For the past four years he has been engaged in semiconductor marketing in Europe, based in France.

The appointment of **J. Ford** as manager of the Service Department Cairo Mill, Oldham, Lancs, is announced by Ferranti Ltd. Mr Ford, aged 56, joined the company in 1926 as a junior in the Meter Department. He was later in the Radio Service Department before being appointed manager of the Instrument Service Department in 1939. Since 1949, he has been chief assistant to the manager of the Service Department.

Henry Davies, M.Eng., F.I.E.E., formerly head of the sound group in the B.B.C. Engineering Designs Department, has been appointed technical consultant to Mellotronics Ltd. He will be particularly concerned with the manufacture of the programme effects generator developed by the B.B.C. Mr. Davies joined the B.B.C. in the Research Department in 1935.

M. G. McBride, B.Sc.(Eng.), F.I.E.E., has been appointed chief engineer of Sangamo Weston Ltd. Mr. McBride, who is 55, joined the company's engineering department in 1937 after studying at the City & Guilds Engineering College, London. He left in 1950 to become chief engineer of the Record Electrical Company but in 1957 rejoined Sangamo Weston as contracts manager, Instruments Division.

Surrey Printed Circuits Ltd, announce the appointment of **Geoffrey A. Head** as production control manager of their Hounslow factory. Mr. Head was previously with Mullard Ltd, and G. A. Stanley Palmer Ltd.

OBITUARY

Alfred Bernard Howe, O.B.E., M.Sc., A.R.C.S., F.I.E.E., who died on 17 September while on holiday, was assistant head of the B.B.C's Research Department when he retired in 1960. He joined the British Broadcasting Company in 1924. He was one of the first to apply the principles of acoustics to the design of broadcasting studios, and became the first head of the acoustics section of the Research Department in 1929. In 1937 Howe transferred his interest to television, and was the Research Department representative at Alexandra Palace until the outbreak of war in 1939. He became the first Head of Television, Research Department, in 1946. From 1953 until his retirement he was assistant head of the Research Department. After retiring from the Corporation he joined the I.T.A. as a part-time assistant to the Chief Engineer and finally retired in 1966.

John Hopkins, for the past two years consultant to SGS-Fairchild for the audio market, died in mid September, aged 66. Prior to joining the company he had spent 21 years with Mullard after serving throughout the war in the Royal Air Force.

Microwave Semiconductor Devices

Experimental work on new solid-state generators for the GHz region revealed at MOGA 68 conference

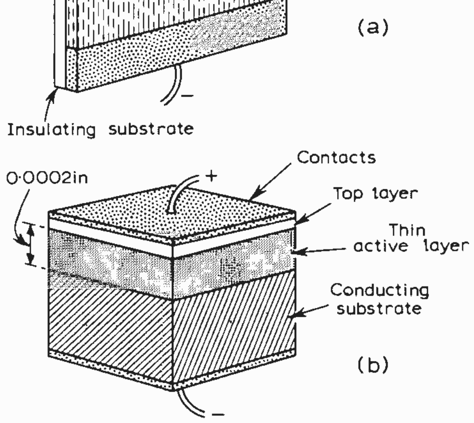
Only a few years ago people were saying that the transistor would never displace the thermionic valve in applications which demanded the highest frequencies and the highest powers. Since then we have seen developments in the transistor, and in semiconductor technology in general, which have slowly but surely eroded the substance of that idea and may eventually disprove it altogether. Furthermore it has not been just a matter of unilateral development—either high power *or* high frequency. Although these two requirements are to a large extent mutually exclusive in semiconductor technology, we are nevertheless beginning to see the emergence of solid-state devices which can displace, for example, klystron tubes and medium-wave transmitter valves. A particular field of interest at the moment is millimetre-wave communications systems—the rest of the radio spectrum having been pretty well filled—and a number of organizations are exploring what can be achieved with semiconductor devices in transmitters and receivers at these frequencies As in other fields, the main benefits to be obtained from using solid-state devices are small size, reliability, long life and low voltage power supplies.

Some of the latest advances in this field were revealed at the recent MOGA 68 conference in Hamburg (see also November 1968 issue, p.393). When the previous MOGA conference was reported on in this journal* the Gunn-effect diode seemed the most promising experimental solid-state device for generating frequencies in the GHz region. Since then it has come on to the market as a commercial product, but in the meantime it has been superseded in the laboratory by a new type of diode which is capable of operating at higher frequencies, and with higher power at any frequency, than all other solid-state devices. This is the "limited space-charge accumulation diode" or "l.s.a. diode" invented by J. A. Copeland of Bell Telephone Laboratories, U.S.A. Fig. 1 (a) shows the construction of the device, which, as can be seen from (b), is broadly similar to that of a Gunn-effect diode. The operating characteristic, however, is very different. The maximum frequency of Gunn diodes and other similar devices is limited by the transit time, which is the time taken by a space-charge (a concentration of electrons or holes) to travel through the device. The smaller the transit time, the higher the frequency. Thus, higher frequencies can be attained in transit-time limited devices only by making the active region of semiconductor shorter. This in turn limits their power at high frequencies.

In the l.s.a. diode the space-charge is dissipated within the material (usually n-type gallium arsenide) during each cycle before it builds up appreciably (hence the name "limited space-charge accumulation"). Radio frequency power can be generated by an l.s.a. diode because, above a certain threshold value of applied voltage and electric field, n-type gallium arsenide becomes a negative-resistance material. If a fixed bias voltage above this threshold level is applied to the diode, the negative resistance causes an oscillating voltage to be developed in which the total voltage across the diode swings first well above and then below the threshold electric field during each cycle.

The unique feature of the l.s.a. mode of operation is that the oscillating field swings above the threshold field long enough to generate a negative resistance but not long enough for the carriers to rearrange themselves into space-charge waves or domains. When the field swings below threshold, any minor space-charge irregularities are smoothed out before the next cycle begins.

Fig. 1. Structure of the l.s.a. diode (a) compared with that of the earlier Gunn-effect diode (b) which must be relatively thin in the direction of current flow.



Because the diode is not transit-time limited, it can be made thick enough to withstand relatively high applied voltages. Practical devices are therefore made long in the direction of current flow and thin in a direction perpendicular to current flow, as shown in Fig. 1(a). Normally the operating frequency of the diode is determined by an external resonant circuit (not by the thickness of the semconductor material or by transit time), so the power generated is practically independent of frequency.

The performance of l.s.a. diodes relative to other semi-conductor microwave generators is shown broadly in Fig. 2, which is taken from a review paper presented at Hamburg by C.A.P. Foxell of A.S.M. Ltd.

The operation of l.s.a. diodes under pulsed conditions at centimetre and millimetre wavelengths was reported on by B. Jeppsson, of Cayuga Associates, U.S.A. This worker claimed, for example, that 1.2kW of pulse power had been produced at 8GHz and several watts at 50GHz, and said that, with a modification of the l.s.a. mode, useful c.w. power was obtainable above 30GHz. A mercury-reed system was used for producing the fast rise-time pulses needed and the impedance of this device had to be adjusted to suit the diode impedance to prevent the diode from being destroyed. A typical duty cycle for the pulse operation was 10%. Jeppsson also described experiments with a "hybrid" mode of operation, which seemed to be a mixture of the normal l.s.a. mode and the normal Gunn-effect mode. This, he said, gave frequencies higher than the transit-time frequency and significantly higher powers and efficiencies than with the normal modes. The diodes had been operated with bias voltages five times the threshold voltage and with pulse lengths between 50 and 400ns, and, for example, with a bias of 200V, oscillations of 1.6GHz at a power of 130W and an efficiency of 17% had been obtained. Another American worker in this field, at R.C.A., had reportedly obtained 140W of r.f. power at 2.2GHz with 27% efficiency.

A further variation on the straightforward

*"Microwaves à la Mode", *Wireless World*, November 1966, p.572.

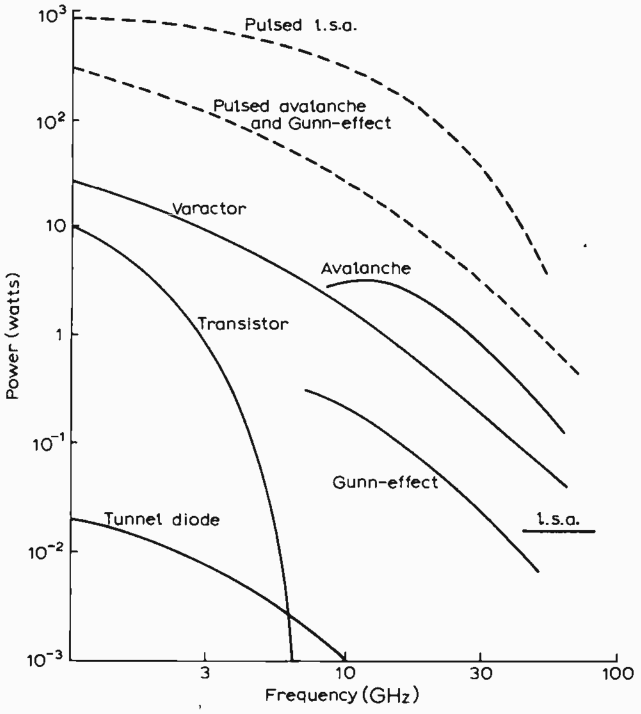
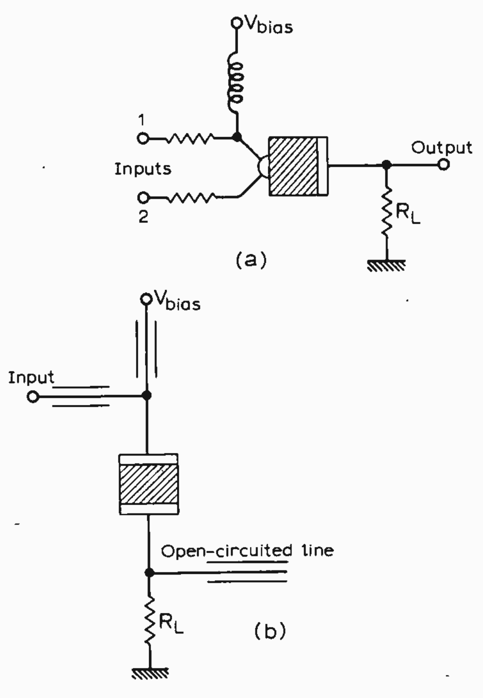


Fig. 2. Power and frequency performance of various solid-state generators of microwaves. (Information supplied by C.A.P. Foxell.)

Gunn and l.s.a. diode was described by S. Kataoka, of the Electrotechnical Laboratory, Tanashi, Tokyo. This was a relatively long and thin element of bulk GaAs (about 2mm long and 50-200 μm thick) sandwiched between two sheets of barium titanate which were described as "dielectric loading". The effect of the barium titanate sheets, various shapes of which had been tried, was to suppress the normal Gunn mode oscillation (the suppression being more effective when the sheets were backed with metal). When this device was mounted in a resonant cavity and a bias voltage applied, oscillations at frequencies ranging from 10MHz to 10GHz had been obtained from the same element.

Fig. 3. Two microwave logic elements using the Gunn effect: (a) an AND gate; (b) a one-bit storage element.



(The characteristic Gunn-mode oscillation, without the dielectric loading, would have been a single frequency of about 100MHz.) Kataoka claimed that the device had also been used for amplification at microwave frequencies. The mechanism by which the domain suppression took place was not understood, but a member of the audience suggested it was not due to short-circuiting of the Gunn-effect electric fields but to the effect of the capacitance, provided by the dielectric sheets, on the current through the device.

The use of Gunn diodes to form high speed logic elements operating at microwave frequencies was described by H. L. Hartnagel of Sheffield University, and an outline of this work was reported last month†. As was explained, the leading edge of the pulses in these logic elements is formed by the sudden drop of current when an electric-field domain is formed, while the trailing edge of the pulses is the termination of the current drop that occurs when the travelling domain reaches the anode end of the device and is discharged. Fig. 3 shows two examples of logic elements constructed on this principle. In the AND gate (a), a steady bias voltage is applied across the Gunn diode through the inductor and the output load resistor R_L. The two input resistors permit the electric field applied to the diode to be raised above the threshold necessary for domain formation only when both input terminals receive a voltage signal simultaneously. If the input resistors are removed the device becomes an OR logic element. Diagram (b) in Fig. 3 shows a one-bit storage element obtained by using a Gunn diode in conjunction with transmission lines. The diode is normally biased below the threshold value for domain formation. When a signal is applied to the input terminal a domain is launched, and the output signal produced by it across R_L travels along the right-hand open-circuited transmission line, is reflected back, and on returning to the diode triggers a further domain, so maintaining the "on" condition of the element and storing the input signal. Hartnagel said that such a memory element can be used in conjunction with AND elements to build up a shift register. In complete logic systems employing numbers of interconnected elements he claimed that the "fan-out" (maximum number of paralleled logic elements which can be triggered reliably by a single logic element) can be as large as 7.

One form of microwave signal amplifier is the parametric type, based on a mixing process in a non-linear reactance provided by a varactor diode. G. I. Haddad, of the University of Michigan, U.S.A., described an unusual type of device in which a series of varactor diodes (8 in one example) was mounted inside a transmission line to provide *travelling-wave* parametric amplification. The transmission line was of the ladder type as used in devices (e.g., travelling-wave masers) where slowly propagating electromagnetic waves are required. Alternatively an inter-digital line structure could be used. The energy for amplification was applied to the varactor diodes by a "pump" wave propagated along the line. Haddad claimed that such a device could provide a gain of 30dB, tunable over a frequency range of about 500MHz. A typical operating region was in the X band (7–12GHz).

†"Microwave Computers", *Wireless World*, November 1968, p.401.

Conferences and Exhibitions

Further details are obtainable from the addresses in parentheses

LONDON

Dec. 2-6 — Olympia
Engineering Materials and Design
(Industrial and Trade Fairs, Commonwealth House, New Oxford St., London W.C.1)

Dec. 4-12 — U.S. Trade Centre
U.S. Aviation Electronics Show
(The American Embassy, P.O. Box 1AE, Grosvenor Sq., London W.1)

OVERSEAS

Dec. 2-4 — New York
Applications of Simulation
(J. Reitman, Norden-United Aircraft Corp., Norwalk, Connecticut 06856)

Dec. 2-4 — Washington
Realibility Physics Symposium
(I.E.E.E., 345 E.47th St., New York, N.Y. 10017)

Dec. 3-6 — Paris
Computers on board Satellites
(Centre National d'Etudes Spatiales, 129, rue de l'Universite, Paris 7)

Dec. 4-6 — Miami Beach
Circuit Theory Symposium
(I.E.E.E., 345 E.47th St., New York, N.Y. 10017)

Dec. 9-10 — Chicago
Consumer Electronics Conference
(D. Ruby, Zenith Radio Corp., 6001 W. Dickens Ave., Chicago, Ill. 60639)

Dec. 9-11 — Chicago
National Electronics Conference
(Nat'l Electronics Conf., Oakbrook Exec. Plaza 2, 1211 W.22 St., Oak Brook, Ill. 60521)

Progress in Acoustics

Latest research reported at Sixth International Congress on Acoustics, Tokyo.

An interesting development at this year's international acoustics congress in Japan was the holding of two symposia, one before the congress, at Sendai, and one immediately after at Kyoto. The Sendai meeting was on physical acoustics and was of a notably high standard. The other meeting was concerned with speech and was held at the international conference hall at Sakyo-ku, Kyoto, which is a most impressive building set in an enchanting location. These symposia enabled specialist groups to get together in a way not possible with a full-scale meeting, and is a pattern that should commend itself to future congress organizers. The following items have been selected from the 430 papers as being of particular interest to *Wireless World* readers.

Architectural acoustics. The non-linear properties of resonators and their utilization for improving the acoustic conditions in rooms were discussed by Czarnecki of Poland. Ingard has shown that the non-linear properties of Helmholtz resonators arise from the dependence of the effective resistance of resonators on the particle velocity in the neck. At values of particle velocity greater than 50cm/sec part of the radiated energy is lost through swirls at the edge of the aperture. Czarnecki has come to the following conclusions as the result of his experiments:

1. Because of the non-linear properties, the absorption coefficient may depend on intensity at high levels and the changes increase with sharp opening edges of the aperture.
2. Depending on the surrounding conditions of the resonator, the non-linear losses can cause an increase or decrease of the absorption coefficient.
3. The existence of resonance systems in rooms can be a cause of curvilinear sound decay on the logarithmic scale.
4. The non-linear properties of resonators may be applied to change the acoustic signal dynamics in halls, which can lead to an improvement of the intelligibility of speech.

Speech. Today research into speech is an interdisciplinary science involving linguistics, phonetics, physiology, physics, psychology and electrical engineering. Professor G. Fant of Sweden suggested that intensified investigations into the structure of speech signals and their production and perception should lead to a foundation for man-made communications, economy of digital speech encoding and to new methods and aids for communicating with the hard-of-hearing and deaf. The emphasis today was on the temporal dynamics of speech structures and the development of models for prediction purposes. In psychoacoustics and hearing, computer modelling of the mechanical and neural activities of the ear had facilitated understanding of human perception and its relation to the physical properties of acoustic signals.

In a session devoted to speech recognition problems a paper which attracted much attention was one by Kersta, U.S.A., on speaker identification by voice prints. It is not a new idea to use voice prints in a similar way as fingerprints for identification purposes but now the procedure has apparently been put into operation in the U.S. and has led to criminal convictions being made. An interesting industrial development described by Koshikawa, Japan, was a real-time coloured display of sound spectrograms. In this system a coloured contour map is used to display the instantaneous spectrogram instead of the usual brightness modulation and it has proved very effective for signal detection in noise.

Ultrasonics. In this section were a number of papers concerned with various types of delay lines and, not unexpectedly, with the growing interest in surface waves. A contribution by Tournois and Lardat of C.S.F., France, for example, dealt with the use of Love waves* in dispersive delay lines. The lines had bandwidths of up to 30MHz and compression rates of the order of 150 to 200. The interesting feature of these Love waves is that the group delay curve has an inflection point, in the vicinity of which the curve linearity is very good for a relatively wide bandwidth. At present the lines suffer from rather large insertion losses due to the wave excitation being carried out at the surface. This loss may be avoided if the whole delay line is constructed from the same material without the use of a bonding agent. Lines made in such a manner are known as integrated or monolithic delay lines, and two papers on them were presented by a group of workers from an electrical communication laboratory in Tokyo. Ashida, Sawamoto and Toyoda described a delay line consisting of a thin piezoelectric circular ceramic disc with dot- and ring-shaped electrodes on both faces. By electrically "poling" the electroded parts in the thickness direction it was possible to generate cylindrical elastic waves on applying a suitable a.c. voltage. The annular ring between the electrodes served as a cylindrical elastic waveguide, and to avoid interference from the waves reflected at the disc circumference the dot and concentric ring were located off-centre of the disc. In the other integrated delay line, described by Inamura and Ikeda, a longitudinal wave launched by a transducer is converted into a shear wave by reflection. Consequently the line is characterized by a rather long delay, and in the absence of adhesive bonds it has also a good mechanical stability.

Acousto-electronics. In transparent acousto-electric materials optical probing provides one of the best methods to study acoustic properties, since measurements can be made at points within the specimen. Of the various optical techniques, Brillouin scattering gives the most detailed information and it has been utilized by Zemon and Zucker, U.S.A., to investigate the parametric amplification of acoustic waves in CdS. This amplification is due to non-linearity arising from the interaction of the bunched space charge associated with one acoustic frequency with the electric field associated with another acoustic frequency. For materials such as GaAs and GaSb, which are only transparent in the infra-red, other optical methods are more sensitive. A paper by Inuishi and Ishida, Japan, was concerned with the current oscillations of acousto-electric origin which are characterized by the propagation of an acousto-electric domain. The electrical properties of the domain structure were investigated using a capacitive probe, and Brillouin scattering was utilized to investigate the acoustic flux generated in the domain. The last-mentioned experiment enabled the time variations, the spatial distributions and the frequency spectrum of the acoustic flux to be studied.

An industrial exhibition of both audio and ultrasonic equipment was held during the period of the congress and the development of acoustical industries in Japan formed a significant part of the opening address to the congress by Junichi Saneyoshi, President of the Acoustical Society of Japan. Indicative of the magnitude of the industrial acoustical output is the fact that in 1967 the production of loudspeakers in Japan reached 88 million units. Some twenty-two manufacturers exhibited ultrasonic equipment of a wide variety. Ultrasonic applications in medicine are flourishing to such an extent that a Japanese Society of Ultrasonics in Medicine has been in existence for four or five years and has a current membership of over 200 people.

R. W. B. STEPHENS

* No connection with Radio Love (see p. 444).—ED.

Noise in Transistor Circuits

2. Noise figure : Negative Feedback : Measurements

*by P. J. Baxandall** *B.Sc. (Eng.), F.I.E.E., F.I.E.R.E.*

The theoretical mechanisms producing noise in transistors have been thoroughly investigated by Van der Ziel and others in several important papers[5,6,7,8,9]. While these papers are by no means easy to read and understand, some quite simple and useful conclusions may fortunately be deduced from them.

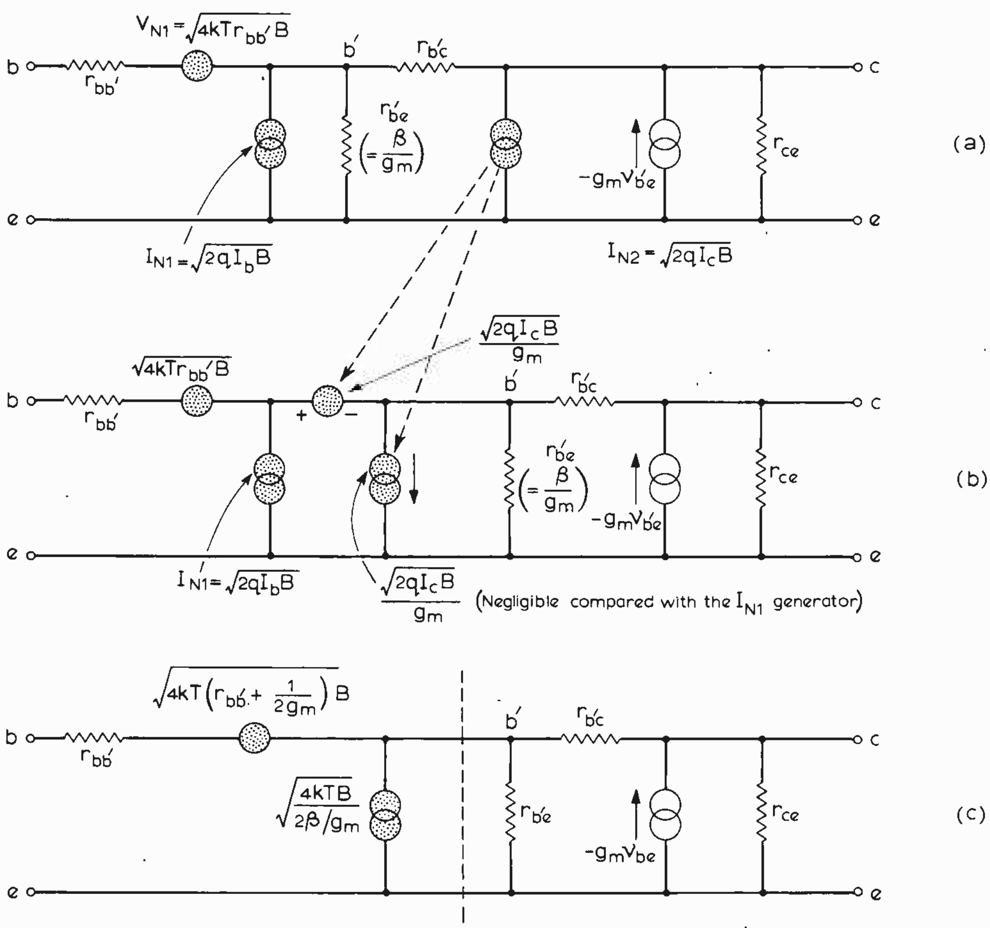
Equivalent circuits representing the internal noise mechanisms of a transistor have usually been of the common-base T type[1,8]. However, the advantages of thinking in terms of the hybrid π equivalent circuit for noise purposes[10] are considerable, just as they are, in the author's opinion, for other aspects of transistor circuit work. Further, a very welcome simplification of the noise theory as put forward by Van der Ziel can now be made, because the thermally-generated leakage currents, which play a significant role in determining the noise performance of germanium transistors, can normally be neglected when silicon planar transistors are used, as will usually be the case nowadays.

* Royal Radar Establishment.

With this simplification, and ignoring flicker noise for the time being, there are three significant noise mechanisms in a transistor, which are very easily remembered when described in the following manner:

(a) Johnson noise in the extrinsic base resistance $r_{bb'}$.
(b) Shot noise on the base current.
(c) Shot noise on the collector current.

Fig. 9. Noise generators in the hybrid-π equivalent circuit.



The corresponding three generators, which are uncorrelated at low frequencies, are shown in Fig. 9(a), and are shaded to emphasise that they are noise generators in contrast to the normal "mutual conductance" generator of the hybrid π circuit.†

It should be emphasised that the Fig. 9(a) circuit is based on low-frequency considerations only, and that the noise performance at frequencies which are a substantial fraction of f_T cannot be satisfactorily obtained merely by adding the usual hybrid π capacitances to it. The intrinsic noise mechanisms become partially correlated at higher frequencies, leading to a poorer noise performance. However, up to frequencies approaching $f_T/\sqrt{\beta}$, which includes all normal audio work and some r.f. applications as well, these effects do not need to be taken into account for ordinary engineering design work.‡

While the attractively easy-to-remember three-noise-generator equivalent circuit of Fig. 9(a) could be used as it stands for calculating the noise performance of existing transistor amplifier stages, it is found much more convenient, *for design purposes*, to represent the noise behaviour of a transistor, or any other linear amplifying device for that matter, by only *two* noise generators placed right at the input terminals, i.e. arranged as in Fig. 10.**

† Mr. S. W. Noble, of the Royal Radar Establishment, has shown that the circuit of Fig. 9(a) is *exactly* equivalent at low frequencies to the well-known T-circuit, as given, for example, in Fig. 5 of reference 11, and that, assuming no correlation between the three noise generators in the latter circuit, the three generators in Fig. 9(a) are also uncorrelated. An independent check on the equivalence of the two circuits was obtained by calculating the low-frequency noise-figure formula from Fig. 9(a), without introducing any approximations, and this agreed exactly with equation (19) of reference 11.

‡ At audio frequencies, as explained later, it is best, for good noise performance, to operate at a very low value of collector current, e.g. 10 μA. Even a fast silicon planar transistor, such as the BC109, then has an f_T of only a few hundred kHz, so that the "low-frequency regime" only just includes the whole audio spectrum. However, in most r.f. applications, where flicker noise is not involved, it is better, from several points of view, to operate at much higher values of collector current. and then the "low-frequency regime" may extend up to some MHz.

** By choosing the values of V_N and I_N correctly, together with the right degree of correlation between them, the noise of any linear amplifier, and its variation with source impedance, may be correctly represented. This is considered in more detail in reference 11.

The problem is thus to convert Fig. 9(a) to the form of Fig. 10. The first move is to :ploit the fact that the right-hand noise-ırrent generator in Fig. 9(a) may be :placed by the two 100%-correlated :nerators of Fig. 9(b), as indicated by the roken-line arrows. It will be found that ıese two generators produce the same noise ıtput from the transistor, whatever source ; load are connected to it, as does the single :nerator from which they are derived. (It interesting to find that, taking $r_{b'c}$ as ıfinite, the two generators cancel each ther as far as feeding noise current into the ase signal source is concerned—this ought) be so, because the single generator they :present is purely in the output circuit.)

Now in Fig. 9(b), since $r_{b'e}\, g_m = \beta$ and ince $I_c/I_b \approx \beta$, the right-hand noise current enerator is of approximately $\sqrt{\beta}$ times maller magnitude than the left-hand one nd can therefore be neglected without erious error.

The next move, which will be seen later o be sensible, is to express all the remaining hree uncorrelated generators in Fig. 9(b) in erms of resistance values which would ›roduce the same magnitude of noise by one of the Johnson noise formulae (7) or (8); the generator labelled $\sqrt{4kTr_{bb'}B}$ is, of course, ılready in that form. This can be done by ıtilizing the basic fact for a transistor that $g_m = qI_c/kT$. Thus, substituting $q = kTg_m/I_c$ in the formula for the right-hand voltage generator in Fig. 9(b), this generator becomes $\sqrt{4kTB(1/2g_m)}$, i.e. as for the Johnson noise voltage in a resistance of $1/2g_m$.

Similarly, the current generator $\sqrt{2qI_bB}$ in Fig. 9(b) becomes:

$$\sqrt{\frac{4kTB}{2I_c/g_m\, I_b}}$$

Taking I_c/I_b as being equal to the small-signal current gain β—which is a more accurate approximation with some transistors than with others—the last expression becomes equal to:

$$\sqrt{\frac{4kTB}{2\beta/g_m}}$$

i.e. as for the short-circuit Johnson-noise current in a resistance of $2\beta/g_m$.

We thus arrive at the approximate equivalent circuit of Fig. 9(c), and it will be seen that this is of the same form as Fig. 10, except for the presence of the noiseless resistance $r_{bb'}$. However, it is shown in the Appendix that, provided $g_m\, r_{bb'}$ is $<< 2\beta$, the effect of $r_{bb'}$ may be neglected with little error. For a fairly typical modern transistor with $r_{bb'} = 200\ \Omega$ and $\beta = 200$, $g_m\, r_{bb'}$ is less than a tenth of 2β for collector currents up to 5 mA. In all normal audio applications, and many others too, the working current will be well under this value, and we may then take the noise equivalent circuit as being nearly enough that of Fig. 9(c) *without* $r_{bb'}$ *and with no correlation between* V_N *and* I_N.

The final conclusion is thus that, for many practical purposes, we may represent the noise of a transistor (ignoring flicker noise) sufficiently accurately by means of two uncorrelated noise generators as shown in Fig. 10, where:

V_N is as for the Johnson-noise voltage in a resistance

$$R_{Nv} \approx r_{bb'} + 1/2g_m \quad . . . (15)$$

and I_N is as for the Johnson-noise short-circuit current from a resistance

$$R_{Ni} \approx 2\beta/g_m \quad . . . . . (16)$$

It is the usual present-day practice to express V_N and I_N in terms of microvolts and microamps in a bandwidth of 1Hz,†† but their expression in terms of R_{Nv} and R_{Ni} seems very much preferable and has been strongly advocated by Dr. E. A. Faulkner of Reading University[11,13]. The full virtue of Dr. Faulkner's method will become apparent from what follows in the next section of the article.

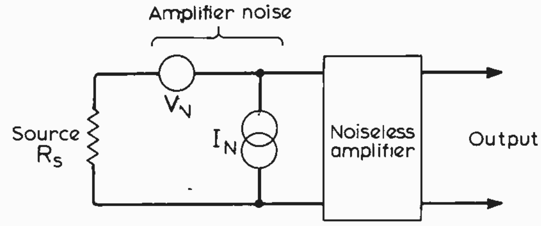


Fig. 10. Representation of amplifier noise by two generators right at the input terminals.

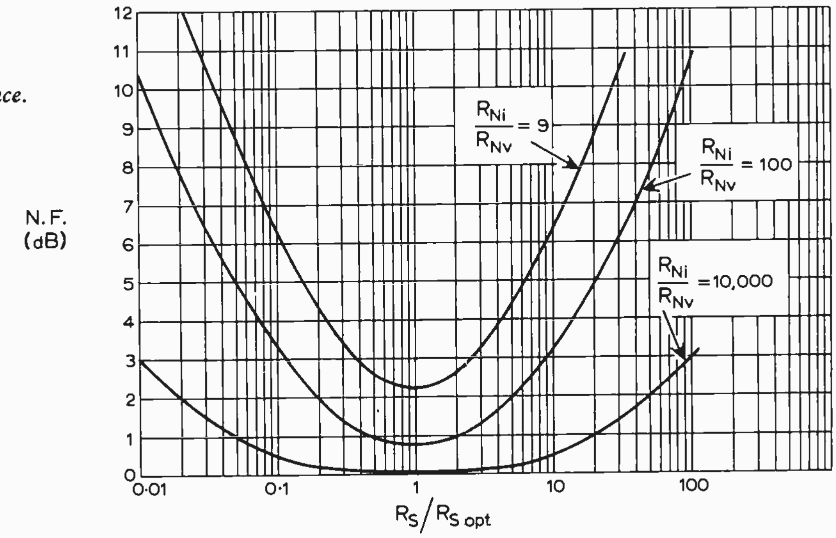


Fig. 11. Variation of Noise Figure with source resistance.

Noise Figure

The noise figure of an amplifier, fed from a resistive signal source R_S as in Fig. 10, is a measure of the amount by which the total noise output exceeds what it would be if the amplifier were ideal and the only noise came from thermal agitation in R_S. Thus:

Noise Figure =

$$= \frac{\text{Total noise output power}}{\text{Noise output power due to source only}} \quad . . . (17)$$

†† Often the rather barbarian expressions "microvolts per root cycle" and "microamps per root cycle"—or ". . . per root hertz"—are used!

This ratio is often expressed in dB, and when there is no correlation between V_N and I_N (Fig. 10), it is easily shown that:

$$\text{N.F.} = 10 \log_{10}\left[1 + \frac{R_{Nv}}{R_S} + \frac{R_S}{R_{Ni}}\right] \text{dB} \quad . . . (18)$$

where R_{Nv} and R_{Ni} have already been defined.

It is evident from the form of equation (18) that there must be an optimum value of R_S which will make the noise figure a minimum, i.e. give the best noise performance. Calling this optimum value of source resistance $R_{S\,opt}$, we have, not surprisingly, the result:

$$R_{S\,opt} = \sqrt{R_{Nv}R_{Ni}} \quad . . . (19)$$

It is also obvious from (18) that for a good, i.e. low, noise figure, R_{Ni} must be very much greater than R_{Nv}. For example, if $R_{Nv} = 200\ \Omega$ and $R_{Ni} = 20\ \text{k}\Omega$, it is immediately evident that a fairly good noise figure is achievable and that the optimum source resistance is the geometric mean of 200 Ω and 20 kΩ, which is 2 kΩ. The ease with which these things may be seen at a glance when the transistor noise information is given in the form of R_{Nv} and R_{Ni} values is a great advantage of the method when compared with the usual practice of quoting V_N and I_N values for a bandwidth of 1 Hz.

On substituting the value of R_S given by equation (19) in equation (18), we get the result:

$$(\text{N.F.})_{\min} = 10 \log_{10}\left[1 + 2\sqrt{\frac{R_{Nv}}{R_{Ni}}}\right] \quad . . . (20)$$

and by further substituting the values of R_{Nv} and R_{Ni} given by equations (15) and (16) into (20), we obtain:

$$(N.F.)_{min} = = 10\log_{10}\times\left[1+\sqrt{\frac{1+2g_m r_{bb'}}{\beta}}\right] \quad \ldots (21)$$

This gives the minimum noise figure that will be obtainable, *at a given value of d.c. working current* in the transistor, if R_S is adjusted (e.g. by suitably choosing the ratio of an input transformer) for optimum performance. However, we are also free in many cases to choose the value of the d.c. working current, and this may be varied, keeping R_S optimized all the time, to obtain the lowest possible value of minimum noise figure. This latter operation involves finding the minimum value of $(1 + 2g_m r_{bb'})/\beta$. Now $2g_m r_{bb'}$ normally reaches unity at a collector current somewhere in the region of 50 μA, so no large improvement would be expected to result from reducing the collector current to a very much lower value than this. Indeed, with some transistors, the fall-off in β at very low currents, say less than 10 μA, more than offsets the slight further reduction in $(1 + 2g_m r_{bb'})$ achieved, and the minimum noise figure then gets worse again. However, in situations where flicker noise is significant, there is a marked overall advantage, as will be seen later, in operating at very low values of collector current, such as 1 μA or even less.

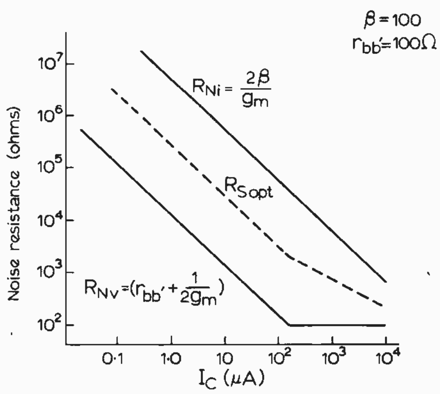


Fig. 12. Variation of R_{Nv} and R_{Ni} with collector current.

Sometimes, in practice, the value of R_S is fixed by circumstances over which the designer has no control, and the problem is to choose the value of collector current which will then give the minimum noise figure. On substituting the values of R_{Nv} and R_{Ni} given in equations (15) and (16) in equation (18), and then differentiating with respect to g_m, we find that the condition for minimum noise figure is $g_m = \sqrt{\beta}/R_S$. Thus, if $R_S = 1\ \text{k}\Omega$, and $\beta = 100$, we get $g_m = 10$ mA/V, which corresponds to $I_c = 0{\cdot}25$ mA.

As an example of what can be achieved when we are free to choose the value of R_S, consider a transistor such as a BC109 running at a collector current of 10 μA. Take $\beta = 200$, $r_{bb'} = 200\ \Omega$[12]. The g_m value will be 0·4 mA/V, so that, from (15), $R_{Nv} = 1{\cdot}45$ kΩ, and from (16), $R_{Ni} = 1$ MΩ. From equation (19) we then get $R_{Sopt} = 38$ kΩ, and substituting this in (18), or from (20) or (21), we obtain a noise figure of 0·32 dB.

Noise figures not much greater than this are indeed achievable in practice with good modern silicon planar transistors at audio frequencies, but it is important not to overlook the fact that, having obtained a very good noise figure for the first stage of an amplifier, the second stage may easily contribute as much noise as the first, or even more.

With regard to the last point, the danger arises particularly when the second stage, as is often the case in practical designs, is run at a much higher current than the first. The trouble is caused by the current noise generator (see Fig. 9(c)) of the second transistor, which, because of the high working current, will be of relatively large magnitude. It may thus produce more noise current, particularly at low frequencies, because of flicker noise, than that coming from the collector of the (very-low-g_m) first stage. Dr. Faulkner has recommended that the second stage of a low-noise amplifier should be run at the same low collector current as the first stage, though it is not always worth carrying things quite as far as this—some compromise with other requirements will often be struck, even in an enlightened design.

Fig. 11 is simply based on equations (18) and (19), and shows how the noise figure increases as R_S is changed from its optimum value R_{Sopt}. The important point is that provided the optimum noise figure is good enough, i.e. provided R_{Ni}/R_{Nv} is large enough, the value of source resistance becomes very uncritical. Thus it may be worth aiming at a very good minimum noise figure not so much for its own sake but rather because it makes the amplifier capable of giving a tolerably good noise performance over a wide range of source resistance values.

Fig. 12, based on a contribution to *Electronics Letters* from Dr. Faulkner[13], is a plot, on a "straight line approximation" basis, of equations (15) and (16), and also illustrates the meaning of equation (19).

A slight complication in all the above, which should now be mentioned, is that, according to reference (10), the value of $r_{bb'}$ which gives the correct input impedance does not, in general, give the correct value for the noise generator. At low currents, however, $r_{bb'}$ is in any case swamped by $1/2g_m$ (see Fig. (12)), so uncertainty about its value does not matter much. But the true value of much of the above simple theory is not so much that it enables precise calculations to be made, but rather that it helps one to appreciate the principles involved and avoid misdesign caused by ignorance. It is often sufficient to obtain the correct order of magnitude of noise effects in the design stage, and to make experimental checks later if necessary.

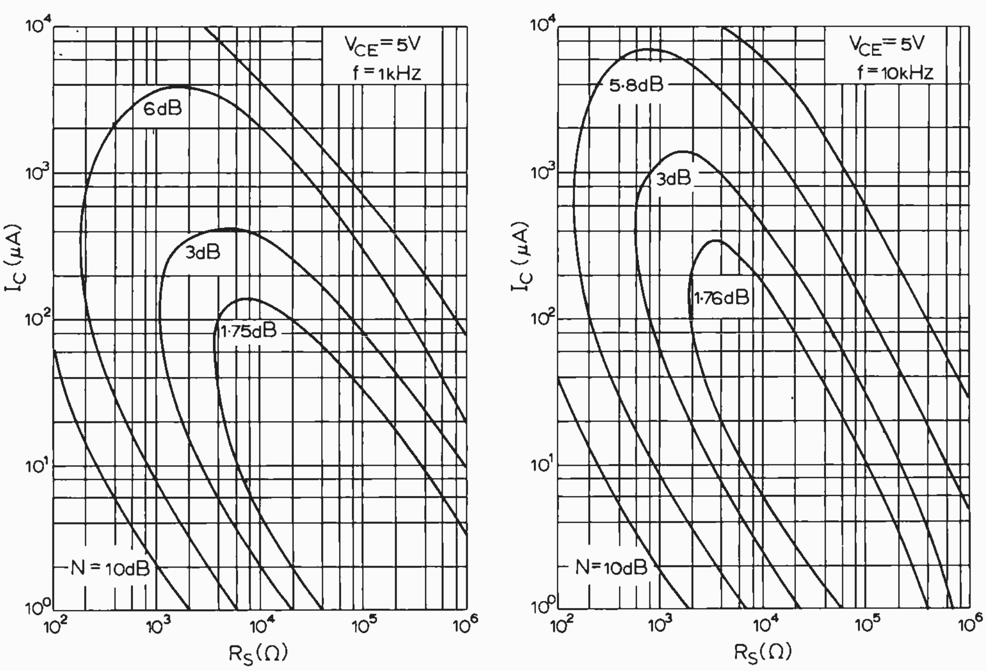
Another method of presenting noise data for a transistor is shown in Fig. 13, and is self explanatory. (Taken from S.T.C. data sheet; the Mullard data sheets do not give such detailed noise information.)

Flicker Noise[1]

Flicker noise, or "$1/f$" noise, is exhibited by all normal amplifying devices, and transistors are no exception. To quote from reference 10: "Flicker noise is known to arise from the generation or recombination of carriers on the surface, although other physical processes can also produce it. For example, it can also arise as a result of temperature fluctuations. Note that only 0·001°C fluctuation in temperature can cause 2 to 3 microvolts of fluctuation in voltage across a forward biassed diode."

From reference 14, on which the following

Fig. 13. Contours of constant Noise Figure vs. collector current and source resistance for type BC109 transistor.



information is based, it would seem that, for a planar transistor, flicker noise can be represented as an increase in the current noise generator (see Fig. 9(c)) below a certain frequency, the voltage noise generator not exhibiting flicker effect.‡‡ Thus the resistance R_{Ni} representing the current noise generator falls in value below a certain frequency, so we replace equation (16) by:—

$$R_{Ni} = \frac{2\beta}{g_m(1 + \omega_F/\omega)} \quad . . . (22)$$

‡‡ Actually there is evidence that R_{Nv} does exhibit flicker effect, but its value does not begin to rise until a much lower frequency than ω_F.

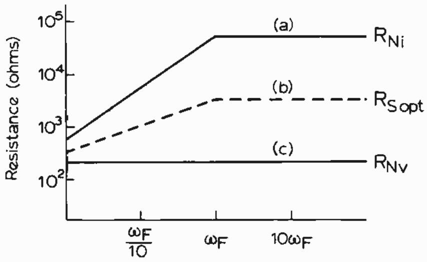


Fig. 14. Input noise generators for a transistor exhibiting flicker noise. $\beta = 100$, $r_{bb'} = 100\ \Omega$, $I_C = 100\ \mu A$.

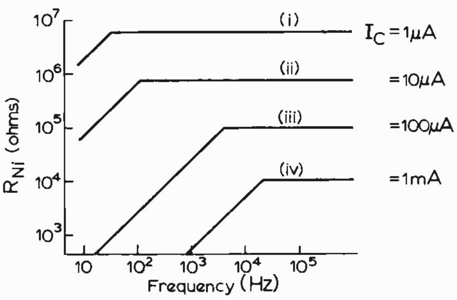


Fig. 15. Variation of R_{Ni} with frequency and collector current for selected 2N3707.

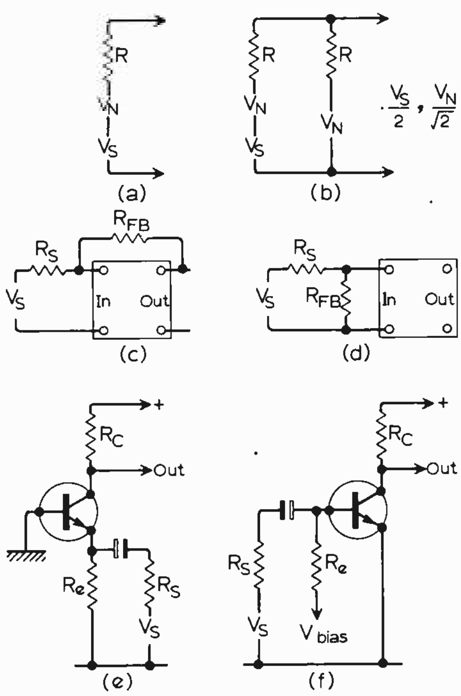


Fig. 16. Negative feedback and noise.

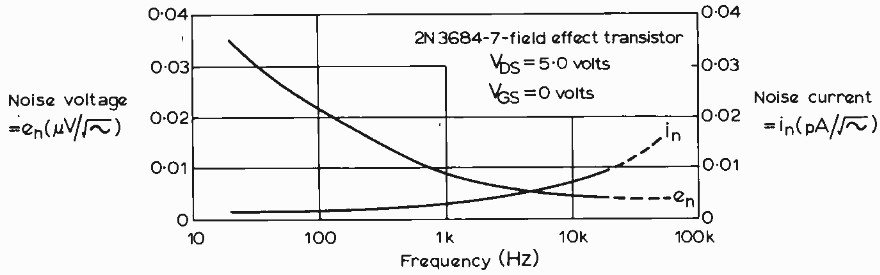


Fig. 17. Equivalent input noise voltage and current vs. frequency, for a junction f.e.t.

Fig. 14 shows the variation of R_{Ni}, R_{Nv} and R_{Sopt} with frequency.

The parameter ω_F, the flicker-noise corner frequency, characterises the "flicker-noisiness" of the transistor; it is a function of the collector current, I_c. Fig. 15 shows the behaviour of a transistor with regard to flicker noise, as a function of frequency and collector current. The lines are best-fit lines, of the same form as in Fig. 14, to a series of experimental measurements done at Reading University on a selected specimen of the low-noise transistor 2N3707, and represent an exceptionally good transistor from the flicker-noise point of view. It will be seen that, for a collector current of 1 μA, $\omega_F/2\pi$ is only about 60 Hz, and this particular specimen will give a noise figure of better than 1 dB from a 100-kΩ source over the whole frequency range 25 Hz to 40 kHz. Clearly it is particularly advantageous to operate a transistor at very low current when a good noise figure is required *at very low frequencies*.

Negative Feedback and Noise

Negative feedback as such has no effect whatever on the noise figure of an amplifier at any given frequency, though the passive components introduced for the purpose of applying the feedback may do so.

The golden rule for preserving good noise figure is to avoid introducing *passive resistive attenuation* of the signal.

Consider a resistive signal source, with a signal voltage V_S and a Johnson noise voltage V_N, as shown in Fig. 16(a). Now, as shown in Fig. 16(b), imagine an extra resistor of the same value as the signal source resistance to be shunted across. This shunt reduces by a factor of two the signal voltage appearing at the output leads shown, and does likewise for the source Johnson noise voltage, *but* it also produces its own Johnson noise voltage V_N which appears attenuated by a factor of two at the output leads. There are thus two uncorrelated noise voltage components of $V_N/2$ at the output, so that the total output noise voltage is $V_N/\sqrt{2}$. The net effect of adding the extra resistor is thus to attenuate the signal by a voltage factor of two, but to reduce the noise voltage by a factor of only $\sqrt{2}$.

Clearly, to minimise the loss of signal-to-noise ratio caused by a shunt resistor, the resistor value must be much higher than that of the source. A practical example of a situation in which these issues arise is shown in Fig. 16(c) and (d), where, for good s/n,

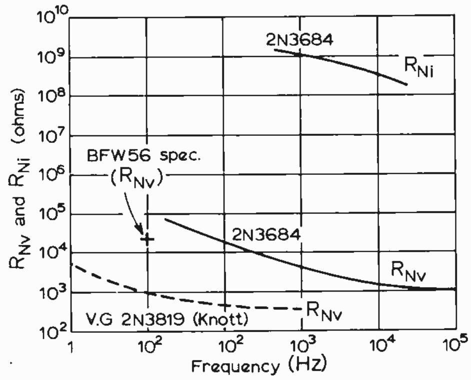


Fig. 18. Variation of R_{Nv} and R_{Ni} with frequency for 2N3684 and 2N3819 f.e.ts.

R_{FB} should be made several times R_S at least. The s/n, at any one frequency, will be just the same for the two circuits shown.

Another example of the same broad principle is shown in Fig. 16(e) and (f). Here the significant thing is that there is passive resistive attenuation of signal because the signal source is shunted by a resistor R_e; the fact that in the left-hand circuit the output current is allowed to flow through the parallel combination of R_S and R_e to provide negative feedback does not in itself affect the signal-to-noise ratio.

Noise in f.e.ts

The noise performance of an f.e.t., like that of an ordinary transistor or any other amplifying device, may be expressed in terms of V_N and I_N noise generators in the input circuit of an imaginary noiseless f.e.t.

Fig. 17, which is taken from Union Carbide Application Note AN-1 (June 1965), shows experimental values of V_N and I_N (here called e_n and i_n) as a function of frequency. It is stated that the values of V_N and I_N are not very dependent on the d.c. operating current, provided the drain-to-source voltage exceeds the pinch-off value.

The same information as is presented in Fig. 17 is given in a form much easier to appreciate in Fig. 18 (full-line curves); this diagram also includes (broken-line curve) data on a specially-selected and unusually good sample of 2N3819 reported upon by K. F. Knott of Salford University.[16]

While the sample of f.e.t. giving the broken-line curve has a quite splendid noise performance, it is unfortunately the case, at present, that very large variations indeed in flicker noise occur between different samples of nominally the same f.e.t. However, f.e.ts with a definite specification on flicker noise can now be bought—e.g. the Texas BFW56, which has an upper limit on R_{Nv} as indicated by the cross in Fig. 18. This transistor costs over £3 at present.

Comparing Fig. 18 with Figs. 12 and 14, it will be seen that an f.e.t. has an enormously greater ratio of R_{Ni} to R_{Nv} than an ordinary transistor, and it will also be noticed that flicker noise appears in the voltage generator (represented by R_{Nv}) rather than in the current noise generator. Indeed the current-noise generator magnitude appears to fall off as the frequency is reduced, if one can believe this R_{Ni} curve. According to reference 17, the increased current noise at high frequencies is due to "induced gate noise", analogous to "induced grid noise"[18] which appears at much higher frequencies in valves. Nevertheless it would seem that, at sufficiently low frequencies flicker noise on the gate current must become dominant, causing R_{Ni} to fall off again at very low frequencies.

However, because of the enormous ratio of R_{Ni} to R_{Nv} in an f.e.t., very low noise figures can be obtained under suitable operating conditions. For example, from Fig. 18, with a 1 MΩ source, which is about the optimum, being half way between R_{Nv} and R_{Ni} on the log scale, equation (18)

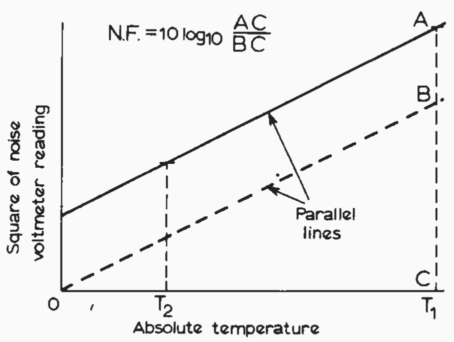


Fig. 19. Technique for measuring noise figure. T_1 *= room temperature ≈ 290°K.* T_2 *= liquefied gas temperature.*

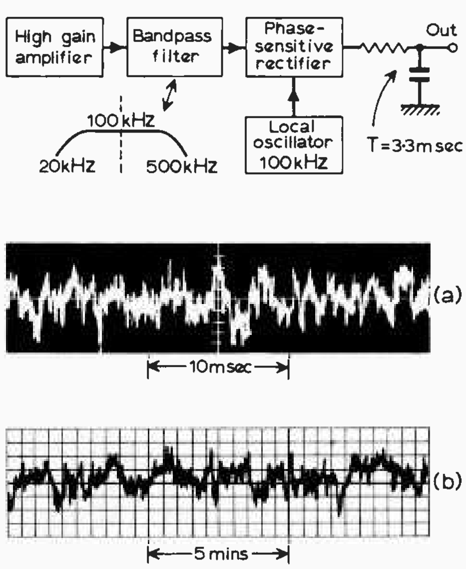


Fig. 20. System used for generating white noise: (a) result from system shown; (b) l.f. version with T = 10s.

yields a noise figure at 1,000 Hz of 0·02 dB.

In many applications, with source resistances not exceeding a few hundred kilohms, only R_{Nv} need be taken into account, just as with the equivalent noise resistance of a thermionic valve.

The following simple formula is often quoted for the voltage noise of an f.e.t.:

$$R_{Nv} = 0{\cdot}7/g_m \quad . . . (23)$$

in which R_{Nv} is in kΩ if g_m is in mA/V

Knott reports, as a result of measurements on large numbers of f.e.ts, that above about 10 kHz, R_{Nv} does in fact approach the value given by this formula—so that at these high frequencies increasing the working current does reduce R_{Nv}—but that at much lower frequencies, where flicker noise is dominant, increasing the current increases R_{Nv}. Since these effects are in opposite directions, there will be a frequency band over which varying the working current has very little effect on R_{Nv}, and this may be the reason for the remark, in the Union Carbide Application Note referred to above, that V_N and I_N are not very dependent on the d.c. operating current.

An important point to appreciate is as follows. With ordinary transistors, whilst very good noise performance can be obtained at audio and sub-audio frequencies, the low collector current required necessarily makes the high frequency performance very poor, even using fast silicon planar transistors. With f.e.ts, however, the good low-frequency noise performance is maintained up to frequencies of some MHz. Thus, using f.e.ts, it is possible to design an amplifier with a first-class noise performance over a very wide frequency band, to an extent which is quite impossible with a straightforward amplifier using ordinary transistors.

Measuring Noise Figures

In the opinion of the author, who has used no other method for over ten years, much the easiest and generally most satisfactory way of measuring the noise figure of an amplifier is to dip the source resistor in liquid nitrogen or other liquefied gas and observe the drop in the output noise level of the amplifier.*** A check should be made that the resistance value of the source resistor does not change significantly on cooling it down, though a normal wire-wound resistor will be found satisfactory in this respect. It is not essential to use a true r.m.s. reading output meter, as only the ratio of two mean squared output voltages is required—indeed an AVO on an a.c. volts range will often suffice. The noise figure is deduced in the manner shown in Fig. 19.

This technique is particularly effective for measuring good noise figures, e.g. 1 dB, where slight uncertainties regarding noise bandwidths, or the calibration of noise-generating diodes, often render more normal methods very difficult.

*** More conveniently, the amplifier input is switched between two resistors of equal value, one at a low temperature and one at room temperature.

Generating White Noise at Low Frequencies

Noise diodes, and several other methods of generating Gaussian noise for test purposes, suffer from the difficulty that unwanted flicker noise tends to be produced below, say, 100 Hz.

A technique which is quite free from this difficulty is to generate the noise at around some easy frequency, such as 100 kHz, and then heterodyne it down to zero frequency in the manner shown in Fig. 20. This is the technique that was used to generate the white noise shown in some of the earlier illustrations. The local oscillator and frequency changer were, in fact, part of a transistor b.f.o. designed at R.R.E. some years ago, and the high-gain amplifier was a general-purpose valve laboratory amplifier of even greater age! The same basic set-up is an inherent part of a "lock-in amplifier" system designed at R.R.E. by E. F. Good, and the lower recording in Fig. 20 was obtained with this equipment. The time base speed has been adjusted to have the same ratio to the noise bandwidth in both pictures, and it is interesting to note that, despite the enormously different absolute time scales, the general appearance is the same.

Needle Fluctuations of Noise Meters

In some noise measurements the noise-indicating meter will give a nice steady reading, whereas in other circumstances it may be found that the needle dithers about so much that it is difficult to decide what reading to note down.

The narrower the bandwidth of the noise being measured, the longer must be the effective time-constant of the rectifier and meter to produce a given amount of needle fluctuation. For the case where the noise bandwidth is determined by a sharp-cutting filter, the relationship between the quantities involved is as shown in Fig. 21. The factor "2" inside the square-root sign is different for other shapes of noise pass-band, but nevertheless the formula given will still give an answer which is of the right order, and this is usually all that is needed.

Gaussian noise is, of course, assumed in deriving this formula.

Some Noise Bandwidths

It is sometimes inadvertently overlooked that the noise bandwidth of a circuit is not, in general, the same as its "3 dB down" bandwidth.

For an ordinary tuned circuit, as for the *CR* lag in Fig. 22, the noise bandwidth is $\pi/2$ times the 3 dB-down bandwidth.

With two equal lags, each of time-constant *CR*, not loading one another, the response will be 6 dB down at $1/2\pi CR$, and the noise bandwidth is $1/8CR$.

With a simple *CR* a.c.-coupling, giving a low-frequency cut which is −3 dB at $1/2\pi CR$, the lower limit of the equivalent rectangular noise response will extend down to $1/4CR$.

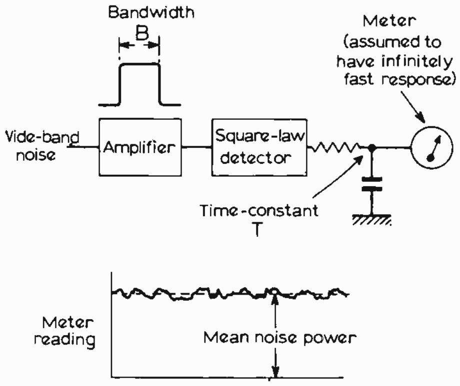
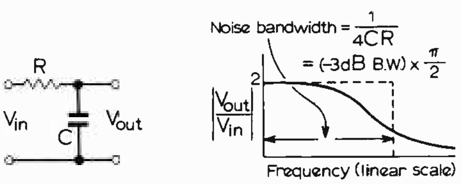


Fig. 21. Noise-meter needle fluctuations:

$$\frac{\textit{r.m.s. reading fluctuations}}{\textit{mean reading}} = \frac{1}{\sqrt{2BT}}$$

(e.g. for a bandwidth of 1 Hz, a smoothing time constant of 50s is required to reduce the r.m.s. meter fluctuations to 10% of the mean reading.)

Fig. 22. Noise bandwidth. The area under the broken-line rectangle is the same as that under the curve.



Acknowledgement. The author would like to thank this colleague, Mr. S. W. Noble, for having helped him, over a period of many years, to acquire a better understanding of noise problems—and, in particular, for having shown that Fig. 9(a) is exactly equivalent to the usual T circuit at low frequencies, when the author had concluded, through a slip in algebra, that this was not strictly the case!

Thanks are also due to Dr. E. A. Faulkner, whose contributions on noise topics have been found very helpful and thought-provoking.

This article, which is based on an internal lecture given by the author at R.R.E., is contributed by permission of the Director.

Appendix

Values of V_N and I_N in Fig. 10 to make Fig. 10 exactly equivalent to Fig. 9(c).

The problem is to find the values of the two noise generators in Fig. 10 which will make this circuit equivalent to Fig. 9(c) under conditions when the presence of $r_{bb'}$ cannot be neglected. These generators will necessarily be partially correlated, even though those of Fig. 9(c) are not. Their magnitudes, however, are easily obtained, since the noise e.m.fs seen looking back towards the source from the terminals of the noiseless amplifier must be the same in both circuits for the simple conditions of a short circuit, and an open circuit, across the source terminals.

In the circuit of Fig. 9(c), with a short circuit between 'b' and 'e', we see, looking to the left of the broken line, an e.m.f. 'E' acting in series with $r_{bb'}$ given by:

$$E^2 = 4kTB\left(r_{bb'} + \frac{1}{2g_m}\right) + \frac{4kTB}{2\beta/g_m}r_{bb'}^{\,2}$$

or

$$E^2 = 4kTB\left(r_{bb'} + \frac{1}{2g_m} + \frac{r_{bb'}^{\,2}}{2\beta/g_m}\right)$$

For the Fig. 10 situation, with $R_s = 0$, the e.m.f. seen from the noiseless amplifier input terminals is simply V_N. For equivalence of the two circuits we therefore have:

$$V_N^2 = 4kTB\left(r_{bb'} + \frac{1}{2g_m} + \frac{r_{bb'}^{\,2}}{2\beta/g_m}\right) \quad . . . \text{(i)}$$

With an open circuit between 'b' and 'e' in Fig. 9(c), we see, looking to the left of the broken line, a current source of value:

$$\sqrt{\frac{4kTB}{2\beta/g_m}}$$

In Fig. 10, with $R_s = \infty$, we simply see I_N. Hence:

$$I_N = \sqrt{\frac{4kTB}{2\beta/g_m}} \quad . . . . . \text{(ii)}$$

Looking at equation (i), it will be noticed that V_N^2 involves, in the third term, the same noise current generator

$$\sqrt{\frac{4kTB}{2\beta/g_m}}$$

which appears in (ii), so that V_N and I_N are partially correlated. Provided, however

$$\frac{r_{bb'}^{\,2}}{2\beta/g_m} \text{ is } << r_{bb'} + \frac{1}{2g_m} \quad . . . . . \text{(iii)}$$

the amount of correlation will be negligible. It is easily shown that the condition for the two sides of (iii) to be equal, is approximately:

$$g_m = 2\beta/r_{bb'} \quad . . . . . \text{(iv)}$$

If $r_{bb'} = 100\ \Omega$ and $\beta = 100$, (iv) gives $g_m = 2000$ mA/V, which corresponds to a collector current of 50 mA.

We have thus established that the last term in (i), which may be called the correlation term, may be neglected, for normal engineering purposes, provided the working current does not exceed, say, 5 mA.††† This condition will be satisfied with a large factor to spare, except in some high-frequency amplifiers.

Thus equation (15) may be used to determine R_{Nv} in most practical design work, but at high values of collector current, the expression becomes:

$$R_{Nv} = r_{bb'} + \frac{1}{2g_m} + \frac{r_{bb'}^{\,2}}{2\beta/g_m} \quad . . . . . \text{(v)}$$

Equation (16) is, however, applicable even at high currents. Equations (v) and (16) are plotted in reference 15 as universal curves, though in terms of V_N and I_N for a 1 Hz bandwidth instead of in terms of R_{Nv} and R_{Ni}.

††† Reference 11, in equation (21), gives a condition for negligible correlation, which, whilst correct, appears to be unnecessarily stringent for normal practical purposes.

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Encoded Keyboard for Computers

Based on the estimate that by 1975 some 75% of computer costs will be for peripheral equipment, mainly remote terminals, Honeywell Controls' Micro Switch Division set itself the task of developing an extremely reliable low-cost keyboard, envisaged as a terminal through which data can enter the complex network of peripheral equipment connected to a remote computer and for the extraction of information. Whereas in 1960 only a quarter of the cost of a computer system was spent on peripheral equipment, by 1967 this figure had risen to 43%.

It is expected that computers will play an increasing role in office routine and, because office staff have a working familiarity with typewriters, the new Honeywell keyboard is designed to resemble a typewriter keyboard. Communications between remote terminals could be so rapid that the enormous amount of mail passing between business locations might largely disappear.

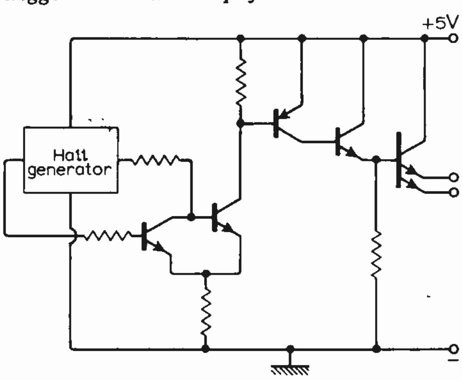
A single major benefit of this alpha/numeric keyboard is the elimination of moving contacts which, besides providing longer life and higher reliability, brings a number of other advantages. It is electrically compatible with logic devices in other equipment (voltage and current levels are of the same order) and the usual bounce gate and delay circuits are not required. Operating speed is virtually unlimited since it could be keyed at the same speed as the logic circuits themselves. Furthermore the output from each key is electrically identical and no compensation for variations in contact resistance from switch to switch is required.

The secret of this high-speed contactless operation lies in the use of the Hall effect as a function of the key switch. (Hall effect is the variation of p.d. appearing round the edges of a specially treated semiconductor when it is passed through a magnetic field.) The special semiconductor is diffused into a silicon microcircuit which is inserted into the press-button key moulding itself and, when the key is depressed the microcircuit passed between two plastics magnets linked to form a U-shape. On the same silicon chip as the Hall generator is a trigger circuit followed by a Darlington pair providing an output of 3.5V from each key when operated. A circuit diagram of the microcircuit and an enlarged photograph of the actual chip are shown. The chip terminals are bonded to the lead frame which is fastened to one of two printed circuit boards within the keyboard.

A discrete binary computer code is provided for each key, encoding being achieved by a second printed circuit board mounted below the key termination board. By a process of inter-connection between the two printed boards, the keyboard can be encoded to suit hardware using hexidecimal, Boudot, 6-way binary, USASCII, EBCDIC or special codes according to user requirements. In its quiescent output state the keyboard has 50μA leakage current and in the operated state the maximum output current source is 10mA. Either positive or negative output is possible.

No fixed price is available at present but by mid-1971 Honeywell expect the price to be less than £60. The keyboard components are being imported from America and assembled at Honeywell Controls' factory in Scotland until consumer demand allows manufacture of the complete unit in the U.K., except for the silicon chips.

Circuit diagram of the microcircuit showing the three distinct sections; Hall generator, trigger circuit and amplifier.



Announcements

RCA-ICL joint venture. RCA Great Britain Ltd and International Computers Ltd. have announced the formation of a jointly owned company RCA Magnetic Products Ltd. The new company will manufacture tape and other forms of magnetic products in Great Britain for the British and export markets.

Member firms of the **Association of Public Address Engineers** and several other companies are staging a joint display at the Basle International Exhibition of Industrial Electronics (INEL) which takes place from 4th-8th March next year. The Association's own three-day exhibition opens in Harrow, Middx., on 11th March.

Hunting Engineering Ltd., Electrocontrols Division, Dallas Road, Bedford, announce a marketing and manufacturing agreement with Automatic Timing and Controls of America. The agreement covers the complete range of **weigh-cells** and associated electronics.

A complete range of **medical electronic monitoring equipment,** manufactured by Harco Electronics Ltd, of Canada, is now available in the U.K. through S.E. Laboratories (Engineering) Ltd., 606 North Feltham Trading Estate, Feltham, Middx.

Marine television. A total of 41 vessels of Ellerman Lines Ltd., and Bibby Line, Ltd., are to be equipped with multi-standard television receivers by Marconi Marine. The vessels are also to have aerial arrays, for the reception of transmissions in Bands I and III.

Racal Communications Limited, have received a £27,000 order for a consignment of their "Squadcal" **s.s.b. manpacks** for the Zambian Army.

Guest Electronics have been appointed sole U.K. representatives for the entire range of products manufactured by **Theta Instruments Corporation** of New Jersey, U.S.A.

Dual Electronics, British agent for **Dual** hi-fi equipment from Germany, are now also marketing the German **Wega** brand audio equipment. Wega Sales Division, Dual Electronics Ltd., Radnor House, London Road, London, S.W.16.

Aveley Electric Ltd announce that their marketing interests of **U.S.S.R. products** will be confined to a few selected items of particular interest to British industry and not to the wide range of products publicized at the time of the recent Soviet Exhibition in London.

The sound and television distribution system for the 2,000 luxury homes in the City of London's **Barbican development scheme** will use the standard British Relay h.f. multi-pair system. Distribution to the first completed block of 114 flats includes BBC-2 colour.

A £15m contract has been won by Standard Telephones and Cables Ltd for the supply and installation of a broadband **microwave telephone transmission system** covering a route length of 1,600 miles in four Brazilian states—Rio de Janeiro, Espirito Santo, Minas Gerais and Sao Paulo. The microwave equipment will be of the latest solid-state 7GHz type with channel capacities of 300, 600 and 960. Also included in the contract is 1,250 miles of coaxial cable and multiplexing and power equipment for 128 stations.

Standard Telephones and Cables Ltd have been awarded a contract worth £150,000 by the Indian Department of Civil Aviation, to supply **instrument landing systems.** Calcutta, Bombay and New Delhi airports will be fitted with the STAN 37/38/39 ILS which is capable of automatically landing suitably equipped aircraft in "zero-zero" visibility conditions.

The Marconi Company have been awarded a contract worth nearly £½M by the Telecommunications Department of the Malaysian Government for the installation of a two-way **tropospheric scatter system** to provide a telephone and telegraph service between East and West Malaysia.

For the supply of **transportable h.f. stations,** Racal (Canada) Ltd, Ottawa, a subsidiary of Racal Electronics Ltd, of Bracknell, Berkshire, have been awarded a contract valued at almost $1.4M by the Canadian Department of Defence Production.

A comprehensive **"nurse-call" communications system** and television and radio relay have been installed by British Relay in the new ward block of King's College Hospital, London.

The Marconi Company has recently installed and commissioned a £4,000 **closed-circuit television system** in the Jessop Hospital for Women, Sheffield. The camera used in the system, the Marconi V322B, has been designed specifically to meet the needs of educational closed-circuit television.

Three new 16mm **colour educational films** are available from Mullard Ltd. The titles are "The Klystron", and "Atoms and their Isotopes" parts 1 and 2, dealing with naturally occurring isotopes and man-made isotopes respectively. The films may be hired or purchased from the Mullard Film Library, Kingston Road, Merton Park, London, S.W.19.

Douglas A. Lyons and Associates Ltd. have changed their address from 32 Grenville Court, S.E.19, to 8 Ryecotes Mead, Dulwich Common, London, S.E.21. (Tel 01-693-2855.)

Wireless World Colour Television Receiver

7. Intermediate-frequency amplifiers

Fundamentally, the i.f. amplifiers of a colour television receiver are substantially the same as those of a 625-line monochrome set. They differ considerably from those for 405-line television, however. For the British 625-line system, the polarity of the vision modulation is the opposite of that used in the 405-line system; the tips of the sync pulses correspond to maximum carrier level instead of to minimum. Frequency modulation is used in the sound channel instead of amplitude modulation, and, of course, the bandwidth needed for the vision signal is some 5MHz instead of only 3MHz.

The addition of colour affects the requirements very little except to make the bandwidth requirements more stringent. It is necessary for the i.f. response curve of a colour receiver to be smoother and more precisely tailored than that of a black-and-white set. It is also necessary that the shape of the curve should not change very much with variations in the setting of the gain control. It is usually said that the phase response of the amplifier is important for colour. This is true, but it does not normally have to be given much separate consideration. As long as minimum-phase networks are used, which is generally the case, the phase and frequency responses have a fixed relation and it is necessary only to consider the frequency response. Matters are helped, too, by the adoption in this country of the PAL system, which is less critical than the N.T.S.C. to defects of phase response.

The sound and vision signals are radiated on separate frequencies from separate transmitters. They are received on a common aerial and then amplified and converted to two separate intermediate frequencies in the tuner unit. The frequencies chosen are 33.5MHz for sound and 39.5MHz for vision. The vision signal is of the vestigial sideband type with a bandwidth of some 5MHz, so that the vision i.f. amplifier requires to have a −6-dB response at 39.5MHz and at about 34.5MHz. The colour sub-carrier is 4.43MHz and so falls in the i.f. amplifier at 35.07MHz.

In monochrome reception an excessive drop in response around 35MHz merely results in reduced definition in the final picture, which may hardly be noticed by non-critical viewers. In a colour receiver, however, the effect is much more drastic and cannot fail to be noticed, for it can mean the complete loss of colour!

This makes the tuning of a colour receiver much more critical than that of a monochrome set. The cut-off of the i.f. amplifier below 34.5MHz has to be very sharp to avoid interference from the sound signal. Slight mistuning one way brings in sound interference, just as in monochrome. Slight mistuning the other way removes the colour completely from the picture, whereas in monochrome the drop in definition might well pass unnoticed.

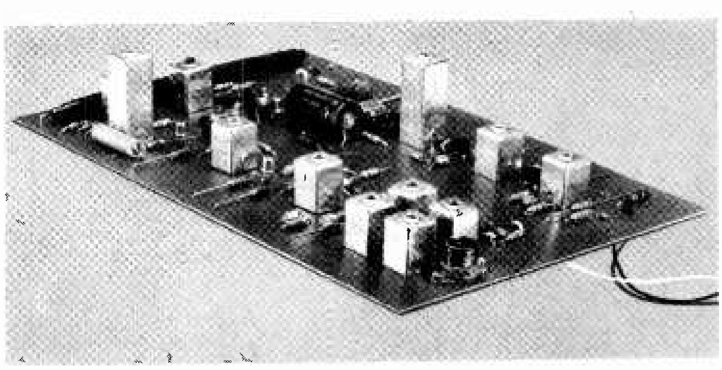
There are two possible ways of treating the sound i.f. channel. One is basically the same as that necessarily adopted in 405-line receivers. It is to have two separate i.f. amplifiers one for vision and one for sound, with no more than, perhaps, a common first stage. This requires the use of a very stable oscillator in the frequency changer because of the narrow bandwidth of the sound i.f. amplifier. As the transmissions are at u.h.f. it is difficult to obtain the necessary stability.

Because of the adoption of frequency modulation for the sound channel on the 625-line system an alternative is possible. This is the use of the so-called intercarrier sound. The sound and vision signals pass together through the 'vision' i.f. amplifier and the response curve is shaped so that the response at the sound carrier is at least 26dB below that of the vision signal. At the video detector itself, or in a separate detector, the difference frequency of 6MHz between the sound and vision signal is produced and bears the frequency modulation of the sound signal. It will necessarily be affected also to some extent by the amplitude modulation of the vision signal. This is not great, however, as long as the sound signal at the detector is always weaker than the vision signal. This is the reason for the relative attenuation of at least 26dB of the sound signal in the i.f. amplifier. This is needed to ensure that on peak white and on saturated colour signals, when the vision signal reaches its minimum values, the vision signal is still stronger than the sound.

The 6-MHz f.m. sound signal thus produced is taken from the detector and amplified in the sound i.f. amplifier, which is tuned to 6MHz, and which ends in an f.m. detector, usually a ratio detector. Fairly high gain is needed for the 26-dB loss in the main amplifier has to be made up and good limiting action is needed to remove any amplitude modulation of the signal produced by the video signal.

Fig. 1 shows the complete circuit diagram of the vision and sound i.f. amplifiers together with the vision a.g.c. amplifier, and the first video stage. There is a three-stage vision i.f. amplifier, with a diode detector and a unity-gain first video stage. This feeds the luminance amplifier from its collector through a

General view of the printed-circuit board which carries all parts shown in Figs. 1 and 2



delay line to equalize the transit times of the luminance and chrominance channels. It feeds the a.g.c. amplifier and the chrominance amplifier from its emitter.

A two-stage d.c. amplifier provides gain-control bias for the first i.f. stage and for the tuner. The intercarrier sound signal is taken from the video detector and fed to a two-stage 6-MHz amplifier which culminates in a ratio detector.

The circuit embodies eight transistors and five diodes. All the transistors are silicon n.-p.-n. types and so require their bases and collectors to be positive with respect to their emitters. The transistors are thus like valves with positive grids in respect of the supply voltage polarity. However, Fig. 1 may seem a little confusing at first because it is the positive of the supply which is earthed to chassis.

It will be remembered from Part 4, Power Supply, that a common mains transformer winding provides, through separate rectifiers and smoothing circuits, two 20-V supplies, one with its negative earthy and the other with its positive earthy. The first is used for the chrominance circuits, the second for the i.f. amplifiers. If this were all, there would be no reason why both supplies should not have their negatives earthy. However, certain stages in the chrominance circuits need a 40-V supply, and by arranging the 20-V supplies with one having a positive earth and the other a negative, the 40V can be obtained across the two without any extra components.

Input circuit with traps

Although it appears to complicate matters the positive earth of the i.f. amplifier supply does not really do so. To avoid getting confused it is best to regard the −20-V line as the base line and to measure all voltages from it.

Referring again to Fig. 1, the input tuned circuit has the coil L_1. The tuner culminates in a similar coil and is connected through a short length of coaxial cable to the bottom end of L_1. In effect, there are two tuned circuits, one in the tuner and one in the amplifier, which are bottom-end capacitance coupled by a capacitor in shunt with the capacitance of the cable. This capacitor is not shown in Fig. 1, since it is fitted at the tuner.

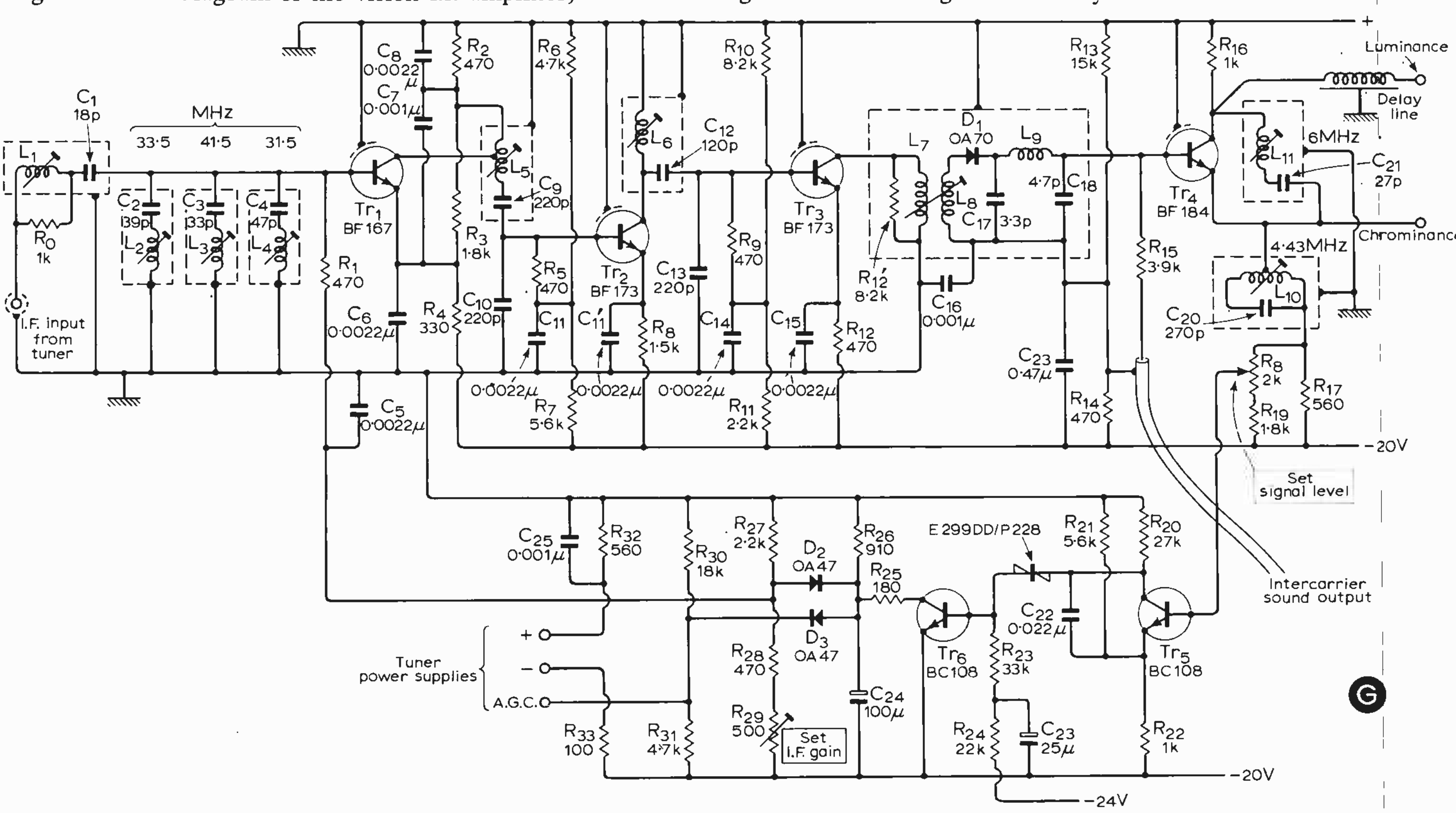
The transistors used all have an input capacitance of about 45pF. Ignoring the trap circuits for the moment, the tuning capacitance for L_1 is C_1 of 18pF in series with the 45-pF input capacitance of Tr_1. The two form a capacitance potential divider across L_1 so that, in effect, Tr_1 is tapped well down the tuned circuit. The tuned circuit is thus less heavily damped than would at first appear by the base-feed resistor R_1 of 470 Ω in shunt with the input resistance of Tr_1. This tapping down is needed to obtain proper damping of the tuned circuit, but it is also desirable because Tr_1 has a variable base bias for gain control. Its input impedance varies with bias, and tapping down reduces the effect of this upon the tuned circuit. The resistance R_0 in shunt with L_1 provides some additional damping.

The other input circuits are wavetraps. The first and most important is L_2C_2 which is tuned to the sound channel of 33.5MHz; the next L_3C_3 is tuned to 41.5MHz to reject adjacent-channel sound; and the third, L_4C_4, is tuned to 31.5MHz to reject adjacent-channel vision (from a station on the other side, of course). Within the vision-channel pass-band L_2C_2 and L_4C_4 are both capacitive; their effective capacitance increases towards the high-frequency end of the pass-band and tends towards the sum of C_2 and C_4, or 86pF. The other circuit L_3C_3 is inductive in the pass-band and to some extent offsets the capacitive loading of the other circuits.

The whole network is a complex one. In practice, the bandwidth of the whole amplifier is determined very largely by the 33.5-MHz and 41.5-MHz traps. The other circuits in the amplifier largely dictate the shape of the response within the pass-band, and they can reduce the bandwidth, but they cannot appreciably increase it above that set by the traps.

Basically, L_1C_1 and the tuned circuit in the tuner form a band-pass filter with a performance considerably modified by the traps on the secondary. The rest of the amplifier has single-tuned circuits as interstage couplings and the three circuits form a stagger-tuned triple with bandpass characteristics. The detector coupling L_7L_8 looks like a coupled pair, but the coils are so

Fig. 1. Circuit diagram of the vision i.f. amplifier, first video stage and automatic gain control system



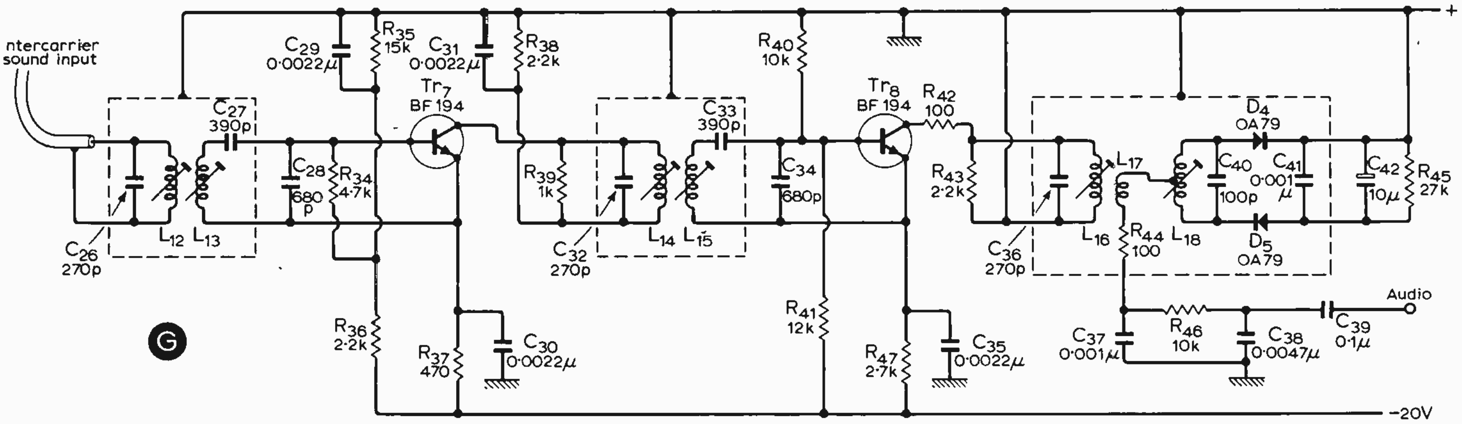


Fig. 2. Circuit diagram of the intercarrier sound i.f. amplifier. It is built on the same printed-circuit board as the vision amplifier

ightly coupled that they act virtually as one and form a single :ircuit tuned to 37MHz. The other tuned circuits are staggered, one at 35.5MHz and the other at 38.5MHz. These are the nominal frequencies used in the initial line up; they are afterwards nodified experimentally to obtain the correct response curve.

In order to minimize the effect of variations in the output mpedance of Tr_1 with gain control, the collector of this transistor s tapped well down the inductance L_5. The next transistor Tr_2 is capacitance tapped down the circuit, being connected to the junction of C_9 and C_{11}, each of 220pF. Because of the input capacitance of Tr_2 the tapping point is a little more than half-way down the circuit. This is the circuit tuned to 33.5MHz.

Since Tr_2 operates under fixed-bias conditions its collector need not be tapped down the next coil L_6, but the base of Tr_3 is capacitively tapped down, and further than in the case of Tr_2, since C_{12} is 120pF, while C_{13} is 220pF plus some 45pF input capacitance of Tr_3. Damping of the tuned circuits is provided by the base feed resistors R_5 and R_9 of 470 Ω each, and each in shunt with the input resistance of the following transistor.

D.C. Conditions

The d.c operating points of Tr_2 and Tr_3 are well stabilized. In the case of Tr_2, the base-feed resistance R_5 is taken to the potential divider R_6R_7 across the supply. By Thévenin's theorem, this is equivalent to connecting R_5 to the -20-V line through a resistance of $4.7 \times 5.6/10.3 = 2.5$k Ω in series with a battery of $20 \times 5.6/10.4 = 10.8$V. So far as d.c. is concerned, therefore, the base is returned to $+10.8$V (with respect to the -20-V line) through some 3k Ω. The emitter is returned to this same line through R_8 of 1.5k Ω.

It is possible to deduce the operating conditions approximately in very simple fashion. The base current is likely to be very small compared with the collector current, and with a silicon transistor the base is always about 0.65V positive to the emitter. If we further assume that the voltage drop in the 3-k Ω base feed resistance is small compared with the 10.8V to which it is returned, the potential of the emitter relative to the -20-V line is $10.8 - 0.65 = 10.15$V. Since R_8 is 1.5k Ω, the emitter current is $10.15/1.5 = 6.8$mA. Measurements, using the Model 8 Avometer on its 25-V range, give 10.8V for the base return and 10.15V for the emitter, with 20.5V for the supply. Current was not measured since this involves disconnecting components to insert a meter, and when a printed-circuit board is used one avoids this as far as possible.

In the case of Tr_3 the circuit arrangement is the same but the component values are very different. The equivalent base circuit is a resistance of $2.2 \times 8.2/10.4 = 1.73$k Ω in series with 470 Ω to make a total of 2.2k Ω returned to $20 \times 2.2/10.4 = 4.12$V. The emitter voltage is thus $4.12 - 0.65 = 3.47$V, and as R_{12} is 470 , the emitter current is $3.47/0.47 = 7.4$mA. The collector-emitter voltage, however, is $20 - 3.47 = 16.53$V, compared with $20 - 10.15 = 9.85$V for Tr_2. This is done because Tr_3 has to give a larger signal output than Tr_2.

The video detector, with diode D_1, is conventional and has a load resistance R_{15} of 3.9k Ω. The detector output comprises the complete video signal plus the 4.43-MHz colour components plus the 6-MHz intercarrier sound signal. This last is taken out by connecting the circuit $L_{12}C_{26}$ (Fig. 2) in series with R_{15}, the actual connection being made through a short length of coaxial cable.

The whole signal across the detector load is applied directly to the first video stage Tr_4. This has a 1-k Ω collector load R_{16} and the video signal appearing here is fed out through the 0.6-μsec delay line to the luminance unit described in Part 6.

The main emitter load is the 560-Ω resistance R_{17} which is shunted by a total of 3.8k Ω, making the emitter load effectively, about 490 Ω. The collector load is about the same, so the stage gives slightly less than unity voltage gain between base and emitter and a gain of nearly the same between base and collector. This is because the delay line is terminated in about 1k Ω in the luminance unit, which makes the total collector load about 500 Ω allowing for the resistance of the delay line.

The whole detector circuit is returned to the junction of R_{13} and R_{14}, which is equivalent to returning it through a resistance of $15 \times 0.47/15.47 = 0.455$k Ω to $20 \times 0.47/15.47 = 0.61$V.

The emitter potential is thus about $0.61 - 0.65 = -0.4$V, but the assumption of $V_{be} = 0.65$V does not hold under these conditions and the emitter is actually just about at zero volts with respect to the -20-V line. The emitter current is thus about zero, so the collector-emitter voltage is almost 20V. This is, of course, with no signal, and the detector output is always positive-going.

A tapped tuned circuit is included in the emitter load. It comprises $L_{10}C_{20}$ and is tuned to the sub-carrier frequency 4.43MHz. Its purpose is to increase the cathode load at this frequency and, by increasing the negative feedback at this frequency, to give a trough in the frequency response at the collector output of about 6dB. This reduces the visible effect of sub-carrier frequencies on the picture. Such frequencies tend to produce a crawling-dot effect.

Another trap circuit, $L_{11}C_{21}$ is a series resonant circuit connected between emitter and collector, and tuned to 6MHz. This reduces sound-channel interference in both outputs since at 6MHz it tends to short collector and emitter together.

The trap is included mainly to reduce 6MHz in the chroma output, for in the luminance output the delay line acts as quite a good filter at 6MHz and alone reduces the 6-MHz signal considerably.

The sound i.f. amplifier (Fig. 2) is fairly conventional with coupled pairs of circuits between the stages. The primaries are all tuned by 270-pF capacitors. Except for the detector, the transistors are connected to the secondaries by a capacitance tap the values being 390pF and 680pF. With 45pF for the transistor input capacitance, the lower arm becomes 725pF and in series with 390pF this becomes 250pF, so the total secondary capacitance is much the same as the primary. The tapping down is mainly to prevent the low input resistance of the transistors from damping the secondaries too much.

TR_7 is biased at the base through a resistor of 4.7kμ returned to a potential divider, which is equivalent to a resistance of $15 \times 2.2/17.2 = 1.93\text{k}\Omega$ returned to $20 \times 2.2/17.2 = 2.55$V. The emitter is thus at about $2.55 - 0.65 = 1.9$V and the emitter current is eome $1.9/0.47 = 4$mA. There is a resistor of 2.2kΩ in the collector unit which will give a voltage drop of $4 \times 2.2 = 8.8$V, so the potential between emitter and collector is $20 - 1.9 - 8.8 = 9.3$V. This assumes that the base current is negligibly small. In this case the base-circuit resistance is $4.7 - 1.93 = 6.63\text{k}\Omega$ so the approximation may not be too good.

In the second stage the potential divider resistors are much higher in value and there is no extra series resistor. The effective d.c. base return is through $12 \times 10/22 = 5.45\text{k}\Omega$ to $20 \times 12/22 = 10.9$V. The emitter voltage is $10.9 - 0.65 = 10.25$V and so the emitter current is $10.25/2.7 = 3.82$mA. In the collector there is only a 100-Ω resistor which will drop only 0.38V, so the collector-emitter voltage will be $20 - 10.25 - 0.38 = 9.37$V. In spite of the very different circuit values, the actual operating conditions of the two transistors are virtually the same.

The final transformer is a discriminator feeding a ratio detector and is entirely conventional, the audio output being taken off through a blocking capacitor.

A.G.C. system

Turning now to the a.g.c. system, the vision detector produces an output which is positive-going on sync pulses and so does the video stage at its emitter. The no-signal emitter potential of Tr_4 is about zero and it increases with signal up to a maximum of about 9V. For anything much more than this the stage will bottom. The Set Signal Level control enables anything from the full emitter voltage to about one-half of it to be tapped off and applied to the base of Tr_5. The full range of base voltage of Tr_5 is thus from zero minimum to 9V maximum taking into account the control as well as the signal.

The emitter voltage of Tr_5 will be about 0.65V less, giving a range here of zero to 8.35V and the emitter current in 1kΩ (R_{22}) will be zero to 8.35mA. Actually the emitter is biased positively by $20 \times 1/6.6 = 3$V through $5.6/6.6 = 0.85\text{k}\Omega$. Thus Tr_5 is cut off until the base input exceeds 3.65V. By adjusting the Set Level Control there can be at this point an initial delay to the start of a.g.c. action. When the input to Tr_5 exceeds the delay this transistor draws current and its collector potential falls below the no-signal value, which is actually 10V. As the collector load is 27kΩ the maximum rollector current is 0.74mA, and then bottoming occurs. However, the base input is the video signal and the maximum positive excursions correspond to the sync pulses. Although the mean current cannot exceed 0.74mA, the peak current can do so, for it can flow into the capacitance C_{22} of 0.022μF. Peak currents of the order of the 8-mA or so mentioned earlier can thus flow during the sync pulses without causing bottoming.

The net result is that the collector potential of Tr_5 moves negatively with increasing signal. The collector is connected to the base of Tr_6 through a voltage-dependent resistor and there are then resistors totalling 55kΩ taken to 4V below the -20-V line. Conditions here cannot be easily calculated because of the v.d.r. However, it can be seen that if Tr_5 is bottomed on a very strong signal Tr_6 is likely to be cut-off, whereas if Tr_5 is cut-off on a weak signal, Tr_6 will be drawing a large current. As the signal increases, therefore, the current in Tr_6 will fall from its maximum no-signal value.

With no signal Tr_6 is bottomed or nearly so, and its collector is nearly at the -20-V line. The cathode of D_2 is at $20 \times 180/1090 = 3.3$V. The anode of D_2 is taken to a point at $20 \times 0.47/2.88 = 3.26$V to $20 \times 0.97/3.38 = 5.75$V, according to the setting of the Set I.F. Gain Control. Diode D_2 is normally conductive and remains so until the current in Tr_6 falls sufficiently to bring its collector potential above the delay voltage for which the Set I.F. Level Control has been adjusted. It then cuts off and thereafter leaves the bias on the i.f. stage at the value fixed by the Set I.F. Level Control. While D_2 is conductive the variations of collector potential of Tr_6 are conveyed through it as forward a.g.c. bias to Tr_1.

The other diode D_3 is connected the other way round, and its cathode is joined to a point at $20 \times 4.7/22.17 = 4.1$V. Thus D_3 is non-conductive until the signal level has increased sufficiently to bring the collector voltage of Tr_6 above 4.1V. The output from the cathode of D_3 is then applied as a.g.c. bias to the r.f. stage in the tuner.

In broad outline what happens is this. Initially, there is a general delay on all a.g.c. because Tr_5 is cut-off. As the signal increases Tr_5 becomes operative and a.g.c. is applied through D_2 to the first i.f. stage. At a certain higher level of signal D_2 cuts off and thereafter the i.f. gain is kept at a fixed low level. At around this same point D_3 conducts, and thereafter a.g.c. is applied only to the r.f. stage in the tuner.

Components

The circuit diagram gives details of component values. A 30-V rating is sufficient for all capacitors but there is, of course, no objection to a higher value. Capacitors which are included in coil cans must be physically small, and those which are associated with tuned circuits should have low losses. This is not because low losses are always specially necessary, but to avoid a variable factor. The losses in 'lossy' types are likely to vary greatly from one specimen to another.

Suflex capacitors are a very suitable type for those used in coil cans, but they must be handled very carefully. The leads are rather fragile and are easily broken if subjected to rough handling. The thin leads are doubtless intended to protect the component against excessive heat when soldering, for too much heat can produce an internal short-circuit. This is a definite danger when only very short leads can be used, as when the components are fitted into the coil cans. It is essential to use a heat sink while soldering unless the external lead length exceeds $\frac{1}{4}$in.

The same type of capacitor can be used for by-pass purposes but here small tubular ceramic types are equally suitable. A few 0.001-0.002 F of such capacitors additional to those shown on the circuit diagram may be needed as extra by-pass capacitors at points which may vary in individual cases. Two models of the i.f. amplifier have been built. The first was a hand-made model with copper foil stuck to a board and carved out rather laboriously by hand. When this had been proved a drawing was made and a second model built on a proper printed circuit. This second model needed rather fewer 'extra' by-pass capacitors, but on the strength of two models only it is not possible to predict just what is needed in every case.

All coils except the video detector coupling and the sound discriminator are wound on Brayhead P1011/1 formers with P1001 terminal bases and P5000 short cans and have Neosid screw cores $4 \times 0.5 \times 6/900$. The other two transformers use Brayhead P1003/1 formers with P1001 terminal bases and P5000 long cans. The discriminator has one core the same as the others, but the other core in this and the one in the video detector can are Neosid screw cores $4 \times 0.5 \times 12.7/900$.

Details of the layout, points in construction, and the alignment procedure will be dealt with next month.

Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents

High input-impedance amplifier circuits

In his article "High Input-impedance Amplifier Circuits" in the July issue of *Wireless World* Mr. Towers gives the

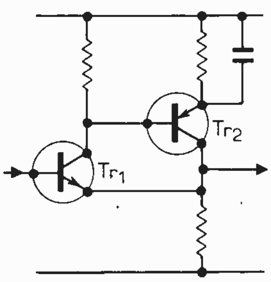


Fig. 1. Complementary common-emitter amplifier

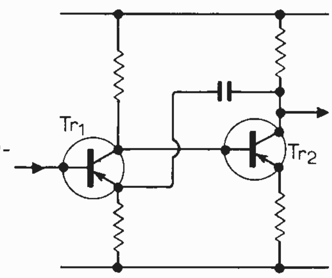


Fig. 2. Two-stage common-emitter feedback amplifier

circuit shown above in Fig. 1 and labels it "complementary n-p-n/p-n-p compound emitter follower" (Fig. 1g). In fact this circuit is a complementary version of the two-stage common-emitter amplifier shown in my Fig. 2 above. In Fig. 1 transistor Tr_2 is not operating as an emitter follower and the 2-stage circuit does not invert the signal; it follows that Tr_1 must be operating in the common-emitter mode.

The circuit does operate as a compound emitter-follower however if the output is taken from the emitter circuit of transistor Tr_2.

K. H. Green
Slough, Bucks.

Thank you for the interesting article by Mr. Towers on "High Input-impedance Amplifier Circuits" published in the July issue of *Wireless World*, which we very much enjoyed reading.

However, there is one point we would like to bring to your notice. That is, the circuits of Figs. 3(b), 3(d) and 4(a) will not function as he suggests. If we look at the equivalent circuit (our Fig. 1) it may be seen that, replacing the bootstrap capacitor by a short circuit (at the frequency of operation), the circuit reduces to that of Fig. 2 since $r_c \gg r_e$. The input impedance of this circuit is less than that for a conventional emitter follower, being

$$r_b - \beta r_e + \frac{R_E R_C}{R_E + R_C}$$

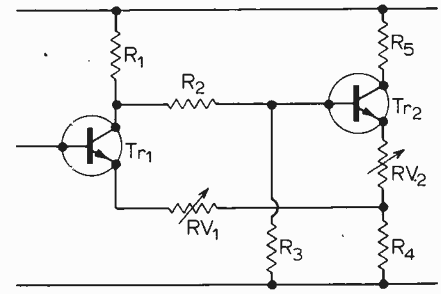
Readers may be interested in a possible modification to the Mullard circuit of Fig. 5(e). The circuit as it stands has an input impedance of 10^{12} Ω at l.f. but this is shunted by the gate to drain capacitance of the BFX63. This gives an input impedance of about 250 MΩ at 1 kHz. This, however, may be improved by a factor of about 30 by boot-strapping the drain as shown in our Fig. 3.

R. Eberhardt and K. Lucas
The University,
Southampton.

Schmitt triggers

In his enlightening article in the October issue on the simplified design of Schmitt trigger circuits, Mr. Marshman, I feel, has omitted to state one fact which may lead the uninitiated into some minor difficulties. It is that by using the potential divider R_1, R_2, R_3 to give reference to V_{on}, Tr_2 must never be saturated, which means the V_0 should always be less than $V_{cc} - V_{on}$.

The 0·1V differential between the bases of Tr_1 and Tr_2 is probably due to the slight



Mr. Stackman's Schmitt trigger circuit in which RV_1 ($RV_2 = 0$) adjusts V_{off} and RV_2 ($RV_1 = 0$) adjusts V_{on}.

difference between V_{BE} of Tr_1, which can saturate at switch on, and V_{BE} of Tr_2, which is not allowed to run in saturation.

It is often required to define the V_{on} or V_{off} of a circuit to within very fine limits and design for very small hysteresis (ripple detectors etc.), and one simple method of doing this is to design a Schmitt circuit to the outside limits of tolerance, and insert a trimming resistor in the manner shown in the diagram.

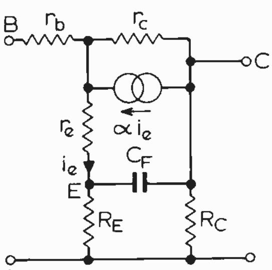
A. D. Stackman
Calne, Wilts.

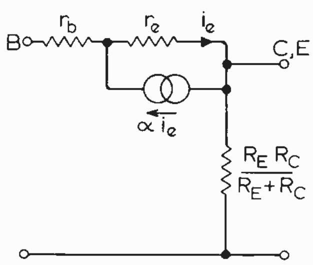
Low-distortion class B output circuit

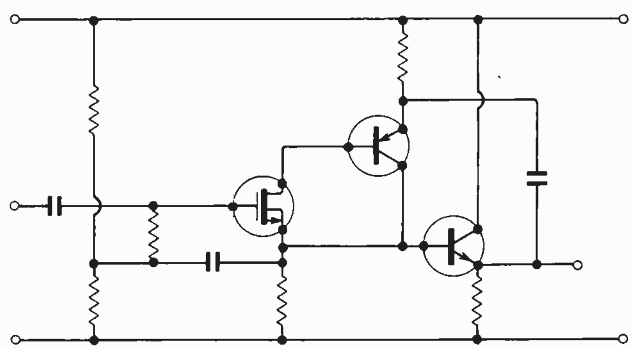
The article under the above title in your April issue introduces some interesting and novel features of design.

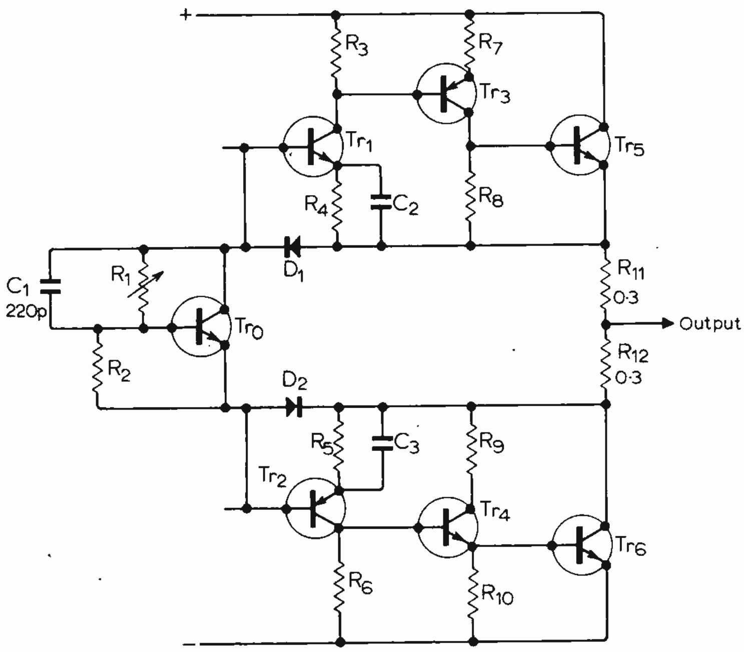
It appears to the writer that the approach to symmetrical operation has been made by speeding up the switch-on of the output transistors, thus sharpening up the toe characteristic. However, a slightly different approach can be made which can, at a slight cost, give more nearly matching toe characteristics, so that one can approach class AB behaviour (but with a less pro-

Figs. 1, 2 and 3 (left to right) referred to in the letter from R. Eberhardt and K. Lucas commenting on Mr. Towers' article









This modified output section of the Quad 303 power amplifier, originally described in our April issue, is discussed by H. W. Holdaway in his letter

nounced toe region than is usual). For purposes of discussion a modified circuit is outlined in Fig. 1.

The principal proposal is to make R_7, R_8 and R_{10} equal. Subject to the dissipation capabilities of Tr_3 and Tr_4 they can be made as low in value as convenient as this can improve conditions in switching Tr_5, Tr_6 at high frequencies, and improves linearity by partly offsetting effects of base current drive to Tr_5, Tr_6. For better symmetry R_9 can also be made the same, but if some asymmetry in voltage distribution can be tolerated R_9 may be reduced to zero with only moderate disturbance on performance. The effect of this change is that to switch on Tr_5 the voltage at the collector of Tr_1 has to fall an amount approximately equal to the sum of the switch on V_{BE} of Tr_3 and Tr_5. This more closely matches effects in the counterpart transistors Tr_2, Tr_4 and Tr_6.

A further benefit is better matching of the division of current at the collector of Tr_1 to that at the collector of Tr_2. Depending on the choice made for R_7 and R_{10}, resistors R_3 and R_6 may be reduced in value. As it is now less vital to speed up switching on to quite the same extent resistors R_4 and R_5 and capacitors C_2 and C_3 may be introduced. Making $R_4 = 0{\cdot}1$ of R_3 and $R_5 = 0{\cdot}1$ of R_6, say, one can make the performance of Tr_1, Tr_2 less critical for variations in matching of the complementary pairs. Capacitors C_2, C_3 can be chosen to partly offset the fall off in current gain of the output transistors at the higher frequencies.

Rather than using a string of diodes the writer has been using a form of silicon transistor bias (transistor Tr_0). This permits setting the quiescent current of the output transistors independently of the d.c. reference level at the output point. The transistor used may be p-n-p or n-p-n but n-p-n is cheaper and usually has higher current gain. For close compensation it can be similar to Tr_1, Tr_2 but quite low breakdown voltage types can be used. Close setting of quiescent current is possible by varying R_1.

The price paid for matching the toe characteristics will be a need to increase the d.c. supply voltage by about 1 volt if R_9 is zero, or about 2 volts if R_9 is matched to R_{10}. The loss in efficiency is not too great, and still small compared to losses in class AB valve circuits.

H. W. Holdaway
Ryde, N.S.W.,
Australia.

Television interference filter

Having been significantly involved in the testing of the Bovill Sporadic-E Filter objectively and subjectively during the last eighteen months or so, I should like to comment on the article "Combating Television Interference" (September issue) and Mr. Bovill's letter (November issue).

The efficiency of the Bovill interpretation of the filter is dramatically depicted in my "The Practical Aerial Handbook" (Odhams Books Ltd.) in terms of carefully controlled AB off-screen photos during a spell of particularly severe spring-time tropospheric propagation in the Torbay area. Without the filter the spurious information so confused the sync as to make locking highly critical, while degrading the picture to an unusable degree. With the filter in circuit normal sync performance was restored and almost all of the patterning was cleared from the picture, at the expense of no more than 500 kHz definition loss.

My lab tests have shown that Mr. Bovill's notch can improve on the rejection ratio of that described in the September issue* when carefully tuned, no doubt due to the reasons mentioned by Charles Bovill in his November letter. This sort of filter running in Band I relies on delicate tuning and balancing for success and when properly adjusted the rejection is so knife-sharp that it is almost possible to "blow away" decibels of rejection! Rigidity of the screened housing is thus a major design requirement and I, too, would query the efficiency of a filter of this kind when housed in a case with flexible sides and with a top cover of dubious and variable inter-conductivity, as suggested in the September issue.

The length of the coax lead can also be critical as I have proved time and time again in the field, and there is also the question of the lead acting as a stub at Band III frequencies, as brought up by Charles Bovill, depending on how well the set's tuner loads the lead and what sort of combining filters—if any—are used at the aerial end.

Finally, I would like to point out that the filter possesses other desirable attributes in wideband v.h.f. relays carrying a multiplicity of carriers in "notching out" unwanted beats, thereby deleting the quantum build-up of signal energy responsible for the progressive worsening of the crosstalk performance in an extended system, normally combated by diminishing the output levels of cascaded repeaters to maintain an acceptable end-of-line crosstalk ratio. A comb-filter for such applications is another interpretation under active consideration by Charles Bovill and his colleagues.

Gordon J. King
Brixham,
Devon.

* The last four "greater than" symbols in the specification on p. 329 should have been "less than" —ED.

Made in . . . . ?

Reference your editorial in *Wireless World* for October, British manufacturers are not alone in using foreign made chassis.

I have a Schaub Lorenz "Tiny S". The case may possibly be made in Germany, but the inside is all Japanese.

J. Holding
H.Q., R.A.F.,
Germany.

Shades of Frankenstein!

Are we now driving our integrated circuits so hard that there is a danger of revolt by them and we must fit "mutiny correction" devices?

The caption to Fig. 1, p. 399, of the November issue would seem to confirm this. What was really meant?*

W. E. Blocksidge
Wirral,
Cheshire.

* The printer misspelt "muting connections".—ED.

Volume 74 Index

The index covering the material published in Volume 74 (March–December 1968) is in course of preparation and should be available in January.

Our publishers will undertake the binding of readers' issues and details will be given when the index is published.

World of Amateur Radio

Slow-Scan Amateur TV Success

Two-way pictures were recently exchanged between A. Backman (SM0BUO), in Stockholm, and S. Horne (VE3EGO), in Ottawa, on 14.18 MHz. This was the first time two-way pictures had been exchanged across the Atlantic by radio amateurs, although in December, 1959, C. McDonald (WA2BCW) successfully transmitted pictures to the United Kingdom. Slow-scan TV has been authorized by the Swedish and U.S. licensing authorities, the former until June 30, 1969, and the latter until March 31, 1969.

Frequencies (in kHz) authorized are as follows:

Sweden	U.S.
3600–3800	3725–3750
7050–7100	7150–7175
14100–14350	14175–14350
21100–21450	21000–21450
28100–29700	28100–29700

Project Moonray

Nicholas K. Marschall (W6OLO/2), writing in the Dutch National Amateur Radio Society (VERON) *V.H.F. Bulletin,* describes proposals to have placed on the surface of the moon a small 2.25kg lunar amateur translator package. This would be carried (if the authorities agree) on the third lunar module (LM-3) and the astronaut responsible would level, aim and turn on the transistor for what would be the first amateur moon-earth contact. Moonray project bulletins and progress reports are broadcast on 14.09 MHz on the first Monday of each month from 2300 to 2330 g.m.t. using the call sign K2SS. The transmissions are made by radio teletype followed at 2330 g.m.t. by an s.s.b. transmission lasting 30 minutes. Full details of the Moonray project can be obtained from Mr. Marschall, P.O. Box T, Syosset, Long Island, New York 11791, or from the European representative, H. Rifet, P.O. Box 13, Schiedam, Holland, who is editor of the VERON *V.H.F. Bulletin.*

Outstanding Services to R.S.G.B.

P. A. Thorogood (G4KD), who has been the manager of the R.S.G.B. annual radio exhibition for the past ten years and the society's London regional representative for an even longer period, has been awarded the Founder's Trophy by the council in recognition of his outstanding services to the society during the past 20 years. The Founder's Trophy was donated by the late René Klein, who founded the society, as the London Wireless Club, in July 1913.

R.S.G.B. President 1969

J. W. Swinnerton (G2YS) is to succeed J. Graham (G3TR) as president of the Radio Society of Great Britain when the latter completes his term of office this month. Mr. Swinnerton has held a licence for many years and has been a member of the council of the society for the past ten years.

Interference on 70cm

Following an approach by the R.S.G.B., the German commercial airline Lufthansa has agreed to restrict the use of certain radio altimeter equipment while their aircraft are in U.K. air space.

New German Certificates

The German National Society (DARC) has approved the issue of two new German amateur radio awards. The first, known as the C.W. Speed Certificate, is being issued by the Nordrhein district of the DARC and is designed to promote telegraphy activity. The second will be issued to those who prove contacts with DARC district R. Further details of the c.w.s.c. can be obtained from H. Trappenberg (DL1OW), D-4018 Langenfeld, Flurstr. 36, and of the w.d.r. from K. Tipp (DJ8CV), D-5603 Wüfrath, Düsselstr. 11.

V.H.F. National Field Day

The most popular annual v.h.f. contest organized by the Radio Society of Great Britain known at V.H.F. National Field Day took place this year during the weekend September 7-8 when 91 entries were received compared with 69 last year. For the first time an entry was received for work done in the 10 GHz band. Individual band winners were: on 70 MHz, the Cumberland and Westmorland v.h.f. group; on 144 MHz, the combined Worcester and Loughborough group; on 432 MHz, the Mid-Essex v.h.f./u.h.f. contest group; on 1296 MHz, the A.E.R.E. (Harwell) Amateur Radio Club; on 2300 MHz, the G3MCS contest group and on 10GHz the Purley and Addiscombe (Croydon) group. The Mid-Ulster group and the Pennine v.h.f. expedition group were Northern Ireland and Scottish winners respectively. The combined Worcester and Loughborough group were Welsh group winners and runners-up in the overall results total with the Surrey Trophy going to the Mid-Essex v.h.f./u.h.f. contest group as the leading entry from England.

Ealing Activity

The Ealing and District Amateur Radio Society gave a demonstration of amateur radio and television at the Hanwell Community Centre on October 26 and 27, when operation was carried out on all bands from 160 metres to 3 cm.

Nigeria News

First holder of the new Chair of Communications in the Electrical Engineering Department at Ahmadu Bello University is Prof. R. Sturley, who until recently was chief engineer, external broadcasting, B.B.C. Although not a licensed radio amateur Prof. Sturley has given an assurance that he will encourage the development of amateur radio among his own students in particular and among those in Nigeria in general. Four members of the Nigerian Amateur Radio Society are on the staff of the university where a concentrated effort is being made among students to encourage them to take up amateur radio as a hobby, to which end an s.s.b. station is operating under the call 5N2AAU. Morse code instruction classes are being run for the second year in succession and elementary radio theory classes are to be arranged if there is sufficient demand.

News from Otley

Meetings of the Otley Radio Society are held every Tuesday evening at the society's own premises in Otley, Yorkshire. The society operates its own station (G3XNO) on top band during club nights. Winner of the recent senior section home constructional competition was F. Pickard with an electronic time switch and binary readout. The junior section was won by P. Fox with a transistor stereo amplifier. Publicity officer is T. George-Powell (G3NND), 82 Forest Avenue, Starbeck, Harrogate.

New I.A.R.U. Member

The Association des Radio-Amateurs de la Principaute de Monaco has been elected to membership of the International Amateur Radio Union and has now applied for membership of I.A.R.U. Region I (Europe and Africa) Division.

Gift from A.R.R.L.

A Viking-Ranger transmitter, donated by the American Radio Relay League for training purposes, is at present under construction in Nairobi under the supervision of Andre Saunders (5Z4KL). The transmitter will eventually operate under the call 5Z4RS with Fred Wade as first trustee of the station. Membership of the Radio Society of East Africa now stands at 110.

Luxembourg Steady Growth

At the annual general meeting of the Luxembourg National Society (RL) it was reported that membership had increased to 111 compared with 98 a year earlier. Since 1965 membership has increased by 50%.

JOHN CLARRICOATS G6CL

The Human Computer Reconsidered

A critical attack on a recent theory

by B. J. Conway, M. J. Hunt and G. J. Liston

In the May issue of this journal there appeared an article under the intriguing title, "The Human Computer". Its author, Mr J. R. Brinkley, proposed a non-linear mixer model for the human mind and a similar model for the process of conception.

The main features of this model are shown in Fig. 1 (reproduced from his article). Let us first decide what properties we expect in a black-box model of this type.

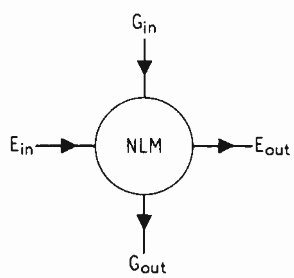


Fig. 1. The individual represented in terms of its information processing functions. G = genetic information, E = environmental information, NLM = non-linear mixer.

(1) The model must be simpler than the original system. This, however, inevitably means that at some point it will break down.
(2) Since we know nothing of the internal workings of the system represented, we can only map the corresponding inputs and outputs of model and system.
(3) When the parameters used for these inputs and outputs are different in model and system (for example, not both voltages and currents), the correspondence between them must be clearly stated.
(4) The model must exhibit the well-known properties of the system it represents.

To be plausible, a model must satisfy points (1) to (4). To be useful however, it must also satisfy a further criterion, viz.,
(5) That it should make clear predictions which can subsequently be verified on the original system. This is the only true test of its validity.

Indeed, the sole *raison d'être* of such a model, which contributes nothing to our understanding of the internal processes of the system it represents is that it should go on to make further predictions of some practical value.

The authors are 2nd year undergraduates at St. Catherine's College, Oxford, all reading physics.

Let us now examine the article in the light of these considerations.

Confused Parameters

We first notice that the writer never makes clear the correspondence between the parameters of the two systems he compares. Indeed, the linkage appears quite arbitrary and varies from case to case. This leads to glaring inconsistencies. For example, he attributes the heightened perception reported under the influence of L.S.D. to a reduction in the non-linearity of the mixer. In the very next paragraph he goes on to associate genius with an unusually ***high*** degree of non-linearity. Different effects are dredged up to account for the heightened perception of colours, distortion of dimensions, detachment from environment, etc. The fact that by permuting the mappings in a different order totally different (and wrong) predictions would have resulted, shows that you can explain any effect on Mr. Brinkley's model, provided that you know the answers in advance. This carries versatility too far.

Even the most fundamental relationships are not preserved by the model. Throughout his discussion he treats G_{out} (see Fig. 1) as a function of E_{in}. In other words, he says that experience gained in life is transmitted via gene modification to succeeding generations. He adopts this Lysenkoist viewpoint solely on the grounds of expedience, ignoring the fact that no experimental evidence has ever been produced to support this theory. Even in the Soviet Union, where strong ideological pressure exists to uphold this doctrine, it is now very much out of favour.

In fact, the author appears to have missed the central point of Darwin's theory. He dismisses random processes as being of secondary importance whereas they are, of course, essential to the whole process of evolution. There is no ***systematic*** selection of favourable characteristics—bad mutations simply die out.

He betrays a similar confusion concerning the processes involved in conception, and the need for his non-linear mixer in this case arises from this confusion. He maintains that twice the required amount of genetic information is present at conception and that the excess must somehow be removed. This is just not true: spermatozoa and ova each contain twenty-three chromosomes—exactly half the number in a normal cell. It follows that at conception there is just sufficient information present to specify completely the genetic structure of the embryo.

The fact that children are not the mean of their parents was cited as further evidence for his model. In fact, this is a direct result of dominant and recessive behaviour in genes, which may even lead to the appearance in the child of characteristics dormant for several generations.

Mysticism

At times Mr. Brinkley waxes mystical. In a remarkable paragraph he purports to explain how a mysterious "life force" defeats the second law of thermodynamics. We do not underestimate the difficulty of proving rigorously that life and evolutionary processes obey the second law, but we maintain that you would have to consider all changes in the universe brought about by these processes and not merely surviving mortals, as Mr Brinkley implies. Clearly, the non-linear mixer does not disobey the second law, so that the author's statement that his model explains the violation of this law by life processes is wrong either way. Either the law is universal, and all systems behave similarly in this respect, or else Mr. Brinkley's model behaves contrary to the system it represents.

Much of the latter part of the article is devoted to the importance of low frequencies in biological processes. We are at a loss to understand the relevance of these frequencies to the transmission of genetic information, this being entirely a problem of molecular structure. Although their importance in the context of speech and vision is clear, our objection in this case is that the author feels obliged to seek an explanation of their origin at an ***atomic*** level.

We feel that this is misguided. To take an example, the vibration of vocal chords accounts perfectly for the low frequencies of the voice. Would the author attempt to explain the note produced by a violin in terms of the high frequency oscillations of the atoms in catgut?

In the same section the writer attaches exclusive significance to the elements H,C,N, and O, dismissing the presence of others such as sulphur and phosphorus—equally vital—a merely adding "variety to the mix".

He tacitly rejects the modern theory of molecular spectra in favour of his own rather eccentric explanation in terms of the combination of atomic frequencies. To this end he assumes some simple relationship between these frequencies and the number of electrons in the outer shell of each atom, basing this view solely on the significance of the arithmetic sequence 1, 2, 3, 4 for the atoms H, C, N and O. If Mr. Brinkley's atomic frequencies are at all related to the electronic structure of atoms they must be frequencies of emitted electromagnetic radiation or (classically) those of electron rotation. The first are measured directly from spectra. In either case they are not in the simple ratios Mr. Brinkley would like for the atoms in question. Thus experimental evidence refutes his assertions.

The rest of what was conjectured about H, C, N and O and of the control by "atomic frequencies" of the temperature range within which life can survive, is likewise untrue. The range of temperature in which life survives is ultimately controlled by the rates of chemical reactions. These slow reactions have rate constants which vary by a factor of between 2 and 3 over a range of about 10 deg. C at normal temperatures, due to the exponential factor exp $(-E/kT)$ in the theoretical expression for the rate constant. The activation energy, E, must be provided by the total thermal energy of the molecules —what possible relevance can atomic frequencies of an electronic kind have to this problem of thermal energy? *Atomic* frequencies do not vary slightly with temperature as Mr Brinkley requires, but are grossly quantised. The main cause of temperature dependence of life processes is thus the exp $(-E/kT)$ factor, which arises in the theory of statistical mechanics from purely thermodynamic arguments, these having no relation to any assumptions about atomic structure, let alone the nature of atomic frequencies.

Referring back to our original set of criteria for judging a model we must conclude that the author's model fails to satisfy the first four taken together. It now remains to see whether it satisfies the fifth: that of verifiable prediction.

Innocuous models might be excused a failure to satisfy our fifth criterion when they are first proposed—although one could have little faith in a black-box model until it had satisfied this criterion—but anything as wide in its scope as Mr. Brinkley's model, leaving a trail of discarded principles in its wake (Darwinism, genetics, molecular binding theory, etc.) must be most rigorously justified. We find, in fact, that the only prediction made by the author from his model is that "genetic and environmental information are of exactly equal importance to the generation of new information and hence to human progress". Since genetic and environmental information in the way that the author uses the terms, are so dissimilar in form it is impossible to equate them. His prediction, therefore, is unverifiable and provides no support for his model. Consequently his conclusion that educationalists should "reconsider their ways" is worthless.

Hence, we conclude that the NLM model also fails on the final count and must be rejected as shedding no new light on the problems it seeks to resolve.

Battery Developments

The 6th International Power Sources Symposium was held at the Hotel Metropole, Brighton from September 24th to 26th. We have selected three papers, from those delivered, which seem of particular importance and interest to our readers. These are summarized below.

Cells with solid electrolytes

The limited shelf life, poor tolerance of temperature changes, and only moderate reliability of primary batteries, has hitherto ruled them out of consideration for a number of serious applications.

Early designs of solid state batteries (using solid electrolytes) resulted in units having long shelf lives, and good tolerance to temperature change, but having low electrical capacity and low current capability, due to the high electrolyte resistance.

However, a new class of solid state systems, with high conductivity electrolytes, has been designed in America[1]. The potential of the individual cell units is 0.66V, and they are capable of delivering 0.9A/cm² when short circuited. Operation has been completely satisfactory over the temperature range—55°C to 74°C. At 25°C ninety per cent of the theoretical capacity can be drawn from the cells at a current density of 50mA/cm².

Fast charging secondary cells

The possibility of rapidly recharging secondary cells greatly increases the variety of their applications. Where there are short intervals between successive discharges, as in some portable power tools, the ability to charge up quickly will allow smaller and lighter cells to be employed—though more frequent charging sessions will be required.

There has been a quest, again in America, for ways of safely recharging sealed nickel-cadmium cells, and batteries of such cells, in one hour or less[2]. Investigation over the past few years has revealed that rapid charging is made difficult only by the disastrous consequences of high level overcharging. As soon as overcharging begins, heat and gas, internally generated, destroy the cell. Provided that the charging current stops precisely when the cell is fully charged, the whole process may be accomplished in one second at greater than 90% efficiency by delivering a 50A pulse to 10mAH cells. After 100 cycles of full charge and complete discharge there was no electrode damage. In practice fast charging rates are limited by the size and cost of the charging equipment required to deliver the high currents.

Fuel cell runs on gas

Development work is being done in England on a fuel cell running on natural gas[3]. A porous diaphragm, containing molten carbonates of lithium and sodium, separates the two electrodes. The anode (on the gas side), is of porous nickel, and the cathode (on the air side) contains silver, and oxides of copper and zinc.

The fuel to be oxidized can be a hydrocarbon mixture containing carbon dioxide, hydrogen gas containing carbon dioxide, or a mixture of steam and carbon monoxide. Carbon dioxide must also be present in the air for the cell to run properly.

A 'hot box' measuring 2ft × 2ft × 2ft, with the active cells occupying one half and a gas processing complex the other, can produce 5kW at 0.5V per cell. The electrical efficiency is about 30%, but waste heat can be used to reform the gas and improve its quality.

REFERENCES

1. Paper 18. "Solid state batteries" by Argue, Croce and Owens, Atomics International (a division of North American Rockwell Corp.) Canoga Park, California.
2. Paper 29. "Rapid recharging of nickel cadmium batteries" by Hadley & Carson Jr., General Electric Co., U.S.A.
3. Paper 39. "Theoretical consideration of a molten carbonate fuel cell running on natural gas" by Bannochie & Clow, Energy Conversion Ltd., Basingstoke, Hants.

Test Your Knowledge

*Series devised by L. Ibbotson** *B.Sc., A.Inst.P., M.I.E.E., M.I.E.R.E.*

7. Valves

1. The main advantage of the oxide coated cathode over tungsten and thoriated tungsten cathodes is that it
(a) can be indirectly heated and give reasonable emission efficiency
(b) is less susceptible to poisoning
(c) has a longer life
(d) is less easily damaged by ion bombardment

2. The material most commonly used to make anodes and grids for small thermionic vacuum valves is
(a) tungsten
(b) copper
(c) nickel
(d) iron

3. In a normal triode valve the grid is
(a) much nearer to the anode than to the cathode
(b) half way between anode and cathode
(c) very near to the cathode
(d) in contact with the cathode.

4. In a thermionic vacuum diode operating in the space-charge limited condition the anode current is not significantly dependent on
(a) anode voltage
(b) cathode temperature
(c) electrode areas
(d) electrode separation.

5. A diode with a tungsten cathode is operating in the temperature limited condition. Richardson's equation suggests that the current should not change as the applied voltage is increased; in practice we observe a small increase in current. This is due to
(a) a reduction of the effective work function of the cathode by the electric field at its surface
(b) tunnelling of electrons through the potential barrier at the cathode surface
(c) a rise in temperature of the cathode due to thermal expansion.

6. The potential at the centre of the space charge in a thermionic vacuum valve in normal use is
(a) lower than cathode potential
(b) equal to cathode potential
(c) between cathode and anode potential
(d) equal to anode potential.

* West Ham College of Technology, London, E.15.

7. In a triode used as a small signal class A a.c. amplifier the alternating component of anode current is in phase with the alternating component of grid-cathode voltage
(a) under all conditions
(b) provided the anode load is resistive
(c) provided the frequency is not too high
(d) provided both the anode load is resistive and the frequency is not too high.

8. One of the following has the same order of magnitude in triodes and pentodes
(a) the amplification factor
(b) the capacitance between anode and control grid
(c) the mutual conductance
(d) the anode slope resistance.

9. For a triode or pentode there is usually specified a maximum value which the resistance of the external circuit between control grid and cathode must have when the valve is in use as a class A amplifier. This is
(a) so that the input impedance of the valve will not be too high
(b) to reduce the Miller effect
(c) to prevent oscillation
(d) so that positive ions captured by the control grid will not significantly alter its potential.

10. During normal operation secondary emission of electrons from the anode occurs
(a) in all thermionic vacuum valves
(b) only in indirectly heated valves
(c) in tetrodes and pentodes only
(d) in tetrodes only.

11. The potential relative to the cathode of the control grid in a thermionic vacuum valve
(a) is never allowed to become positive
(b) always becomes positive at some point in the cycle of input voltage
(c) is allowed to become positive in small-signal amplifiers, but not in power amplifiers
(d) is allowed to become positive in large power amplifiers, but not in small-signal amplifiers.

12. During the operation of a large power amplifying valve the anode generally becomes very hot. This is mainly due to
(a) heat received by radiation from the cathode
(b) heat received from the cathode by conduction through the valve envelope
(c) heat generated by the large anode current due to high resistivity of the anode material
(d) heat released when the electrons give up their kinetic energy on striking the anode.

13. When bottoming is allowed to occur during the operation of a pentode damage may be done to
(a) the anode
(b) the suppressor grid
(c) the screen grid
(d) the control grid.

14. For a pentode, having fixed grid voltages in the normal range, an anode current/anode voltage curve is plotted. If the screen grid voltage is increased and the curve replotted the second curve is found to
(a) coincide with the first curve
(b) lie entirely below the first curve
(c) lie entirely above the first curve
(d) cross the first curve at an anode voltage equal to the original screen grid voltage.

15. A pentode will act as a good constant current generator; over a wide range of anode voltage the anode current changes very little. The physical reason for this is
(a) the space current is controlled almost entirely by the screen voltage
(b) the cathode emission is space charge limited
(c) the anode lead has a large resistance
(d) the suppressor grid current increases as the anode voltage increases.

16. A variable-μ pentode is designed for use as an amplifier with a gain which can be varied over a wide range. The variation of gain is achieved by varying
(a) the anode voltage
(b) the screen grid voltage
(c) the control grid bias voltage
(d) the heater current.

17. The beam tetrode construction can only be used satisfactorily in valves designed for power amplification. This is because
(a) the input impedance between the control grid and cathode is low
(b) a large space current is needed to drive secondary electrons back to the anode
(c) the beam forming action only works when the anode voltage is high
(d) the large separation between the screen grid and the anode causes the electron transit time to be significant.

Answers and comments, page 479.

December Meetings

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

LONDON

2nd. I.E.E.—Discussion on "Terminology for use in electrical measurements" at 17.30 at Savoy Pl., W.C.2.

3rd. I.E.E.—"Representation of multi-variable system behaviour by loci in the complex plane" by Dr. A. G. J. MacFarlane at 17.30 at Savoy Pl., W.C.2.

3rd. I.E.E.—Discussion on "Sampling techniques applied to signal recovery and display" at 17.30 at Savoy Pl., W.C.2.

3rd. Inst. Electronics—"Electronics in automation" by J. Reed at 18.45 at the London School of Hygiene & Tropical Medicine, Keppel St., W.C.1.

4th. I.E.R.E.—"Project technology—electronics in the schools" by G. B. Harrison at 18.00 at 9 Bedford Sq., W.C.1.

4th. S.E.R.T.—"Automatic train control" by I. Smale at 19.00 at the London School of Hygiene & Tropical Medicine, Keppel St., W.C.1.

5th. I.E.E. Grads.—"On the future of world communication" by Prof. C. Cherry at 18.30 at Wimbledon Technical College, Gladstone Rd., S.W.19.

6th. R.T.S.—"The use and abuse of closed-circuit television in anatomical teaching" by Dr. E. H. Ashton at 19.00 at I.T.A., 70 Brompton Rd., S.W.3.

9th. I.E.E.—Discussion on "The use of digital computing in navigation systems" at 18.00 at the Royal Aeronautical Society, 4 Hamilton Pl., W.1.

10th. I.E.E.—"Corona tubes" by Prof. F. A. Benson at 17.30 at Savoy Pl., W.C.2.

10th. I.E.R.E.—"Audio communication between divers" by B. Ray at 18.00 at 9 Bedford Sq., W.C.1.

11th. I.E.E.—"Broadcasting stereophony" by D. E. L. Shorter at 17.30 at Savoy Pl., W.C.2.

11th. I.E.R.E.—"Taking a close look at contacts" by Dr. T. Davies at 18.00 at 9 Bedford Sq., W.C.1.

12th. I.E.E.—Discussion on "The role of thin and thick films in micro-miniature equipment" at 17.30 at Savoy Pl., W.C.2.

12th. R.T.S.—"Television visual effects" by J. Kine at 19.00 at I.T.A., 70 Brompton Rd., S.W.3.

13th. I.E.R.E. & I.E.E.—Colloquium on "The technology of modern micro-circuit digital equipment" at 10.30 at Savoy Pl., W.C.2.

16th. I.E.E.—Discussion on "Electronic properties of the vitreous state" at 17.30 at Savoy Pl., W.C.2.

18th. I.E.E.—Colloquium on "Linear and non-linear device modelling for efficient design" at Savoy Pl., W.C.2.

19th. I.E.E.—"Matricon cathode-ray tubes" by G. Heftman and D. S. Hills at 17.30 at Savoy Pl., W.C.2.

BELFAST

2nd. I.E.E.T.E.—"The story of colour television—so far" by J. P. Hunt at 19.30 at Ashby Institute, Queens University, Stranmillis Rd.

5th. I.E.R.E.—"Metal oxide semiconductor transistors" by Prof. W. D. Ryan at 18.30 at the Ashby Inst., Stranmillis Road.

BRIGHTON

6th. I.E.E.—Christmas lecture: "There is more to electronics than meets the eye" by Dr B. H. Venning at 15.00 at the College of Technology.

BRISTOL

18th. I.E.R.E. & I.E.E.—"Instrumentation tape recording" by T. Read at 19.00 at the University.

CAMBRIDGE

11th. S.E.R.T.—"Automatic test equipment" by K. Brewster at 19.00 at the Cambridgeshire College of Technology, Collier Rd.

12th. I.E.R.E. & I.E.E.—"Impact of microelectronics for circuit designers" by R. S. den Brinker at 20.00 at the University Engineering Laboratories, Trumpington St.

CARDIFF

6th. R.T.S.—"Modern picture source synchronisation" by J. L. Bliss at 19.00 at Broadcasting House, Llandaff.

11th. I.E.R.E. & I.E.E.—"Circuit and systems design using digital computers" by J. S. Reynolds at 18.30 at the University of Wales Inst. of Science and Technology.

13th. S.E.R.T.—"The c.r.o. and its applications" by R. A. Watson at 19.00 at Llandaff Technical College, Western Ave.

CHELMSFORD

9th. I.E.E.—"The problem of maintaining complex electronic systems" by A. J. Wheeldon at 18.30 at the Lion & Lamb Hotel.

12th. I.Prod.Eng.—"Developments in metrology" by A. C. Dawe at 19.00 at The Hoffmann Manufacturing Co., New St.

CHELTENHAM

10th. I.E.R.E.—"Air traffic control" by D. R. Evans at 19.00 at the Government Communications H.Q., Benhall.

EDINBURGH

11th. I.E.R.E.—"High power u.h.f. transmitters" by D. Ingle at 19.00 at the Napier College of Science & Technology, Colinton Rd.

EVESHAM

9th. I.E.E.—"Concorde electrics" by H. Hill at 19.30 at the B.B.C. Training Centre, Wood Norton.

GLASGOW

12th. I.E.R.E.—"High power u.h.f. transmitters" by D. Ingle at 19.00 at the University of Strathclyde.

13th. S.E.R.T.—"A review of some developments in Post Office telecommunications" by A. Scott at 19.30 at the Y.M.C.A., 100 Bothwell St., C.2.

GLOUCESTER

12th. I.E.E. Grads.—"Video tape recorders" by G. Fry at 19.30 at the Technical College.

GUILDFORD

4th. I.E.R.E.—"Some circuit aspects of m.o.s. devices" by N. E. Broadberry and L. N. M. Edward at 19.30 at the Technical College.

HUDDERSFIELD

12th. I.E.E.T.E.—"Marine navigational aids" by G. J. McDonald at 19.00 at the College of Technology.

LEICESTER

4th. I.E.R.E. & I.E.E.—"Reliable low-distortion transistor audio amplifier" by P. J. Baxandall at 18.30 at the Physics Lecture Theatre, the University.

4th. I.E.E.T.E.—"The Decca Navigator system—a radio aid for ships and aircraft" by A. Brooker-Carey at 19.30 at the College of Technology, The Newark.

13th. I.E.E.—"Solid state devices" by D. T. Davies at 19.00 at the College of Technology.

LETCHWORTH

4th. I.E.E.—Children's Christmas Lecture: "B.B.C. radiophonic workshop" by D. Briscoe at 15.00 at the College of Technology.

LIVERPOOL

11th. I.E.R.E.—"Induction motor speed control" by D. R. Aubrey at 19.00 at the University Dept. of Elec. Eng'g. and Electronics.

11th. I.E.E.T.E.—"Communications by satellite" by V.C. Meller at 19.00 at the Building and Design Centre, Hope St.

MAIDSTONE

2nd. I.E.E.—"Colour television" by B. J. Rogers at 19.00 at the Royal Star Hotel.

MANCHESTER

4th. I.E.E.—"Computer aided design" by J. V. Oldfield at 18.15 at the University of Manchester Inst. of Science & Tech.

19th. I.E.R.E.—"A pay television system and equipment" by Dr. G. L. Hamburger at 19.15 at the University of Manchester Institute of Science and Technology.

MIDDLESBROUGH

5th. S.E.R.T.—"Computer traffic control" by A. Gregory and H. A. Codd at 19.30 at the Cleveland Scientific Institute, Corporation Rd.

NEWCASTLE-UPON-TYNE

4th. S.E.R.T.—"Computer traffic control" by A. Gregory and H. A. Codd at 18.45 at the Charles Trevelyan Technical College, Maple Terrace.

11th. I.E.R.E.—"Film electronics in the seventies" by J. C. Maddison at 18.00 at the Inst. of Mining & Mech. Engrs., Westgate Road.

16th. I.E.E.—"Optical communications" by D. Williams at 18.30 at the Rutherford College of Technology.

NORWICH

5th. I.E.E. & I.Mech.E.—"Men, circuits and systems in telecommunications" by J. H. H. Merriman at 19.30 at the Assembly House.

PORTSMOUTH

10th. S.E.R.T.—"Design and development of colour television components" by A. W. Lee at 19.00 at Highbury Technical College, Dovercourt Rd., Cosham.

PRESTON

11th. I.E.E.—"Colour television receiver design" by B. J. Rogers at 19.30 at the Harris College.

READING

5th. I.E.R.E.—"Digital voltmeters" by G. W. Boulton at 19.30 at the J. J. Thomson Physical Lab, the University.

REDHILL

4th. I.E.E.—"Changing patterns in communications" by D. Wray at 19.30 at the Mullard Research Labs, Salfords.

RUGBY

3rd. I.E.E.—"On the future of world communications" by Prof. C. Cherry at 18.15 at the College of Eng'g Tech.

SHEFFIELD

4th. I.E.E.—"Operation of the Eurovision system" by A. R. Elliott at 18.30 at the University.

10th. I.E.E.—Faraday Lecture "Microelectronics" by P. E. Trier at 19.30 at the City Hall.

SOUTHAMPTON

4th. S.E.R.T.—"Digital integrated circuits" by K. G. Nichols at 19.30 at the College of Technology, East Park Terrace.

TORQUAY

12th. I.E.E.—"Satellite communication" by J. M. Brown at 14.30 at the Electric Hall.

Late November meetings in London

26th. I.E.R.E.—"Frequency modulation transducers" by J. Agar at 18.00 at 9 Bedford Sq., W.C.1.

27th. I.E.R.E.—"World telephone communication" by S. Welch at 18.00 at 9 Bedford Sq., W.C.1.

27th. B.K.S.T.S.—"The usable sensitivity of a radio receiver" by J. Moir at 19.30 at the Royal Overseas League, Park Pl., St. James's St., S.W.1.

29th. I.E.E.—Colloquium "Computer methods in network design and synthesis" at 09.30 at Savoy Pl., W.C.2.

29th. R.T.S.—Symposium "Television news techniques" at 17.00 at the I.T.A., 70 Brompton Rd, S.W.3.

A Flexible Expander/Compressor

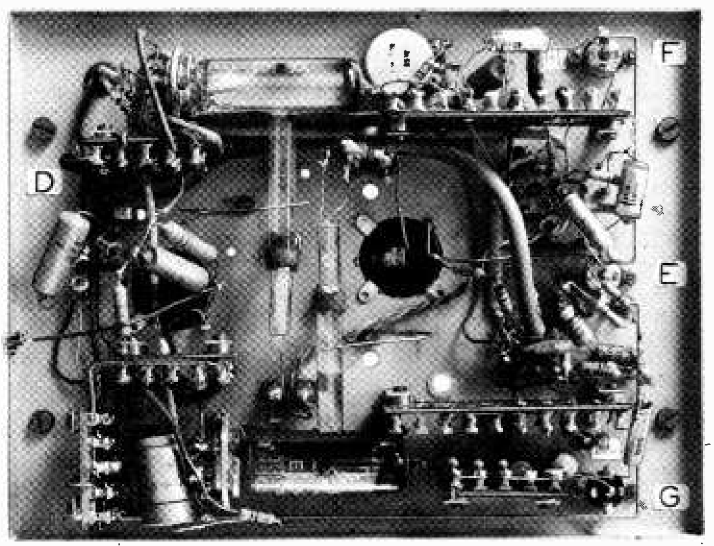
A means of achieving loudness control by using a photo-electric potential divider

by M.B. Catford, B.Sc.*

Some years ago, during the early stages of the now widespread interest in the high quality reproduction of music from disc records, there was a general realization that some degree of expansion of the dynamic range of the recorded sound, within the reproducing circuitry, and automatic in action, could lead to enhanced enjoyment for the critical listener, since it could be used to counteract the peak limiting or compression unavoidable in disc recording. Many records were then unwittingly also records of how not to use a compressor, in that the results of its use were only too evident to the listener's ear. In the last ten years, the advances in techniques, including the universal re-taping and editing of original tapes before cutting the disc record, have made the life of the control engineer easier, so that the compression is today not so obvious. Many listeners to records made in recent times may question the advantage of any expansion of the dynamic range. But a few, super-critical perhaps, seeking the best possible reproduction of the sound as originally recorded, will notice that a passage for cello and oboe which has an average level only 10 dB down on that of the full orchestra, or who are repeatedly disappointed at the degree of surprise which the composer surely intended, at the sudden trumpet call in the middle of the William Tell overture, and are thereby forcefully reminded of the restrictions imposed by the recording process.

*The Dept. of Scientific and Industrial Research, New Zealand. Mr. Catford died in January of this year, before disclosing full details of the circuitry. The details presented here were obtained from extra material supplied by Mr. J. A. Bourne after an examination of Mr. Catford's equipment.

A view of the expander/compressor chassis showing the mounting of the main components. It is believed that the author had a frequency division network in his system, with a separate photoelectric control unit for each part.



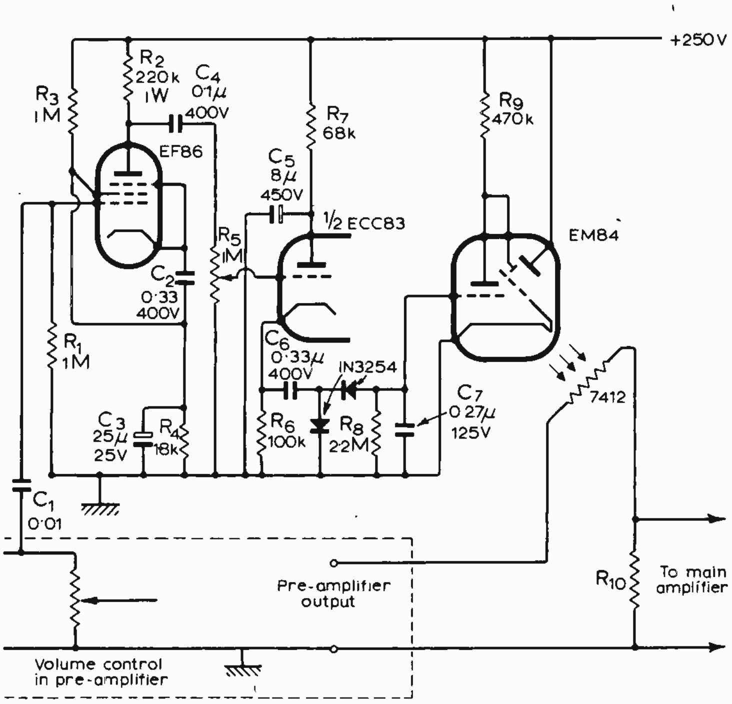
In the other direction, many a tape recording enthusiast must have longed for an easily adjustable compressor, which would look after the unrehearsed peak intensity in his own taping of a live performance.

Offers by manufacturers of a photo-resistive unit, comprising a filament lamp mounted in the same assembly as a photo resistor, may have prompted some of them to reconsider the published circuits for volume expansion, and experiments in that field carried out in days gone by. Those who find that dynamic range expansion or compression is either attractive or essential, may care to try the method used by the writer during the last two years.

The basic idea is simple. Replace the filament lamp as light source with an electronic light source like that of the C.R.O. screen. This has manifold advantages which are not immediately obvious, and can be done with great economy by using as the source, a tuning indicator, EM 84. This valve cum electron gun device needs no high voltage supply; it exhibits two fluorescent strips, normally separated by a considerable distance if input volts are zero, but the proximal end of these strips approach each other more and more closely as the grid input voltage is raised. The amount of light emitted by these strips is approximately proportional to their area. Inspected through a coloured filter, it will be found to contain a large amount of orange-red light, and it is this portion with which the photo-resistor family are concerned. The earlier 'magic eye' indicator with its green fluorescence would not be perceived as a light source by any ordinary photo-resistor.

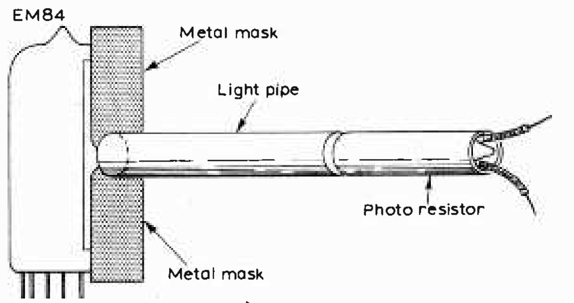
If an EM 84 indicator, to which the audio signal is fed at the triode grid, is placed in a dark box, which also contains a photo-resistor such as the RCA 7412, we can utilize the light-modulated resistance in a network involving only one other normal resistor, so as to form a potential divider which automatically responds so as to enhance signal peaks applied across the network, or to level out these peaks, according to whether the photo-resistor forms the 'top' part or the 'lower' part of the divider.

The photo-resistor so arranged will respond only to the general level of the light intensity within the box. This alone is not satisfactory, for the simplest calibrating test will show that the fluorescing strips of the indicator increase in area in logarithmic relationship to the input signal voltage. This effect, achieved by suitably shaping and disposing the internal electrodes, is ideal for use as a tuning indicator, but as a light source for a volume expander would cause a large change of loudness for a certain input change at a low average signal level, and a very much smaller change in loudness for the same signal change if the average level was high. Clearly something must be done to at least straighten out this logarithmic response, and even, if possible, to reverse its direction. This is



The circuit for audio control of the light intensity of the EM 84 when used as a light source for the photo-resistor. By inverting the potential divider feeding the main amplifier the unit's function may be inverted.

The disposition of parts in the unit. This may better be seen in the photograph.



very easily done. All that is required is that the photo-resistor shall be placed quite close to the screen of the indicator, and at a point mid-way between the two ends of the flourescent strips. When these are well separated, they still emit light, but this is all in the peripheral field of view as seen by the photo-resistor, which therefore almost ignores any small changes in the quantity of light. It is not until the ends of the strips come together, and are almost opposite the close spaced photo-resistor, that it sees them effectively. From that intermediate condition, the now decreasing response of the indicator, because of its logarithmic law, will have more and more effect on the photo-resistor, right up to the apparent point of saturation when the strips meet, and surprisingly, beyond this point, for an increased amount of light is emitted from the strips even when they overlap each other. Such a disposition of indicator and photo-resistor, with normal values of circuit components and supply voltage, can result, for a change of input signal of 20 volts, in a resistive change of 10 megohms to 0.1 megohm, or 100 to 1. As an element in a resistive potential divider used as a volume control, this can be used if need be to occasion really violent loudness change.

Now we can review some of the advantages of such a system. Firstly, since the light flux changes are electronic in origin, and the phosphors used appear to be similar to those employed in the C.R.O., we certainly have instant response. It is in fact fast enough to 'catch' the beginning of a percussion sound, such as a drum tap or a piano note. Secondly, since the input signal is applied to an open circuit, comprising the triode grid of the indicator, it cannot be inadvertently destroyed by burning out. Thirdly, a most important advantage, the response law can be changed at will in a manner impossible with any other form of light source.

A description of a typical expander as used in the writer's equipment will show how this is done. The audio input signal for operating the expander is taken from the live end of the volume control in the pre-amplifier. This is at millivolt level, so it is passed through a one stage voltage amplifier, adjusted to achieve an output of some 25 volts average on the loudest audio passages. This is applied by way of a parallel fed potentiometer to a cathode follower, the potentiometer allowing adjustment of the degree of expansion. The cathode follower, through a double diode connection, feeds a resistance-capacity circuit and the indicator input grid. The time constant of this shunt circuit controls the decay envelope after expansion is cut off by reduction of the audio level. Values here are emphatically non-critical, and a time constant of 1 second is a good starting point for adjustments by trial.

The EM 84 is entirely satisfactory when used as recommended, although if need arises, it is capable of astonishing light output on higher voltage at anode and target. The photo-resistor, RCA 7412 is virtually placed with its envelope axis at right angles to that of the indicator, with a spacing of 1/16 in to 1/8 in between the two components. Virtually—because in practice it is a good idea to interpose a heat insulator in the form of a short light pipe. This consists of a 2 in length of clear glass rod about 1/4 in diameter. This light pipe keeps the temperature sensitive photo-resistor away from the heater of the indicator. Without this precaution, the performance of the expander will gradually fall off during several hours of use. Ideally the ends of the glass rod should be flat and polished, but in practice a clean and chip free break surface works almost as well. Glass seems to be better for this purpose than a clear plastic.

Now the final refinement; a thin metal diaphragm is placed between the indicator and the glass rod light pipe. It is slit at a place opposite the end of the rod. The corners of the slit, and the width of the slit, are altered by snipping with fine scissors or by bending the metal foil with forceps, until trial shows that the mask so formed gives the desired, and stepless, response.

For the majority of the writer's records, the expansion is set at zero. Since those records in which its expanding action seem to be required are from different recording studios, controlled by various recording engineers, using different equipment, it would seem to be an impossible task to attempt an exact compensation for the compression used on any particular occasion. The mask outline, together with the expansion control, are therefore in theory a glorious compromise. In fact it is not a difficult job to adjust things so that even a very critical ear is unaware of just why the record sounds more realistic on this equipment than it does on another which has no expander. This, demonstration sessions apart, is its real function.

The expander can also be used to do some cheating. The dynamic range of a recording can be expanded by settings which result in hearing the loudest passages normally, but all others quieter than as recorded. One can argue about this being less faithful as a reproduction of the original sound, but the end result is very pleasant, since surface noise is inaudible at all times.

New Products

M.O.S. 'Tetrode'

A combination of important valve and transistor features are claimed by Mullard for the m.o.s. transistor type BFS28. With high input impedance and low distortion it can handle a wide dynamic range. It has high gain (18dB at 200MHz) and low noise (2.7dB at 200MHz). All these features make it particularly suitable for use in the front-end of v.h.f. receivers. Cross modulation performance is improved and spurious response reduced to a minimum by the linearity of the device. Low feedback capacitance (0.025pF at 10MHz) ensures operating point stability and reduces oscillator feedthrough. The dual gate construction allows for linear mixing. Encapsulated in a TO-72 can, the maximum drain-to-source voltage is 20V, and maximum drain current 20mA. Mullard Ltd., Mullard House, Torrington Place, London W.C.1

WW 331 for further details

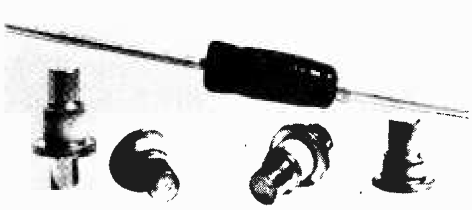
Matched F.E.Ts

Semitron are now providing f.e.ts type C97E and C98E with the basic parameters matched to within 5% and with pinch volts selected to better than 5mV. The f.e.ts are n-channel types and the main application for the matched pairs will be in differential amplifiers. Maximum drift over the temperature range −50°C to +70°C is better than 50μV/°C. Semitron Ltd, Cricklade, Swindon, Wiltshire.

WW315 for further details

Step-recovery Diodes

Hewlett Packard have coined two new parameters for step-recovery diodes which they say will remove the need for component selection within a selected range by circuit designers. The transition from low- to high-impedance upon bias reversal is not a simple step function, but may include a more slowly rising ramp before the main transition and a rounding off of the trailing edge. Hewlett Packard now use the terms "ramping" and "rounding", specified as a percentage of total transition time, to describe these phenomena. Three new step-recovery diodes announced by Hewlett Packard are 5082/0200, /0201, and /0202 that have transition times from 85ps to 300ps, breakdown voltages between 10 and 20%. The devices are available in a choice of two ceramic packages (0.3pF and 0.4nH or 0.2pF and 0.5nH) or in a DO-7 glass package (0.25pF and 4nH). Small quantity price is from about £3 10s to a little over £18 per item. Hewlett Packard Ltd, 224 Bath Rd, Slough, Bucks.



WW 302 for further details

M.O.S.T. Shift Registers

Three new shift registers, one static and two dynamic, now augment the range of m.o.s.t. circuits available from SGS-Fairchild. The static device, the 3300, is a 25-bit, three phase, serial access shift register in a ten-lead TO-100 can. Designed for operation up to 250kHz, it consists of 25 flip-flops arranged in three strings to give input and output access at 16, 8 and 1-bit increments. The output of the last bit in each string is buffered to provide good capacitance driving ability. Characteristics of the 3300 include a noise margin of 1V and a typical power dissipation of 2mW/bit. Only one external clock drive is required as the other two phases are generated internally. The first of the dynamic registers is the 3303 which is a 25-bit serial access shift register which is also in a TO-100 case. The register, which will operate from 10 to 500kHz, consists of two 25-bit serial strings of data storage elements controlled by two common shift lines. The more complex 3320, which is a 64-bit shift register/accumulator, will operate from 10kHz to 2MHz. It incorporates additional input logic to provide control of the loading of new data or the re-circulation of existing information. SGS-Fairchild Ltd, Aylesbury, Bucks.

WW 335 for further details

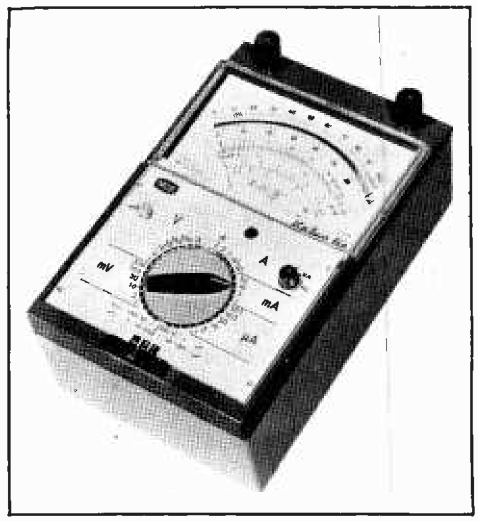
Operational Amplifier

Designed to operate in either the inverting or non-inverting mode, with a wide range of power supply voltages, the Burr-Brown model 3038/25 universal operational amplifier has an f.e.t. input. Input inpedance is $10^{11}\,\Omega$ and offset current is 50pA at 25°C. Voltage offset drift is typically ±15μV/°C at the input. Power supply voltages can be balanced or unbalanced and from ±40V to ±135V d.c. The amplifier's maximum output voltage swing is equal to the supply voltage less 20 volts in each direction. Output current can be as high as ±20mA. Supply rejection is such that if both supplies vary from 40V to 135V at 120Hz the ripple voltage at the amplifier input will be less than 1mV. Up to 100V common-mode voltage can be accepted with a d.c.-to-100Hz common-mode rejection ratio of 90dB. The slew rate is guaranteed to be 12V/μs (minimum) and rises with increasing power supply voltage. The encapsulated model weighs less than 120g and measures 61 × 45.8 × 15.3mm. It requires a maximum of ±10mA quiescent current. Price of model 3038/25 is £83 in 1-9 quantities. A companion unit, model 3138/25 has identical specifications, except that voltage offset is typically 45μV/°C and the price £59. General Test Instruments Ltd., Gloucester Trading Estate, Gloucester, England.

WW 329 for further details

Electronic Multimeter

An electronic multimeter introduced by Smith's Industries employs an f.e.t. chopper/amplifier measuring circuit and costs approximately £70. Overload protection is provided by a fast-acting electro-mechanical cut-out, a fuse, an input circuit flash-over path and various diodes. The meter is powered by four 1.5V miniature cells that are claimed to have an average life of six months. The taut ligament movement is temperature compensated magnetically and has a basic sensitivity of 17μA. Voltage ranges (there are 13 a.c. and 13 d.c.) start at 1mV f.s.d. and finish at 1000V f.s.d. in a 10, $\sqrt{10}$ progression with a sensitivity of 1MΩ/V or 10MΩ which ever is the lower. The dB ranges span −60 to +50 dB, OdB = 0.775V. There are

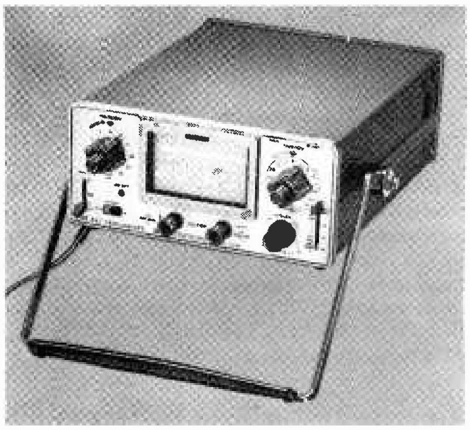


14 a.c. and 14 d.c. current ranges with f.s.ds of 1μA to 3A. Accuracy on the current and voltage ranges at 50 and 60Hz is ±1% falling to ±3% at 20kHz. Resistance is covered in six ranges with f.s.ds from 500Ω to 50MΩ, centre scale of the upper and lower ranges being 1MΩ and 10Ω respectively. The six capacity ranges have f.s.ds from 50nF to 5000μF. The meter can be used in conjunction with an iron/constantin probe to measure temperature in two ranges 0 to 18°C and 0 to 180°C. Smith's Industries, Kelvin House, Wembley Park Drive, Wembley, Middx.

WW 301 for further details

Portable Oscilloscope

Type 323 portable oscilloscope from Tektronix is semiconductor-built and may be powered by external a.c. or d.c. supplies or internal batteries. It is small, weighing approximately 4kg with batteries, and has low power consumption. Bandwidth of 4MHz is provided at 10mV/div. deflection factor. For low signal level applications a 1mV/div. deflection factor is provided at 2.75MHz bandwidth. Sweep rates are 5μs/div. to 1s/div. A X10 sweep magnifier extends the fastest sweep rate to 0.5μs/div. Single control knob automatic or manual level sweep triggering, positive or negative slope, is provided. With no input the automatic trigger mode provides a bright baseline reference at all sweep rates. The c.r.t. uses a low-power, directly heated cathode, providing a display two seconds after turn-on. A 6 × 10 div. internal non-illuminated graticule permits parallax-free measuring. (This instrument



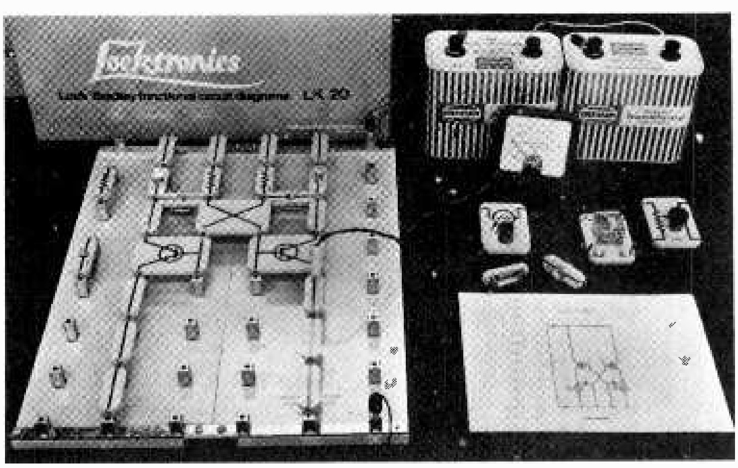
is the first product of the joint venture between Tektronix Inc. and the Sony Corporation.) Tektronix U.K. Ltd., Beaverton House, Station Approach, Harpenden, Herts.
WW 322 for further details

Grey-scale Generator

Marconi Instruments' grey-scale generator type TF 2909 produces 625-line television test waveforms for the measurement of non-linearity distortion. Staircase (5, 7 or 10 steps) or sawtooth waveforms are provided at every fourth or fifth line. The other three or four lines may be switched from black- to white-level at a low frequency rate with manual, remote or internal operation. For the measurement of colour non-linearity, a subcarrier can be superimposed on the staircase or the sawtooth, and 10Hz of sub-carrier reference burst is available on each line. The sub-carrier may be either internal (4.433 MHz) or provided externally from 0.5 to 5MHz. To provide a composite video signal, the waveform can be triggered from an internal crystal oscillator, or by a television studio source. A version of this equipment for 525-line use is available. Marconi Instruments Ltd., St. Albans, Hertfordshire.
WW 333 for further details

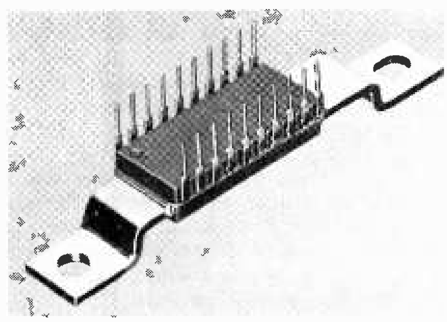
Instructional Equipment

A new teaching aid shown at this year's Manchester Institution of Electronics Show is in the form of a functional circuit diagram called Locktronics. Electronic components are mounted singly underneath carriers which are located via spring contacts between upright metal connecting pillars on a baseboard. The appropriate component symbol is marked on the upper side of the carrier so that when the assembly is completed the circuit diagram is reproduced on the baseboard. A specially constructed probe allows a current meter to be inserted anywhere in the circuit without first having to break the circuit wiring. A large number of circuit configurations are possible using standard kits and, for specialized circuits, blank unmounted carriers are supplied. A. M. Lock & Co. Ltd., Prudential Buildings, Union Street, Oldham, Lancs.
WW 308 for further details.



Plastics Package for I.Cs

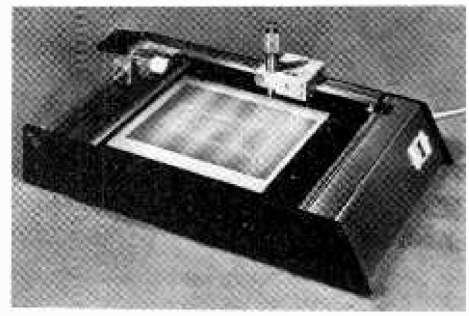
An inexpensive new power plastics package for integrated circuits, the P20, has been introduced by Plessey Microelectronics. Planned eventually to accommodate a variety of chips, the P20 has already made its commercial debut in colour TV receivers produced by the Rank Bush Murphy organization. This encapsulation, which is particularly suited to commercial applications, will also be used for the fully integrated Plessey car radio chip, and Plessey 3 and 5-watt audio amplifiers. Basically a 20-lead in-line plastics package with an integral heat sink, it can be bolted to a further heat sink, or simply to an equipment chassis. The package is designed to dissipate at least 3 watts when used with a suitable heat sink. Lead spacing is standard 0.254cm module, to facilitate use with printed circuit boards, although the electro-tinned leads are



equally compatible with wrapped wiring techniques. Plessey Microelectronics, Swindon, Wilts.
WW 323 for further details

Printed-circuit Scriber

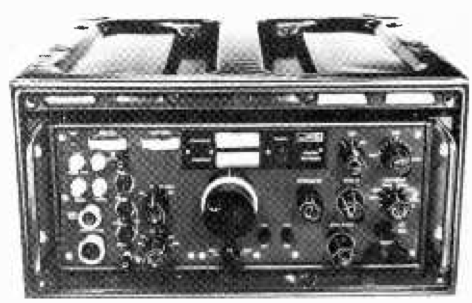
Present trends towards miniturization within the electronics industry and the increased use of microcircuits requires a method of producing accurate printed circuit masters quickly. The Tecam Master-Scriber is a two-axis manually operated co-ordinatograph designed primarily for this purpose and its overall accuracy is within ±0.005in. Used in conjunction with dual-layer scribing film it has a working area of 25.5 × 20.5cm illuminated internally by four fluorescent lamps. Movement along each axis is damped by a pad



system. The tool position is indicated by a dial gauge on each axis calibrated in 0.005in divisions and four interchangeable tools in a range of bit sizes provide for line scribing, track scribing, circular pad cutting up to 0.1in diameter leaving a central dot for drilling and an ink dotter to mark additional drilling centres. Overall dimensions of the instrument are 53 × 30 × 18cm and the price is around £150. Techne (Cambridge) Ltd., Duxford, Cambridge.
WW 338 for further details

Military Communications Receiver

The civil communications receiver type PR 155 has been redesigned and developed by Plessey to provide a military communications receiver designated PR 1552. The new model provides for a.m., c.w., s.s.b., f.m., ph.m. and f.s.k. signals, and has a continuous tuning range from 15kHz to 30.1MHz. On f.s.k., shifts between 100Hz and 900Hz can be accommodated with keying speeds up to 120 bauds. Normal or reverse keying may be selected by a switch. Seven i.f. bandwidths are provided. All controls are mounted on the front panel and, because of the closed construction, two sockets for service outlets and power inputs are included. Internal power conversion units permit operation from 100 to 125V or 200 to 250V at 48 to 420Hz or d.c. supplies of 12V or 24V nominal, floating or



with negative or positive earthed. The overall dimensions including the case, are 26.7 × 52 × 50cm and the total weight is 26kg. Radio System Division, Plessey Electronics Group, Ilford, Essex.
WW 305 for further details

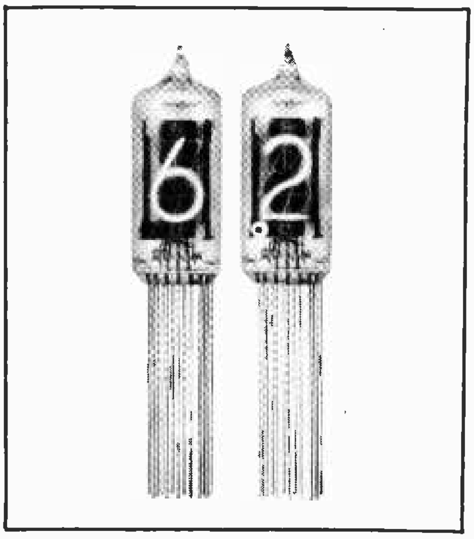
Integrated-circuit Decoders

A new range of integrated circuit b.c.d. to 7-segment decoders has now been added to the Westinghouse 200 series d.t.l. elements marketed in the U.K. by the Microelectronics Division of Ultra Electronics. These decoders provide the 7 line output for driving 7-segment numerical displays in accordance with b.c.d. input information. Input currents and thresholds are compatible with d.t.l. and t.t.l. logic systems. The outputs are positive true outputs which are intended to drive either the gates of s.c.rs or the base of high current or high breakdown-voltage transistors. These s.c.rs or transistors then drive segmented displays. The basic b.c.d. to 7-segment decoder is available in three versions, the WC.237, WC.247 and WC.257 for three different logic options. All three devices are in plastics dual-in-line packages. Ultra Electronics (Components) Limited, Microelectronics Division, 35/37 Park Royal Road, London N.W.10.

WW 303 for further details

Indicator Tubes with Decimal Point

Four new numerical indicator tubes announced by Mullard incorporate a decimal point that can be displayed with or without a numeral. Types ZM1174 and ZM1175 indicate the decimal point on the left of the Arabic numeral (0 to 9), and types ZM1176 and ZM1177 on the right. Tubes ZM1175 and ZM1177 are clear, but the ZM1174 and ZM1176 have red lacquer filters to improve contrast. Fine-wire anodes eliminate obstruction of the numeral. They also have the advantage of being better sputter guards than the perforated plate anodes often used in other tubes and, consequently, almost eliminate discoloration of the face with service. The numerals have a height of 15.5mm, and the decimal point a diameter of 1.5mm. The tubes operate with a minimum



supply voltage of 170V and take a current of typically 2.5mA when displaying a numeral alone; the decimal point current is approximately 0.5mA. Mullard Ltd., Torrington Place, London, W.C.1.

WW 327 for further details

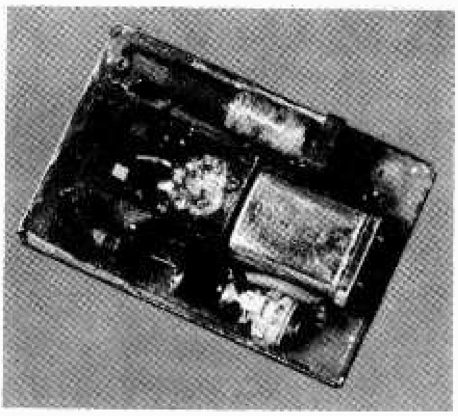
I.C. Power Switch

A power integrated circuit produced by Solid State Products Inc., and packaged in a TO-5 can, is able to switch a.c. (1.5mA-1A at 200V) at frequency of up to 20kHz. It requires only 2mA to turn it on. Various forms are available to meet different requirements. Agents: G. E. Electronics (London) Ltd., Eardley House, 182/4 Campden Hill Road, Kensington, London, W.8.

WW 325 for further details

Temperature-compensated Crystal Oscillators

The use of thin-film techniques has enabled Salford Electrical Instruments Ltd., to produce a 5-MHz crystal oscillator, the first of a new range of temperature-compensated crystal oscillators, measuring approximately 3.75 × 2.5 × 1.0cm. Power consumption is 18mW at 9V d.c. The quartz crystal and the associated compensation network give a stability of ± 3 p.p.m. over the temperature range—10°C to 60°C. The output is a sine wave of 500 mV into 50 Ω. The frequency



range will eventually extend to 20 MHz. Salford Electrical Instruments Ltd., Barton Lane, Eccles, Lancs.

WW314 for further details

Power Amplifiers

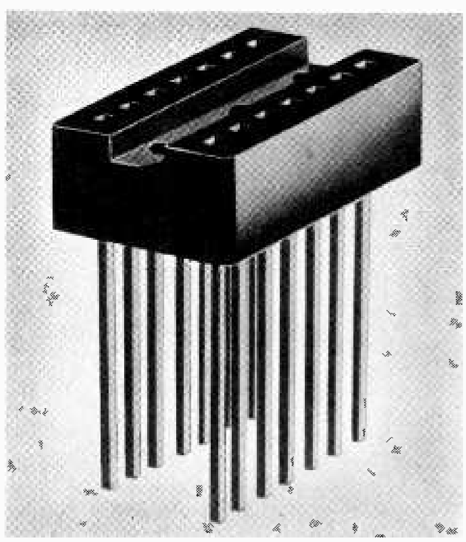
H/H Electronic announce two new amplifiers, the TPA 50 and TPA 100, which can deliver 50W and 100W continuous sinewave, respectively, into loads between 8 Ω and 15 Ω. Total harmonic distortion at any power level up to full rated output, is said to be less than 0.2% between 30Hz and 10kHz for the TPA 100, and less than 0.2% between 30Hz and 20kHz for the TPA 50. The power frequency response is flat from 20Hz to 20kHz ± 0.5dB (ref. 1kHz) for both amplifiers. They will both tolerate output short-circuit under full drive, and are unconditionally stable into reactive loads. Recovery from short-circuit is automatic and virtually instantaneous. Bench standing of 48cm rack mounting versions of the amplifiers are available. The TPA 100 costs £75 and the TPA 50 £49. H H Electronic, 147 High Street, Harston, Cambridge, Cambs.

WW 334 for further details

Dual-in-line Package Socket

A dual-in-line test socket, for mounting 14-lead packages with wide ranges of lead lengths, is being produced by Varelco Ltd. The Series 8358 has double leaf contacts made from phosphor bronze with gold flash over a nickel plate. The contact tails are 0.063cm square on a 0.253cm × 0.759cm grid, and are suitable for making wrapped wire connections. The insulator is a one-piece moulding made of black or brown wood-flour filled phenolic. Varelco Ltd., Newmarket, Suffolk.

WW 319 for further details



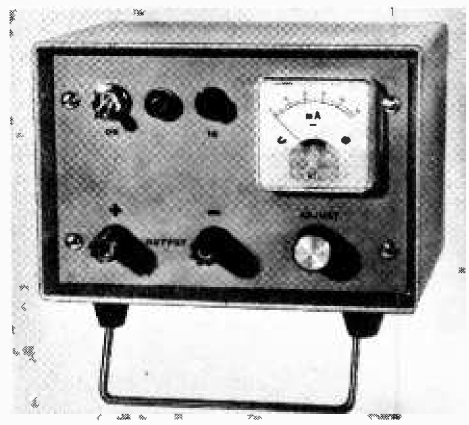
Sealed Microswitches

A new environment-free type 165 series of microswitches now supplements the Plessey Licon range. Offering a dependable snap-action with ratings up to 10A, 30V d.c., 250V a.c., its size (2.2x0.9x2.54cm) enables design space to be conserved. Type 165 provides a one-piece glass-nylon housing with a positive "O" ring plunger seal and epoxy terminal potting to give environmental protection. The basic snap-action is the familiar type 16 which is available in single-pole double-throw or two-circuit versions, with solder, AMP or potted-lead terminations. The Plessey Co. Ltd., Titchfield, Hampshire.

WW 304 for further details

Constant-current Battery Chargers

Two adjustable constant-current nickel-cadmium cell chargers have been added to the range produced by Crowborough Electronics. Accommodating from 1 to 20 cells in series, having capacities up to 1 ampere hour, each of the new units will trickle-charge batteries up to 10Ah. Model CE50 is fully variable from 0 to 50mA and model CE100 from 25 to 100 mA. Charging current is indicated on a front panel meter. The circuit, built with silicon semiconductors is un-



damaged by short-circuits or reversed battery connections. A mains fuse, neon indicator and 1.8m of mains cable are included, together with a pair of 0.92m battery leads. Both models cost £17. Crowborough Electronics, 3 Rotherhill Road, Crowborough, Sussex.

WW 318 for further details

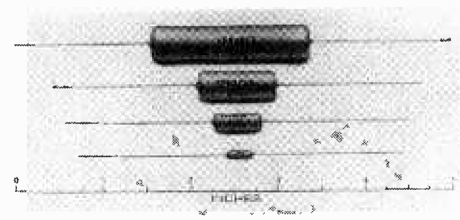
Solid Dielectric Trimmers

Four miniature trimming capacitors with capacitance changes of 5, 10, 20 and 60pF have been introduced by Mullard for use in a.m./f.m. radio receivers and similar applications. The dielectric is a low-loss plastics film that is little affected by temperature changes. The trimmers are assembled in a coloured plastics moulding that will not suffer damage from normal soldering or commonly used industrial cleaning fluids. A slotted brass extension to the rotor shaft enables the capacitance to be adjusted with the tuning tool kept well away from the capacitor plates. Connections are placed to match the 2.54mm (0.1in) grid on circuit boards. Mullard Ltd., Torrington Place, London, W.C.1.

WW 337 for further details

Silicon-coated Resistors

Resistance tolerances between 0.05 and 3% over the range 0.1 to 250,000 Ω are features of a new range of Acrasil wirewound resistors introduced by Sprague U.K. The silicon coating process



allows the use of very small diameter wire to obtain the high resistance values. The standard power ratings are from 1 to 10W. Sprague Electric (U.K.) Ltd., Trident House, Station Road, Hayes, Middx.

WW 317 for further details

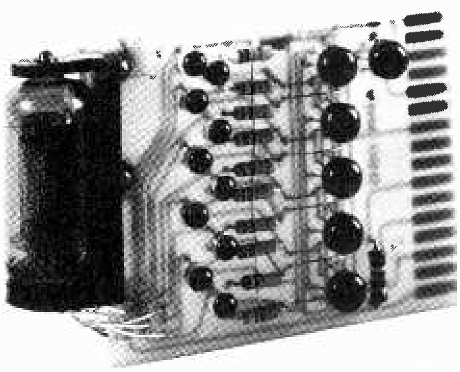
BCD-to-decimal Tube Driver

The 70V break-down voltage specified for these integrated circuits from Transitron Electronics is claimed to completely eliminate oscillation and unwanted background glow in indicator tubes. Two types of decoder/driver have been announced, the TDD1100 and TDD1101. Both can be housed in either 22-lead hermetically sealed flat-packs or 16-lead dual-in-line plastic packages. Both also employ high-level transistor-transistor logic (h.l.t.t.l.). Significant features from the specification are: $V_{IN(1)}$ = 2Vmin; $V_{IN(0)}$ = 0.8V max; I_{CC} = 18mA (TDD1100); I_{CC} = 20mA (TDD1101). Transitron Electronics Ltd. Gardner Rd, Maidenhead, Berkshire.

WW312 for further details

Low-cost Decade Counter/ Display Module

An integrated circuit decimal counter with decoding and drive transistors is produced by APR-Lotus Electronics. The count is displayed on an in-line neon indicator tube which is available with or without decimal points. Counting is possible from d.c. to 2 MHz min. and 4 MHz typical. The anode of the display tube is brought out to the edge connector, so the display can be blanked if required. A store function can be incorporated. The tube requires 180 V (−5% +10%) at 2 mA, and the resistor transistor logic + 3.6 V − 10%



at 125 mA. Logic 0 output is 0.3 V max., and logic 1 1.5 V. Operating temperatures lie between 0 and 55°C. The unit is 7.5 cm long, 6.5 cm high and 2 cm wide (including tube). The edge connector is 16-way with 0.37 cm pitch. APR-Lotus Electronics Ltd., 41 Thunder Lane, Norwich, NOR 84S, Norfolk.

WW 313 for further details

Pulse Generator

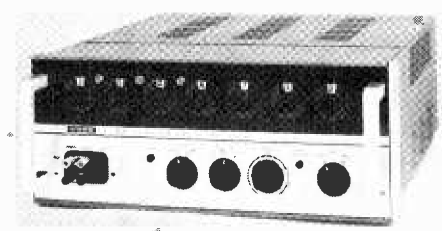
The PG-22 pulse generator from Lyons Instruments will provide pulses variable in width from 10ns to 1s with a 2ns rise-time at repetition rates from 0.1Hz to 50MHz. Output is variable up to 5V into 50Ω or 10V open circuit. Pulses can be delayed for up to 1 sec and normal/complement switching is provided on the front panel. The input circuits of the generator permit external drive from d.c. to 50MHz into 50Ω or high-impedance, synchronous start gating, manual "one-shot" operation or synchronization of the internal oscillator to external frequency sources with a frequency difference ratio as high as 100:1. Comprehensive slope, sensitivity and threshold controls are provided. The sync. output has a variable width control and sync. pulses can be of either polarity. The instrument can be operated in the temperature range 0 to +50°C and is contained in a case

9x38x35cm. The price is £395. Lyons Instruments Ltd, Hoddesdon, Herts.

WW309 for further details

Precise D.C. Voltage Standard

Cohu Electronics have produced an active d.c. voltage standard accurate to 0.001%. This accuracy

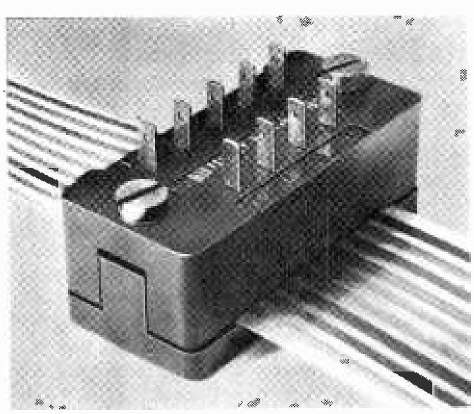


is guaranteed for 30-day periods under standard reference conditions. Three decade ranges supply voltages from zero to more than 1100 volts at up to 50mA. Two units may be connected in series. There is overload protection and self-checking of linearity. Litton Precision Products, 95 High Street, Slough, Bucks.

WW 328 for further details

Connector for Printed Wiring

This connector, from McMurdo, saves time by making it unnecessary to strip the insulation from flexible printed wiring for connection purposes. The film strip is placed in the connector and the clamping screws are tightened. Gold plated teeth, two per way, cut through the insulation to make contact with the conductor without actually penetrating it. The illustrated



connector has nine ways and is designed for use with one-inch wide film strip cable. Current handling capacity is 5A per way. McMurdo Instrument Company Ltd, Rodney Rd, Portsmouth.

WW 321 for further details

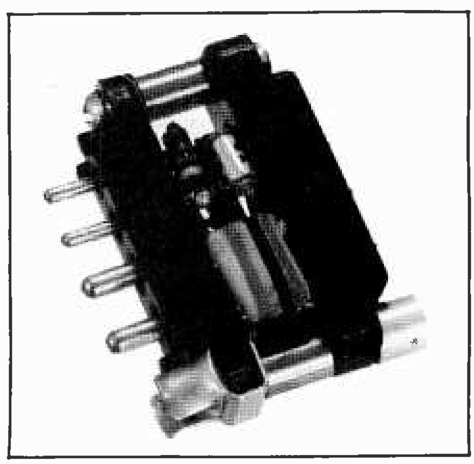
Vibrator Relay

A new resonant-reed relay suitable for remote control applications is being marketed in the U.K. by Leonard Wadsworth & Co. of London. It is manufactured by Meson of New York and consists basically of a vibrating body of nickel-chrome-steel alloy which is clamped at one end and is dimensioned to resonate at a fixed frequency when subjected to a magnetic field which is varied by the application of an a.c. signal of the same frequency. The range of frequencies normally available is from 70 to 800 Hz. Resistance of the energizing coil is usually 600 Ω but resistance values of 3.2–5,000 Ω are available. The smallest level of input signal resulting in contact closure (threshold sensitivity), can be controlled by adjustment of a screw. Bandwidth and response time depend on input operating power. Leonard Wadsworth & Co. Ltd., Broadway House, Broadway, London, S.W. 19.

WW 310 for further details

Pickup Equalizer

Although accurate R.I.A.A. equalization can be provided by top grade control units, a good standard average output from good-quality pickup cartridges is still ± 3dB when using test records recorded to R.I.A.A. characteristic. A series of supplementary equalizer units to further correct the output and provide a final result of better than ± 1.5dB has been developed by B & W Electronics of Worthing, and will be produced to cover a number pickup cartridges now in use. Initially, type SE/A is available for use with either Quad 33/303 or Radford SC2 Series control units and the Shure V15/11 pickup cartridge. It comprises twin passive net-



works built on to connectors designed to plug into the base connector of SME 3009 and 3012 Series pickup arms where it remains within the SME screening shield. B & W Electronics, Littlehampton Road, Worthing, Sussex.

WW 306 for further details

Two-way Counters

Bi-directional counters available in standard units having 4, 5 or 6 digit displays, all with sign indication, have been announced by A & R Designs of Bath. Designated type 181 the new counters supersede earlier types and now have a front panel with adequate space for the inclusion of input and output interface circuitry. Maximum counting speed is 1MHz (nominal) with

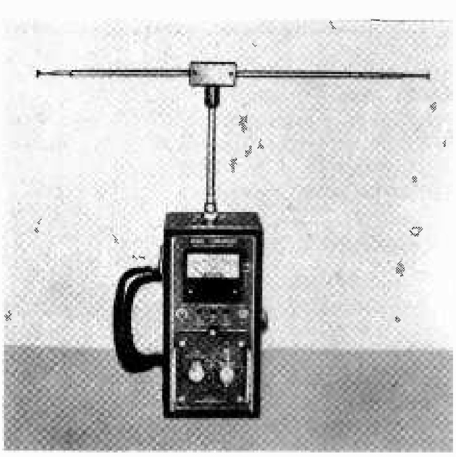
direction logic change in 100ns (nominal). Sign change when passing through zero, without loss of count, is standard. As a result of this new design A & R have been able to construct a two-axis display counter type 1818 which is available with a 5-digit *X* axis and a 5-digit *Y* axis display, the *X* axis having reset to zero facility and the *Y* axis having any number preset facility. A & R Designs Ltd., 1 Vineyards, Bath, Somerset.
WW332 for further details

Microwave Shottky Mixer Diode

Compared with point-contact diodes the Shottky diode, in mixer applications, offers an improved noise performance that is less sensitive to local oscillator drive level. It is apparently easier to produce a device of uniform characteristics with a form of construction to suit the requirements of hybrid thin film circuits. A Shottky mixer diode announced by Mullard is a gallium arsenide device that has a 6.5dB noise figure when operated at X-band frequencies. The diode, which has the type number 148CAY/A, is mounted on a ceramic carrier 0.8 × 0.35mm with metalized "lands" for bonding to circuit substrates. The diode is available in matched pairs for balanced mixer applications. Mullard Ltd, Mullard House, Torrington Place, London W.C.1.
WW 336 for further details

Portable Field Strength Meter

Interplanetric's VFM portable field strength meter employs silicon transistor circuitry and is complete with an all-band adjustable aerial. Two linear meter scales provide direct measurements in decibels and microvolts. An amplified audio signal is available from a phone jack on the front panel. The frequency range is spread across three bands 34-65MHz, 54-109MHz and 178-223MHz. (A u.h.f. plug-in assembly extending the frequency range to cover 465-855MHz is available separately). The sensitivity is 3μV. The unit is supplied in a leatherette case and measures approximately 10×11×23cm. Interplanetric, 39-49 Cowleaze Road, Kingston upon Thames, Surrey.
WW 330 for further details



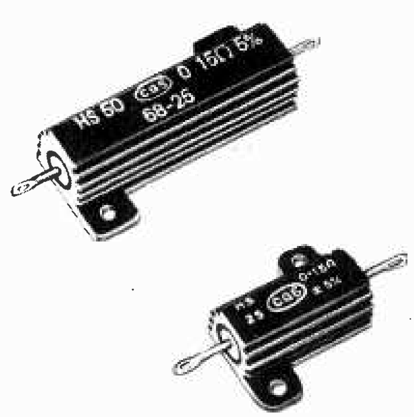
Digital Panel Meters

Single range digital panel meters for the measurement of voltage, current and resistance are to be produced by Advance Electronics in a series containing over 30 different models. Known as the DT340 series, it incorporates a dual slope integration technique for analogue to digital conversion giving accuracy characteristics of 0.1% of reading over extended time periods. Maximum resolution may be 10μV, 100pA or 0.1Ω depending on the model. The display is by neon numerical indicator tubes, with over-range and polarity indication, fitted with a meter face measuring 6.4 × 12.8cm. Models are available with remote control input and b.c.d. printer output. Price for quantities is

about £100 per unit. Advance Electronics Ltd., Roebuck Road, Hainault, Essex.
WW 307 for further details

Resistors with Heat Sinks

The C.G.S. Resistance Company are producing aluminium clad wire-wound resistors with values down to 0.1Ω and power ratings of



25W and 50W. This "HS" series is designed for direct chassis attachment, and the method of encapsulation affords complete humidity protection and insulation of the resistor. C.G.S. Resistance Co. Ltd., Marsh Lane, Gosport Street, Lymington, Hampshire SO4 9YQ.
WW 326 for further details

Mobile Radiotelephone

Integrated circuits (for i.f.), transmission line coupling between transistors, and u.h.f. printed circuits are among the advanced techniques used in the "Star" range of solid-state mobile radiotelephone equipment introduced by Standard Telephones and Cables Ltd. The first models to be available operate in the u.h.f. mobile band (450-470MHz), can be supplied for 25kHz or 50kHz channel spacing and use frequency modulation. The mobile set, available with up to five channels, measures 23 × 18 × 5cm and weighs 2.25kg (see picture), while the two other units—the base-station transmitter-receiver and a remote control unit associated with it—are not much larger. Power

output of the transmitter (both mobile and fixed) is 5 to 7 watts while the maximum frequency deviation is 5kHz or 15kHz. A noise-cancelling microphone is used. the receiver has a sensitivity of 1μV for a s/n ratio of 12dB. Its selectivity is 70dB when tested with two input signals. Audio output is 2W into a 3Ω loudspeaker with less than 5% distortion. With a base-station aerial 50 to 100ft above ground the equipment is said to give noise-free communication through large works, sites, airports, marshalling yards etc. both inside and outside of buildings. *Wireless World* was given a demonstration with the mobile station in a van travelling through tunnels in Central London, and at no time was the signal lost or badly attenuated—showing that u.h.f. energy is effectively diffused by multiple reflections from buildings etc. Standard Telephones and Cables Ltd., Mobile Radiotelephone Division, Oakleigh Road, New Southgate, London, N.11.
WW 341 for further details

Zener Diodes

Two new ranges of zener diodes have joined the products of S.T.C. Semiconductors. Both ranges are metal encapsulated and are available in the preferred values from 3.9V to 200V. The ranges are further subdivided into 5 and 10% tolerance types. Prefixes given to the diodes are as follows: ZD – 1.1W at 45°C amb., 5%; ZM – 1.1W at 45°C, amb., 10%; ZX – 15W at 75°C stud temperature, 5%; ZL – 15W at 75°C stud temperature. S.T.C. Semiconductors, Footscray, Sidcup, Kent.
WW320 for further details

Wheatstone Bridge

Intended mainly for students use, this bridge has an accuracy of better than ±0.25%. The bridge has a measuring range from zero to 1.111MΩ with a minimum sub-division of the decades equivalent to 0.01Ω. The integral galvanometer is shunted by diodes to protect it against overload and a variable sensitivity control is included. All resistors are non-inductive and each arm of the bridge is connected to independent front panel terminals. This latter feature makes it possible to connect the instrument as a simple *L* or *C* bridge using an oscilloscope as a detector. Educational Measurements Ltd, Brook Ave, Warsash, Southampton.
WW316 for further details

Answers to "Test Your Knowledge"—7

Questions on page 470

1. *(a)*. In respect of (b), (c) and (d) the reverse is true.

2. *(c)*.

3. *(c)*. If a high value of mutual conductance is required special constructional techniques are used to allow the grid cathode spacing to be made very small while avoiding, of course, actual electrical contact.

4. *(b)*. The cathode temperature will determine the maximum anode current for which the space charge limited condition holds.

5. *(a)*. This is the "Schottky effect". (b) occurs in high field emission which requires electric fields far greater than those occurring in valves.

6. *(a)*. This is because electrons emitted from the cathode have initial velocities greater than zero.

7. *(d)*. When the transit time of electrons between cathode and anode is a significant fraction of a cycle of the grid signal the anode current lags the grid voltage.

8. *(c)*.

9. *(d)*. Positive ions are continuously formed by collisions between electrons and gas atoms. Many of these ions flow to the control grid forming a continuous ion current. With the degree of vacuum which is usual in triodes and pentodes the size of this current is such that the grid circuit resistance should not exceed about 1M Ω

10. *(a)*. The effect of secondary emission is only observed in the tetrode giving rise as it does to the kink in the anode characteristic. In diodes, triodes and pentodes the electric field at the anode always returns the secondary emitted electrons to the anode.

11. *(d)*. To obtain maximum efficiency in class B or C operation the grid must generally be driven positive. Since this results in grid current flowing the valve must be designed for it.

12. *(d)*. This "anode dissipation" is normally the limiting factor in determining how much power a valve can handle.

13. *(c)*. When a pentode is used as a class A power amplifier the load line is usually chosen so that bottoming occurs at the low voltage end of the anode voltage cycle. As the valve runs into bottoming the screen current rises rapidly. Care must be taken that the maximum permitted screen power dissipation is not exceeded.

14. *(c)*.

15. *(a)*. Due to the presence of suppressor and screen grids the anode voltage has very little effect on the electric field near the cathode.

16. *(c)*. The valve is deliberately designed to have a very curved mutual characteristic with a slope which varies from a high value at small negative grid bias voltage to a very low value for a large negative grid bias voltage.

17. *(b)*. The electrons move across the valve in flat beams. The electron density in the beams must be sufficiently large to produce a potential minimum between the screen grid and the anode so that the secondary electrons return to the anode.

Literature Received

"What can go wrong with printed circuit soldering" is the title of a technical bulletin, TR-1020, which should be of value to every engineer. Produced by Alpha Metals, Inc., 1916 Tubeway Avenue, Los Angeles, RA 3-9044, U.S.A., it discusses and illustrates the causes of de-wetting, excess solder, icicling, webbing, white residues and blow holes. The bulletin is well produced and well written.
WW 375 for further details.

Relay users will be able to assimilate easily the condensed data provided in the new short-form catalogue from Keyswitch Relays. In all 22 relays, each representing a product group, are illustrated and described. Keyswitch Relays, Cricklewood Lane, London N.W.2.
WW370 for further details

Variable Transformers are the subject of a catalogue we have received from Claude Lyons. The catalogue (No. RV68) comes complete with a price list (No. RV 68/1), contains 24 pages, and lists a very large number of different types of variable transformers. There are those for single-phase and those for three-phase operation. There are single units, multiple ganged units and units with different voltage tappings. Also included in the catalogue are a number of suggested circuits. Claude Lyons Ltd., Hoddesdon, Herts
WW361 for further details.

Brief details of 16 pulse generators, 12 digital data generators and six output units are given in a **"Condensed Catalog 1968-69" from Datapulse Inc.** The U.K. Agents for Datapulse are Aveley Electric Ltd., Arisdale Ave., South Ockendon, Essex
WW362 for further details.

"Amateur Radio" is the title of a nicely presented 12-page booklet that has been produced by the International Amateur Radio Union. The booklet has two main purposes; "to introduce amateur radio to those responsible in national administrations for the control of the amateur service and for those members of governments that decide how the amateur services shall be operated in the best interests of all who use the radio spectrum". The booklet presents some interesting facts about, and some of the history of, the amateur radio movement in general. John Clarricoats, Secretary-editor, I.A.R.U., Region I Division, 16 Ashridge Gdns, London, N.13.
WW363 for further details

Precision sliding mechanisms are described in a catalogue from Imhofs under their trade name "Accurides". Accurides do not employ wheel and track methods and are claimed not to wobble, bind or stick and have a constant coefficient of friction. Applications include sliding equipment cabinets, optical systems, X–Y platforms, drafting equipment, etc. Alfred Imhof Ltd., Ashley Works, Cowley Mill Road, Uxbridge, Middlesex.
WW364 for further details

"Solid State Optoelectronics" is a brochure describing a range of components for use in the visible and infra-red parts of the spectrum. Included in the range are gallium arsenide infra-red emitters and trans-ceivers, silicon receivers, device and lens holders, and optical accessories. The brochure provides a brief technical description and a photograph of each item. M.C.P. Electronics Ltd., Alperton, Wembley, Middlesex.
WW366 for further details

Newsletter No. 38 of the **British Amateur Radio Teleprinter Group** contains a number of items that will interest the amateur r.t.t.y. operator. A letter from John Whittington, G3SHZ, describes how he modified a type 3 Creed teleprinter to conform to the I.T. alphabet No. 2 as used by the 7B Creed teleprinter. Membership of B.A.R.T.G. now stands at around 300. L. A. Crane, G3PED, 10 Crescent Road, Tollesbury, Maldon, Essex.
WW367 for further details

A signal conditioning system that will accept inputs of up to ±80V from d.c. to 10kHz is the subject of a leaflet from the electronics division of Wilmot Packaging Ltd. The system, which is of modular construction, includes amplifiers, attenuators, filters and a peak indicating unit that may be combined in such a way as to produce a "standard" output. The equipment could, for instance, be used to standardize the outputs from a variety of transducers. Wilmot offer a customer design service for the equipment. Wilmot Packaging Ltd., Electronics Division, Salisbury Road, Totton, Southampton.
WW365 for further details

Radiospares Catalogue for October to December 1968 follows the same format as earlier editions but is expanded. It is interesting to note that some of the panel meters supplied by RS come complete with a blank scale for marking by the user—a useful feature. From December 27th Radiospares phone number will be 01-253 9561. Radiospares, 13-17 Epworth Street, London E.C.2.
WW368 for further details

"Component Applications Data 1969" also comes from Radiospares. This 64-page booklet gives fuller technical information on the products marketed by RS than the catalogue does.
WW369 for further details

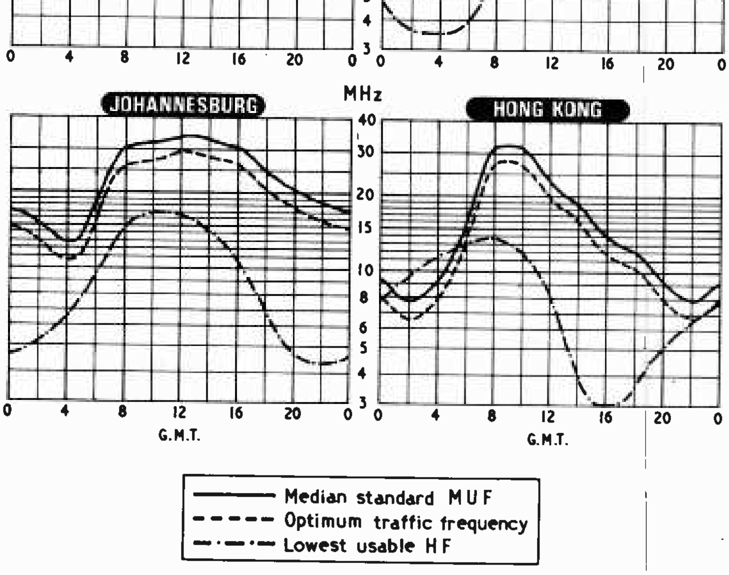
"Audio Talk" lists the definitions of over 1,000 terms and abbreviations used in audio and allied subjects. Prepared by the editorial staffs of *Hi-Fi News* and *Tape Recorder* it is available from Link House Publications Ltd., Link House, Dingwall Avenue, Croydon, Surrey, CR9 2TA, and costs 2s 6d including postage.

H.F. Predictions—December

Compared with recent months northern hemisphere MUFs are higher by day and lower by night although some shorter routes have a subsidiary peak several hours before dawn. E, F1, and Es critical frequencies are lower and have little or no effect on FOTs (optimum traffic frequencies).

LUFs are prepared by Cable and Wireless, Ltd. for reception in this country of medium-power point-to-point telegraph services using directive aerials. They are a guide, by their relative proximity to the FOT, for all types of service.

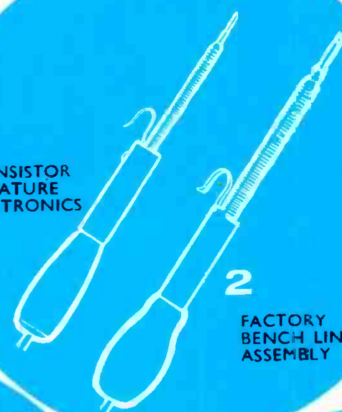
The predictions are based on an Ionospheric Index (IF2) of 116; that predicted for last month was 122 and the measured value for December 1967 was 115. The corresponding sunspot numbers are 104, 102 and 115 respectively.

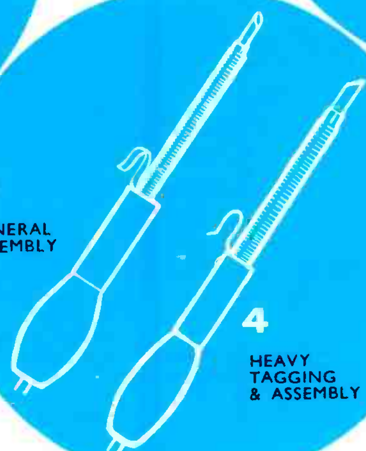


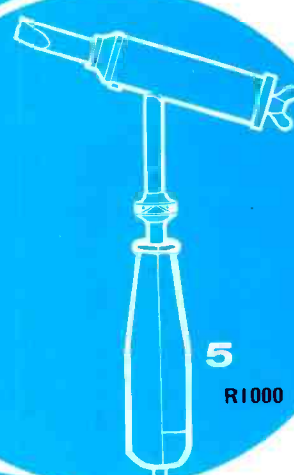
SOLDERING INSTRUMENTATION

ADCOLA
PRODUCTS LIMITED
(Regd Trade Mark)

HIGH EFFICIENCY INSTRUMENTS

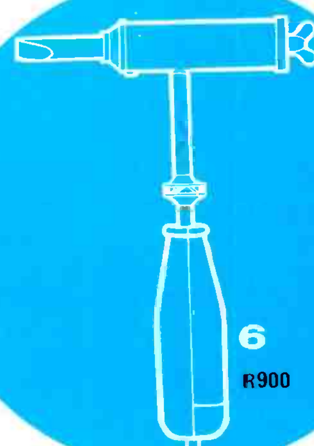






1. $\frac{1}{8}$" DIA.—3.2 mm. dia. detachable bit. Standard temp. 340 c at 19 watts. Special temps from 250 c 400 c. Weight 4.5 ozs. 127 grms.
2. $\frac{3}{16}$"—4.75 mm. dia. detachable bit. Standard temp. 360 c at 23 watts. Special temps. from 250 c 410 c. Weight 6 ozs 170 grms.
3. $\frac{1}{4}$"—6.34 mm. dia. detachable bit. Standard temp. 360 c at 27 watts. Special temps. from 250 c 410 c. Weight 6.5 ozs. 184 grms.
4. $\frac{5}{16}$"—7.9 mm dia detachable bit. Standard temp. 350 c at 30 watts. Special temps. from 250 c 410 c. Weight 7 ozs. 198 grms.
5. OFFSET BIT SIZE $\frac{1}{2}$" 12.7 mm. diameter.
6. RIGHT ANGLE BIT SIZE $\frac{1}{2}$" 12.7 mm. diameter.

BOTH AVAILABLE IN THE FOLLOWING TEMPERATURES
250 c—27 watts, 360 c—50 watts, 410 c—60 watts, 500 c—90 watts Supplied in all voltages from 6 volts to 250 volts



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Bib AUDIO & ELECTRONIC AIDS
-handy accessories that make all the difference and also make useful gifts

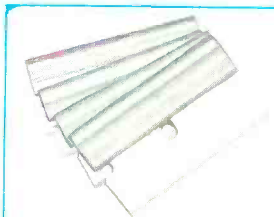
Bib Wire Stripper & Cutter Model 3
Strips insulation without nicking the wire. Cuts wires and cables cleanly. Semi-permanently adjusted. Price 4/6d.

Bib Wire Stripper & Cutter Model 8
De luxe version of Model 3, incorporating a unique 8 gauge selector. Plastic covered handles. Price 9/6d.

Bib Tape Head Maintenance Kit Size E
Specially designed to maintain the tape heads and other parts of the tape recorder in clean condition. Suitable for reel to reel or cassette tape recorders. Contents: Bottle Bib Instrument Cleaner. Two blue Tape Head Applicator tools. Two white Tape Head polisher tools. 10 applicator and polisher sticks. Double-ended brush. Packet cleaning tissues. Instruction leaflet; all in a Folding Plastic Wallet. Price 16/6d. inc. P.T. Applicator and polisher tools and sticks are available separately.

Bib Professional Tape Head Maintenance Kit Size K For Service Organisations, Recording and Broadcasting Studios. Contains bulk quantities of items listed under Size E. Price £3.8.5. inc. P.T.

Bib Ersin Multicore Solder Size 17
Contains 30 ft. of 40/60 Alloy, 18 s.w.g. wound on a handy spool. Suitable for all general Electrical repairs
Price 5/-



Bib Precision Tape Cutters Size M Set of four stainless steel cutters, with special plastic grip, for all types of magnetic recording tape.
Price 2/10d. inc. P.T.

Bib Savbit Solder Dispenser Size 5
Contains 10' of 18 s.w.g. Ersin Multicore Savbit Alloy. Price 2/6d.

Bib Fine Gauge Solder Size 15
21 ft. coil of 60/40 Alloy, 22 s.w.g. Ersin Multicore Solder in a dispenser. Ideal for small components, transistors, diodes, etc.
Price 3/–.

Bib Recording Tape Splicer Model 20
For quick and accurate editing. Precision made, chrome plated clamps, mounted on non-slip base. Complete with razor cutter.
Price 19/6d.

Bib Instrument Cleaner Size A
Anti-static, specially formulated for cleaning delicate instrument panels, plastic, chrome, glass and printed surfaces. Non-flammable, does not smear. 4 fl. oz. in plastic bottle. Price 4/6d.

Bib Ersin Multicore 5 Core Solder Size 12
For Service Engineers and Laboratories. Contains 90 ft. of 18 s.w.g. Ersin Multicore Savbit Alloy on a plastic reel.
Price 15/–.

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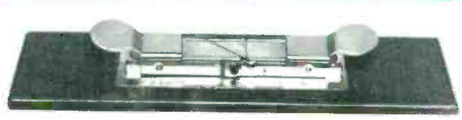

Bib ½" Video Tape Splicer Kit Model 21
Suitable for editing video tapes made on Sony Recorders. Fitted with tape clamps. Complete with a packet of Size M cutters, Size E kit and Size L Hi Fusters in plastic box. Price £9.10.0.

Bib Cable & Flex Shortener
Shortens audio cables and flexes without cutting. Pack of 4 plastic shorteners. Price 2/6d.

All prices recommended retail U.K. only. Obtainable from leading electrical and audio shops. If in difficulty, write to:

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