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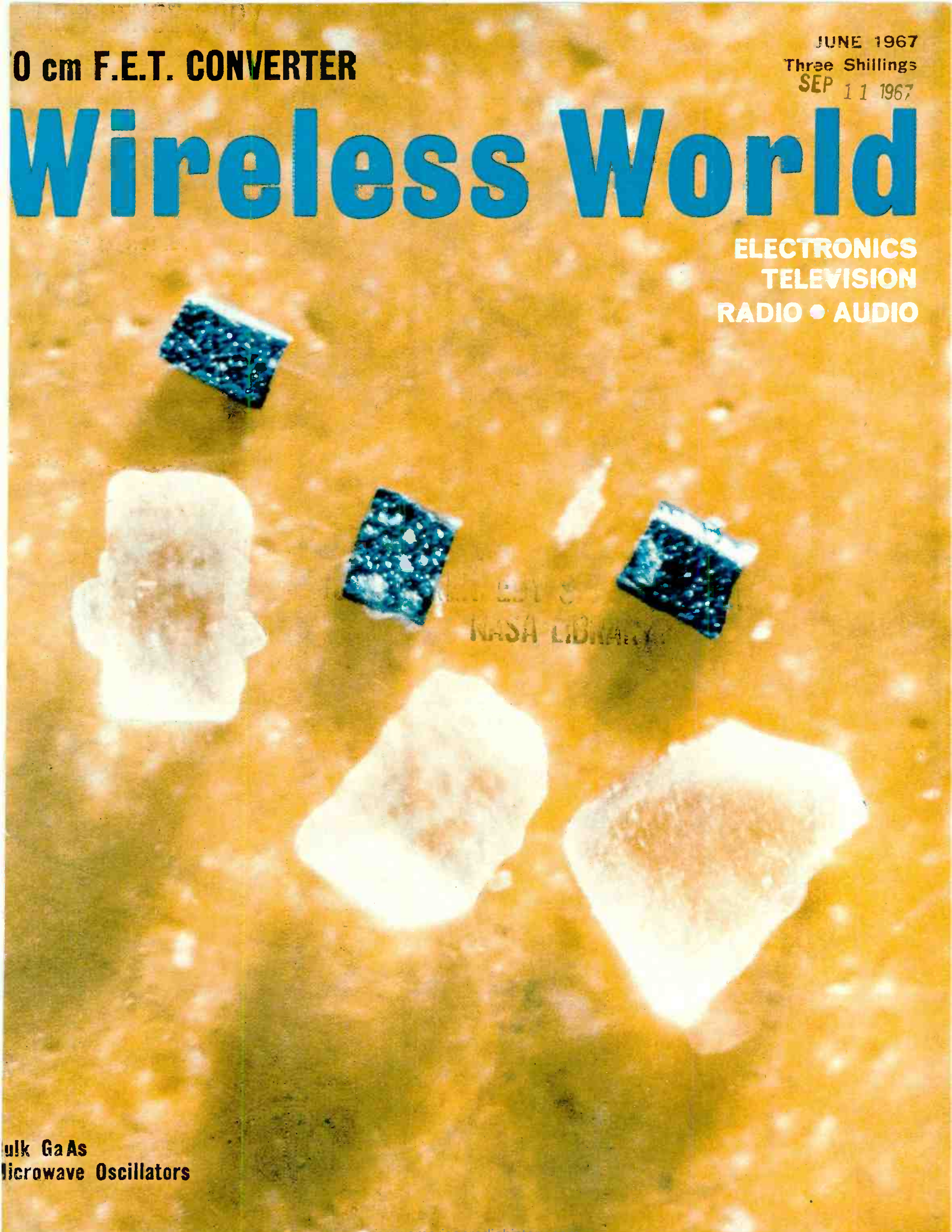

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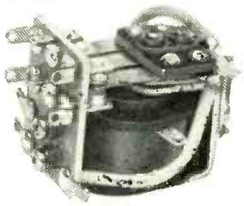

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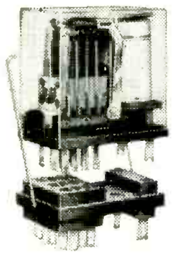

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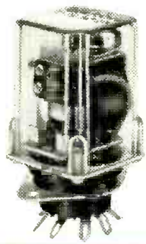

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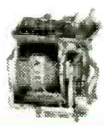

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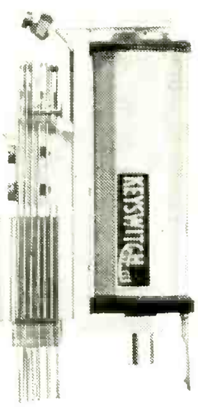

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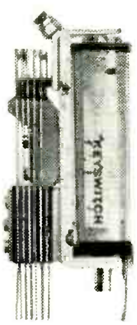

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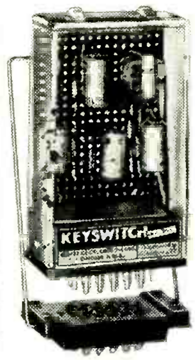

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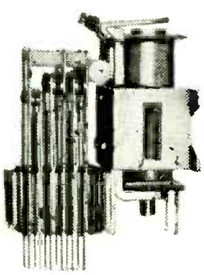

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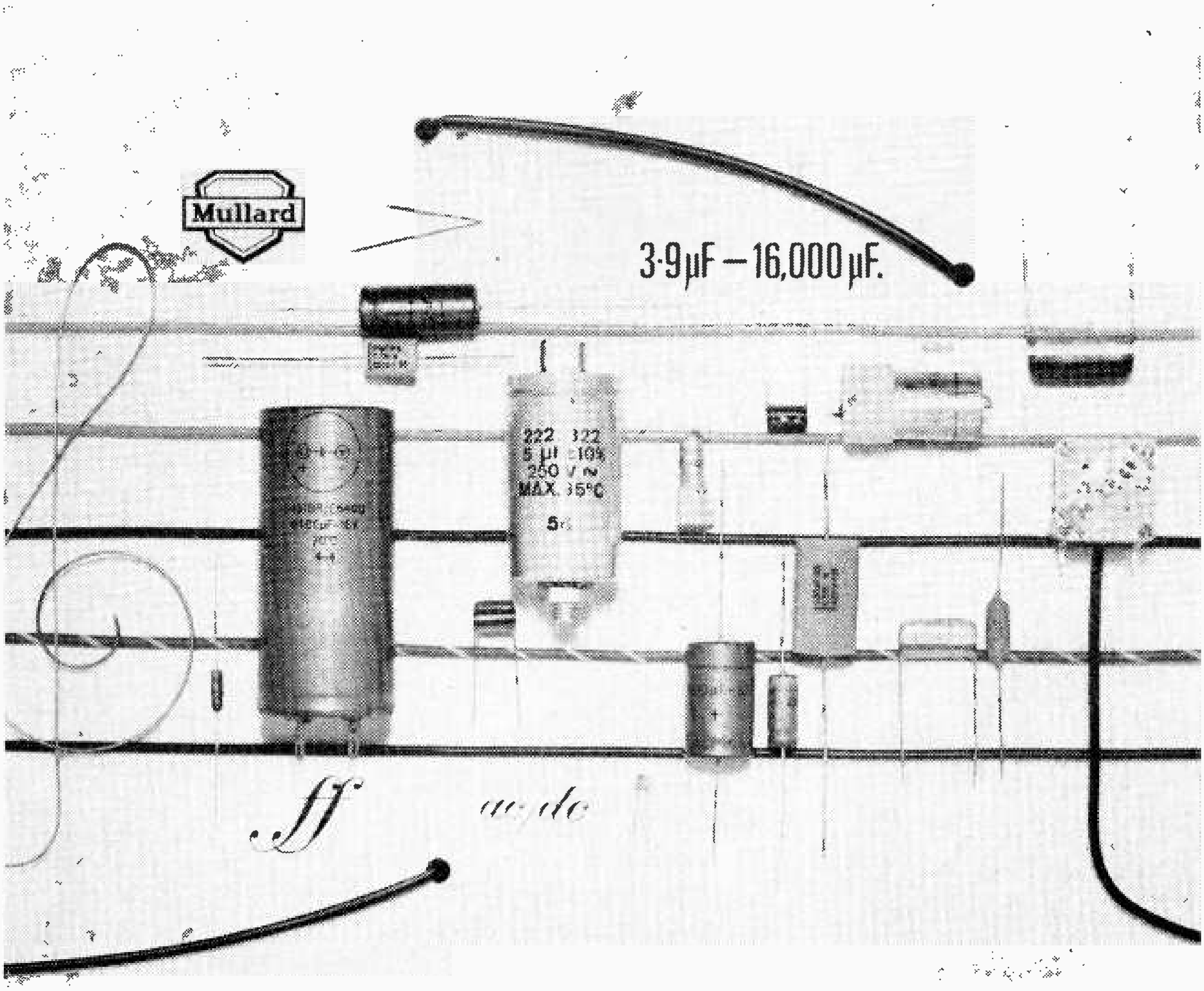

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Engineers—Professional and Technician

IN its latest statement (No. 5) covering exemptions from its examination the Council of Engineering Institutions states that it "cannot in future regard the Higher National Certificate as generally providing suitable preparation for a professional engineer". This supports the statement issued 18 months ago by the Department of Education and Science which said "In the past, higher national certificates have had considerable links with full professional membership of the particular institution concerned. With the growth of full-time courses, the higher national certificate is now emerging primarily as a higher technician qualification in its own right."

Whereas 30 years ago an aspiring engineer could go from school into an engineering apprenticeship and then by dint of hard work, experience and part-time study could gain admission to membership of the professional institution of his particular discipline, this road is now closed and unless the aspirant passes an examination "of an academic standard not less than that of a *degree* in engineering" necessitating full-time study he must remain a technician engineer. Commenting on the fact that in the early days of his career there appeared to be no conscious line of demarcation between professional and what we now term technician engineers, Lord Hinton of Bankside, president of the Institution of Mechanical Engineers, recently said "Development of the basic educational system of this country . . . is creating some line of demarcation between the professional and technician grades. Let us remember, too, that the C.E.I. itself, in establishing its new standards of academic qualification for professional grades of engineering, has made that line of demarcation still more deeply marked."

As for every front line soldier there are many in the support lines so there are said to be four technician engineers for every professional engineer. "We must always remember," said Lord Hinton, "that they [technician engineers] are absolutely essential to the profession and that the worst thing that could happen to the engineering profession would be to allow ourselves to grow to think that the technician engineer is a second-grade citizen. . . . What we really need in engineering is a Florence Nightingale . . . her great achievement was that she made the technician grade of the medical profession respectable, and nursing today is respectable in its own right." The nurse has no desire to be a doctor but after the professional man has done "the initial plumbing in the operating theatre and laid down the course of treatment to be followed" it is the nurse—the technician—who then takes over. Anyone can do nursing but one cannot call oneself a nurse before receiving State Registration which is by examination.

What then is the future for the technician engineer? In the electronics and radio fields there are two organizations (Society of Electronic & Radio Technicians, and Institution of Electrical & Electronics Technician Engineers) which, since they were formed less than two years ago have done much to give recognition to technicians. As readers may have noticed we, in general, include among the "honorifics" of people mentioned only the various grades of membership of organizations which are granted by examination. Whether the organization be as well known internationally as the American I.E.E.E. or as the Royal Television Society in this country, their designatories are not included because membership is by application and selection and cannot therefore rank as a qualification. We consider it is essential for the two technician engineering societies to establish themselves with unerring rectitude by limiting membership to those meeting examination regulations, so that M.S.E.R.T. and M.I.E.E.T.E. are really meaningful.

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Some further notes on

SIMPLIFIED TRANSISTOR CIRCUIT DESIGN

Using little more than Ohm's Law to develop sophisticated D.C. amplifiers

By G. GARSIDE

THE article by C. H. Banthorpe published last August[1] prompted the writer to offer a sequel indicating how, using Ohm's Law and a few assumptions, slightly more sophisticated transistor circuitry may be developed by those experimenters who, in the words of Mr. Banthorpe, regard transistors as being "very difficult to design into circuits." Restrictions similar to those postulated in the previous article will be assumed to exist, and it is hoped to develop Mr. Banthorpe's excellent down-to-earth approach a little further. These restrictions are as follows:—

(i) The article is confined to "normal" bipolar transistors used in small signal applications;

(ii) The transistors are assumed to be working well within their frequency limitations;

(iii) The reader is asked to accept the statement that the forward voltage drop across a semiconductor junction is substantially constant for variations in forward current of two or three to one and is approximately 0.2 V for germanium and 0.6 V for silicon devices. Throughout the following text an average value of 0.4 V will be used for this parameter. The reader can, if he so desires, employ the more accurate values given above in any particular calculation, though this is not usually necessary in the type of design to be discussed.

Justification for the last restriction is given in Fig. 1, which shows the variation in forward volts drop with forward current, for several representative junctions.

THE D.C. WORKING POINT

Let us now consider the basic common emitter circuit of Fig. 2 from the point of view, initially, of d.c. working point only. There are two main disadvantages inherent in this method of setting the d.c. conditions of the amplifier, viz: because the current gains (β) of transistors in the possession of the experimenter may have a range of values covering two or three to one, resistor R must be chosen for each individual transistor if it is desired to set the collector voltage (at point A) at some pre-determined level. This comes about because the transistor used in the configuration shown is current biased, i.e. resistor R is selected to give a base current I_b which then produces a collector current I_c of βI_b which in turn defines the voltage drop across R_L, and therefore the voltage at point A. If β varies from transistor to transistor then, clearly, so must R if a given collector potential is to be maintained. Secondly, for any transistor amplifier, set up at room temperature as outlined above, there may be a variation in β for the transistor of two or three to one as the surrounding temperature is varied. These effects were pointed out in Mr. Banthorpe's article.

To sum up, the circuit must be tailored to each individual transistor, and is even then intolerant of operating temperature changes in that these induce changes in d.c. working point. The normal solution is to employ the circuit of Fig. 3, which will probably be recognized by the reader.

The voltage at point A is still defined by the current in R_L, i.e. the collector current. However, if the transistor has a reasonable β under all temperature conditions likely to be encountered, the emitter and collector currents may be considered to be equal. In other words the current through R_L may be fixed by defining that in R_E. This latter requirement may be met by fixing the voltage across R_E, or, using restriction no. 3, by fixing the base potential of the transistor. A simple potentiometer will perform this function substantially independent of temperature variations.

It may be helpful to consider a numerical example at this point. Suppose we have a transistor having a β at 10°C of 30 and at 35°C of 55. Let the supply available be +6 V, the operating collector current be 1 mA, and assume that point A is required to sit as closely as possible to +3 V.

In the circuit of Fig. 2, let us set up the working point at 10°C. With appropriate polarity reversals, subsequent calculations are of course, equally applicable to circuits using p-n-p transistors.

Now collector current = 1 mA, collector potential = 3V,

therefore $R_L = \dfrac{6-3}{0.001} = 3\,\mathrm{k}\Omega$, and $I_b = \dfrac{I_C}{\beta} = \dfrac{1000}{30} = 33\,\mu\mathrm{A}$.

Also, the base potential is 0.4V, since the emitter is earthed

$$\text{so that } R = \frac{6-0.4}{33} = \frac{5.6}{33} = 170\,\mathrm{k}\Omega.$$

G. Garside is on the staff of the University of Birmingham where he has recently been responsible for instrumentation for the University's two experiments (electron density and electron temperature) which form part of the UK3 payload. He joined the University in 1964 having previously been in the test and inspection department of W. & T. Avery where he was concerned with electronic weighing equipment.

Now suppose the surrounding temperature rises to 35°C. The base potential is still 0.4V (to a good approximation), so that the base current is still 33μA assuming R has no temperature coefficient. The collector current is, however, now $33 \times 55\mu A = 1.8$ mA, giving a collector voltage of $6-(3\times1.8)=6-5.4=0.6$V, i.e. the transistor has virtually no collector-emitter voltage and distortion of any input signal is almost certain to occur. Admittedly, this is the extreme case—zero external emitter resistance—and a certain amount of improvement can be achieved by the inclusion of such a resistance. However, current biasing is generally of limited utility, and other methods are normally preferred.

Suppose we re-design the circuit along the lines of Fig. 3 using the same figures as before: at 10°C, collector current = 1 mA, collector voltage = 3V so that

$$R_L=(6-3)/0.001=3\,k\Omega$$

Let us assume that 0.5V across R_E is a tolerable drop in the supply voltage, then since emitter current I_E is nearly equal to collector current I_c

$$R_E=\frac{0.5}{0.001}=500\,\Omega.$$

The base-emitter voltage = 0.4V, therefore, the base voltage is $0.5+0.4=0.9$V.

Let us set the potentiometer current through R_1 and R_2 much higher than the transistor base current so that variations in the latter have little effect. A potentiometer current equal to the collector current is a good plan, i.e. 1 mA.

$$\text{Therefore } R_2=\frac{0.9}{0.001}=900\,\Omega$$

$$\text{and } R_1=\frac{6-0.9}{0.001+I_b}=\frac{5}{1-0.033}=4.8\,k\Omega$$

Now consider conditions at 35°C. The base potential is substantially unchanged since it is set by potentiometer R_1/R_2, therefore the voltage across R_E is unchanged, and so the current in R_E and R_L is unchanged. Or in other words the working point is unaltered.

It should also be noticed that a transistor having an initial β of 60 would cause considerable revision of the value of R in Fig. 2 but hardly affects component values at all in Fig. 3. It is seen, then, that a working point set as shown in Fig. 3 is comparatively independent of transistor parameters and ambient temperature. These advantages are obtained at some expense, however, namely greater circuit complexity, higher current drain (through R_1 and R_2), some reduction in the collector/emitter voltage because of the voltage developed across R_E, and a lower input impedance for the stage. Never-the-less, these disadvantages are not usually serious, and the stabilized circuit has very predictable characteristics.

So much for the single stage amplifier: but what if, as is usual, more gain is required? Well, one can obviously cascade two or more of the single stage circuits—Fig. 4. Unfortunately, this is really not such a good plan, for the following reasons:

(a) The circuit is wasteful of components (bearing in mind its inadequate performance—see (c) below) since each stage has its own stabilizing network.

(b) Since the collector potential of Tr1 and the base potential of Tr2 are usually widely different, capacitive signal coupling is necessary and furthermore, the low input impedance of Tr2 (in the region of 1000 ohms) dictates that a large value capacitor must be used to avoid a potential divider effect at low frequencies. This involves a bulky electrolytic component for many applications.

(c) The low input impedance of the second stage appears, via the coupling capacitor, in parallel with the

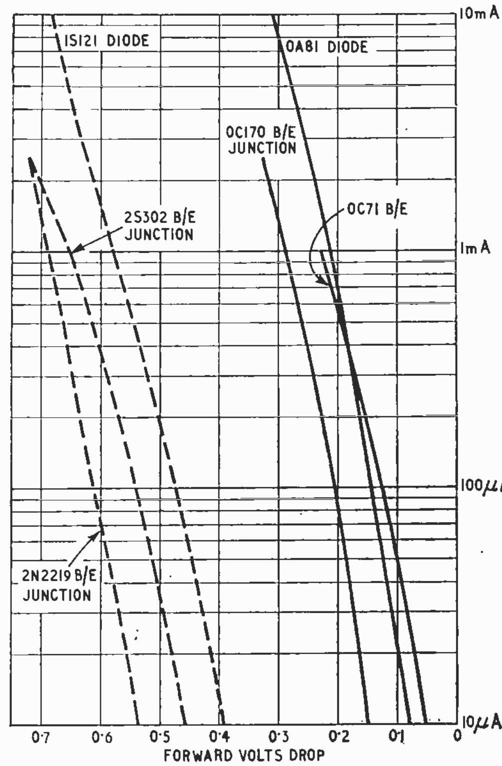
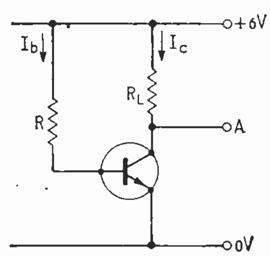
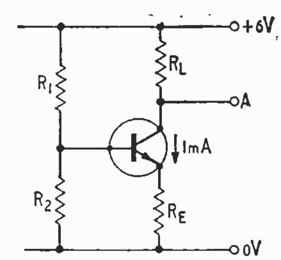


Fig. 1. Variation in forward voltage drop with forward current of some representative semiconductor junctions.



Left: Fig. 2. Simple current biasing.



Right: Fig. 3. Potential divider biasing.

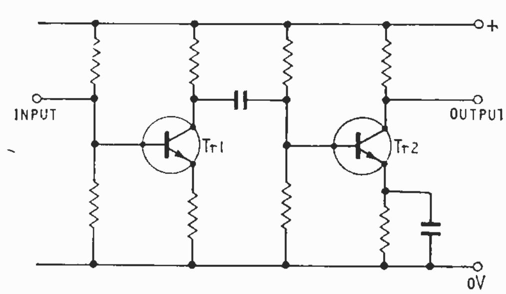


Fig. 4. Two stages in cascade.

first stage load resistor, thus decreasing the gain of the first stage, and the combined two-stage gain is less than the product of the two amplifier gains considered separately.

The writer advocates the use of direct coupled stages employing feedback configurations as a solution to the problem. Such amplifiers are often variations on the so-called " ring of three " amplifier shown in basic form in Fig. 5. At first sight, this seems to be a large step to take from the previous circuits, but a sample analysis will show that the working points for the transistors can be readily fixed using the arguments outlined above plus a little logic.

Consider Fig. 5. Let us say that the collector current in Tr3 is 2 mA (consistent with supplying a few milliwatts drive and ensuring a fairly high β). That in Tr1 is 0.5 mA (the input stage is low level, virtually no power need be supplied by it, the β for Tr1 should still be adequate at 0.5 mA collector current) whilst the current in Tr2 is, as will be seen, relatively unimportant. Let us further presume that the emitter of Tr3 is to be at 1.5V above ground, not restricting the swing available at Tr3 collector too greatly, but at the same time ensuring that base current for Tr1 may be driven through R_{FB}. Then, $R_5 = 1.5/0.002 = 750\,\Omega$.

To obtain the maximum output voltage swing the collector of Tr3 should have a quiescent value midway between the supply line (+6V) and the voltage across R_5 (+1.5V). This is $1.5+(6-1.5)/2$ V positive to earth, i.e. +3.75V. Therefore, $R_4 = (6-3.75)/0.002 = 1.1\text{k}\Omega$.

The base of Tr3 is $1.5+0.4=1.9$V positive to earth and hence the collector of Tr1 is $1.9+0.4=2.3$V positive to earth (remembering that there is 0.4V across a base-emitter junction). Giving R_1 as $(6-2.5)/0.0005 = 7\text{k}\Omega$.

Now suppose a voltage drop of 0.5V across R_2. No more, otherwise the difference in voltage across R_{FB} will be too small to allow the base current for Tr1 to be supplied through a high resistance, this condition being desirable to give a high input impedance to the amplifier. No less, otherwise the stabilizing action to be described will not be adequate. For example, variations in the base emitter voltage for Tr1 become comparable with the voltage across R_2. This implies a voltage at the base of Tr1 of $0.5+0.4=0.9$V and therefore a driving voltage of $1.5-0.9=0.6$V across R_{FB}. Also, for 0.5V across R_2, at the chosen collector current of 0.5 mA in Tr1, $R_2 = 0.5/0.0005 = 1\text{k}\Omega$.

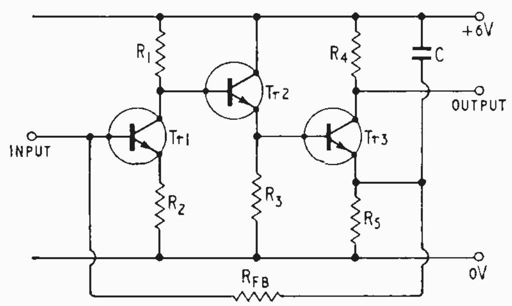


Fig. 5. Basic " ring of three " amplifier.

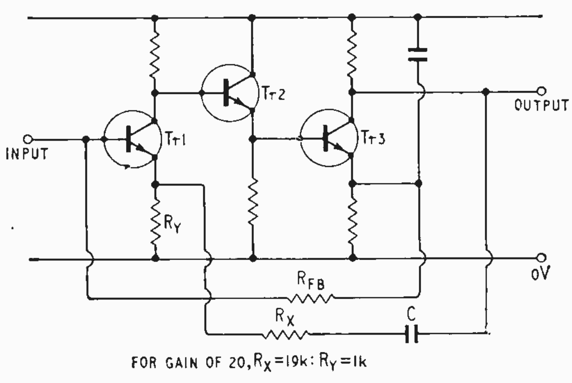


Fig. 6. Ring of three amplifier.

At a collector current of 0.5 mA, the β of Tr1 is unlikely to fall below 15, giving a base current for Tr1 of $0.5/15\text{ mA} \approx 33\,\mu\text{A}$. This current is supplied via R_{FB} which therefore gives R_{FB} as $0.6/33 = 18\text{ k}\Omega$.

It only remains to choose a value for R_3. (The emitter potential of Tr2 is defined, via a 0.4V drop, by the collector potential of Tr1, and is unaffected by the value of R_3.)

The only purpose of emitter-follower Tr2 is to act as an impedance converter, so that the input impedance of Tr3 (Z_{IN3}) does not appear across the collector load of Tr1. The main requirement of Tr2 is to provide a high input impedance. The input impedance for Tr3 will be of the order of 1 kΩ since the stage is effectively operating as a grounded-emitter amplifier, capacitor C ensuring that there is no signal voltage present at the emitter terminal. To avoid lowering the load seen by Tr2 emitter to any appreciable extent a value of R_3 at least ten times Z_{IN3} would be a good choice. The input impedance for emitter follower Tr2 is then approximately $\beta . Z_{IN3}$, if R_3 is much greater than Z_{IN3}. So let us set R_3 at 22kΩ.

The d.c. design is now complete, the reader should note that although Tr1 is currently-biased (similarly to the transistor in Fig. 1) there is a stabilizing feedback action which offsets variations in component parameters and conditions of ambient temperature. Suppose the collector current in Tr1 increases owing to some parameter change (an increase in the β of Tr1, perhaps) then more volts are dropped across R_2 and R_1, the latter causing the potential of the base of Tr2 to fall. The emitter of Tr2 " follows " the base change (remember the 0.4V) so Tr3 base potential falls, and so does the voltage at Tr3 emitter (that 0.4V again). It is seen, then that the increase in Tr1 collector current which was postulated, has caused the ends of R_{FB} to move nearer to each other in potential. The current through R_{FB} is thereby decreased, and so is the collector current of Tr1 ($=\beta\times$ current in R_{FB}). Hence stabilizing compensation is provided, of an extremely effective nature since the d.c. gain of the amplifier loop is applied to combating working-point variations.

It is felt that despite many omissions and simplifications sufficient guidance has now been given to enable the experimenter, using little more than Ohm's Law, to design quite sophisticated direct-coupled transistor amplifiers. Let us now give some thought to the a.c. parameters of these systems.

SIGNAL CONSIDERATIONS

Values of input impedance, output impedance and gain for the single-stage stabilized circuit of Fig. 3 may be obtained by similar calculations to those given by Mr. Banthorpe, with the proviso that the input impedance for the stage should include the effect of a resistance $R_1R_2/(R_1 + R_2)$ in parallel with the transistor input impedance obtained by calculation. This will be recognized as being simply the effective resistance of R_1 and R_2 considered in parallel for signal voltages.

For high-gain, multi-stage amplifiers, however, a little more care is necessary. It has already been mentioned that if simple cascaded stages are to be used (Fig. 4), the interactions between them must be taken into account: e.g., the load imposed by a later stage modifies the impedances and gain of its driver. If amplifiers are used of the direct coupled type described in the d.c. working point example above, it becomes easier to " tailor " the gain of the circuit by a.c. negative feedback applied as in Fig. 6.

The advantages of such circuits will be apparent if the reader bears in mind that, amongst other things, the feedback shown has the following effects:

(i) The input impedance of the amplifier is increased, so loading of earlier stages may usually be neglected.

(ii) The output impedance is decreased, so loading by later stages may usually be neglected.

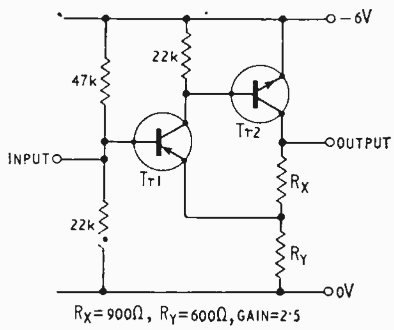
(iii) If the amplifier gain with feedback is reduced considerably from the gain without feedback then the gain with feedback applied is substantially independent of transistor parameters and variations in ambient temperature.

Quantitative investigation of (i) and (ii) above is outside the scope of this article, analysis of the effects of negative feedback on amplifier input and output impedances being a subject not to be approached without a little more facility in algebraic manipulation than has been assumed. However, if the original restrictions are borne in mind, especially that concerning operating frequency, it will be appreciated that any amplifier under discussion may be considered to have purely resistive input and output impedances. If this simplifying assumption is made, it becomes relatively easy to measure these circuit parameters by the method described later. Since this is often quicker than the corresponding calculation, and usually allows design to proceed and is recommended for the experimenter.

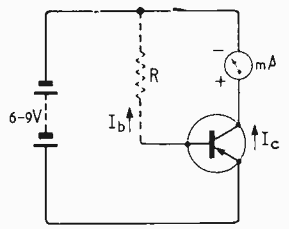
If a high gain amplifier has a fraction of its output fed back to the input, in such a way as to oppose the input signal, and if this fraction, which we will call p, is large, then the gain of the amplifier will be very nearly $1/p$. i.e. if the fraction was $\frac{1}{24}$th, then the gain would be 24. The fractional feedback p can almost always be achieved by the use of a resistor combination, which becomes the sole gain-defining element. The writer has seen such an amplifier, admittedly built with top-class transistors, which has a stable gain of two hundred and fifty times, though in general stable gains of more than a hundred or so are not obtainable, because of the wide β spread likely in a random selection of transistor types.

Fig. 6, then, shows the " ring-of-three " set for a gain of 20. The output voltage appears at the collector of Tr3, and a fraction of the output is applied at the input to the amplifier by means of the divider R_x and R_y. Any effect of the d.c. conditions of the circuit is prevented by C. The fractional feedback p is then approximately $R_y/(R_x + R_y)$ and so the gain is $(R_x + R_y)/R_y$, from the expression given earlier.

Lastly, a mention of the possibilities of complementary connection may be useful. Since both p-n-p and n-p-n devices are now readily available on the general market the advantages made possible by circuits employing both types may be exploited. One method by which this may be accomplished is shown in Fig. 7. This circuit has stabilizing d.c. feedback to set the working point, and once more, the small signal a.c. gain is defined by the ratio of resistors R_x and R_y. The output signal appears across



Right: Fig. 7. Complementary amplifier.



Left: Fig. 8. Simple method of measuring transistor d.c. gain.

R_x and R_y in series, so that a fraction $R_y(R_x + R_y)$ is fed back to the input by virtue of the Tr1 emitter connection. The gain is hence $(R_x + R_y)/R_y$ using the rule given above. It is left as an exercise for the reader to deduce the d.c. working point, given that Tr2 collector has a quiescent potential of $-$ 3 V.

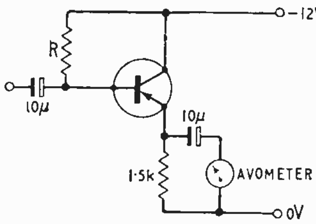
Of course, if a fixed value of gain is unnecessary, as is the case in many amplifier applications, the gain-defining feedback may be omitted (Fig. 5) then the circuit becomes that of a high gain amplifier with fairly high input impedance (because of the absence of by-pass capacitor across R_2) and fairly low output impedance (because the usual 2 or 3 mA collector current in Tr3 implies a low value of collector load) and will perform very satisfactorily provided that source and load impedances are low and high respectively.

Once more, it has been found necessary to omit much material, and the writer feels that serious experimenters should regard these notes as an introduction only: if a little time is spent building the circuits described above and, where available test equipment permits, checking the predicted values of d.c. working point, amplifier gain, etc., then more comprehensive books on transistor circuit design may be approached with the confidence fostered by experience.

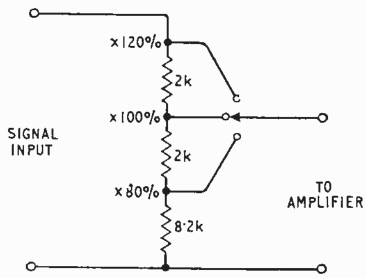
MEASUREMENTS

Much mention has been made of various device and circuit parameters, notably transistor common emitter current gain (β) and amplifier gain and input and output impedances. Perhaps an indication of how these quantities may be measured approximately, with the minimum amount of test equipment would provide a useful adjunct to the notes given above.

A crude but effective measure of the d.c. β may be obtained simply by the use of a battery (of some 6 to 9 V), an Avometer or other suitable milliammeter and a box of resistors (Fig. 8). With the transistor base open-circuit, the collector current meter should read zero. If the reading is more than a few micro-amps and the transistor is of the small, general purpose, low power type under discussion, then it is best left in the junk-box! Next, a resistor R is selected until a suitable current (2 or 3 mA) is indicated on the collector current meter (I_c). The base potential is



Left: Fig. 9. Low frequency a.c. voltmeter.



Right: Fig. 10. A stepped input attenuator.

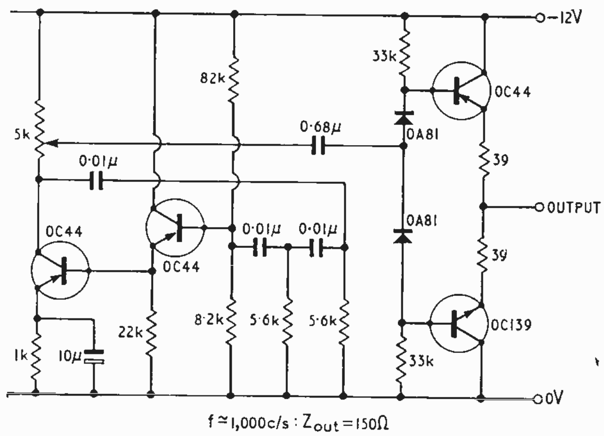


Fig. 11. Signal generator suitable for the measurements described.

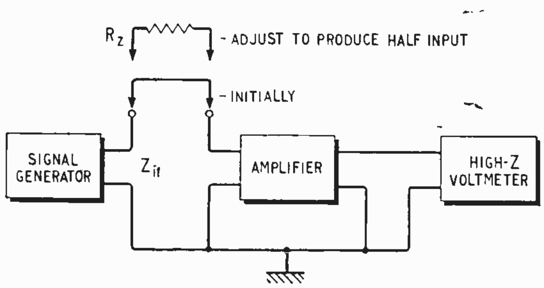


Fig. 12. Measurement of input impedance.

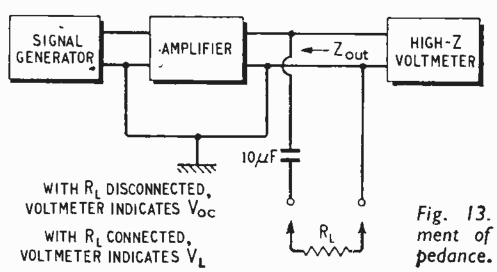


Fig. 13. Measurement of output impedance.

0.4 V above the emitter line, so the base current in mA is $(V_e - 0.4)/Rk\Omega$ and hence β is I_c/I_b. Battery polarity is to be reversed, of course, for n-p-n devices. It is as well to note that the test described only measures the d.c. current gain, but if the operating frequency at which the transistor is to be used is much lower than the latter's cut-off frequency, there will be little error in using the value so obtained in signal calculations.

The measurements here are, in theory, as simple as the determination of β above. All that is required is a high impedance a.c. voltmeter (in clumsy but well-understood terminology) and a source of signal voltages, preferably of variable frequency and low output impedance.

For low frequencies (up to a few kilocycles) Fig. 9 depicts a quite adequate signal voltmeter, formed by the combination of the ubiquitous Avometer (Model 8 Mk. II) and a high input-impedance, emitter-follower buffer. The transistor should be chosen to have as high a β as possible, and resistor R selected to give an emitter potential mid-way between the supply lines. (The reader will recognize, in this exception to the "rules" given earlier, one of the omissions which was mentioned at the end of that section!) Stability of the d.c. working point has been sacrificed to obtain a high input impedance, ensuring that negligible load is applied to the circuit under test. The peak-to-peak excursion of the input signal should not exceed three-quarters of the emitter-follower's supply line voltage, say, and the Avometer should be used on the highest (alternating voltage) range consistent with reading accuracy. In order to use this circuit to obtain meaningful measures of amplifier performance, care must be taken to ensure that overloading of the amplifier, with attendant signal distortion, is not occurring during the tests. A rapid check for linearity may be made in the region of the test conditions by reducing and increasing the amplifier input signal by equal amounts about the operating value, and observing that the amplifier output undergoes similar (but larger) changes. The incremental variations in input signal may conveniently be obtained from a combination of series resistors (Fig. 10). This check is particularly important when making measurements of amplifier output impedance.

The other item of test equipment, the signal generator, is not so simply acquired. However, a fixed frequency generator, of low output impedance, is not difficult to construct, and will suffice for many measurements. Fig. 11 shows a circuit providing a test signal of approximately 1 kc/s, and having a usable output impedance of 150 Ω. (See the notes concerning the measurement of output impedances below.) In the writer's version the potentiometer allowed the output amplitude to be varied up to a maximum of 3.5 V peak-to-peak.

Thus equipped, the reader is now in a position to make useful, if approximate, measurements of the characteristics of an amplifier operating at audio frequencies where reactive effects may usually be neglected and terminating impedances considered to be purely resistive in nature.

The input impedance (Z_{IN}) may be found by applying a test signal to the amplifier input terminals and noting the output voltage on the high impedance voltmeter connected across the amplifier output terminals, Fig. 12. A check for linearity of operation should be made at this point. Now in place of the direct connection between signal generator and input terminal, a resistor is inserted, and its value selected so that the output meter indicates one-half of the original reading. Under these conditions, the signal voltage appearing at the input terminals must be one-half of its former value, but this signal voltage is developed across Z_{IN}, so that the input impedance is

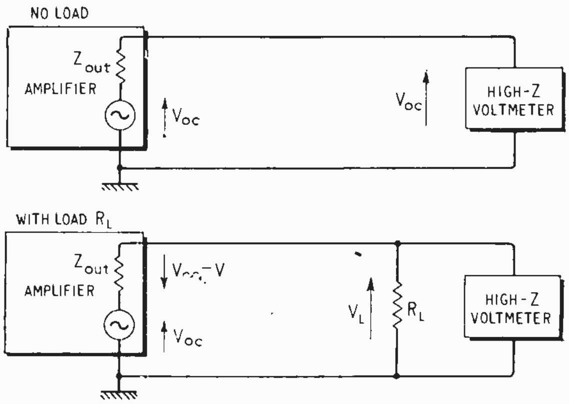


Fig. 14. Equivalent circuit of Fig. 13.

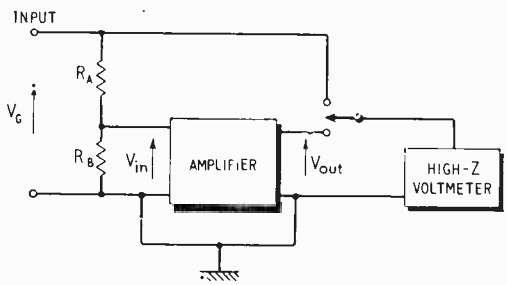


Fig. 15. Measurement of amplifier gain.

equal in value to the inserted resistor, i.e., $R_Z = Z_{IN}$. At first sight, the same principle could be used to determine the output impedance (Z_{OUT}). However, whilst amplifiers of the type under discussion may have an equivalent output impedance which is quite low, it is by no means necessarily true that the amplifier will drive an undistorted signal into a load equal to this value of Z_{OUT}, also limiting of the waveform often occurs with relatively large values of load resistance. In the writer's experience more modest loading will give results which are more trustworthy when it is not possible to monitor the output waveform on an osciloscope. Use of the amplifier is then restricted to this level of loading, but good circuit design usually seeks to bring about this state of affairs anyway.

Accordingly, the method is to apply a signal to the input terminals as before, noting its value on the output voltmeter (V_{OC}). Linearity of operation may conveniently be checked at this juncture. A load resistor is now coupled to the amplifier output via a large capacitor (whose reactance at the signal frequency is small compared with the load resistor) and adjusted in value to produce, say, a 10% drop in output voltage. This represents a loading small enough not to cause distortion, but at the same time large enough to cause a significant decrease in the output meter reading. This new value (V_L) of the output voltage should be noted (Fig. 13).

Now considering the equivalent circuits of Fig. 14: in the open circuit case the output current is negligible and the corresponding voltage drop across Z_{OUT} is very small, so that the equivalent voltage generator may be assigned an output voltage equal to V_{OC}. With the load applied, the voltage developed by the output current flowing in Z_{OUT} is $V_{OC} - V_L$ and therefore the following equation is true: $Z_{OUT}/R_L = (V_{OC} - V_L)/V_L$. And from this we obtain $Z_{OUT} = R_L/V_L.(V_{OC} - V_L)$ allowing the output impedance to be calculated from the meter readings.

An estimate of the amplifier gain may be obtained as follows: a large input signal is fed to a series resistor combination R_A and R_B (Fig. 15) and the small voltage developed across R_B applied to the amplifier input terminals. R_B should be made no larger than one-tenth of the amplifier input impedance Z_{IN} (calculated, or measured as described above). R_B is in parallel with Z_{IN} and may, therefore, be neglected so the input signal is very nearly $V_{IN} = R_B/(R_A + R_B)V_G$. V_G being the signal generator voltage. The latter may be measured by the high impedance voltmeter, and so the magnitude of the input signal (usually only a few millivolts) may be calculated. All that remains is to perform the linearity check, and, this being satisfactory, to transfer the voltmeter to the amplifier output terminals, and note the output voltage (V_{OUT}). Then, clearly, the gain is given by V_{OUT}/V_{IN}.

It will be seen that the method essentially consists of determining the small input signal, V_{IN}, which is otherwise too small to measure in the absence of expensive instruments.

In conclusion, it is hoped that experimenters at present unfamiliar with transistor techniques have been convinced that semiconductor circuit design is not completely arbitrary, and that the advantages conferred by the small size, weight and power requirements are not obtained at the expense of behaviour which is at best unpredictable and at worst incomprehensible. The reader who takes the trouble to familiarize himself with the characteristics of transistors, and who thereby gains experience of their applications will discover a versatility impossible with valves—complementary configurations and transistor/f.e.t. combinations are obvious examples. The table below gives the results of measurements made by the writer on a typical audio amplifier, using top-quality instruments in one case, and in the other using the equipment described above.

Audio amplifier (nominal 22 times gain)

Parameter	Value obtained by oscilloscope measurement	Value obtained by equipment described
Amplifier output voltage	0.85 V r.m.s.	0.80 V r.m.s.
(This was a check on the effectiveness of the high impedance voltmeter described)		
Amplifier Input impedance	39 kΩ	37 kΩ
Amplifier output impedance	143Ω	185Ω
(The discrepancy here was due to signal distortion at the loading used. Allowance was made for this when making the oscilloscope measurement with the waveform under observation, but not during the Avo measurement, as this was considered to be a more valid simulation of the experimenter's case.)		
Amplifier gain	21	24

REFERENCE

1. " Simplified Transistor Amplifier Calculations." C. H. Banthorpe. *Wireless World*, August 1966.

DESIGNING LARGE-SIGNAL HANDLING V.H.F./ U.H.F. CONVERTERS

70cm amateur radio circuit using field effect transistors

By U. L. ROHDE

AFTER the publication of designs for transistor 2-metre converters in the July 1966 issue of *Wireless World*, the author received a great many letters from people asking for a design for a large signal handling converter with a dynamic range of at least 120 dB and working up to 435 Mc/s. As Texas Instruments have reduced the prices of their field-effect transistors and now offer a v.h.f. germanium f.e.t. for 7s. 11d. in small quantities, a new f.e.t. converter has been designed to satisfy the requirements of both extremely small signal reception and the handling of signals up to 500 mV without detectable overloading. In addition to a new 2-m converter, the author has developed a 70-cm converter which is thought to offer better characteristics than those of most circuits at present in use.

The transistor used in the input stage of the new converter is the TIS34, an n-channel epitaxial planar silicon field-effect device. This is actually a 2N3823 transistor selected to meet the requirements necessary for operation up to 200 Mc/s. Figs. 1 to 4 shows the small-signal common-source admittances as a function of frequency at V_{DS} = 15 V and V_{GS} = 0V. It should be noted that Re y_{fs} is a linear function of I_D and reaches its maximum value at $I_D = I_{DSS}$ (V_{GS} = 0). As the gate electrode is formed by a reverse-biased p-n junction, the variation of capacitance with bias, as shown in Fig. 5, has to be considered, as it can cause detuning effects.

The large dynamic range of the converter—more than 120 dB—calls for a considerable amount of a.g.c. To maintain a high signal-to-noise ratio, delayed attenuation of the signal ahead of the following 28-30 Mc/s receiver is necessary. The range of attenuation should be at least 30 to 40 dB per stage, with minimum attenuation of 0.25 dB because the converter's noise factor is increased by this amount. Applying a large amount of a.g.c. to the first r.f. stage would cause detuning effects, which would

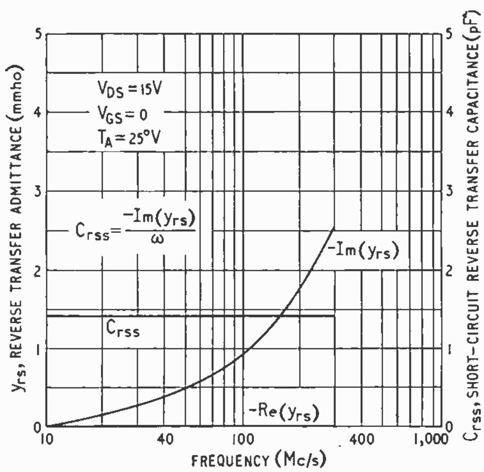


Fig. 2. Small-signal common-source reverse transfer admittance vs. frequency for TIS34.

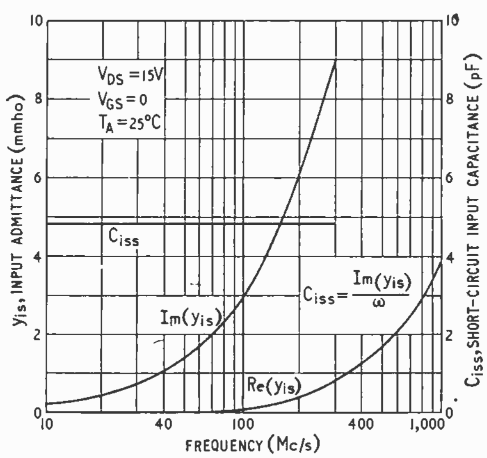


Fig. 1. Small-signal common-source input admittance vs. frequency for TIS34 f.e.t.

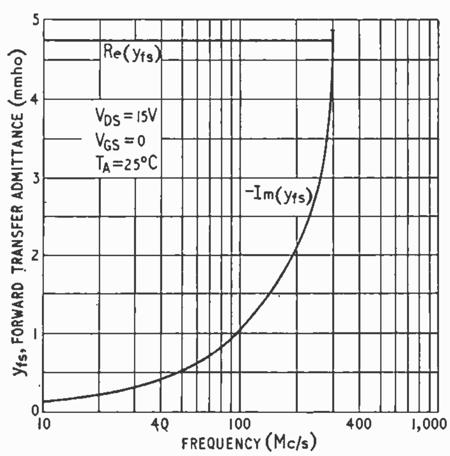


Fig. 3. Small-signal common-source forward transfer admittance vs. frequency for TIS34.

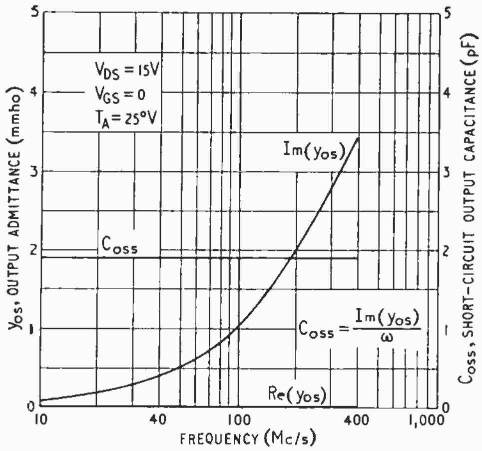


Fig. 4. Small-signal common-source output admittance vs. frequency fot TIS34.

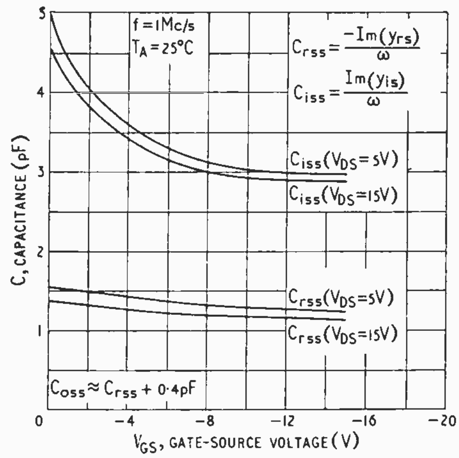


Fig. 5. Common-source short-circuit input and reverse-transfer capacitances vs. gate-source voltage for TIS34.

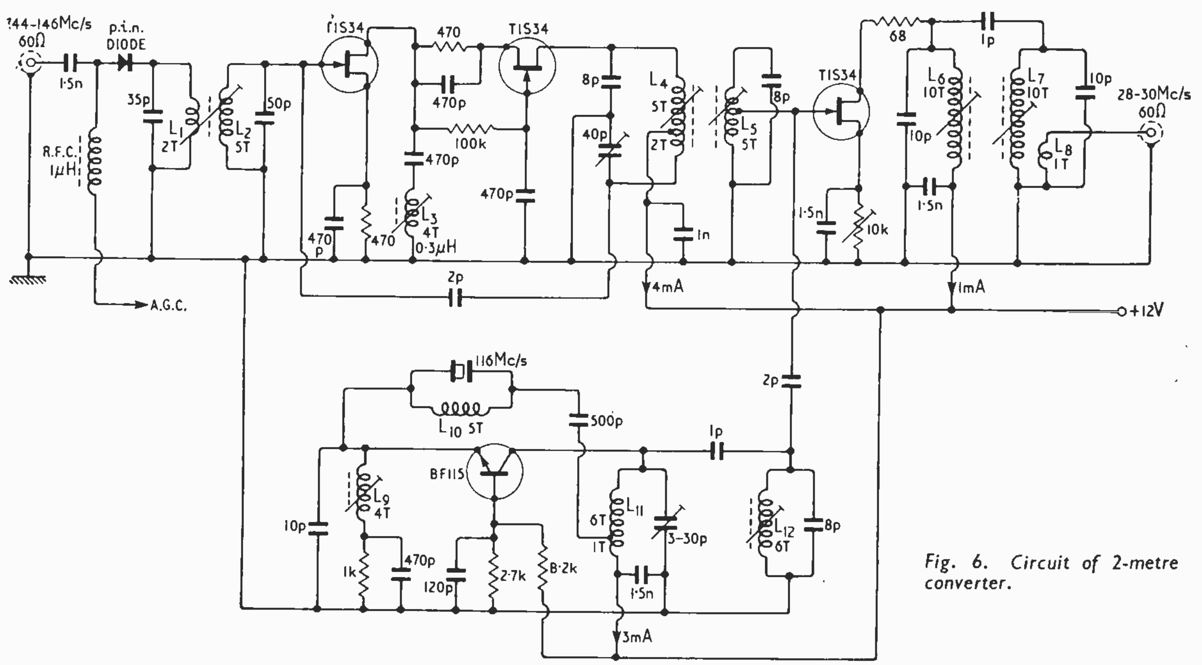


Fig. 6. Circuit of 2-metre converter.

ultimately increase unwanted signals a few hundred kc/s from the desired frequency. At the same time, a linear characteristic over the operating range is necessary in order to prevent signal mixing and generation of harmonics.

A p-i-n diode, type A3021, designed by H.P. Associates (an affiliate of the Hewlett Packard Co.) meets these requirements. This recently developed device is a voltage-controlled attenuator. First described last year[1], a technique for using the device has been successfully applied in the TFM-100 tuner made by the Fisher Radio Corporation. At frequencies above 50 Mc/s it can be considered as a variable resistor rather than a conventional diode. It is characterized by a high dynamic resistance, greater than 10,000 Ω, which is produced by a wide, high-resistivity layer adjacent to its junction. This resistance may be controlled directly by an a.g.c. voltage. Capacitance per unit of junction area is very low, but the conductivity of the resistive layer is increased by the presence of a stored charge (conductivity modulation). At zero bias the bulk resistance is between 7 and 10kΩ. With forward current, conductivity modulation causes the bulk resistance to drop very rapidly (almost linearly) from 7kΩ to 5Ω, which gives the minimum attenuation of 0.25 dB. The a.g.c. given by the device should be delayed until the signal strength at the aerial terminals is approximately 1mV.

Fig. 6 shows the circuit diagram of the 2-metre converter, which uses an improved cascode arrangement with two TIS34 field effect transistors. The voltage divider across the primary of the second band-pass filter, together with the input filter, transforms the output admittance to the input, so that power matching with simultaneous

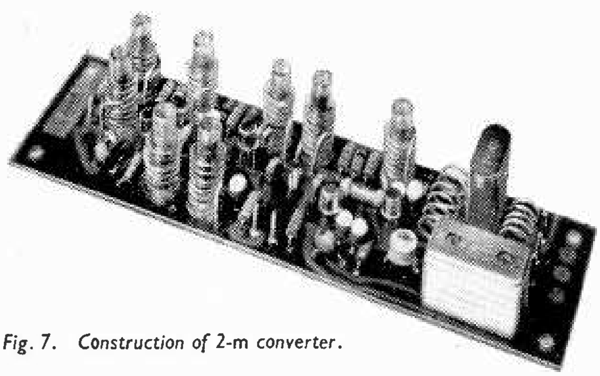


Fig. 7. Construction of 2-m converter.

noise minimum and minimum v.s.w.r. is obtained at the input. As a result of the much smaller increase of noise from the noise minimum with the same noise factor at the band edges, a considerably wider transmission bandwidth is obtained for constant noise factor without reduction of selectivity, as may occur with other feedback arrangements. As an absolutely optimum noise figure is required, the so-called Miller capacitance, C_{DG}, of the first f.e.t. is tuned out, but the stability is not affected. The p-i-n diode is placed in series with the aerial terminal, providing the a.g.c. by the method mentioned above. As can be seen from Fig. 7, the band-pass filters are air-coupled, and they provide at least 88 dB image rejection.

The mixer circuit is slightly different from those of the designs published earlier. First the TIS34 could be replaced, if desired, by the low-cost TIXM12 germanium planar f.e.t., a p-channel type. However, as the author preferred to have an all-silicon transistor circuit, this device was not, in fact, used in his converter. By changing the polarity of the f.e.t. circuitry, the TIXM12 may be used in all stages with no other alteration of the circuit apart from this. This germanium f.e.t. will, however, give slightly less gain (3 dB per stage) and the overall noise figure may be 10% higher. Secondly, it was found that, using no gate resistor and producing automatic bias by the source resistor, the cross-modulation characteristic may be improved, the gate being taken to a tapping two-third of the way along the coil. A careful measurement, using the circuit of Fig. 8, was made to find the optimum mixing gain as a function of oscillator voltage, the bias being all the time adjusted for optimum mixing. Two silicon f.e.ts were tested, to find the difference between possible I_{DSS} values.

The 2N3819 is a cheap 2N3821, or a low-frequency version of TIS34 with twice the capacitances of that device; it has an I_{DSS} of 4mA, while the TIS34 has an I_{DSS} of 16 mA maximum. Fig. 9 shows the power gain of the mixer as a function of the normalized input oscillator voltage, which is provided from a 60 Ω source (the 0 dB reference voltage being $2V_{eff}$ at 60 Ω). The cross-modulation characteristic of the TIS34 was found to be 10 dB better than that of the 2N3819, partly due to the skewing effect caused by the larger C_{DG} capacitance. It should be noted that the loss introduced by the band-pass filter is 6 dB, so that the gain should be 18 dB maximum.

The oscillator requires zero phase shift between the emitter and collector current. This is provided by the input tuned circuit, consisting of 10 pF capacitor and a variable inductor. In the feedback loop the 5th overtone crystal (made by Quarzkeramik of W. Germany) operates at 116 Mc/s. Several crystals made by other companies were tested but they failed to give the same stability. A band-pass filter was used to obtain the necessary output signal from the oscillator, as the influence of the feedback system on the mixer could be observed in some cases.

As it may be of interest, the required a.g.c. circuit, which needs an r.f. signal of 200 mV from the selected final intermediate frequency, is shown in Fig. 10. The signal is applied to the base of an n-p-n silicon transistor, a low-cost industrial plastics-case type. The amplified signal is rectified and fed to another silicon transistor, which acts as a d.c. amplifier and conducts if a signal is applied. This transistor controls the base voltage of a p-n-p silicon transistor, which in addition regulates the diode current. The input signal of the a.g.c. system should

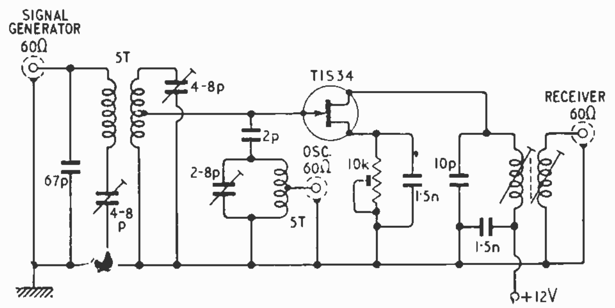


Fig. 8. Test circuit for mixing gain.

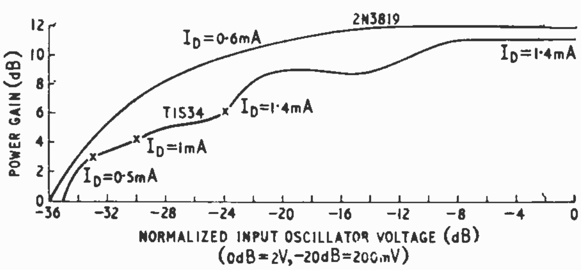


Fig. 9. Mixing power gain vs. oscillator voltage.

PERFORMANCE OF 2-m CONVERTER

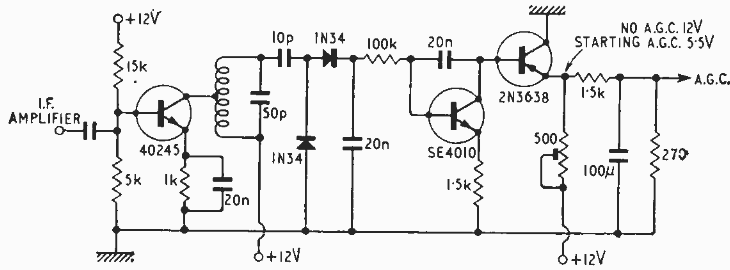
Power gain	35dB
Image rejection	88dB
Gain control	40dB
Noise figure	1.8dB
Input voltage for 1% intermodulation	800mV
Wipe-out effect for 3dB loss of gain	500mV

Cross-modulation of 1% will be generated between one signal of 10mV, unmodulated, and another of 300mV, 40% modulated, spaced in frequency by 500kc/s. Using full a.g.c. the unwanted signal may be 2V and the desired signal 0.5V.

PERFORMANCE OF 70-cm CONVERTER

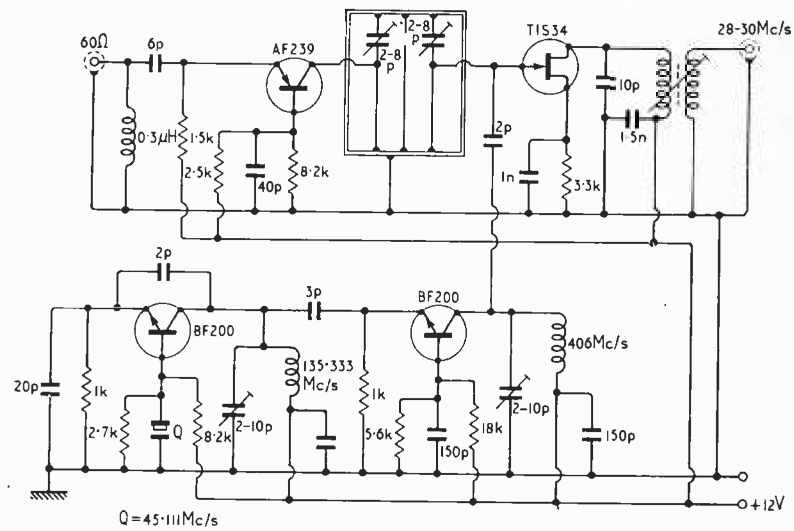
Power gain	27dB
Image rejection	45dB
Gain control (at AF239)	35dB maximum
Noise figure	3.5dB
Input voltage for 1% intermodulation	170mV
Wipe-out effect for 3dB loss of gain	150mV

Cross-modulation will be generated between one signal of 2μV, unmodulated, and another of 150mV, 40% modulated, spaced in frequency by 500kc/s.



(Left) *Fig. 10. An a.g.c. circuit used by the author*

(Below.) *Fig. 11. Circuit of the 70-cm converter*



be low enough that the a.g.c. action will start only when the aerial voltage reaches 1 mV. Before the a.g.c. circuit starts to operate, the i.f. a.g.c. circuit should already be working.

In order to explore the possibilities of field-effect transistors at u.h.f., a 435 Mc/s amplifier was built using the 2N3823 device. Intended specially for the u.h.f. range is the SF7489, which is a 2N3823 with superior characteristics. It was found that the gain was 10 dB at 435 Mc/s; this figure could also be obtained from a TIS34 at 435 Mc/s, but the gain dropped at more than 6 dB per octave.

Finally, a 435 Mc/s converter, as shown in Fig. 11, was constructed and tested. The AF239 bipolar transistor provides a gain of 15 dB with a noise figure of 3.3 dB. As the mixer performance[2] proved superior to that of other configurations, the circuit was constructed and incorporated, but it has no particularly new design features. The grounded-base amplifier delivers the u.h.f. signal to the band-pass filter, which is followed by the TIS34 mixer. The oscillator circuit is crystal controlled, and a tripler stage acts as an amplifier to obtain the necessary power.

The author wishes to thank Mr. F. J. Andeweg, Section Manager of Texas Instruments, Dallas, U.S.A., for supplying the transistors, and Mr. F. L. Mergner, Vice-President of the Fisher Radio Corp., for providing information on the a.g.c. circuit.

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1. "P-i-n diode and f.e.ts improve f.m. reception," by Fred L. Mergner. *Electronics*, August 22 1966, pp.114-118.
2. Texas Instruments, F.E.T. Application Handbook, u.h.f. mixer using a 2N3823.

Travelling-Domain Television Camera?

A SOLID-state image sensing panel for television cameras with scanning performed by electric-field domains travelling through the bulk semiconductor was one intriguing possibility hinted at during an I.E.E./I.E.R.E./I.E.E.E. conference on integrated circuits held at Eastbourne (2nd-4th May). The idea is an extension of the DOFIC (Domain Originated Functional Integrated Circuits) concept described in the March issue, p. 131, and was revealed by C. P. Sandbank, of Standard Telecommunication Laboratories, who is largely responsible for this fundamental approach to "molecular electronics." In the DOFIC the travelling domains "read" a conductivity pattern impressed into the GaAs semiconductor, so converting the spatial pattern into a variation of current with time. The conductivity profile, however, can be produced by means other than a permanent built-in structure—in this case by a temporary pattern of incident light. Here the conductivity of the drift path is locally modified by extra current carriers excited by the incident photons. A suitable scanning rate could be achieved since the domains can be made to travel at velocities from 1 cm/sec to 10^7 cm/sec.

This "analogue" approach has not been developed to anything like the same extent as the "digital" solid-state image sensing panel using an array of photodetectors with scanning by X-Y addressing, as exemplified by RCA and Plessey (see p. 274 this issue), but Sandbank did reveal that he had obtained crude video signals from a DOFIC device. He felt that the complications of the computer-like circuitry in "digital" devices might be a disadvantage, and questioned whether this technique was really going in the right direction.

P. J. W. Noble, describing the Plessey panel, said that they expected to have a 200-line version in a matter of months, and mentioned that his establishment was experimenting with solid-state image displays, using integrated arrays of gallium phosphide light-emitting diodes. K. M. McKee of RCA read a communication from his colleague P. K. Weimer, who has developed a solid-state television camera at RCA Laboratories (see January issue, p. 12, which mentioned that a 256 × 256 array of photoconductive elements on 2 thou' centres had now been produced. Further points from the conference will be dealt with in a future issue.

PHYSICS EXHIBITION

Each time the Physics Exhibition is held one hears complaints, sometimes justified, that the exhibition is becoming more "commercial" and that originality is becoming less evident. A welcome innovation which perhaps gives some protection against any such tendency was the concurrent instrument exhibition organized by S.I.M.A. and also held at Alexandra Palace. The review which follows, however, includes only some of the more interesting items from the Physics Exhibition.

THIN-FILM LASER MACHINING

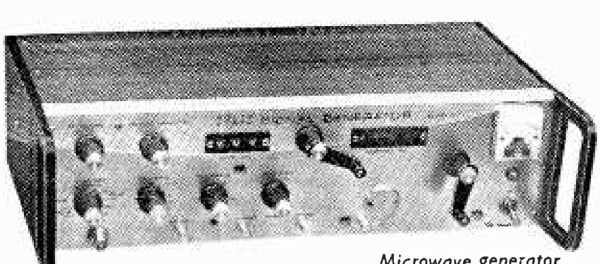
Laser circuit-making for integrated and thin-film circuits, using a helium-neon laser as a "heat pencil" and a co-ordinate positioning table for moving the work under the beam, was demonstrated by Standard Telecommunication Laboratories. The experimental equipment can be used either for "machining" circuits out of thin films deposited on optically transparent substrates (the laser beam evaporating away the film material where it "writes") or for making interconnections between the cells of an L.S.I. array of integrated circuits. In the second application the laser can be used either for machining masks for use in standard photolithographic processes or for direct deposition of metal on to the i.cs by evaporation from a "donor" metal film on a transparent substrate held in contact with the array.

It was the thermal machining of thin film circuits which was actually demonstrated. Here the use of a laser has the advantage over electron beam machining that the heating effect takes place only at the surface and does not penetrate into the material. Furthermore, since the energy transfer depends on the absorbed power, once a thin surface film on an optically transparent substrate has been evaporated no further heating of the substrate occurs. Infra-red light from the laser (wavelength 1·15 μm) is directed by a mirror and lens on to the thin-film substrate, giving a machining spot diameter of about 5 μm. The tape-controlled co-ordinate positioning table which moves the work is similar to that used by S.T.L. for their spark micro-engraving process.* Actuated by X and Y lead screws driven by stepping motors, the table has a positional resolution of 12·5 μm and positional accuracy of ± 6 μm (though these figures are expected to be improved). Maximum speed of movement is 1 cm/sec.

*" A spark micro-engraving technique for thin-film circuits". *Wireless World*, June 1966, p. 313.

FIRST GaAs MICROWAVE INSTRUMENT

Gunn-effect microwave signal generator, covering 8 to 16 Gc/s, is claimed by the makers, Flann Microwave Instruments, to be the first instrument using this particular form of generation by a bulk semiconductor device. Advantages of the technique are, of course, small size and weight, low voltage operation and the possibility of using transistor circuitry for modulation. The main disadvantage at present would appear to be the small power output compared with klystron and other tube signal generators—actually 0·5 mW—but the makers say that they hope eventually to be producing instruments with 5 mW output. The Gunn-effect diode (provided by S.T.L.) is connected into a broad-band, high-Q coaxial resonater. Tuning is by a piston, which is operated, through a frequency-linearizing cam mechanism, by a handle on the front panel. Output power is coupled through a matched piston attenuator to the output r.f. connector. Attenuated level and frequency are indicated by digital read-outs. Frequency read-out accuracy is 1%. Built-in circuits allow the microwave signals to be modulated in amplitude by c.w., square waves and pulses, and in frequency up to a deviation of ± 15 Mc/s.



Microwave generator using Gunn-effect device.

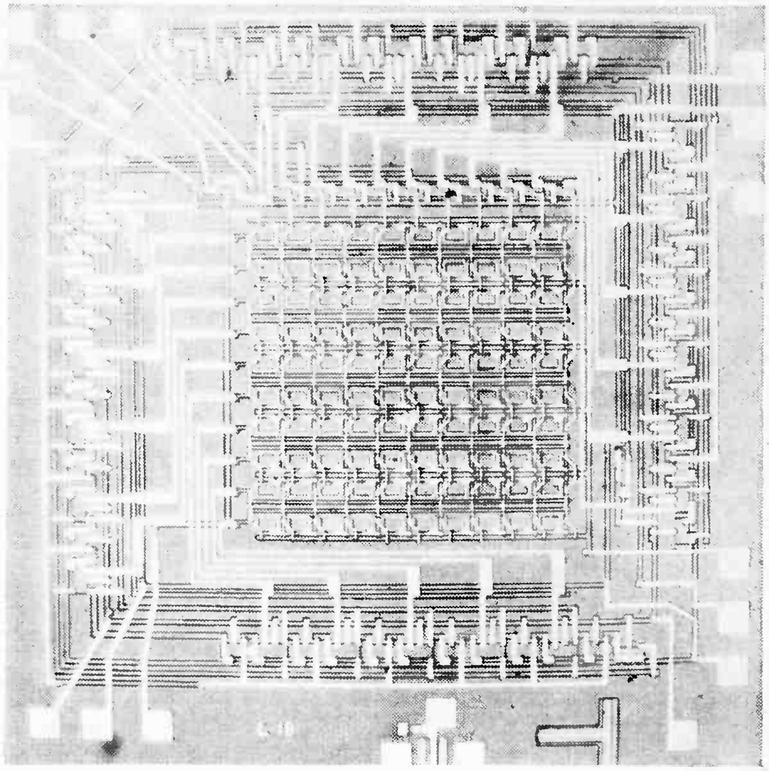
NOVEL RANGE FINDER

A passive method of determining the range of a source of radiation from a detector was demonstrated by the Electronics Research Laboratory of Plessey. The method is general and can be applied to fields in which spherical waves have a signal strength given by $S=S_o/r^n$ the term S_o being signal strength at unit distance. In principle a parameter of the field is compared with the gradient (spatial) of the field. This latter can be found by differentiating the above equation and then eliminating S_o. In the demonstration, a light source was used with a photodiode as detector, the current in the diode being proportional to the intensity, which follows the inverse square law. The gradient was determined by measuring the change in intensity corresponding to a small change in detector distance. The I and $\delta I/\delta r$ signals are then compared using an analogue divider and multiplied by -2, thus giving a continuous range reading. The principle can be applied to moving sources by measuring temporal gradient, giving the approach time. Hence velocity could also be obtained. Possible applications include sound range finding (e.g., foghorn range), road and rail vehicle control, isotope tracing, field surveying, and so on.

INTEGRATING PHOTODIODE ARRAY

Solid-state image sensing panel which could eventually lead to pocket-torch size television cameras was shown by Plessey's Allen Clark Research Centre. Constructed by integrated-circuit technique using p-n junction photodiodes and m.o.s. field-effect transistors, it has a 10×10 matrix of photodiodes and the associated scanning and reading circuitry all on a 0.1-in square chip of silicon (see photo). The principle of light sensing is that first the capacitance of each junction photodiode is charged through a m.o.s.t. (switched on by a pulse applied to its gate), then the charge is allowed to decay through the diode; the rate of decay is determined by the diode reverse current which, in turn, is proportional to the intensity of the incident light. Thus the light intensity is measured by the rate of decay, and this is indicated by the voltage across the diode at a given time after the charging pulse. This voltage is detected, without affecting the capacitance discharge rate, by a m.o.s.t. source-follower circuit (the photodiode being connected to the high impedance gate input of the f.e.t.).

A wide range of sensitivity and an ability to detect very low levels of light are obtained by allowing the effect of the incident light to be integrated over as long a period as possible. Thus with television scanning, each diode is charged once per field and the sampling of its decay voltage can be delayed until the end of the field period, just before the diode is recharged for the next field. In this application, with a regularly repeating charging pulse the diode voltage waveform is a sawtooth, and it is the frequency of the sawtooth which determines the light sensitivity of the system.



Integrated 10x10 photodiode matrix in the centre measures 0.04 in square.

For television scanning of the photodiode X-Y matrix, a pulse coincidence principle is used for charging and voltage sampling the diodes in turn. Two sets of scanning pulses, X for horizontal and Y for vertical, are used, and the m.o.s.t. circuitry is arranged so that when an X-pulse and a Y-pulse are coincident a particular diode in the array is charged and the next diode horizontally is voltage sampled. The X-pulse then jumps to the already sampled diode, charges it, samples the subsequent diode, and so on. Ring counters are used.

Successful application of the image sensing panel to television will, of course, depend on whether a sufficiently fine structure of photodiodes can be fabricated by this method to provide the necessary resolution for, say, the 625-line standard. There are, however, other applications for the technique, such as computer storage, pattern recognition and industrial position-sensing.

OPTO-ELECTRONIC PRESSURE GAUGE

Digital pressure gauge, using an integrated-circuit opto-electronic digital encoder for displacement sensing, was shown by the Automation Group of Plessey. Gas or liquid pressure is applied to a Bourdon tube and the resulting movement causes displacement of a slotted mask in front of an integrated line of photodiodes. Total length of the photodiode line is less than 1mm. Light from a lamp is directed through the 16 microns wide slots in the mask and the resulting image is focused onto the photodiodes, so that movement of the mask causes the diodes to be differentially illuminated.

Associated with each diode is a sensitive m.o.s.t. detection circuit which gives a sawtooth waveform of amplitude proportional to the average incident light intensity (see note above for principle of operation). The outputs from each pair of adjacent diodes are fed into a m.o.s.t. integrated differential amplifier, so that zero output from the amplifier indicates that the two diodes are equally illuminated. Differential amplifiers to the left of such a coincidence point give relatively positive outputs and to the right relatively negative outputs. The outputs from the differential amplifiers are used to provide a 4-bit binary coded indication of the Bourdon tube displacement and hence of pressure. It is hoped to construct a 9-bit unit eventually and the device on show really represented the 4 least significant digits of such a unit. By the use of a vernier technique a displacement resolution of 2 microns is obtained.

HALL-EFFECT SYNCHRO

In a new type of synchro shown by Muirhead fixed magneto-resistive elements were used in place of windings, thereby eliminating slip rings and brushes and the problems associated with them, and making possible considerable reduction in size. The prototype device was only 0.3 in in diameter (see photo). It has a permanent magnet rotor and a concentric Mumetal magnetic shield. Two indium arsenide Hall elements, mounted mutually at right angles and tangentially with respect to the rotor, are excited from a two-phase a.c. supply, and current flows along them. Pick-off electrodes are attached to opposite sides of the semiconductor elements, and the sinusoidal output signals from these vary in amplitude and phase with the magnetic-field variation resulting from the turning of the rotor. The two InAs elements are mechanically adjusted relative to each other in order to set the phase difference of their outputs accurately to 90°. Synchros in this form have been constructed with an electrical-error variation of less than ± 10 min of arc. The use of the device as a continuously adjustable

A 0.3in diameter synchro using Hall-effect elements.

phase shifter was demonstrated, using a Lissajous figure on a c.r.o. In this application the output is typically 30 mV and the operating frequency range extends from zero to well into the kc/s region.

NOVEL PATTERN RECOGNITION METHOD

A new process of pattern recognition was demonstrated by the Automatic Methods Group of the University College London Department of Physics. The principle is to analyse the pattern into its elements by a 20×20 sensing matrix of photodetectors and then identify the pattern by the relative positions of vertices formed by the meeting of lines (e.g. three in the top half of an "A"). This method has been developed initially for use in studying particle tracks in high-energy particle-physics experiments, but is thought to have possibilities for automatic recognition of alpha-numeric characters and so on.

The vertices are detected by using a special-purpose computer, with parallel inputs and parallel processing, to simultaneously sum the outputs of square-formation groups of photodetectors all over the sensing matix. This means that each of the 400 photodetectors has its output summed with the outputs from its neighbouring photodetectors. Each of the resulting sums is then compared in the computer with a threshold value. When a particular square group of photodetectors encloses a vertex the sum value will be above the threshold, and when such a square encloses only a space or a continuous line the sum will be below the threshold. In this way the presence of a vertex in a particular position is detected, and in the demonstration equipment this was shown on an output display formed by a two-dimensional array of electric lamps. The summation and thresholding is done in two stages to achieve maximum precision in vertex location.

50 c/s SAMPLING FILTER

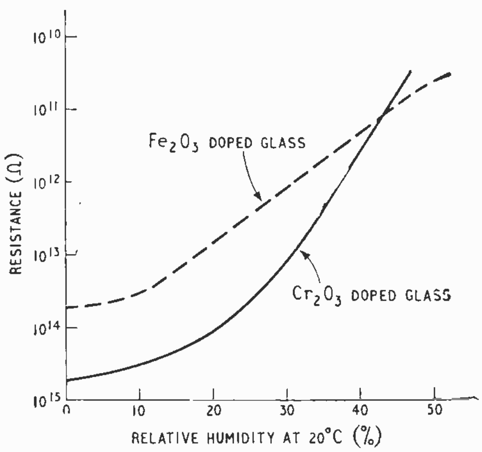
Many exhibits demonstrated or relied on processes by which signals could be separated from circumfusing noise, and such went under the guise of phase detectors, auto-correlators and synchronous sampling filters. In certain applications (e.g., Hall effect measurements and investigation of v.l.f. phenomena) it is desired to remove mains interference, i.e., 50 c/s and harmonics. The synchronous sampling filter is one method of allowing this and the technique is similar to that of the *n*-path filter of Franks and Sandberg (see for example *RC* Active Filters, March 1966 issue, p. 129. Here, the approach aimed at frequency translation of filter responses, whereas in the present case a comb-like filter response is the aim). The principle was not new, similar techniques apparently having been used around 1890 to auto-correlate physiological signals and also, we understand, considerably earlier—in the 17th century.

In the sampling filter shown by the Cavendish Laboratory of Cambridge University a periodic bandstop response was obtained. An input signal is presented to a rotary switch rotating at 50 c/s and connecting the signal in turn to one of a bank of capacitors. Any periodic signal at the input and of the switch frequency will be stored in the capacitors, individual capacitors being associated with the same amplitude of sample of the input wave, and each capacitor storing a different sample of the period. In the filter shown, the rotating switch action is achieved by using a 32-section ring counter, driven at a 50 c/s rate and operating transistor switches (as in Fig. 2(c), p. 130, March 1966 issue). Provided many sections are used, harmonics of the clock rate will be passed giving a comb filter response. By taking the output across the common resistor in series with the capacitors, a bandstop response is obtained. If the commutation frequency can be locked to the input frequency, frequency tracking is achieved, and in one application variations in mains frequency are so made irrelevant. Bandwidth is of the order 0.1 c/s.

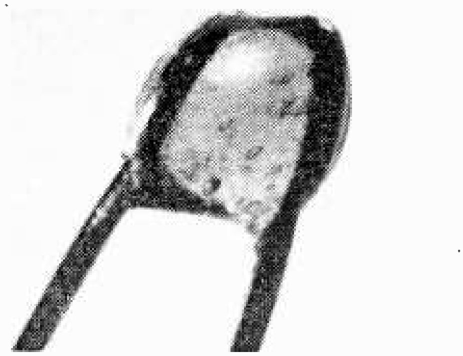
SEMICONDUCTOR WATER VAPOUR DETECTOR

Many metallic oxides which are intrinsically semiconductors exhibit changes in electrical conductivity with adsorption and desorption of impurities on their surfaces. For example, glass doped or coated with a film of Cr_2O_3 and Fe_2O_3 shows a pronounced change in resistance with changes of atmospheric humidity. It has been demonstrated that this change in resistance is due to the impurity perturbing the surface structure and thus altering the electronic conductivity rather than electrolysis of adsorbed water (there are no electrolysis products).

A detector based on this principle consists of a small glass bead coated or doped with metal oxide and supported between two platinum wire electrodes (see illustration). The resistance of the detector may be measured by using a fixed potential and measuring the



Showing change in resistance with humidity of glass water-vapour detector.



Glass-based semiconducting water-vapour detector with fast response

current after d.c. amplification. Resistance changes of a few decades can be obtained (see graph), e.g. with a glass doped with chromic oxide a change in relative humidity from 20% to 43% (20°C) gives a change in resistance from 10^{11} to $10^{11}\Omega$. A feature of this sort of detector is the rapid response (a few seconds) and the device may find industrial application because of this. Another is that the equilibrium of the detector is mainly independent of the velocity or pressure of the "carrier" gas, being determined by the partial pressure of water vapour over the surface. It is possible that other gaseous impurities could be detected by similar devices.

Work on these devices was carried out at the Atomic Energy Establishment, Winfrith.

MILLIMETRE HOLOGRAPHY

A convenient method of assessing the properties of a three-dimensional object as regards, for instance, radar reflections in the microwave regions was demonstrated by E.M.I. Electronics. A microwave hologram was made and an image reconstructed optically with a reduced copy of the hologram. This is believed to be the first millimetre-wave application of holography although the principle had been established by D. Gabor in respect of X-ray "illumination." Theoretically magnifications can be obtained equal to the ratio of the two wavelengths involved.

A 70 Gc/s radar source was used to illuminate an aircraft. This also provided a reference beam, so this and the reflected energy from the object interfered. To record a hologram at these wavelengths (normally, of course, the wavelengths used are optical and photographic plates are used) a wavelength converter must be used and this was provided by a microwave aerial and detector, and a light source and modulator. This converter was arranged to mechanically scan a 50 cm square area and the resulting intensity-modulated light pattern was recorded by a camera with an exposure time equal to the scan time for a complete frame. The reduced (5 mm square) hologram is then used to reconstruct a visible image with a laser, the density distribution indicating the intensity of the microwave reflection from the object.

CdS OSCILLATORS

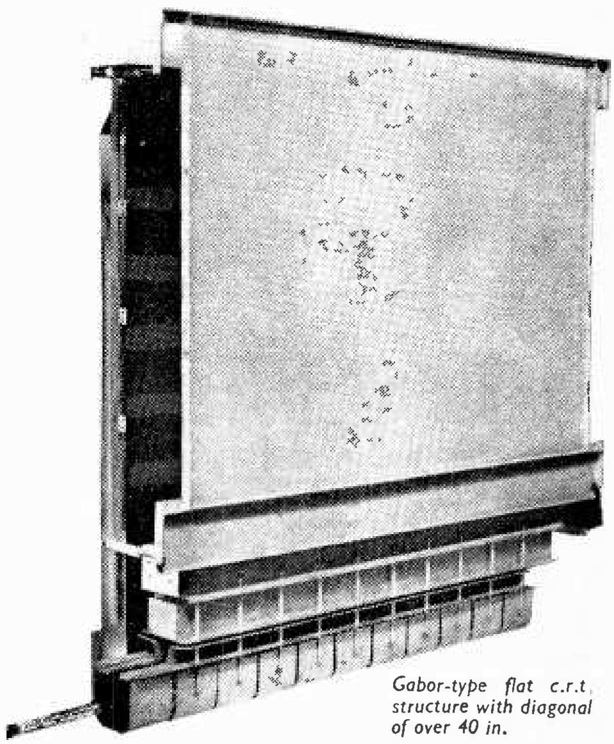
Acoustic amplification in piezoelectric material (e.g., CdS, which is also photoconductive) has been known for some time and was first observed by D. L. White. When a voltage is applied to photoconducting CdS so that the resulting electron velocity is greater than the velocity of sound in the material, acoustic waves can be amplified. So far, such devices have been lossy due to the transducers, and thermal phonons tend to produce noisy devices. This thermal noise, however, can be turned to good effect in producing oscillations. Carefully prepared specimens of CdS whose surfaces are flat and parallel form an acoustic cavity and those lattice waves for which there is round-trip gain increase in intensity until non-linear effects reduce or stabilize gain. Modulation is produced of the direct current at frequencies related to the lattice wave frequency. Frequencies in the range 4-900 Mc/s can be produced depending on conductivity and a linewidth of a discrete frequency can be 2 kc/s. Power levels are in the mW region.

Varying the voltage across the specimen gives frequency modulation and the R.R.E. exhibit showed a f.m. v.h.f. transmitter-receiver link.

FLAT TELEVISION TUBE

A flat Gabor-type c.r.t. for large-screen television, exhibited by 20th Century Electronics, is the result of the company's development of the original concept of Gabor[1] and Aiken[2]. Only the internal structure was shown (see photo). In operation the glass envelope has to be continuously evacuated. The structure on view comprised an electron gun (at the bottom), a linear array of horizontal-deflection electrodes (also at the bottom), a fluorescent screen and an array of vertical deflection electrodes placed a short distance behind the screen—these being in the form of conducting strips parallel to

1. "Flat Tube for Colour TV" *Wireless World*, December 1956, p. 570.
2. "A Thin Cathode Ray Tube" by W. R. Aiken, *Proc. I.R.E.*, 45, December 1957.



Gabor-type flat c.r.t. structure with diagonal of over 40 in.

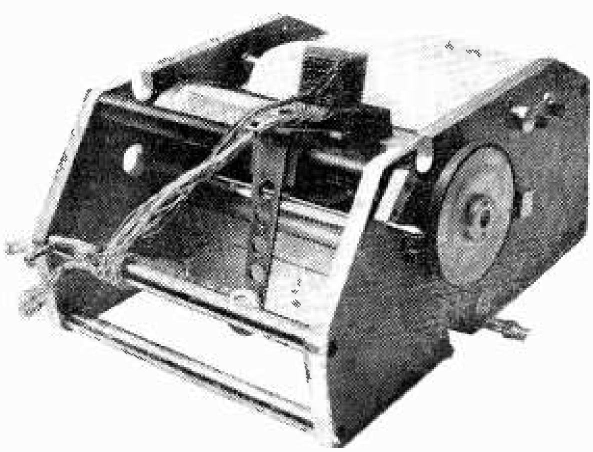
the horizontal deflectors and the screen. The electron gun projects a collimated beam of electrons into and along the mechanical centre of the horizontal deflection array. When the beam arrives at an electrode which is near the cathode potential of the gun it is deflected from its projected path. It is then accelerated into the higher potential of the space between the screen and the vertical deflector electrodes, and is finally deflected on to the screen by reducing the voltage on a selected vertical electrode to cathode potential.

By sequentially raising the potential of the horizontal deflection electrodes from cathode to the gun-anode potential, the point of deflection of the electron beam can be swept along the electrode array. Similarly, a sequential reduction of the voltage of the vertical deflection electrodes from screen to cathode potential sweeps the electron beam from the top to the bottom of the screen area. The effective lens formed by the focusing action of the two deflections is more tolerant than conventional cylindrical electrostatic lenses, and a large diameter electron beam can be used to give a higher electron beam loading on the flourescent screen. The tube operates at an average beam current of 1.0 mA and a final accelerating potential of 10-15 kV.

MAGNETIC PRINTING

A Magnetic-powder high-speed printer, demonstrated by Standard Telecommunication Laboratories, is expected to make possible, ultimately, a printing speed of about 60,000 characters per second. Called the Ferrodot printer, it operates by magnetically recording on a 4½-in diameter revolving drum a pattern of magnetized dots forming the alpha/numeric characters or picture to be printed. The drum surface passes through a bed of resin-coated nickel-zinc ferrite powder, which is attracted on to the pattern of dots. The resulting powder pattern is then transferred to a moving roll of paper, on which it is fixed by melting the resin with radiant heat.

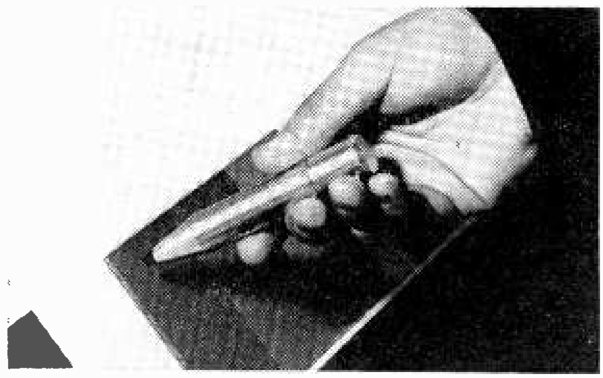
Recording is done by a special multi-track head which provides 160 tracks per inch and by which alpha/numeric characters are built up on the basis of a 9×15 matrix of dots. For each track the recording element in the head uses an ultra-pure iron core 0.004 inch in diameter wound with a single-layer coil of wire only 0.001 inch in diameter. Cross-talk between tracks has been made extremely small. Electro-deposited cobalt nickel has been used for the drum surface, which has to have high remanence in order to attract the magnetic powder. The



recording head elements are driven from electronic logic circuits which at present allow 64 possible characters to be printed. Character size and fount may be varied by using appropriate circuits; line justification and variable character spacing are also possible. At present the printing speed obtained is 5,000-10,000 characters per second.

VERSATILE BLIND AID

Blind person's aid in "pocket-torch" form, demonstrated by Plessey's Electronics Group, uses an oscillator and small loudspeaker (or earpiece), the audible note from



Blind aid using photocell to control frequency of audio oscillator.

which is varied in frequency by the output from a photoconductive cell transducer. Based on a design by the Royal National Institute for the Blind, it was originally intended to assist in teaching science to blind children—the idea being that a wide range of physical variables could be observed by using interchangeable transducers —but the device has now been extended for general use and is at present undergoing trials. The audible note, which is produced by a battery-powered blocking oscillator variable from 0 to 9 kc/s, gives an indication of the intensity of the light picked up, its directional properties (according to how the aid is pointed) and its wavelength (by virtue of the spectral response of the cell). By use of the device a blind person can, for example, detect the headlights of approaching vehicles at night, recognize the different colours of ripe and unripe fruit, sense the different surface textures of walls, etc., read the positions of pointers on dials, walk a straight course on a given bearing relative to magnetic North, follow the shapes of traces on c.r. tubes, and check diabetic test charts. Any transducer producing a conductance change between 0.01 μmho and infinity can be used in the aid.

MEASURING 100-500 KV

The electro-optic Kerr effect is well known and by means of it rotation of the **E**-vector plane of polarized monochromatic light is achieved under the influence of an electric field in certain materials. Light having passed through such substances is rotated according as $I = I_{max} \sin^2 (\pi E^2/2E^2_{max})$ (for reception in a 90° plane) where I represents transmitted light intensity and E electric field. Consequently the applied voltage may be determined from the rotation angle. The function is periodic, the period decreasing with increased field. This results in a 100% change in light intensity for a 2% change in applied volts (for $E/E_{max}=5$). Thus if relative light intensity can be determined to within 10%, a voltage resolution of 0.2% is obtained.

In an experimental set-up sodium light can be passed through a polarizer into a Kerr cell containing nitrobenzene. An output polarizer is set to give zero light output when the applied voltage is zero. The voltage to be measured is applied to the cell and the resulting light intensity fed to a storage oscilloscope *via* a photomultiplier.

In order that the cell liquid is protected against appreciable ionization the nitrobenzine is continuously de-ionized by a dialysis or ion-exchange cell in which an applied field directs ions through permeable cation and anion membranes.

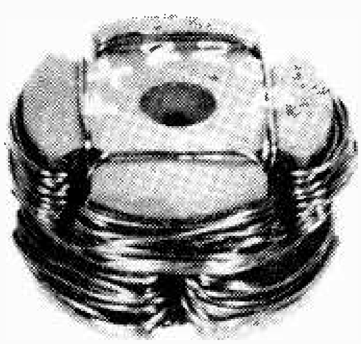
The apparatus was developed by the Electrical Inspection Directorate at Bromley.

TRACKING ERROR OF VARACTOR DIODES

A problem which arises with the use of variable capacitance diodes for tuning more than one tuned circuit at once is that of tracking. Poor control of impurity distribution close to the diode junction has in the past produced poor quality varactor diodes, samples of which can have widely varying parameters. Epitaxy and stringent material control have, however, led to devices which can be used to give a tracking error of 1% or less. Tracking error in this instance is defined as the error in capacitance between the diode in question and a standard diode after circuit trimming and matching at two points in the capacitance range. This should not be confused with the tracking error which applies to two circuits tuning different frequency ranges, as in superhet receivers. Diodes with quoted tracking errors of $\leqslant 1\%$ were shown by A.E.I. (e.g., the DC 1017).

NEW TYPE OF VARIABLE INDUCTOR

A novel method of producing a variable inductor (and also a variable transformer) has been developed at the Post Office Research Station. The inductor is produced by winding commercially available ferrite pot-cores in a special way (see photograph). The wall sections or limbs of the two halves of a ferrite pot are wound so that current flows in opposite directions around adjacent limbs. The two halves are then mounted for rotation relative to one another around the common axis with limbs facing each other. Gap width and friction can be controlled by use of glass cloth impregnated with p.t.f.e. between halves and springs.



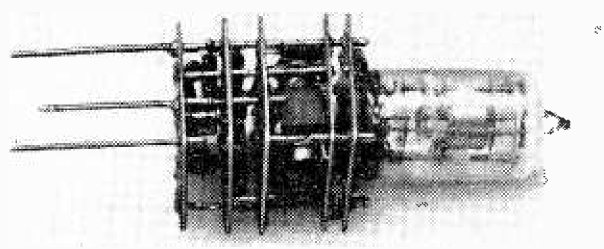
Method of winding pot-core assembly to give variable inductor or transformer.

Varying the position of the two halves relative to one another gives approximately a linear variation of inductance with angle of rotation. The inductance, of course, depends on the mode of connection of the windings.

Inductors of high Q and adequate stability have been produced by this method. Q factors of approaching 400 in the Mc/s region and inductance ranges of about 1-4, 4-16, and 16-60 μH have been obtained. By switching the windings, the whole range of 1-60 μH can be covered.

MINIATURE STABLE OSCILLATOR

To avoid the high power requirement and/or size of ovens for crystal oscillators, an oven arrangement has been developed by the Marconi Company in which the crystal and heater—a transistor—are enclosed in a TO5 can. A thermistor, also in the can, senses temperature and corrects for changes *via* a bridge network and amplifier and



Stable oscillator with crystal, transistor and thermister in TO5 can.

the transistor heater. The TO5 case is enclosed in an evacuated glass envelope and supported by their platinum wires. Oscillators using this technique have been built with a consumption of 300 mW, a warm up time of 70 s and a temperature range of -55°C to $+90^\circ$C. Typical frequency stabilities of 1 in 10^6 and 10^8 are obtained for long and short terms respectively. A demonstration model showed that with the insulating vacuum *removed* constant temperature and frequency could be maintained, slight draughts causing rapid variations in heating current. The first such production oscillator is announced on p. 308. Another type has also been developed which employs a simpler form of thermal insulation, the can and other components being encapsulated in foamed plastic.

EDUCATIONAL EXHIBITS

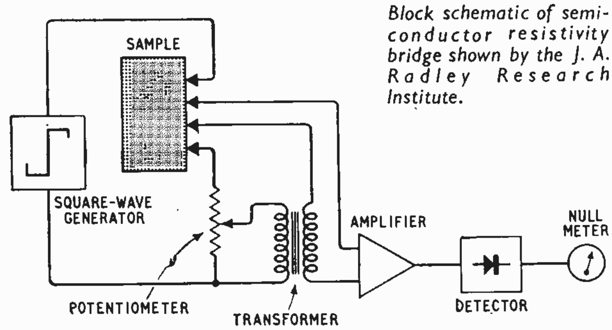
Activities in computer building and teaching techniques were manifest at the West Ham College of Technology stand which held a digital computer designed and built by a third year student. It used 20% tolerance components and cheap semiconductors and was constructed of four basic units; two shift registers, an arithmetic unit, and a clock pulse generator. The action of each of these units can be demonstrated separately, addition and subtraction processes can be shown either in direct operation, to indicate the "carry" facility, or in one complete operation. Also there was the Ormskirk Grammar School construction project—teaching elementary computer science—which includes a series of "concept cards" made of cardboard discs. These rotate behind a front disc to demonstrate various basic functions of logic circuits; windows in the front card at input and output points show the logic function as a series of steps.

These cards include a half adder, control logic, and comparison logic. There were patch boards designed by the school, and constructed by junior pupils to teach the functional operation of gates and multivibrators; logic gate modules were also shown, these being the next step up from basic gates. Other items included in this stimulating project was arithmetic and control units for Boolean algebra work and a register intended to serve as a binary adder, shift register, scaler, ring counter, or a clock. The interesting feature of this basic register circuit is that change of function is carried out by external switching.

A silicon transistor d.c. amplifier which has a single input switch with diagrammatic presentation was shown by the Unilab division of Rainbow Radio (Blackburn) Ltd. It measures very small d.c. currents in the ranges 0-10^{-9}A, 0-10^{-10}A, and 0-10^{-11}A, and the overall accuracy of the instrument—between 3 and 4 %—should be acceptable to most schools science departments. Any 0-1 mA moving coil meter of small bench or larger demonstration type could be used as an indicator, provided that its internal resistance is less than 500 Ω, in order to preserve linearity. Electrostatic work can be carried out with the internal low leakage capacitor, and, provided the capacitance of the object to be tested is small compared with the internal 0.001 μF, a direct indication of electrostatic charge can be read. Full scale deflection of 10^{-9} C is provided and this can be extended by additional external capacitance. Accessories are available to permit studies of the absorption of alpha particles, thoron decay, ionization currents in air, photoelectric effect, and pH measurements. It is also capable of measuring up to 10 kV d.c. at 1 MΩ/V.

A helium-neon laser for use as a teaching aid was demonstrated on the Ferranti stand. A simple experiment was carried out to measure the wavelength of light with a steel rule. Other experiments, enabling the principles of diffraction, interference, photo-elasticity, and geometric optics to be shown, are fully described in a handbook supplied with this laser in the CP series. As a compact d.c. excited source with a uniphase output of 0.25 mW at 6328 Å, it is completely self-contained with integral power pack.

The study of semiconductor properties in physics laboratories of universities and colleges is one of the applications of the semiconductor resistivity bridge shown by the J. A. Radley Research Institute, although the instrument was primarily designed for the checking of germanium and silicon samples in production and development departments of industry. It measures values between 0.01 and 1000 ohm/cm with an accuracy of 5%, and gives direct readings of resistivity on a ten-turn potentiometer (scale length of 1000 divisions). A low-frequency square wave is applied to the outer probe contacts with the measuring potentiometer in series. A voltage is tapped off from the potentiometer and applied to the primary of the transformer. The secondary winding is in series with the inner probes, and 180° out of phase with the primary. The unbalance voltage is amplified, rectified and applied to the null detector (microammeter).



Block schematic of semiconductor resistivity bridge shown by the J. A. Radley Research Institute.

Although the Nuffield Foundation did not have a stand this year, there were electronic instruments by several manufacturers on display which were designed with such teaching projects in mind. The Telequipment 551E oscilloscope for schools, for example, incorporates the recommendations made by the Nuffield Committee for the Teaching of Modern Physics and Science Association for simplicity of control and absence of unwanted industrial features. It possesses a five-inch flat-faced tube, a Y amplifier with a frequency response of d.c. to 3 Mc/s and maximum sensitivity of 100 mV/cm, a time-base with six pre-set sweep speeds from 100 ms to 1 μs/cm and triggering facilities which are automatic for repetitive signals up to about 1 Mc/s. The trigger level control selects any point on the input signal slope, and selection can be positive or negative. Another company supplying instruments designed for the Nuffield Science Teaching Project is Advance Electronics, who for many years have been supplying electronic instruments to schools and other educational bodies. Each of the new instruments has a Nuffield reference number, and they include 2¾-in and 5-in tube oscilloscopes, the latter 'scope having facilities for Z axis modulation (intensity modulation), three instruments for a.c./d.c. and l.t. power supplies, and a scaler timer. This last instrument, the SC2, has a built-in variable h.t. supply for use with a Geiger-Mueller tube. It measures intervals from 1 ms to 1,000 s, and the timing period can be started and stopped manually or by photo-diodes. Counting facilities will count regular pulses up to 1 kc/s, and random pulses with a minimum separation of 250 μs. It possesses an internal standard 1 kc/s oscillator.

On the educational service stand of Mullard there were again several interesting and useful exhibits. Full circuit and construction details were available for a 1 Gc/s solid-state microwave oscillator. This is the fundamental frequency radiated at about 80 mW, sufficient power for demonstration purposes in a laboratory for example. In order to permit experiments using audible tones, the output is interrupted at 400 c/s by a multivibrator. A suitable receiver for this oscillator is based on the 500 mV Mullard LP1153 module which is used with a GN2 detector diode and pre-amp stage. Demonstrations using transmission lines, waveguides and aerials can be carried out with this oscillator, which is driven by a 12 V supply. A pulse operated stepping motor was also shown. Full circuit details were given of controlling such a motor by pulses from two pairs of bistable multivibrators, and of the diode gates used for switching sequences. Other facilities of this circuit design were pulse shaping for input signals which were not suitable for operating the electronic switch because of slope or amplitude. It is also worth noting that there is now full constructional data on the student's modular oscilloscope exhibited last year. This is a four part project intended as a teaching aid, and it is designed around the Mullard DG7/32/01 three-inch c.r.t. The four modules are power, display (including tube, scan coils, brilliance and focus controls), timebase with a time scale continuously variable between 10 c/s and 25 kc/s, and the amplifier, which possesses a sensitivity of about 0.5 V for full 7 cm Y scan. Also on the stand was an electronic thermometer, using a negative temperature coefficient resistor connected in a bridge circuit. The differential amplifier used in this design employs BSY11 silicon mesa n-p-n transistors.

WORLD OF WIRELESS

B.B.C. Stereophonic Test Transmissions

THE B.B.C. Third Network stereo test transmissions schedule has recently been modified from that published in the March issue. The modified arrangements shown in the table greatly increase the usefulness of the transmissions. Initially, tests conducted after normal transmissions had consisted of a 250 c/s tone transmitted in the left-hand channel, but this was later changed to include a 440 c/s tone for the right-hand channel and different depths of modulation, zero and ±8 dB levels being transmitted with respect to 40% modulation.

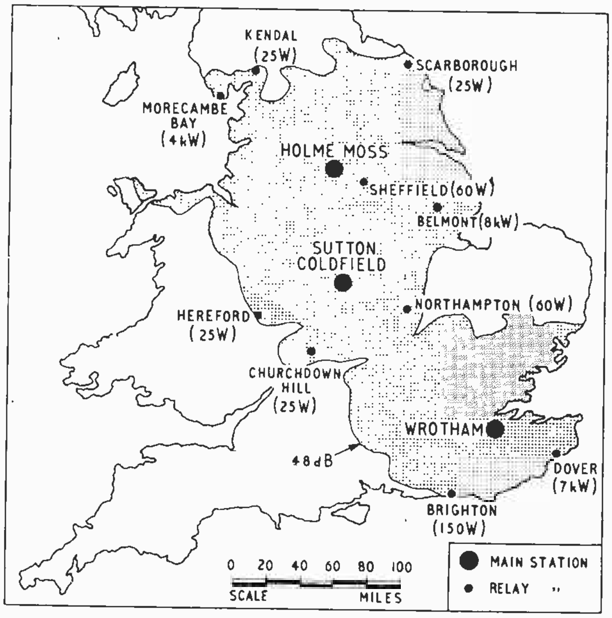
The new schedule, which came into effect on 24th April, now includes a 440 c/s tone in both channels, but identification of the two channels is still possible since the 250 c/s tone is only transmitted at intervals in the left-hand channel. In-phase and anti-phase signals are now transmitted and also a tone sequence transmitted separately in both left- and right-hand channels.

Time	Left-hand channel		Right-hand channel	
	pitch (c/s)	level*(dB)	pitch (c/s)	level*(dB)
23 30	250	0	440	0
23 32	440	0	440†	0
23 35	440	+8	440†	+8
23 37	440	+8	440	+8
23 39	250	+8	440	+8
23 40	250	0	—	—
23 44	—	—	440	0
23 47	tone sequence (60, 900, 5000, 10,000 c/s)	−4	—	—
23 48		—	tone sequence (60, 900, 5000, 10,000 c/s)	−4
23 51	250	0	—	—
23 52	—	—	—	—
23 53	mono transmission			

*Zero level corresponds to 40% modulation before pre-emphasis.
†Right-hand channel in anti-phase with left channel.

These detailed transmissions take place only on Wednesdays and Saturdays, on other days a 250 c/s tone is transmitted in the left-hand channel only from about 4 min after normal programmes until 23 55. Normal modulation level is 40% (before pre-emphasis).

Stereophonic transmissions now take place with selected programme material on Third Network frequencies of 91.3 Mc/s (Wrotham), 92.4 Mc/s (Dover), and 92.3 Mc/s (Brighton), but early next year the Holme Moss (91.5 Mc/s) and Sutton Coldfield (90.5 Mc/s) transmitters, together with a number of relay stations, will be radiating stereo programmes.



Coverage of the v.h.f. sound transmitters which will be radiating stereophonic programme material by early next year. The three southernmost stations are already transmitting stereo programmes. Relay transmitters (apart from Sheffield) use directional aerials. The 48 dB contour is field strength relative to 1 µV/m for a receiving aerial height of 30 ft. It is regretted that on the map shown last month some of the relay transmitter sites were omitted.

UK 3 Further Details

THE launching of the UK 3, the first all-British satellite in the Anglo-American space programme took place on 5th May. The experiments carried in the spacecraft were detailed in "UK 3, Britain's Scientific Satellite" in the March issue, but additional information on the altitude sensing has since become available.

For some of the experiments it is necessary to know the satellite attitude relative to the earth. The sun angle and an additional angular co-ordinate are required to completely define the attitude. For the sun angle, sensors developed at R.A.E. are used which are similar to the "optical potentiometers" seen at the Physics Exhibition in 1965 (see p. 238 May 1965 issue). For the second co-ordinate the method of comparing the received telemetry signals with the spacecraft polar diagram (used for Ariel II) has had to be abandoned, and an alternative optical method has been developed. The idea is to monitor the satellite while the ground is in darkness and the craft in sunlight, and to observe and record flashes of sunlight from reflecting surfaces (as was done with Telstar). Reflecting surfaces at known angles give coded flashes, a different number occuring for the different angular directions involved. (Four flashes per revolution are given anyway from the boom cell arrays.) Ground recording is done by cameras at various locations.

It is estimated that by the end of this year the **B.B.C's colour service** wil cover about 74% of the country's population. The main stations (with channel number in parentheses) involved in this service are Belmont, E. Lincs (48), Black Hill, Lanarks. (46), Crystal Palace, London (33), Divis, N.I. (27), Dover, Kent (56), Durris, Kincardine. (28), Emley Moor, Yorks. (51), Llanddona, Anglesey (63), Oxford (63) subject to the availability of a colour programme link, Pontop Pike, Durham (64), Rowridge, I.O.W. (24), Sudbury, Suffolk (44), Sutton Coldfield, Warwicks. (40), Tacolneston, Norfolk (55), Wenvoe, Glam. (51), and Winter Hill, Lancs. (62). Relay stations linked with the above are at Aberdare, Brierley Hill, Bromsgrove, Caerphilly, Guildford, Hertford, Kilvey Hill, Kidderminster, Lark Stoke, Merthyr Tydfil, Pontypridd, Reigate, Rhondda, Tunbridge Wells.

As there will not be a composite **domestic television and radio show** in London this year a number of receiver manufacturers are organizing independent shows. We have received the following information on companies who are holding trade shows this summer. (All shows will be from 20th to 24th August unless stated otherwise.)

A. J. Balcombe (Alba): Cafe Royal, London, 21-24 August.
Decca Radio and TV: Kensington Palace Hotel, London.
Dynatron: De Vere Hotel, London.
Fidelity Radio: Kensington Palace Hotel, London.
General Electric Co.: Carlton Tower Hotel, London.
Hacker: Prince of Wales Hotel, London.
Philips Electronic and Associated Industries: Majestic Hotel, Harrogate; Royal Garden Hotel, London, 4-8 September.
Pye; Grosvenor House, London.
Rank Bush Murphy: Royal Lancaster Hotel, London.
Standard Telephones & Cables: Kensington Palace Hotel, London.
Thorn Electrical Industries: Cafe Royal (Marconiphone), London; Royal Garden Hotel (HMV/Ultra, Ferguson), London.

Dealers can obtain tickets for these shows by applying to the individual companies.

Collaboration between **design and production** engineers, and a sympathetic understanding of each other's problems are necessary if theoretical concepts are to be successfully translated into production models. This is the underlying theme of a four-day conference sponsored by the Institution of Electronic and Radio Engineers, with the Institution of Production Engineers and the Institution of Electrical Engineers. This conference with the title "Integration of Design and Production in the Electronics Industry" will be held at Nottingham University from the 10th to 13th July. Papers read at this conference will cover such subjects as design for production, how and what products shall be made, cost and quantity considerations and automatic assembly and testing. Registration details may be obtained from the Institution of Electronic and Radio Engineers, 8-9 Bedford Square, London, W.C.1.

At the annual general meeting of the **Radio & Electronic Component Manufacturers' Federation** on April 19th the following member companies (with the name of their representatives in parentheses) were elected to the council. Belling & Lee (N. D. Bryce), A. F. Bulgin & Co. (R. A. Bulgin), Formica (C. R. Jennings), A. H. Hunt (S. H. Brewell), McMurdo Instrument Co. (F. W. Irons), Morganite Resistors (J. Thomson), Mullard (Dr. F. E. Jones), Multicore Solders (R. Arbib), and Standard Telephones & Cables (E. E. Bivand). Dr. F. E. Jones, managing director of Mullard, is the new chairman of the Council. Mr. A. F. Bulgin has resigned from the presidency which he has held for six years.

Pulse-counting F.M. Tuner.—Torotor v.h.f. "front-end" modules for the pulse-counting f.m. tuner design described by E. D. Frost in the December 1965 issue are now obtainable. However, the author advises us that a suitable alternative is available from Henry's Radio Ltd., of 303 Edgware Road, London, W.2. The tuner, which is a double superhet type, is suitable for reception of stereo broadcasts and may be used with the decoder design published in the January 1966 issue.

The 5th **International Aerospace Instrumentation Symposium** is to be held at the College of Aeronautics, Cranfield, Bedford, from March 25th to 28th, 1968. Inquiries to the Symposium Organizer, Department of Flight, The College of Aeronautics, Cranfield, Bedford, England.

Colour TV in Holland.—The Netherlands government have made known they do not object to Dutch television starting regular PAL transmissions as from January 1968. The second network in Holland is capable of transmitting colour and their first network is to be adapted this year. The number of registered television sets in the Netherlands on February 1st this year was 2,387,526.

A 16mm colour film entitled "**The Radio Sky**", made by A.E.I., is now available on free loan from C.O.I. Central Film Library, Government Building, Bromyard Avenue, London, W.3. Numbered UK 2617 it is contained on three reels and lasts 28 minutes. The film observes the growth of radio-astronomy from its beginnings in 1933 to the present day.

The future establishment of a **Non-Destructive Testing Centre** and a Ceramics Centre has been announced by Mr. Wedgwood Benn, the Minister of Technology. The U.K.A.E.A. have been asked to establish these centres at Harwell to provide research and development and to make available the experience gained to British industry.

Due to an oversight the name of the contributor (M. Mann, B.Sc.) was omitted from the note on "**Wire Mesh Aerial Reflectors**" in the May issue.

Special Courses

Bath University of Technology is to sponsor a five-day non-residential course for **sixth form science teachers** on Current Developments in Physics from 4th to 8th September this year. A series of about twelve lectures, supplemented by films, will be on the following topics, astrophysics, low temperature physics, oceanography, nuclear physics, solid state and vacuum physics, and X-ray structure analysis. The overall objective of this course (given by members of the School of Physics at the Centre for Adult Studies, Ashley Down, Bristol 7) is to consider some of the important developments in physics in the last decade. Places on the course are limited to 30 to permit individual practical work. Apply to the secretary of the Centre. (Fee, including lunch and refreshments each day is 10 gn.)

Recommencing in October, is a one-year post-graduate course in **quantum electronics** at the Department of Electronics, University of Southampton. This leads, by examination, to the Diploma in Quantum Electronics, and by an additional project to the M.Sc. The main part of the course covers lasers, opto-electronics, optical communications, holography, non-linear optics, and masers. Applications to the Academic Registrar, The University, Southampton.

Digital circuit techniques will be dealt with during a two-week full-time course at the Borough Polytechnic London, S.E.1, from 19th to 30th June. Electronic and logical principles of digital systems will be considered, and the use of discrete components, integrated circuits, and fluid logic. Lectures, laboratory and tutorial work will include applications to computers, control systems, telephony and data transmission. Suitable for those with knowledge of electronics to about graduate level. Apply by 9th June to the secretary. (Fee for the course inclusive of lunch and refreshments will be £20.)

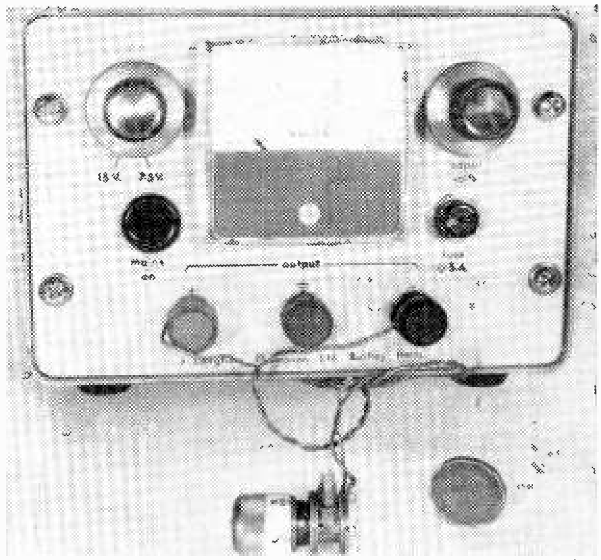
Sandwich engineering diploma courses conducted by the Twickenham College of Technology—including one on **electrical, electronic and control engineering**—are detailed in the 1967-68 prospectus from the Department of Engineering Technology. It also lists the industrial organizations and other employers associated with them. Applications for admission must be made to the head of the Department of Engineering Technology, Twickenham College of Technology, Egerton Road, Twickenham, Middlesex.

OUR COVER

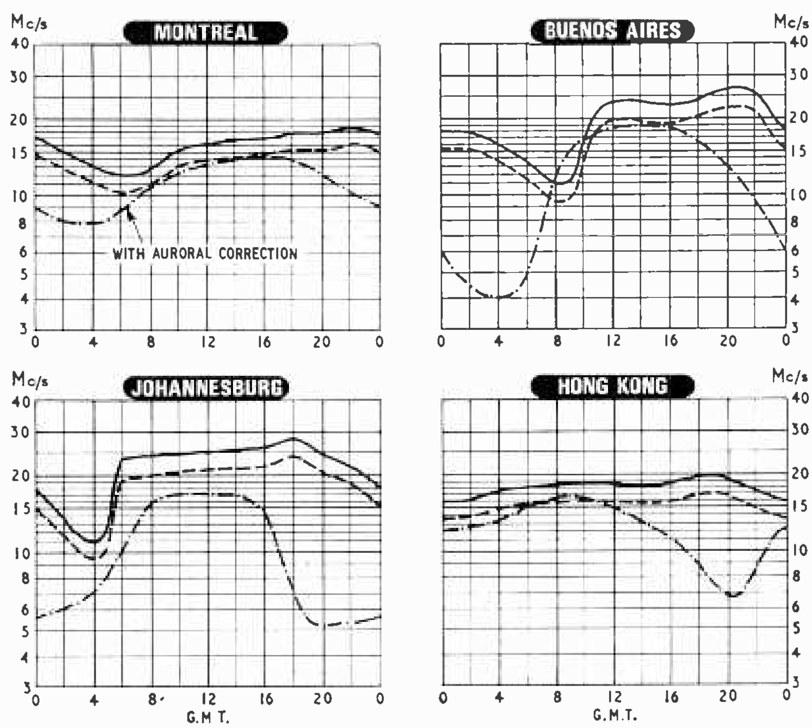
Bulk Semiconductor Microwave Oscillator

EXPERIMENTAL microwave semiconductor devices compared with granules of ordinary refined sugar are shown on our cover this month. The devices are made of gallium arsenide and are bulk-effect oscillators under development at Bell Telephone Laboratories. Such devices differ from more conventional semiconductor devices in that they rely on bulk semiconductor effects, and not on narrow junctions formed from doped material, for their operation.

The theory of the bulk semiconductor oscillators was first proposed in 1961 by Ridley and Watkins (Mullard Research Laboratories) and by Hilsum (R.R.E.), but it was not until 1963 that Gunn (I.B.M.) announced observation of oscillations in gallium arsenide. (The mechanism of the Gunn, or transferred electron, effect was outlined briefly in the August 1965 issue p. 416.) Since then much work has been done on these devices, particularly with a view to commercial application, and last year the first device was put on the market by Mullard. The device was developed jointly by Associated Semiconductor Manufacturers and Mullard Ltd and is made from a thin layer of GaAs epitaxially deposited on a substrate. Output is 5 mW between 7 and 12 Gc/s from a d.c. supply of 150 mA at 6 V. (Tuning can be accomplished with a variable cavity resonator.) With other devices outputs of 100 mW (c.w.) have been obtained at 14 Gc/s and frequencies of up to 35 Gc/s have been generated. More recently, the first commercial instrument to use a GaAs oscillator was announced at the Physics Exhibition (see p. 274). This is a solid-state microwave signal generator tunable over 8-16 Gc/s.



GaAs generator, designed and built by F. Warner and P. Herman at R.R.E., with power supply unit. (Crown copyright photograph).



———	MEDIAN STANDARD MUF
- - - - -	OPTIMUM TRAFFIC FREQUENCY
—·—·—·—	LOWEST USABLE HF

H.F. PREDICTIONS JUNE

THE charts, which were prepared by Cable and Wireless, Ltd., show median standard MUF, optimum traffic frequency (FOT) and lowest usable frequency (LUF) for reception in this country.

Increasing solar activity over the past few months has brought higher frequencies into general use. Although the flat curves promise extended daytime working, the upper and lower limits for 90% circuit availability (FOT and LUF respectively) are closely spaced requiring careful choice of operating frequency. MUFs are based on a predicted Ionospheric Index (IF2) value of 97 which is a little over midway in the range. The measured value for June 1966 was 55.

LUFs shown are for commercial telegraphy but will be similar for reception of high-power broadcasting stations.

Colour Receiver Techniques—6

REPLACING THE MISSING COLOUR SUBCARRIER

How the receiver isolates the synchronizing colour burst from the composite video signal and uses the burst to keep the colour local oscillator in step with the chrominance suppressed-subcarrier of the received signal, so that the oscillator can supply the correct subcarrier re-insertion drive to the synchronous chrominance demodulators

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

YOU cannot understand how the receiver handles colour signals unless you understand the colour burst itself. An earlier article ("The Colour Television Signal," January, 1967 issue) described the burst in detail, but Fig. 1 reproduces the main features again here for easy reference. It shows the waveform of a single line of 625-line, 50 fields/sec colour transmission, You will see the colour burst is a short (2·5μs) train of 10 cycles of 4·43Mc/s sinewave, following closely (0·8μs) after the 4·7μs line sync pulse. The burst is symmetrical about the black level and has a peak-to-peak amplitude equal to that of the line sync pulse. It takes about 10μs in all from the start of the line sync pulse to the restart of the video information.

It is usual to refer to the colour burst frequency as 4·43Mc/s, but it is actually 4·43361875Mc/s, and exactly tied in phase (and thus frequency) to the transmitter suppressed colour subcarrier. At the transmitter, this subcarrier is suppressed after it has been modulated in phase for colour hue and in amplitude for colour saturation. At the receiver, it has to be regenerated in a colour local oscillator, exactly synchronized with the transmitter subcarrier so that the hue and saturation information on the sidebands can be extracted again. The colour burst, as a sample of the transmitter subcarrier frequency, is the reference that is used to ensure that the receiver local oscillator is completely synchronized with the suppressed subcarrier. Although the colour burst is sent out for only a short period at the beginning of each line, the local oscillator synchronizing circuit works in a sort of flywheel sync arrangement that holds the synchronism throughout the whole line.

COLOUR BURST PROCESSING IN THE RECEIVER

Fig. 2(a) shows in broad terms how the colour burst signal is processed in a receiver. The composite (vision plus sync) signal, taken off at some point after the video detector, is amplified in the first stage, A. In the next, B, the burst "gate" stage, the vision modulation and line sync pulses are removed to leave only the colour sync burst. This is then phased-detected in stage C, and the detector output applied to a reactance stage, D. This reactance stage holds the colour subcarrier-regeneration local oscillator, E, in phase synchronism with the burst. Finally the synchronized oscillator output is used to provide subcarrier drive to synchronous colour-difference demodulators, direct in the case of the $R-Y$ one F, and via a 90° phase-shift stage, G, to the $B-Y$ one, H.

Fig. 2(b) shows the arrangement of Fig. 2(a) in more detail as it will be met in a practical receiver for U.K. transmission in the 625-line, 50 fields/sec, swinging-burst, PAL system. Each of the sections of Fig. 2(a) can be followed into the numbered blocks of Fig. 2(b). The first stage, A, is the a.c.c.-controlled chrominance amplifier (a.c.c.=automatic chrominance control, i.e. colour a.g.c.). From this, the signal passes on to the burst-gate amplifier, B, which is shut off except when "gated" open by a line flyback pulse during the colour burst. As a result of this gating, only the isolated colour burst reaches the burst phase detector, C, the line sync pulse and video signals being blocked off. The burst level at the detector is fed back via an a.c.c. network to provide a.g.c. for the first stage amplifier.

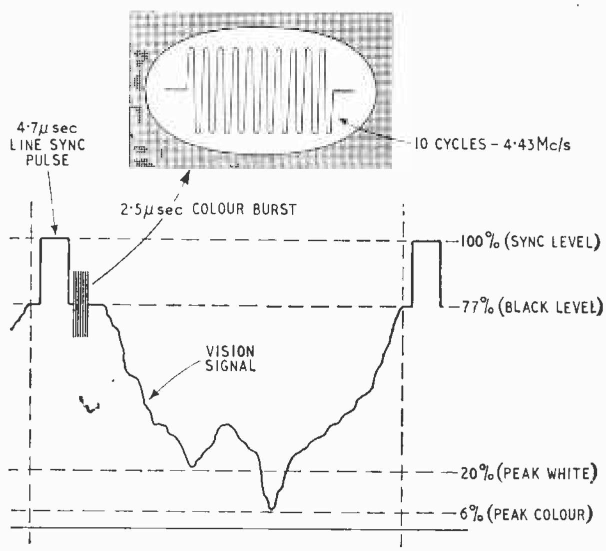


Fig. 1. Colour burst in relation to sync pulse and vision information in composite demodulated signal after video detector on 625-line, negative modulation system.

*Newmarket Transistors Ltd.

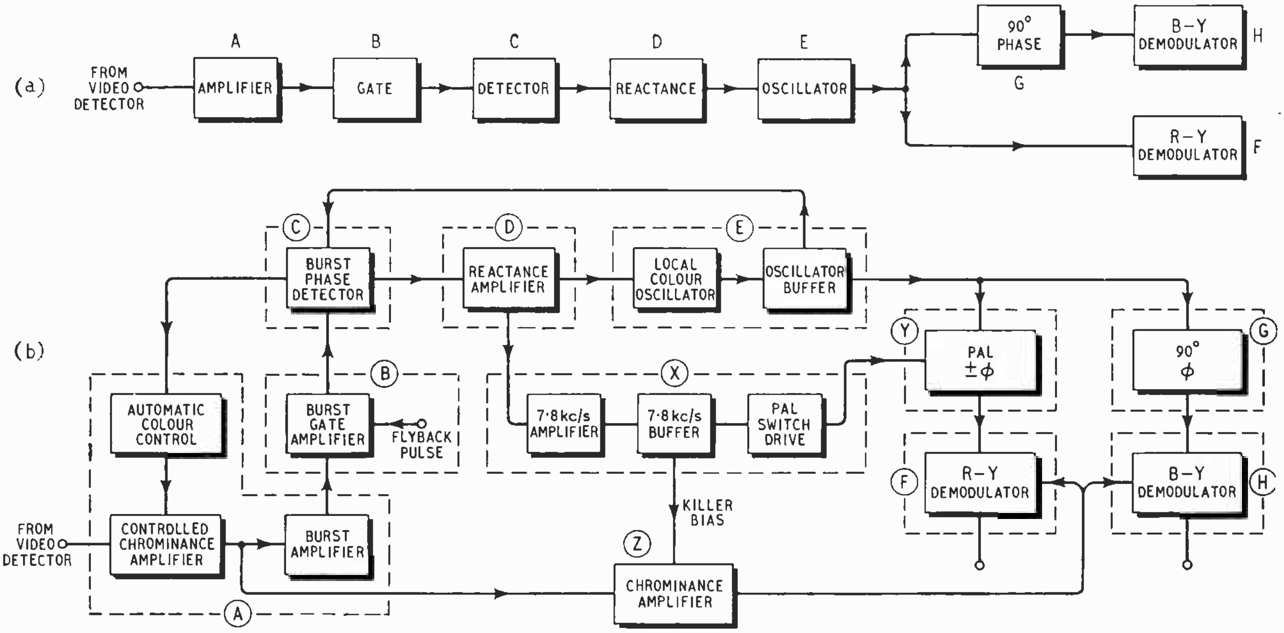


Fig. 2. Extracting colour burst sync signals from mixed luminance, chrominance and sync signals after video detector and using them to synchronize local colour subcarrier oscillator to provide synchronous drive to colour-difference demodulators: (a) basic stages in process; (b) more detailed provisions for PAL "swinging burst" system.

Besides providing colour a.g.c., the burst phase detector, C, in Fig. 2(b) compares the phase of the output fed back from the local oscillator, E, with the phase of the colour burst. If the two signals are exactly in phase, the detector output is zero, but if they differ, the detector provides a d.c. correcting signal proportional to the difference. This error signal is applied to the reactance control stage, D, which in turn varies the local oscillator frequency to bring it into step with the colour burst phase. The local oscillator section comprises a crystal-controlled oscillator followed by a buffer stage to reduce oscillator loading.

The output of the local oscillator, E, in Fig. 2(b), now synchronized with the colour burst, is used to provide carrier-reinsertion drive to the chrominance demodulators, F and H, with a 90° phase shift stage, G, interposed in the *B—Y* drive. The drive to the *R—Y* demodulator passes through a stage Y which reverses the oscillator drive phase on alternate lines in step with the alternate-line reversing of the *R—Y* phase implicit in the PAL (Phase Alternation Line) system.

The switching drive to Y is provided by a separate "PAL identity" section, X, in Fig. 2(b). The input to this section comes from the reactance amplifier, D. This amplifier, besides controlling the oscillator, provides a separate "ripple" signal at half-line frequency 7·8125kc/s (usually referred to as 7·8kc/s). This signal arises because in the swinging-burst PAL transmission, the zero-reference phase of the colour burst is switched on alternate lines ± 45° about a mean of —180° from the *B—Y* phase, at the same time as the *R—Y* phase is switched ±90° about *B—Y*.

The section X in Fig. 2(b) which processes the 7·8kc/s ripple signal is known as the "ident" (identity) amplifier, because its main purpose is to identify the *R—Y* phase in the line of transmission being received and switch to the correct phase position of Y. The separate stages of X are first a 7·8kc/s tuned amplifier, then a buffer amplifier ending in a switch drive section. This receiver section also provides separately a "colour killer" bias to ensure that the chrominance amplifier, Z, operates only when colour is being received.

In the rest of this article we will examine circuits from a commercial design by Mullard to see how the various functions outlined in Fig. 2 can be carried out in practice. The circuit of Fig. 3 corresponds to sections A and B in Fig. 2(b). Tr1, the controlled chrominance amplifier, receives from the separate luminance amplifier a composite video signal of up to 3 V amplitude, black-to-white, which corresponds to a 250 mV peak-to-peak colour burst signal. The 33pF, 68 Ω high-pass input filter suppresses the luminance signal. After amplification in Tr1, the remaining chrominance and colour burst information is passed on from the secondary of T_1 to the 4.43 Mc/s tuned colour burst amplifier, Tr2. The output of Tr2 is further amplified in the burst gate amplifier Tr3, and passed on via T_2 to the phase-detector. The amplification in the three stages produces a colour burst output of about 10 V peak-to-peak at the phase detector input. This voltage is kept relatively constant by the d.c. feedback control loop to the base of Tr1, with rectification in diode D_1. This is referred to as automatic chrominance control, because the gain of the Tr1 stage is thus controlled by the amplitude of the incoming colour burst. The chrominance signals, which also pass through Tr1 and which are taken off at its output to a separate chrominance amplifier, are subject to the same a.g.c. control by the burst amplitude. At the output of Tr1, the signal amplitude, measured in terms of the reference burst amplitude, is kept constant about 100 mV p-p.

In Fig. 3, stage Tr2 is a fairly straightforward 4.43 Mc/s-tuned amplifier, which rejects much of the chrominance information. However, any residual noise or chrominance modulation passed on to the colour sync stages could lead to erratic operation of the local oscillator. Therefore, Tr3, the colour burst gate amplifier, is designed to "open" only when the colour burst is present. To achieve this, a —50 V 10μs, flyback pulse,

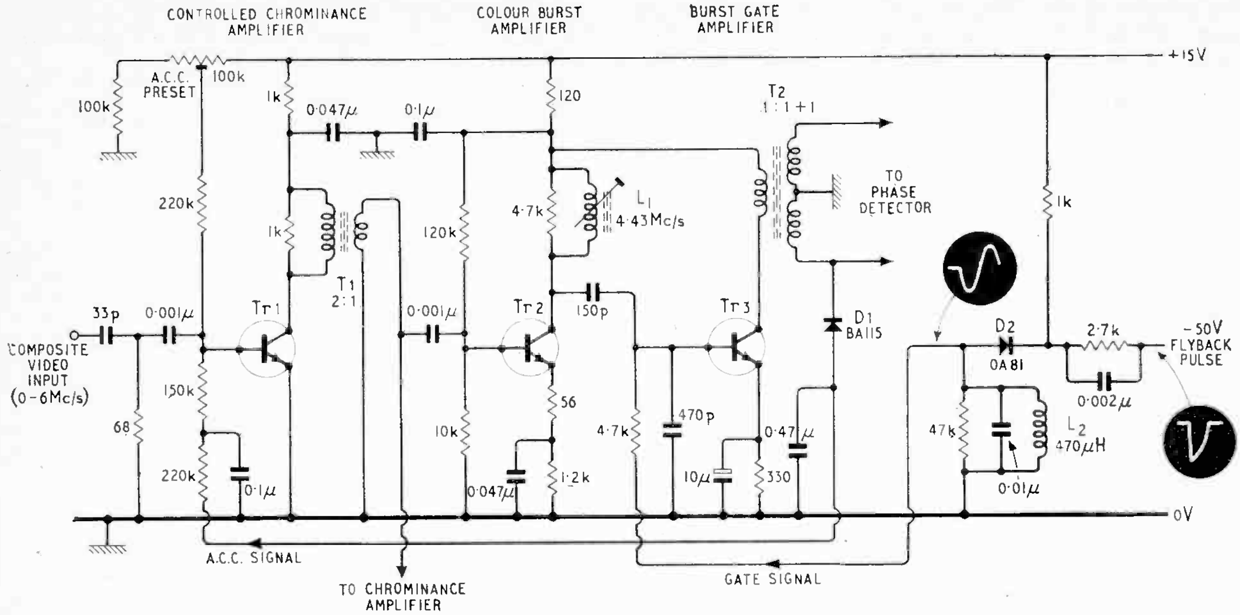


Fig. 3. Amplifying and separating colour burst: typical circuit arrangement.

differentiated by a 0.002μF, 1kΩ network at the right, is applied via diode D_2 to a 0.01μF, 470μH tuned shaping circuit. This generates an initial negative pulse of about 5 V peak followed by an overswing positive pulse of about 3 V peak. This overswing pulse coincides in time with the colour burst, and is applied via 4.7kΩ to the normally cut-off transistor Tr3, to hold it conducting during the colour burst. This arrangement permits only the colour burst to pass through T_2 to the phase detector.

COLOUR BURST PHASE DETECTOR

The process of colour burst phase detection is illustrated in Fig. 4, which shows a circuit arrangement for the stage that was shown as a block, C, in Fig. 2(b). The 10 V peak-to-peak, 4.43 Mc/s, colour-burst signal described in the previous section is applied to the primary of the discriminator input transformer, T_1. The opposite-phase, secondary signals are applied in series with the discriminator diodes D_1, D_2 via 0.001μF isolating capacitors. Meanwhile the output fed back from the 4.43 Mc/s controlled local oscillator is passed into one winding of a transformer T_2, and is applied in parallel to the same diodes via its secondary winding. Any phase difference between the colour burst input frequency and the local oscillator feedback frequency gives rise to an undirectional a.c. output at the point X, which is smoothed by the low-pass filter, 0.01μF, 15kΩ, 0.47μF, 10kΩ to produce a control d.c. voltage at point Y. The phase of this d.c. is arranged so that it can be used to apply correcting action to the local oscillator to bring it into phase with the colour burst input.

COLOUR SUBCARRIER REINSERTION

How the d.c. error signal from the phase detector controls the colour oscillator frequency in detail can be seen in the circuit of Fig. 5, which corresponds to sections D and E of Fig. 2(b). The signal is fed to the base of the d.c. amplifier transistor, Tr1, which forms a variable reactance stage controlling the variable capacitance diode, D_1. The 10kΩ potentiometer in the base circuit of Tr1 is used to set up the d.c. bias on the amplifier so that with no burst input there is a reverse d.c. voltage of about 5 V on the variable capacitance diode D_1. Under these conditions, the diode capacitance in series with the 4.43 Mc/s crystal ensures that the oscillator stage, Tr2, oscillates at almost exactly the subcarrier frequency. When, now the burst is allowed to pass through the phase detector circuit, the oscillator will phase-lock easily. An additional

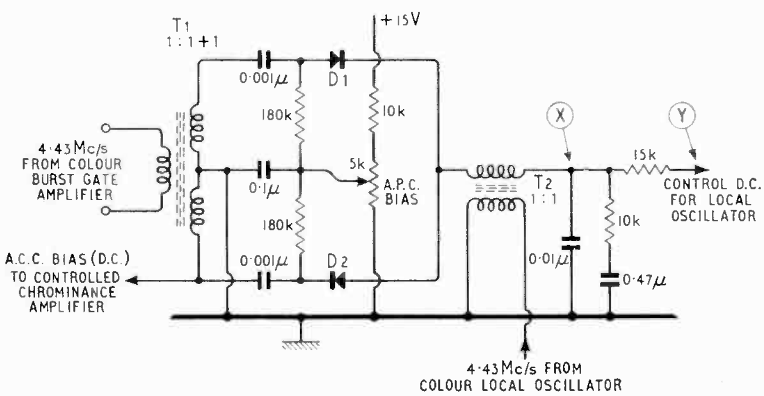


Fig. 4. Colour burst phase detector which compares the phase of the receiver's colour subcarrier-regeneration local oscillator with the phase of the incoming burst of 10 cycles of 4.43Mc/s on each line and produces an error-correcting d.c. voltage to bring local oscillator into phase with colour burst.

adjustment of the 5kΩ potentiometer in Fig 4 then permits setting up the circuit for symmetrical holding operation about the centre of reference phase.

Stage Tr3 in Fig. 5 is an emitter-follower inserted as a buffer amplifier to provide a low output impedance to drive the demodulators and provide feedback to the phase detector. The system as described will have a typical hold-in range of about 1 kc/s on 4,443,618 c/s and a catching range of about 500 c/s, but this can be modified by varying the values of the 10kΩ filter component at X in Fig. 4.

From the collector of Tr1 in Fig. 5 there is a separate signal take-off to drive the PAL line-by-line phase switching circuits.

PAL LINE-BY-LINE PHASE SWITCHING

The take-off referred to above is shown in Fig. 6 applied to the input of the first stage Tr1 of the PAL switching section. This input signal is the swinging burst 7.8 kc/s ripple, which is present at the collector of the previous d.c. amplifier, and it is amplified in Tr1, which is tuned to 7.8 kc/s by L in conjunction with the capacitors C_1 and C_2 in the collector circuit.

In black-and-white transmission without the colour burst, there is no 7.8 kc/s ripple input, and only a small noise output appears at the collector of Tr1. This is not amplified by Tr2 because there is no d.c. base supply current to Tr2 and that transistor is therefore held cut-off. When the 7.8 kc/s colour burst ripple signal does come through, it is rectified by the OA81 diode, D_1, and biases the transistor Tr2 on. Positive feedback from the Tr2 emitter via 680Ω to the junction of C_1, C_2 greatly increases the effective Q of the tuned circuit. As a result a large 7.8 kc/s ripple signal appears both at the emitter of Tr2 and at the OA71 diode, D_5. The smoothed output of D_5 provides a positive voltage which is taken off on a separate line to bias the chrominance amplifier into conduction. Meanwhile, the ripple signal at the emitter of Tr2 passes on to be used to ensure that the phase control switch circuit Tr3, Tr4 switches in the correct phase to drive the demodulator circuits.

Fig. 5. Receiver local oscillator circuits for regeneration of colour subcarrier in phase with subcarrier suppressed at transmitter, showing reactance stage controlling 4.43Mc/s crystal oscillator.

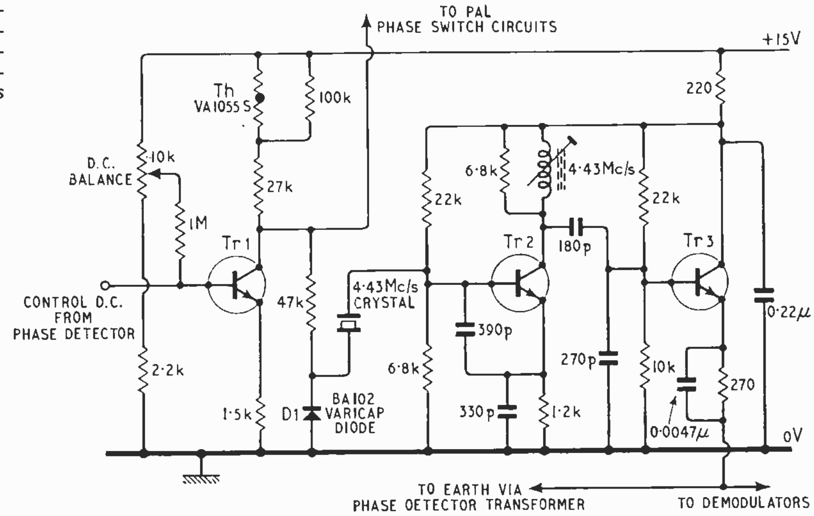
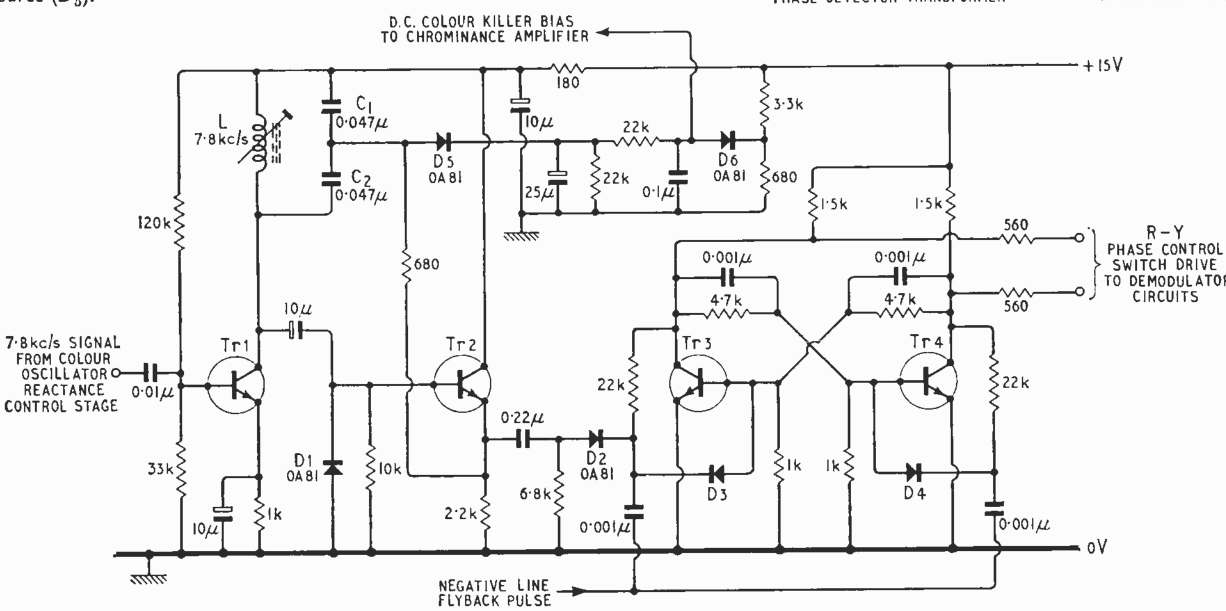


Fig. 6. PAL phase switching circuits, comprising 7.8Mc/s amplifier (Tr1), buffer emitter-follower (Tr2), PAL alternate-line R-Y phase switch bistable (Tr3, Tr4) and d.c. killer bias source (D_5).



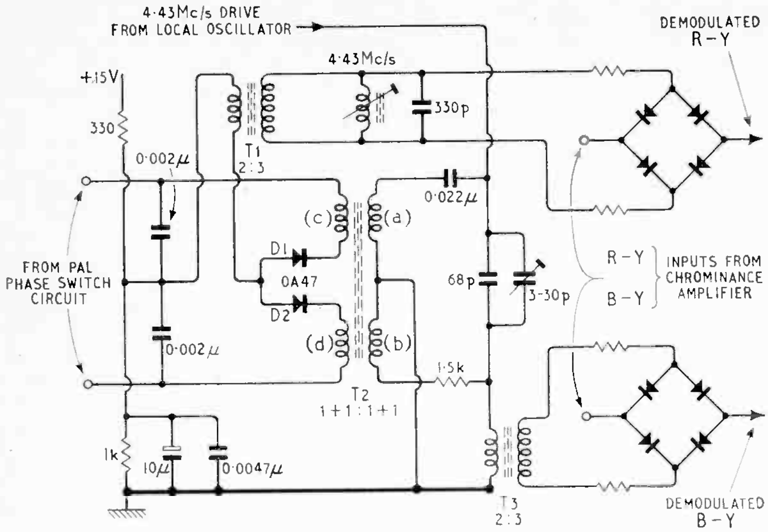


Fig. 7. Circuit for alternate-line phase reversing of local oscillator drive to R-Y colour-difference demodulator.

Tr3 and Tr4 in Fig. 6 form a conventional Eccles-Jordan steered bistable which is caused to switch back and forth under negative line-flyback pulses applied to the junction of the two 0.001μF capacitors at the foot. This bistable must switch over in the correct phase relationship with the R-Y ± 90° phase in the transmission. If it is out of phase, the R-Y chrominance signal would be detected as $-(R$-$Y)$ and thus the colour reproduction would be grossly upset. The correct phasing of the bistable action starts with the 7.8 kc/s ripple signal at the emitter of Tr2. This is differentiated in a 0.22μF, 6.8 kΩ network, and produces a series of positive trigger pulses every other line on the output side of the diode, D_2. When the bistable is switching correctly, these pulses merely assist the triggering by helping to drive on the side opposite to the one that is being cut-off by the negative line pulses. If the bistable is out of step, however, the positive output pulse from D_2 counterbalances the negative trigger pulse passing to the left-hand transistor base and holds back the bistable for one count to bring it into step with the transmission. (If you do not understand fully how the Eccles Jordan bistable works, you should consult some standard treatment such as is to be found in the author's "Transistor Pulse Circuits" Iliffe Books, 1964.)

SWITCHING PHASE OF LOCAL OSCILLATOR DRIVE TO DEMODULATORS

Looking back to Fig. 2(b), you will see that the PAL switch drive output from section X is applied to the PAL phase switch section Y which is in series with the oscillator drive to the R-Y demodulator. Circuitry to carry out this function is given in Fig. 7. You will see the 4.43 Mc/s output from the controlled oscillator coming in from the top of the diagram. In the first instance it feeds through a 0.002μF capacitor to the winding, (a) of the transformer T_2. If the diode D_1 is conducting and D_2 is cut off, the signal is transferred by the top winding (c) to the left-hand winding of the second transformer T_1 in one phase direction. Conversely, if D_2 is conducting and D_1 cut off, the signal is transferred in the opposite phase from winding (d) of T_2, again to the left-hand winding of T_1. Now, the square wave output from the previous Eccles-Jordan circuit feeds into the two left-hand input terminals and alternately switches D_1 on (with D_2 off), and D_2 on (with D_1 off). As a result, the 4.43 Mc/s drive into winding (a) of T_2 is transferred to the left-hand wind-

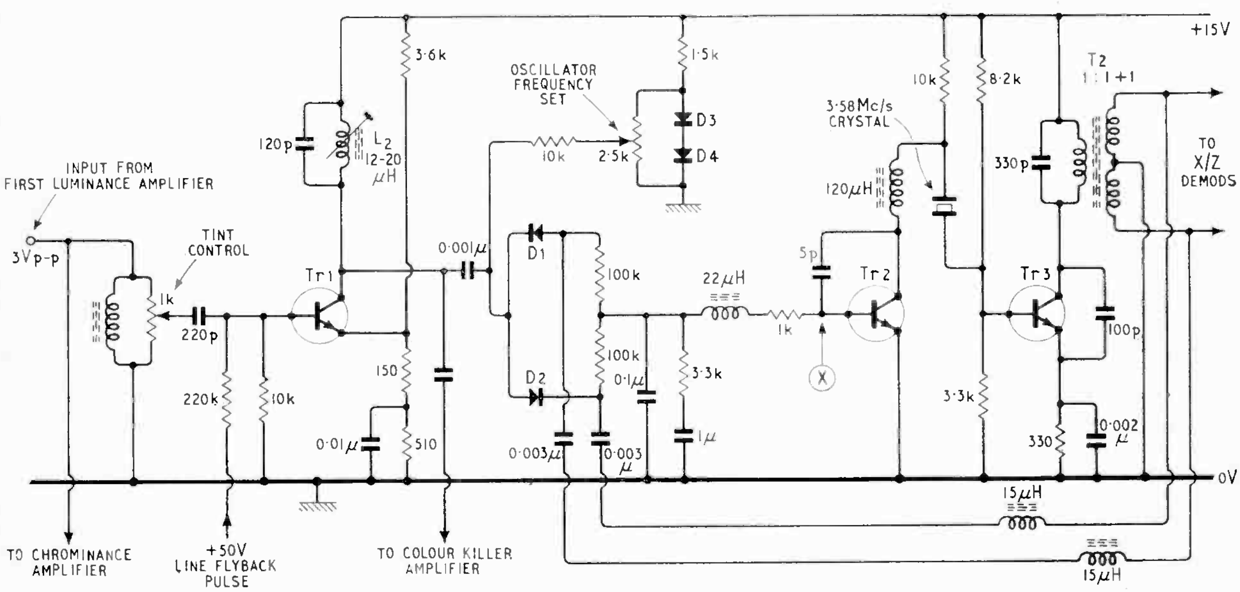


Fig. 8. Illustrative complete N.T.S.C. receiver colour subcarrier-regeneration oscillator section (Fairchild Semiconductors).

ing of T_1 with its phase reversed on alternate lines. The secondary (right-hand) winding of T_1 thus provides a phase-switched 4.43 Mc/s signal for carrier-reinsertion drive in the *R-Y* demodulator in proper phase synchronism with the *R-Y* phase as switched on alternate lines of the PAL transmission.

And now, what of the drive to the *B-Y* modulator in Fig. 7? Through winding (b) of T_2 and the 68pF, 3-30pF, 1.5 kΩ network, the 4.43 Mc/s signal from the oscillator arrives at the top of the primary winding of transformer T_3 adjusted exactly 90° out of phase with the drive to winding (a) of T_2. This is precisely what is required to drive the *B-Y* demodulator which is fed from the secondary of T_3. If you look back to Fig. 2(b) again you will see this 90° phase shift network set out as section G.

One of the penalties of the PAL swinging-burst system of transmission is the need for these complex phase switching and steering circuits, but it should be recognised that they are largely merely refinements of the basic arrangement set out in Fig. 2(a) earlier on. To underline this, it is well to take a look at how a receiver deals with the problem of subcarrier regeneration in the N.T.S.C. American system (which does not have the complications of PAL switching and swinging-burst features).

N.T.S.C. COLOUR SUBCARRIER REGENERATION

Fig. 8 derived from a Fairchild semiconductor applications report illustrates the simpler problems of a non-PAL, N.T.S.C. type receiver in regenerating the colour subcarrier.

The 1KΩ potentiometer at the input varies the phase (by tapping across an inductor) of the colour burst which is part of the composite video signal that is fed to the burst amplifier is made operative by a positive pulse of about 5 μs. This is applied to the biasing resistors in the base of Tr1 from the line flyback transformer. The colour burst output of Tr1 is fed to the automatic phase control detector diodes, D_1 and D_2. From the same point, a take-off is also available to control a separate colour killer amplifier.

The crystal-controlled, common-base oscillator, Tr3, is held in phase with the colour burst by comparing its output with the burst in the automatic phase control detector circuit, D_1-D_2, and producing a correcting signal proportional to the difference in phase. In Tr3 the feedback, to support oscillation, is from the collector through a capacitance matching network of 1000pF and 0.002μF to the emitter. The base of the oscillator is bypassed to ground through the 3.57945 Mc/s crystal (operating in the series mode) and a series LC network comprising the capacitance of the reactance transistor, Tr2 and the inductance in its collector. (Note that the 3.58 Mc/s crystal frequency is appropriate to N.T.S.C. transmission system in America.) Two chrominance reference signals of opposite polarity are taken from the output transformer of Tr3, which has a tuned primary. These are used to provide the necessary local oscillator drives to the X/Z synchronous demodulators.

The outputs of stage Tr3 are also fed back through 15 μH and 0.003 μF to the phase detector diodes D_1, D_2. This detector circuit compares the phase of the oscillator feedback signal with the input burst signals, and produces a d.c. error correcting signal at the point X proportional to the difference between the two. This error signal changes the bias on Tr2 and thus varies its output capacitance, and this varies the crystal oscillator frequency to bring the two frequencies into step.

The 2.5 kΩ potentiometer in the input network of D_1, D_2 is used to adjust the bias on the diodes so that the d.c. output of the detector is near zero when the oscillator is locked in phase.

It is hoped that sufficient information has been given on the operation of colour subcarrier regeneration in both the PAL swinging bust and the N.T.S.C. systems for you to understand the principles on which these circuits work. If you are interested in further design details, you should consult the useful paper "Hybrid Colour-difference Decoding Circuits" by D. S. Hobbs in *Mullard Technical Communications*, Vol. 9, No. 85, of January, 1967.

JUNE CONFERENCES & EXHIBITIONS

Further details can be obtained from the addresses in parentheses

BIRKENHEAD
June 27-29 Technical College
Instrument & Automation Exhibition
(Birkenhead Technical College, Borough Rd., Birkenhead)

HARROGATE
June 7-9 Royal Hall
Industrial Physics—The Contribution of Government-Sponsored Laboratories
(I.P.P.S., 47 Belgrave Sq., London, S.W.1)

MELTON MOWBRAY
June 20-22
Instrumentation & Control Equipment Exhibition
(Production Engineering Research Assoc., Melton Mowbray)

ABROAD
June 5-9 Menton
I.F.A.C.-I.F.I.P. International Conference—"Digital Computer Applications to Process Control"
(Association Française de Régulation et d'Automatisme, 5 rue de Liège, 75 Paris, 9e)

June 6-9 Washington
Laser Engineering and Applications
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)

June 12-14 Minneapolis
Communications Conference
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)

June 19-21 St. Louis
Microelectronics Symposium
(R. Pellin, Monsanto Co., 800 Lindbergh, St. Louis, Missouri)

June 19-22 San Diego
Biomedical Engineering
(D. L. Franklin, Scripps Clinic & Res. Foundation, La Jolla, Calif.)

June 19-23 Rome
Scientific Congress & Exhibition on Electronics
(Rassegna Elettronica, via Crescenzio 9, Rome)

June 25-28 New York City
Consumer Electronics Show
(Electronic Industries Assoc., 2001 Eye St., N.W., Washington, D.C. 20006)

June 27-July 2 Budapest
Colloquium on Thin Films
(Optikai Akusztikai és Filmtechnikai Egyesület, Szabadsag ter 17, Budapest 5)

PERSONALITIES

J. H. H. Merriman, O.B.E., M.Sc., A.Inst.P., F.I.E.E., who has been deputy engineer-in-chief in the Post Office since 1965, has succeeded **D. A. Barron,** C.B.E., M.Sc., F.I.E.E., as engineer-in-chief, although under the reorganization of the G.P.O. his title will be senior director of engineering. Mr. Barron has retired after 40 years' service. Mr. Merriman, a physics graduate of King's College, London, did post-graduate research on non-linear oscillations to gain his masterate. He joined the staff at the Dollis Hill Research Station in 1936. During the war he set up and ran radio laboratories at Castleton, near Cardiff, working on v.h.f. for multi-channel telephony. In 1960 he took charge of the Overseas Radio Planning & Provision Branch. He was for a time international vice-chairman of the C.C.I.R. study group concerned with broadband microwave relay systems.

J. H. H. Merriman

J. D. Clare, M.Sc., M.I.E.E., who joined Raytheon Company last August as vice-president and also as deputy general manager of Raytheon Europe, has now been appointed general manager of the latter, which comprises A.C. Cossor and the Sterling Cable Company in the U.K. and companies in Italy, Switzerland, France and Denmark. Mr. Clare, a graduate of Birmingham University, was with Sobell Industries for five years until 1950 when he joined the Royal Radar Establishment, Malvern, on the development of radar and missile systems. From 1955 until 1962 he served with the Ministry of Aviation, for the last two years as director of guided weapons research and development. On leaving the Ministry he joined Standard Telecommunications Laboratories at Harlow, of which he was managing director and director of research. For two years immediately prior to joining Raytheon Mr. Clare was vice-president and technical director of I.T.T. Europe.

J. R. Brinkley, M.I.E.R.E., managing director of Pye Telecommunications Ltd., since 1956, has resigned and joined Standard Telephones & Cables Ltd. as executive director of the Radio Group. He will be responsible for the radio communication, broadcast, mobile radio and avionics activities of S.T.C. Mr. Brinkley began his career with the British Post Office and was a research engineer at the Dollis Hill Research Station. In 1942 he went to the Home Office where he was concerned with the development of police radio. He joined Pye Telecommunications in 1948 as chief engineer and subsequently became its first technical director.

J. R. Brinkley

A. Cormack, B.Sc., M.I.E.E., joined Racal Communications Ltd. at the end of March as technical director. Mr. Cormack, after gaining his honours degree in electrical engineering at Manchester University, led various communication projects at the G.E.C. Hirst Research Centre up to the end of 1961. In 1962 he was appointed chief engineer of the Radio Communications Division of G.E.C. (Electronics) Ltd., at Coventry, where he became technical manager. Since the end of 1965 he has been technical director of British Communications Corporation Ltd.

A. Cormack

C. M. Benham, B.Sc., A.C.G.I., F.I.E.E., chairman of Painton & Co., has been elected to the Council of the Confederation of British Industries. He started his industrial career at Standard Telephones & Cables in 1925 after taking his engineering degree at Imperial College, London. From 1933 to 1937 he was head of the radio communications engineering department of S.T.C. at New Southgate. In 1937 he joined Mr. P. R. Painton, who had founded a small company to manufacture wire-wound resistors in Northampton. Upon the death of Mr. Painton later that year Mr. Benham took control of the company, which now employs about 1,400. He is now executive chairman. He has always taken an active part in the affairs of the Radio and Electronic Component Manufacturers' Federation and in 1955/56 he was chairman and is at present the treasurer. Since his school days he has been an enthusiastic radio amateur and now operates under the call sign G4TZ.

C. M. Benham

Stanley R. Rundle, M.I.E.E., has been appointed an executive director of Aerialite Ltd. He joined the company from Aluminium Laboratories Ltd., as works manager of the Cable Division in August 1965 and will continue in this capacity as works executive director.

A. G. Perry has recently been appointed export sales manager of Storno Ltd., the Camberley, Surrey, subsidiary of Storno of Denmark, manufacturers of radio communication equipment. Mr. Perry joined Storno from Amplivox Ltd., having earlier held senior managerial positions in Pye Telecommunications Ltd., where he specialized in v.h.f./u.h.f. radiotelephone systems.

Derek J. Steel, B.Sc., M.E.E., who is 33, has been appointed field sales manager of the Microelectronics Division of the Marconi Company, which he joined in 1958 as a graduate apprentice. After graduating at Manchester University he spent two years at the University of Louisville, Kentucky,

D. J. Steel

where he took his master's degree in electrical engineering. He did his National Service as a 2nd Lieutenant in R.E.M.E. from 1960 to 1962 and returned to Marconi's Specialized Components Division, of which he later became chief of sales.

D. H. W. Busby, manager of the Mullard Service Department for the past two years, has assumed commercial responsibility for the co-ordination of the planning, production and distribution of integrated circuits and thin-films in both the Industrial Markets Division and the Entertainment Markets Division. Mr. Busby began his service with

D. H. W. Busby

Mullard Ltd. in 1950 in the Central Applications Laboratory, prior to which he was for two years in R.E.M.E. working on gunnery control equipment. In 1958 he left the company to become chief engineer of Beam-Echo, but rejoined Mullard as deputy service manager in 1963. The new manager of the Service Department is **E. Lintern,** who has been with Mullard since 1939 and became deputy service manager in 1966.

A. E. Cawkell, M.I.E.R.E., was recently appointed consultant to the Institute for Scientific Information, Philadelphia, and will be widening its interests in the U.K. and on the Continent. The Institute is concerned with scientific information, culled from the world's journals, and the rearrangement of it by computer in such a way that some relevant fraction is available to a particular scientist or engineer. The information is available in various forms —for instance, in the "Science Citation Index," "Index Chemicus," or "Current Contents," or by weekly computer search in order to print out items in a field selected by a scientist. Mr. Cawkell, who contributed an article on indexing technical information to our issue of September, 1962, founded in 1948 his own company, Cawkell Research & Electronics Ltd. (now a member of the Simms Group). He relinquished his directorship of the company in 1963.

F. W. Dawe, A.C.G.I., F.I.E.E., who two years ago retired from the managing directorship of Dawe Instruments Ltd., has been appointed director of engineering with Sealectro Ltd. of Farlington, Portsmouth, and will be responsible for the direction of all research, design and development. Before forming his own company (now part of the

F. W. Dawe

Simms Group) 1945, Mr. Dawe had held technical exectutive positions with Marconi Instruments, E. K. Cole, The Gramophone Co. and Edison Swan.

OBITUARY

Harold E. Renyard, who on March 31st, at the age of 73, retired from the managing directorship of Rendar Instruments Ltd., died on April 22nd. An apprentice of Robert Paul, the well-known instrument maker, he joined Wright & Weaire Ltd., of which Rendar Instruments is a subsidiary, in 1921.

NEWS FROM INDUSTRY

NAVIGATOR BREAKTHROUGH IN AMERICA

DECCA have received an initial order for twenty four sets of their Navigator, worth about $1M, from the American company Seaboard World Airlines for their DC8 aircraft. Each equipment will consist of a duplicated installation of the Decca/Dectra Mk 17 receiver, Omnitrac digital computer and interface unit, and the Flight Log pictorial display.

The American VOR/DME system (V.h.f. Omni-directional Range/Distance Measuring Equipment) was established as a world standard at the ICAO Conference of 1959 and it is now mandatory that aircraft carry such equipment. Decca feel that this order reflects the growing opinion that the American equipment is not the complete answer to the increasing air traffic problem and marks a breakthrough in the struggle for acceptance of their concept of navigation.

Track and positional information is given by the Flight Log pictorial display which consists of a movable chart on which the aircraft's track is automatically traced, digital information contained on the chart edge informs the Omnitrack computer of the chart's position thereby completing a servo loop. Any point on this chart can be selected, range and bearing information is then given regarding the aircraft's position relative to this point or the equipment will steer the aircraft to the required position via the automatic pilot.

ANGLO-FRENCH RADAR FOR RUSSIA

AN agreement has been reached whereby the Anglo-French partnership of the Marconi Company and Thomson Houston-Hotchkiss Brandt will supply a "Secar" secondary radar system to Vnokovo Airport near Moscow for evaluation. Vnokovo is one of the major airports serving Moscow and is the site of the centre that controls air traffic throughout the area. "Secar" has been recently sold to Eurocontrol where it will be used for the regional air traffic control centres of Brussels and Shannon.

"Secar" is used to supplement primary radar and to improve the control centre's "picture" of the air traffic situation at any given time. A transreceiver mounted in the aircraft is supplied with information of the aircraft's height, identification and two other parameters. The equipment, when interrogated by means of a transmission from the ground, transmits this information in digital form to be displayed in the air traffic control centre. The process does not require any assistance from the aircrew.

QUEEN'S AWARD TO INDUSTRY

THIS year's list of the recipients of the Queen's Award to Industry conferred for efficiency as demonstrated by increasing export achievement or technological innovation was recently announced. The companies cited in the electronics field were as follows.

For technological innovation, **Cambridge Instrument Co.** for their scanning electron microscope, the Stereoscan; **Crosfield Electronics** for electronic equipment for use in the printing industry; **Ferranti** for electronic summation metering equipment, numerical control equipment, a lightweight inertial platform, digital microcircuits and digital computers; **The General Electric Co.**, for telecommunications equipment; **Joseph Lucas** for high voltage transistors; **Short Brothers and Harland** for a guided weapons system; and **Smiths Industries** for marine radar.

For export achievement, **British Aircraft Corporation** for aircraft and guided weapons systems. **Decca** for radar equipment. **Smiths Industries** for marine radar.

The **British Export Marketing Advisory Committee** was set up in 1965 to formulate proposals for strengthening the marketing of British goods in America. In their recently published report it was pointed out that Japanese exports of radio receivers to the U.S.A. were worth nearly $111M whereas Britain's exports fell just short of $400,000. BEMAC feel that this is not due to the quality of British goods but because of lack of marketing expertise. The Japanese have studied and imitated the best in American marketing techniques and have recruited American salesmen and business experts, while Britain, with a few exceptions, has done none of these things.

The American Phantom F.111s and the Hawker Siddeley 801s to be supplied to the British Services will be equipped with the **Marconi** h.f. communication equipment type AD 470 which was originally designed for the TSR2. The AD 470 employs transistors throughout with the exception of the 1 kW output stage which is a ceramic tetrode valve. The output and drive stages together with the power supply are housed in a pressurized compartment and are cooled by circulating air through this compartment via a heat exchanger. A choice of 280,000, 112,000 or 28,000 channels is available depending on the channel spacing.

Ferranti have formed a new display device department that will be housed at Gem Mill, Chadderton, Lancs. The department will continue with the work previously carried out by the display section of the electronics department on machine/man communication equipment by developing not only individual components but complete display equipments based on these components. Work is already being carried out on cathode-ray tubes, gas discharge devices, red and green gallium phosphide lamps for film marking and visual use and gallium arsenide devices for use as infra-red emitters. Other responsibilities will include the production of high purity gallium arsenide for Gunn-effect and variable capacitance diode oscillators.

Orders totalling over £1M have been received by **EMI** for their **colour television equipment** since its unveiling a short time ago. The equipment, designed for European and American standards, uses solid state circuits and includes cameras, slide scanners, vision mixing and switching equipment, encoders, decoders, etc. EMI's latest camera, the type 2001, utilizes four lead-oxide vidicon tubes, one of which is used exclusively for the luminance content of the complex transmitted signal, this simplifies colour registration problems and provides a good quality luminance signal.

Micro Electronics Ltd., Hong Kong manufacturers of silicon planar devices, are moving into the U.K. market, their offices will be at Wembley, Middlesex. The company, which has specialized in the production of epoxy encapsulated transistors with an output now in excess of two million units per month, plans to enter the fields of integrated circuits and complex components.

An order from the East African Posts and Telecommunications Administration to install v.h.f. multi-channel equipment along a three hundred mile route has been received by **The Marconi Company**. The link, which is between Dodoma and Dar-es-Salaam in Tanzania, is part of a two-thousand-mile telephone loop which provides the trunk circuits between Kenya, Uganda and Tanzania. The new equipment will transmit and receive up to 96 telephone channels at the same time, or each channel may be sub-divided to form either eighteen or twenty-four telegraph channels.

Autonetics & Co., Chesterfield, Derbyshire, have been appointed sole U.K. agents of Matrix, Los Angeles, California. Matrix products consist of modular coaxial, twin-axial and tri-axial switches that can be supplied in any configuration from a 1×2 to a 1×20 matrix, these can be stacked to form any X-Y matrix. Another product in the range is a low-speed tape recorder (10in/min).

G.E.C. have succeeded in breaking into an American-dominated sector of the Canadian telecommunications market with an order for **P.C.M.** telephone equipment to be supplied to the New Brunswick Telephone Company. Although the order is small, G.E.C. feel that it is an important one in that the Canadians have chosen a British product in preference to at least four similar systems produced in North America.

The Communications division of **Redifon** has received an order from the G.P.O. for the supply and installation of equipment for a new high-power v.l.f. transmitter at Criggion, North Wales. The major part of the order is for a 500 kW v.l.f. amplifier using three vapour cooled P.A. stages that can be arranged to operate singly or in parallel driven by three multi-stage 5 kW amplifiers. The transmitter will normally operate on two frequencies in the band 16-19.6 kc/s that will be generated by frequency synthesisers employing a 100 kc/s reference source.

Texas Instruments Inc. are to produce a new line of sealed rechargeable nickel-cadmium batteries and power packs. The power sources, which are built to customers' specifications, consist of batteries, charging and control circuitry integrated into self contained units. The batteries are manufactured by a new process, developed by Texas Instruments, that results in a high cell-to-cell uniformity. Other power sources that are currently being developed and evaluated by Texas Instruments are fuel cells that produce power by an electrochemical process using hydrocarbons.

The Cambridge Instrument Company has acquired the whole of the share capital of **H. W. Sullivan Ltd.** A spokesman for the Cambridge Instrument Company said "this brings together two companies whose joint expertise in the design, manufacture and marketing of precision electrical instruments should prove a powerful unit in the industry." The Cambridge Instrument Company's scanning electron microscope, the Stereoscan, which received the Queen's Award to Industry, is at present capturing world markets against fierce competition. H. W. Sullivan which was founded in 1895, is best known for its precision calibration standards.

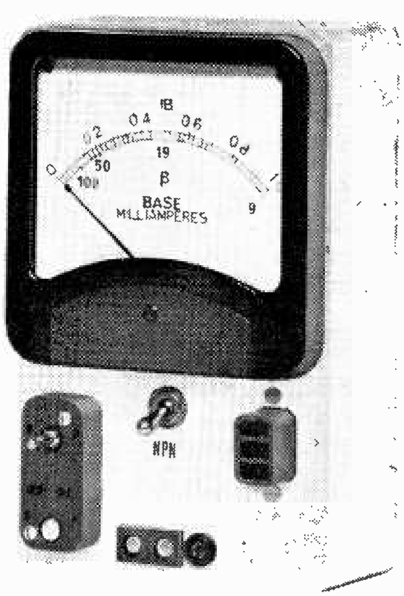
The English Electric Valve Company have acquired new factory premises at Benfleet, Essex, to cope with the growing demand for their cathode-ray and storage tubes. The new factory is only seventeen miles from their headquarters at Chelmsford.

Antiference Ltd., of Aylesbury, Bucks, are to market the crosshatch and dot generator manufactured by Video Circuits, of Barnet, Herts., which is described in the New Products section in this issue.

SIMPLE D.C. BETA TESTER

Using Constant Current Circuit for Testing all Types of Low-current Transistors

By G. WATSON*

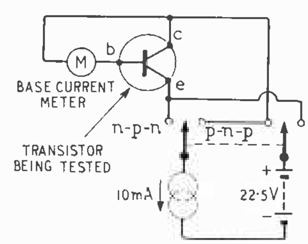


A quick and accurate check of the h_{FE} of a transistor is made at $I_E = 10$ mA and $V_{CE} \approx 2$ V. No adjustments are required other than setting a polarity switch. Both germanium and silicon transistors of either polarity can be measured. An incorrectly set polarity switch causes no damage.

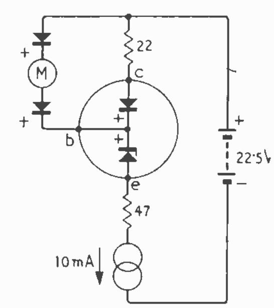
THE transistor under test has a precise 10 mA supplied to its emitter, and the resulting base current is measured by a meter connected between its base and collector (Fig. 1). The meter, a 1 mA d'Arsonval movement, is connected in a silicon bridge rectifier configuration so that it will always read forward for either polarity of base current. In addition to linear calibration in current, the meter has an h_{FE} calibration. This calibration has a range of from 9 (since with $I_B = 1$ mA, $h_{FE} + 1 = 10$) to 500 say, but the higher values of h_{FE} are severely cramped. For many applications the I_B necessary for a given emitter current is of more interest than h_{FE}, however, if a more linear h_{FE} calibration is required then a d'Arsonval movement with shaped pole pieces may be used. An improvement in the scale cramping of some 3 : 1 around the $h_{FE} = 100$ point should then be possible. The emitter current which is held constant for both temperature and voltage variations is produced from a 22.5 V battery inserted in series with a two-terminal constant current circuit.† Polarity of this current source is varied by a d.p.d.t. switch inserted after the series connection. No current can flow through the circuit unless a transistor is plugged in and therefore it is not necessary to have an on-off switch. When a transistor is plugged in, the V_{CE} is determined by the voltage drop in the meter circuit added to the V_{EB} offset; this voltage should normally lie between 1.5 V and 2.5 V. This figure is well above the saturation region of modern transistors at 10 mA of current and yet it does not represent an excessive dissipation likely to heat up the junction appreciably and so give false readings.

CONSTANT CURRENT CIRCUIT

This circuit is required to produce a constant current regardless of applied voltage and temperature variations with good long term stability. For the application in question, an overall figure of $\pm 1\%$ would be acceptable bearing in mind the expected accuracy of medium priced d'Arsonval movements. The circuit described (Fig. 3) is well able to meet a $\pm 0.25\%$ tolerance however. For this, the specification is 0 to 50°C and with a terminal voltage of 8 to 20 V. Initial setting of the current value is necessary, but this does permit an exact factor of ten to be had between meter f.s.d. and the 10 mA. The circuit employed compares the voltage drop across a Zener diode fed from a constant current, with a " potted down " version of this same Zener voltage added to the voltage drop across a current sampling resistor. This comparison is carried out in a long-tailed pair stage which drives the base of a transistor in series with the whole circuit. Any change of current through the whole circuit is seen as a change in the voltage drop across the sampling resistor and this unbalances the long-tailed pair which applies suitable correction to the series transistor. The primary causes of current change in this circuit are the finite value of h_{OE} and the temperature dependence of



Left: Fig. 1. Basic measuring circuit. Transistor current is held constant at 10 mA and base current measured.



Right: Fig. 2. Conditions obtaining when supply voltage is reversed (p-n-p transistor). Base-collector voltage drop plus drop across 22Ω resistor is not normally sufficient to overcome potential across the two silicon rectifiers in series with the meter. Provided transistor $V_{(BR)EBO}$ is high enough current though transistor will be inhibited.

* Formerly with the Marconi Company Ltd.

† See, for example, "Simple Constant Current Circuit" G. Watson, *Wireless World* August 1966 p. 403 (and ensuing correspondence).

h_{FE} in the series transistor. Temperature effects in the comparator stage are largely balanced out and the Zener diode is chosen to have a low temperature coefficient of voltage The balanced nature of the current drawn by the comparator long-tailed pair means that its contribution to the overall current does not vary. A small variation in the current flowing through this stage does occur owing to temperature variations in its common mode V_{BE} offset. This effect is small, but is allowed for by choosing a Zener diode with a small negative temperature coefficient; this also offsets the results of the rise of h_{FE} in the series transistor. The Zener current is 8 mA and the remaining current is made up of 1 mA for the potentiometer chain, needed to adjust the d.c. input levels to the comparator, and 1 mA for the comparator itself. Overall minimum voltage drop across the circuit is determined by the bottoming of the series transistor when the Zener voltage and sampling voltage drops are reached. A conservative figure of 7.5 V is necessary.

DESIGN DETAILS

The constant current circuit has two basic imperfections. These are first that the h_{OE} of the series transistor, and the h_{OB} of the comparator transistors are not infinite; secondly that the circuit is not self-starting. The finite value of h_{OE} in the series transistor, together with its h_{FE} variation with temperature are opposed by the loop gain of the circuit. The loop gain is about 35 with average transistors, and although it adequately opposes these variations it is advantageous to apply a little correction by injecting a small current proportional to the overall circuit voltage into Tr1 base by means of a resistor. This same resistor also makes the circuit self-starting if it is returned to the base of the series transistor instead of to its emitter, as there is then a small initial current available to this transistor to allow it to bring the rest of the circuit into conduction. Plastic-encapsulated

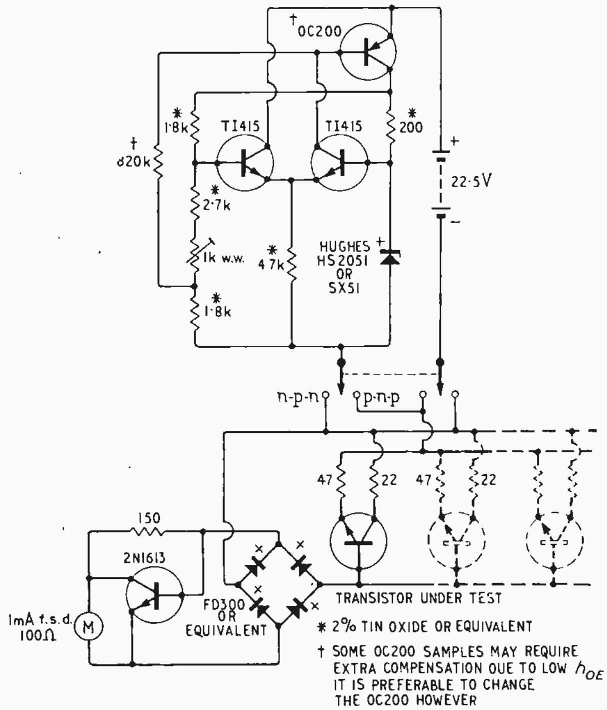


Fig. 3. Circuit of complete d.c. β tester.

transistors are used for the comparator stage since they are very cheap, reliable enough and provide adequate gain for this application. The series transistor was also selected because of its low cost. A few samples of these transistors show a rather low h_{OE} and require a different value for the compensator resistor. Other types may, of course, be used if the requirements of $V_{CEO} = 20$ V and h_{FE} of from 20 to 50 say, are fulfilled. The a.c. loop stability of the circuit is more than adequate using the quoted transistor types, but if a v.h.f. p-n-p transistor is used it would be advisable to apply a large capacitor between its base and emitter to form a major frequency determining time-constant in the loop.

Stopper resistors as used with tube circuits are wired directly to each transistor connector. These are included to avoid the possibility of parasitic oscillation due to coupling between connecting leads, when v.h.f. transistors are being tested. A 22 Ω resistor is included in each collector, and a 47 Ω resistor in each emitter lead. These have no effect on circuit operation; the 22 Ω collector resistor merely subtracts a small constant voltage drop from the V_{CE} supply to the transistor.

Meter circuit. The meter circuit has three functions. First, it ensures that the meter always gives a forward reading for either polarity of base current. Secondly, it provides a fair portion of the V_{CE} voltage applied to the transistor. This voltage as previously stated varies between some 1.5 V for a high-gain germanium type, to about 2.5 V for a low-gain silicon transistor. This variation is mainly due to the varying forward drop of the diodes in the bridge rectifier with varying base current requirements. The final function of the meter circuit is that of protecting the meter from the full 10 mA which would flow if the collector connection were not made during a test. This protection is achieved by having a 150 Ω resistor in series with the 100 Ω of the meter, and driving the base of a silicon transistor from this series combination. The emitter and collector of the transistor are connected across the movement. When the current flowing into the meter circuit exceeds some 2.5 mA, the V_{BE} potential barrier of the transistor is overcome, and the resulting collector to emitter conduction effectively shunts the meter so that it does not in fact even read full scale. The protection circuit has no effect on normal meter readings. Since the reverse leakage of the bridge rectifiers is extremely low it follows that all the base current flows into the meter.

Construction. The unit is constructed in a standard die-cast box of 7.5 × 4.5 × 2.0 in and is furnished with suitable rubber pads underneath. Bases for TO-18, TO-5, and TO-3 transistor configurations are fitted, together with a connector for transistors with long leads, and three binding posts. Otherwise the panel has only the d'Arsonval movement and the d.p.d.t. polarity switch. The 22.5 V battery is mounted inside the box, as its life can be expected to be at least a year.

PERFORMANCE

Once the emitter current has been set up, it requires no further attention. Operation is confined to plugging in the transistor and setting the polarity switch. Should the switch be set incorrectly there will be no meter reading, but no damage results to either the transistor or the tester. The equivalent circuit of a transistor driven with incorrect polarity is shown in Fig. 3. The transistor behaves as a series combination of a forward conducting diode, i.e. the base-collector junction, plus a Zener diode whose Zener voltage is equal to the transistors BV_{EBO}. The amount of current flowing through the transistor depends on the relative values of BV_{EBO} and the battery voltage; it will in any case be 10 mA for a BV_{EBO} of less than 13 V. The meter measures the voltage drop across the forward-biased junction plus 220 mV due to the stopper resistor, but it is hampered by having to overcome the hold-off potential of the rectifier diodes in series with it. Unless the base-to-collector voltage drop is excessive, there will be no meter reading. Modern transistors are able to withstand a reverse base current of 10 mA without mishap.

Correct circuit operation is possible until the battery voltage falls below about 11 V under load. No test facility has been included in the prototype as it is sufficient to connect a 10 mA meter between the base and emitter test terminals to check circuit operation. It is possible to add the facility of checking transistors at a higher current, say 100 mA, by switching in a suitable circuit and shunting the meter itself. A larger capacity battery would be called for and the 100 mA condition should be obtainable on a press-button only in order to avoid possible damage to low power devices inadvertently. Measurements at $V_{CE} \approx 10$ V could also be included on this present device by inserting a good quality 8.2 V Zener diode in series with the base supply lead.

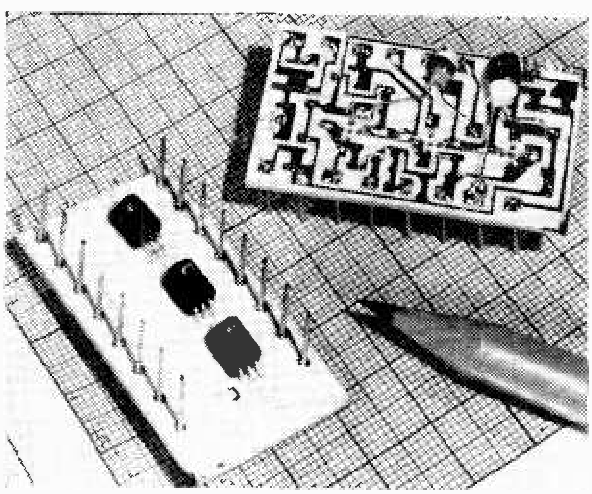
A rough check on collector-to-base leakage current at 22 V is possible by connecting the transistor's base and collector wires to the tester's emitter and base binding posts; the full scale reading is of course 1 mA.

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

Thick Film Circuit Production

THICK film circuits are being increasingly produced now by a number of companies both in this country and in the U.S.A. Some of the U.K. firms engaged in the production of thick film circuits are Welwyn Electric, A.B. Metal Products, Centralab and now S.T.C. It has been estimated (by S.T.C.) that by 1971-2 the U.K. market for thick film circuits will be approaching £4M. (For comparison the same source suggests that the thin film market will be worth over £4M, films being expected to represent a third of the microelectronics market at that time.) U.K. film circuit capability is second only to the U.S.A. and it is felt that the U.K. could gain over half of the European market, expected by S.T.C. to be worth more than £15M in four years.

U.K. production of thick film circuits has recently been augmented by S.T.C's Paignton factory going into production with an initial target of 500 000 units a year, this being expected to grow to 6 000 000 by 1972.



Thick film circuits with added transistors and miniature tantalum electrolytic capacitors. Transistors are S.T.C's new plastic encapsulated types. Semiconductor integrated circuits can also be attached to the substrates by the inversion technique.

The great advantage of thick film circuits is, of course, that vacuum deposition or evaporation techniques are not required and for quantities of passive components above 5 000, thick film construction offers the cheapest method of production for tolerance ranges of ±1% and ±10-20% for resistors and ±20% for capacitors (excluding electrolytics, of course). Generally speaking resistor values of from 50 Ω to 500 kΩ and capacitor values of 20 pF-10 nF can be economically fabricated, but absolute maximum values of 6.7 MΩ and 35 nF are imposed.

The method of manufacture of thick films is basically that of screen printing special inks onto a ceramic substrate, and then hardening, soldering and glazing. Initially, the film circuit designer prepares a layout drawing ten times normal size, the exact form depending on component values, tolerance and dissipation, since these govern the choice of resistive material used. From the layout plastic photographic masters of the resistor, connection, capacitor electrode, capacitor dielectric and glaze patterns are produced to an accuracy of ±0.001 in. These patterns are photographically reduced by a factor of 10 and used in a screen-making process. Ink is forced through the screens on to alumina substrates. The order of screening on to the substrate is naturally governed by the required firing temperature. This is 500, 750 and 900°C for glaze, resistors and conductors respectively. Most of the components so produced will be within ±10% or 15% at this stage. Closer tolerances are achieved in an automatic process by abrading the film with alumina powder, carried in a jet of air. The conductor regions are then solder coated, discrete components or s.i.cs added and the film components glazed. If necessary the circuit may be resin encapsulated.

Typical resistor materials are based on a palladium-silver metal powder mixed with a lead glass powder and dispersed in a liquid carrier. For conductors the ink is based on platinum and silver or gold. Capacitor material depends on application: decoupling or less critical capacitors use a barium titanate dielectric whereas those for h.f. application use titanium dioxide.

London Radio & Electronic

THE biennial British Radio and Electronic Component Show opens at Olympia on Tuesday, May 23rd, for four days. Looking through the advance information received from some of the 300 exhibitors one might well ask "What is a component?" for the exhibits will vary from sub-miniature piece parts used in component manufacture, through integrated circuits and a wide variety of discrete components, to sophisticated instruments.

With such a diversity of techniques as that to be displayed it is impossible to survey trends exemplified at the show except in a very general and rather unsatisfactory manner. We propose therefore in our next issue to review instead of a selection of the new products seen at the Show.

Although primarily a trade show (complimentary tickets are issued by most of the exhibitors) the public will be admitted and there will be much on view to interest both the professional and non-professional reader of *Wireless World.* Admission costs 5s.

The exhibition, sponsored by the Radio and Electronic Component Manufacturers' Federation, will be open each day from 10.00 to 18.00.

LIST OF THE EXHIBITORS AND PLAN OF THE EXHIBITION

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A.B. Metal Products	168
A.D.S. Relays	400
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A.P.T. Electronic Industries	407
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Allen Taylor Transformers	203
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Beckman Instruments	474
Bedco	507
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Belling & Lee	308
Berec International	279
Bonnella & Son	405
Bradley, G. & E.	320
Brandauer & Co.	57
British Electric Resistance Co.	213
British Insulated Callender's Cables	309
British Physical Laboratories	150
Brush Clevite Co.	315
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Cambion Electronic Products	109
Cannon Electric	278
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Computor Interfaces	477
Concordia Electric Wire & Cable Co.	100
Connollys (Blackley)	495
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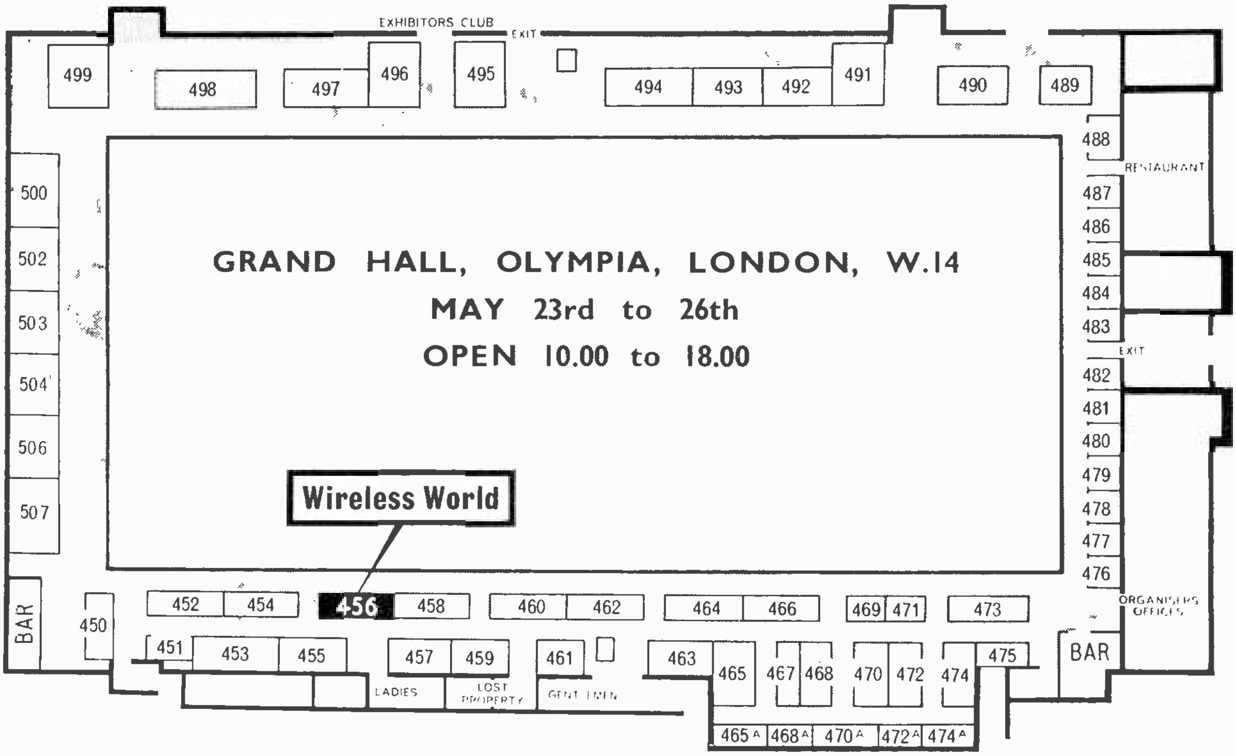
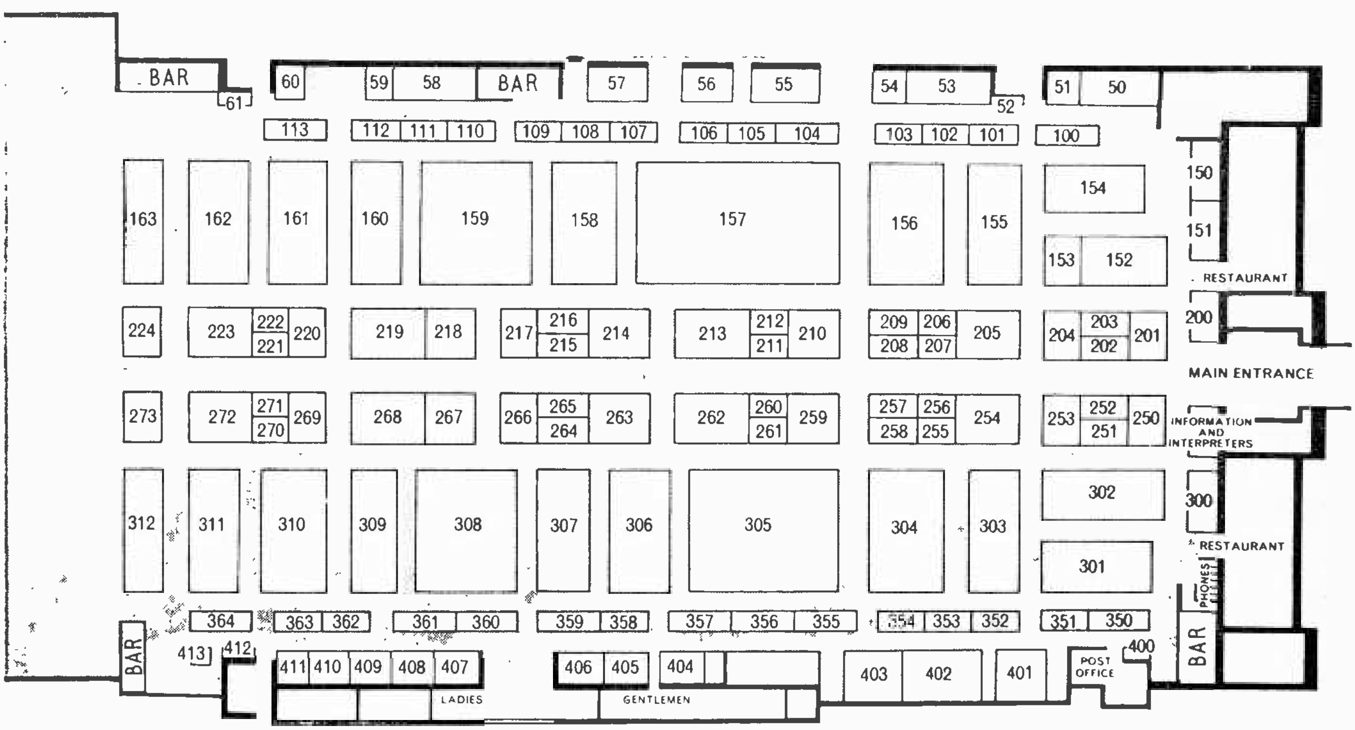
Component Show





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WORLD OF AMATEUR RADIO

European OSCAR Satellite

DESIGNED and constructed by a German radio amateur, Karl Meinzer (DJ4JC), a European satellite carrying amateur radio equipment is now in the hands of the OSCAR Association, California, where it is being prepared for launching from a United States space vehicle. The EUROSCAR Project has been sponsored by the International Amateur Radio Union, Region I Division, who together with member societies and individual amateurs have financed the construction of the satellite. The two-metre transponder is powered by a 26 V non-rechargeable silver-zinc battery supplying enough power for approximately eight weeks' operation. The transponder will relay signals from 144.1 Mc/s ± 40 kc/s to 145.9 Mc/s ± 40 kc/s with inverted side bands, e.g. 144.14 Mc/s will appear at 145.86 Mc/s. The peak envelope power will be one watt and a 2.5 metre-long Yagi aerial will be used. All modes of transmission including c.w., s.s.b., a.m., f.s.k. and a.f.s.k. can be relayed via the transponder. The receiver sensitivity has been designed particularly with the legal power restrictions as they apply to European amateurs in mind. The transponder was balloon-tested from Hanover, Germany, before being sent to the United States. When the European amateur radio satellite is successfully launched it will be the fourth in the OSCAR (Orbiting Satellite Carrying Amateur Radio) series, the first three having been constructed in the United States. Contacts up to 8000 km should be possible with good signal-to-noise ratios.

Has the Peak Passed?—While the world total of amateur transmitting licences at the end of 1966 showed an increase over the previous year, the United States Federal Communications Commission recorded 10,000 fewer licensed amateurs at that date compared with the 1965 figure of some 260,000. In reporting this fact the A.R.R.L. speculated whether the fall-off was accentuated by the reluctance on the part of many amateurs, long inactive, to pay $4.00 for the renewal of their licence. Until recently no charge was made in the United States for an amateur transmitting licence.

More E-M-E Successes on 420 Mc/s.—During the weekend April 15th/16th successful earth-moon-earth contacts were made on 420 Mc/s between the American station W2IMU/2 and stations in England (G3LTF) and Switzerland (HB9RG). The E-M-E path distance was almost half a million miles.

Aurora Back-scatter Reports Required.—Under the auspices of the Max-Planck Institute for Ionosphere Research, two v.h.f. beacons with aerials beamed on the north-west auroral region are being established, one in Schleswig-Holstein, Northern Germany, and the other near Falun, 100 miles north-west of Stockholm, Sweden. Calls to be used are, respectively, DL0PR (the letters PR signifying polar reflection) and SM4MPI (the letters MPI signifying Max-Planck Institute). The German beacon will operate on 145.971 Mc/s and the Swedish beacon on 145.960 Mc/s. Call signs will be sent once a minute from 175 W transmitters operating into aerials with a gain of 13 dB. Reports of aurora back-scatter reception of either beacon should be sent to Dr. G. Lange-Hess (DJ2BC), Max-Planck Institute, 3411, Lindau, West Germany.

Knokke Convention.—For the last two years Belgium radio amateurs, resident in and around the coast towns of Knokke and Ostende, have organized an International Convention which has attracted wide support from all parts of Europe. The 1967 event, to be held at the Casino, Knokke, during the weekend September 17th-18th, will feature an International Mobile Rally starting from London, Paris, Brussels, Amsterdam, Bonn, Geneva and other European centres. Mr. Lucien Vervacke (ON4LV), Lippenslaan 284, Knokke 1, secretary of the organizing committee, will provide full details on request. The event is being officially supported by the Belgium national society (U.B.A.).

A.R.M.S. Rally at R.A.F. Alconbury.—Most important outdoor event in the calendar of the Amateur Radio Mobile Society is the Annual Mobile Rally which this year is to be held on Sunday, June 18th, at R.A.F. Alconbury, a U.S.A.F. operational base near Huntingdon. Prominent feature of the event will be a trade show sponsored by more than 100 firms in the industry, many of whom will be displaying material shown at the R.E.C.M.F. Exhibition. The Exhibition will open at 1000, close at 1800 and admission will be free. Amateur radio talk-in stations will be operating throughout the day on several bands.

Muscular Dystrophy Patients will Benefit.—All profits from the Hamfest and Mobile Rally to be held on Sunday, June 11th, at Mote House, Mote Park, Maidstone, Kent, from 12.00 to 20.00 are to be donated to the Home for Muscular Dystrophy Patients. Talk-in stations will be operating from 10.30 on 2, 4 and 160 metres.

JOHN CLARRICOATS, G6CL.

Transistor Curve Tracing

By G. B. CLAYTON* B.Sc., A.Inst.P.

TRANSISTORS of the same type often have characteristics which are not identical and which do not agree precisely with the manufacturers' published characteristics, and circuits are normally designed to permit such variations. However, it is sometimes necessary to know the characteristics of a particular transistor with fair precision or to match the characteristics of two transistors. Then, it is advantageous to be able to obtain a set of transistor curves. The direct method of point by point determination with the aid of ammeters and voltmeters is simple though tedious, and it is far more convenient if an oscilloscope display is easily obtainable. It is doubtful if a commercial curve tracer is economically justifiable unless many displays are required, but it is well worth while constructing some simple permanent arrangement for displaying frequently used characteristics.

The principle of operation of a curve plotter is illustrated in Fig. 1. A p-n-p transistor is shown under test; half cycles of an alternating voltage rectified by diode D provide a negative sweep of the collector voltage, and are used to produce the horizontal deflection of the oscilloscope. A voltage proportional to the collector current appears across the resistor R, and this is used to produce the vertical deflection. Base current for the transistor is supplied through the series resistor R_2, and the value of this resistor should be sufficiently large to ensure that negligible change in base current takes place during the collector voltage sweep. A series of curves are displayed using different values of base current selected by the switch.

A simple, inexpensive, practical arrangement based on the above principle is seen in Fig. 2. A variable amplitude collector voltage sweep is obtained from the 50 cycle mains supply using a simple transformer (the choice of transformer is in no way critical, and in the original unit a Radiospares 12 V filament transformer was used) and potentiometer arrangement. A variable transformer would be preferable for this purpose, but would be more expensive. A reversing switch on the diode selects either a negative or positive sweep enabling both p-n-p and n-p-n transistors to be tested. A collector load resistor selected by switch S_1 is used to ensure that the maximum allowable collector power dissipation of the transistor under test is not exceeded. The magnitude of the base current increments is determined by the resistor in series with the base supply, and this resistor is selected by switch S_2. In one position of this switch no series resistor is in circuit, this position of the switch is used when the characteristics of field effect transistors are being displayed. Manual switching between curves is achieved by S_3 (the added complexity of electronic stepping of base current increments was not considered worth while in view of the fact that the unit was not to be in continual use). The base current is derived from an external, low voltage d.c. supply producing a negative base for p-n-p transistors, and a negative base for p-n-p transistors. A 10 V supply gives 0.02 mA increments of base current with the 100 kΩ series resistor in circuit. Two sets of transistor terminals are provided, with switch S_1 selecting a particular transistor and thus enabling the characteristics of two transistors to be rapidly compared or matched.

The oscilloscope used for display purposes should have d.c. coupled horizontal and vertical amplifiers. Calibration of the display is obtained directly from the calibrated gain setting of these amplifiers. Vertical deflection is produced by the collector current flowing through a 100 Ω resistor, thus with the oscilloscope ver-

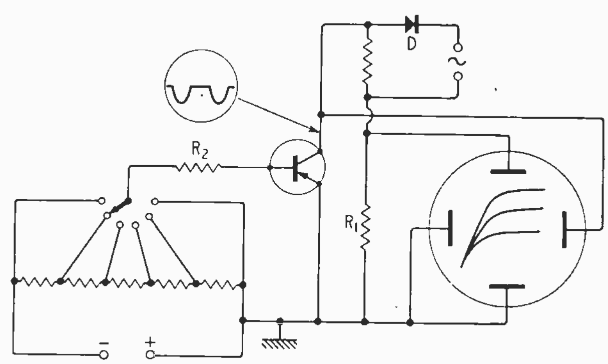
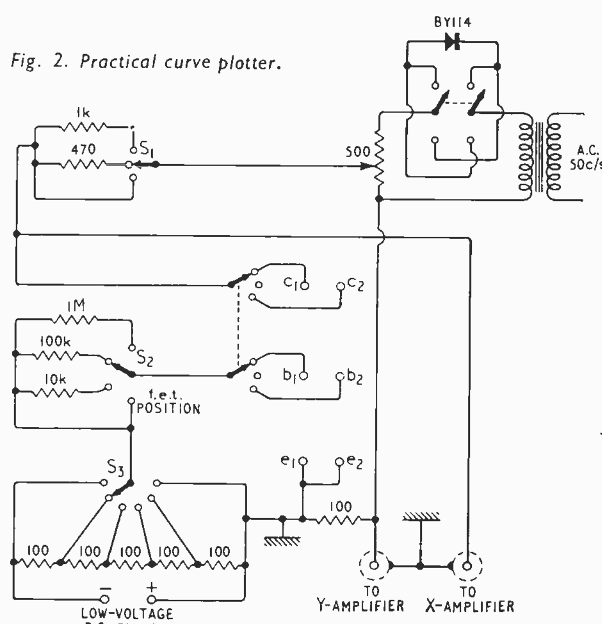


Fig. 1. Principle of curve plotter.

Fig. 2. Practical curve plotter.



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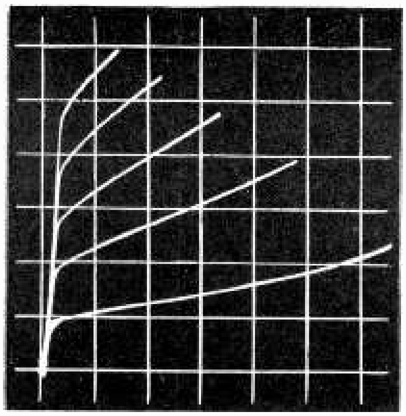


Fig. 3. Characteristics of 2N 1307
Vertical 1 cm – 2.5 mA
Horizontal 1 cm 2V
Base current increments 0.02 mA

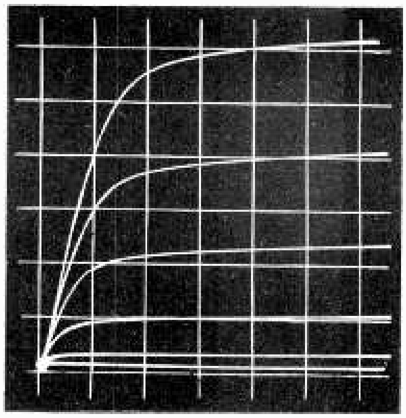


Fig. 4. Characteristics of f.e.t. 2N 2386
Vertical 1 cm – 1 mA
Horizontal 1 cm = 2V

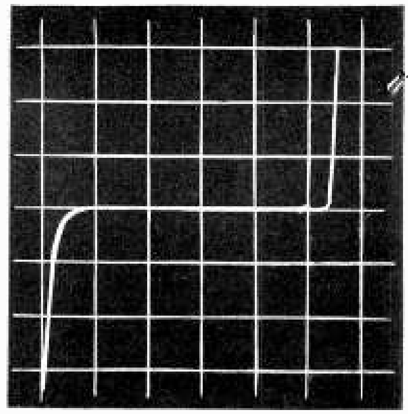


Fig. 5. Characteristics of silicon Zener diodes
Vertical 1 cm = 2.5 mA
Horizontal 1 cm — 1V

tical amplifier gain set at say 0.1 V/cm, the vertical current scale of the displayed characteristics would be 1 mA/cm. If the horizontal amplifier is not calibrated, a preliminary measurement of the amplitude of the collector voltage sweep made by displaying it on the vertical channel enables the calibration of the horizontal axis of the displayed characteristics to be subsequently deduced. An example of the type of display obtained with the unit is shown in Fig. 3, where a set of common emitter characteristics for a p-n-p transistor type 2N1307 are displayed.

The characteristics of field effect transistors are quite easily obtained with the unit; common source characteristics for the junction gate f.e.t. type 2N2386 being shown in Fig. 4. Field effect transistors are connected to the unit with source to the terminal provided for the emitter, gate to the terminal provided for the base, and drain to the terminal provided for the collector. The polarity of the drain voltage sweep used depends on the type of device. A negative sweep is required for p channel devices and a positive sweep for n channel devices. The gate electrode has a high input resistance and no resistor is required in series with the gate voltage supply. The polarity of this gate voltage supply is dependent on the type of f.e.t. being tested. Depletion type p channel devices require a positive gate supply and n channel devices require a negative gate supply. Enhancement type devices require opposite gate voltage polarity.

Diode characteristics are readily obtainable with the unit. The diode to be tested is connected to the terminals provided for emitter and collector, switching the polarity of the voltage sweep causes both forward and reverse characteristics to be displayed. Fig. 5 shows the forward and reverse characteristics of a zener diode obtained with the unit.

Books Received

Circuits for Digital Equipment by C. J. Dakin and C. E. G. Cooke, describes rather than gives a detailed explanation of the behaviour of the various electronic equipments associated with digital techniques. Introductory chapters discuss pulse generation and amplification together with the switching characteristics of transistors and diodes. In the section describing logical circuits the use of the tunnel diode as a high speed logical element is examined. Successive chapters cover the various forms of storage that may be encountered with their attendant reading, writing and addressing circuits. A topic often omitted from books such as this is the problem of binary indication but in this volume a chapter is devoted to the subject. The final chapter deals with the problems of achieving reliability in large digital systems. Pp. 433. Price 105s. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1.

Transistors for Audiofrequency, by G. Fontaine (from the Philips Technical Library available in German, French, Spanish and Dutch). The operation of transistors is described in some detail, the text being augmented by tricolour illustrations that bring their point home with remarkable clarity. A full account is given of the behaviour of transistors in the various types of audio-frequency amplifier while working under both large and small signal conditions. This book should be of value to both the student and the engineer. Two further books, intended as sequels to this work, are at present under active preparation, these being Transistors for Radiofrequency and Transistors for Pulse Techniques. Pp. 382. Price 68s. Macmillan & Co. Ltd., Little Essex Street, London, W.C.2.

Pal Colour TV, prepared by Central Technical Services, Mullard Ltd. This book, which describes the PAL system and Mullard circuits, was originally intended for television set manufacturers, however, because of the wide topical interest in colour television, Mullard have now made it available to the general public after adding a section on theory of the PAL system. A complete hybrid 25in dual standard colour television receiver is described in detail, a chapter being devoted to each section of the receiver. Although all the circuits are included and fully described Mullard wish to stress that the information given is not intended to be enough to enable the reader to construct a television set. Also some of the components used are not at the present available on the retail market. However, for those wishing to obtain a knowledge of colour television techniques the book should prove most useful. Pp. 100. Price 12/6. Home Trade Sales Division, Mullard Ltd., Mullard House, Torrington Place, W.C.1.

LETTERS TO THE EDITOR

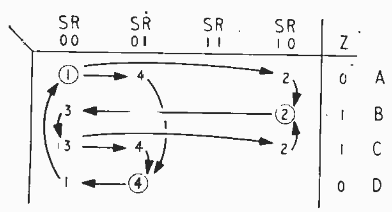
The Editor does not necessarily endorse the opinions expressed by his correspondents

"Sequential Logic Design"—Some Omissions

THE article in your May issue on "Sequential Logic Design," by Mr. H. R. Henly, could, I think, be misleading in a number of respects.

First, the output is said to be a function of the previous "state" as well as of the present inputs. This should, of course, be "states." The Memory is not necessarily limited to the state immediately previous, though naturally the longer the memory the more complex the logic.

Secondly, a properly constructed primitive flow table will not have two stable states with the same number as in the author's Fig. 3. There are two steps in simplifying the primitive flow table, the first is the identification of equivalent states, and the second the merging of rows. If it had not been obvious that the state labelled (1) in row E is equivalent to the state labelled (1) in row A it would have been labelled (5). It would then have been necessary to examine whether states (1) and (5) are equivalent. For states to be equivalent it is necessary not only that they should have the same inputs and outputs, but that they should respond in the same way to every sequence of inputs which might follow. Here this is clearly the case, and so one draws up the flow table as shown below (the arrows are, of course, normally omitted).



Primitive flow table for S-R (set-reset) bistable redrawn by the Rev. K. S. Hall.

Now follows the merging of the rows AD, and BC.

Finally the sequence diagram is not a necessary preliminary to drawing up the flow table. In more complex cases no sequence diagram can be drawn, but the flow table can always be drawn up directly from the verbal specification.

K. S. Hall

The City University,
London, E.C.1.

Reference:—S. H. Caldwell, "Switching Circuit and Logical Design" (Wiley) Ch. 12.

The author replies:

I AM grateful to the Rev. K. S. Hall for drawing attention to certain omissions in my recent article. Unfortunately in an article of this nature it is difficult to decide where to introduce simplifying assumptions in order to keep it to a reasonable length.

Referring to his first point; the state of a circuit at any time is a direct function of its last state and indirectly a function of its history prior to that; i.e., referring to Fig. 1 of my article, the inputs to the combinational logic which determine the next state are the input variables and feedback circuits whose individual states define the present state. There are no terms present which explicitly represent any previous states of the circuit. I therefore feel that my original statement suffices.

As far as the flow diagram is concerned, I agree that its usefulness decreases with the complexity of the problem. I would, however, advocate its use wherever possible since it is often very useful as a means of organizing one's thoughts.

H. R. Henly

Brighton, Sussex.

Constant Current Circuits

MR. PASCH ("Letters," May) has rightly pinpointed a deficiency in much conventional regulator design. Those fortunate people with unlimited mains-derived voltages cannot know the agony of battery-circuit designers scratching around to save the last few precious millivolts.

The variation proposed by Mr. Pasch is admirable as a high efficiency basic reference circuit, but does suffer from a disadvantage where high stability is required in that the Zener current is linearity dependent on the d.c. current gain of Tr2 (Fig. 3, p. 229). This circuit can also be considered as a particular case of the more general form of Fig. A with $R_2=\infty$; $R_3=0$. If the current in R_2 is much greater than the base current of Tr2 then the dependence of Zener diode current on transistor gain is greatly reduced. Change in V_{be}, particularly with temperature, becomes the significant source of drift. This can be controlled by keeping the voltage across R_2 appreciably greater than the V_{be} of Tr2. Any desired compromise can then be achieved between stability of Zener current and efficiency. An alternative approach to the problem of low supply voltages is to design reference circuits using components other than low drift Zener diodes. Such a circuit is the subject of an article to be published in a later issue.

One quibble with Mr. Pasch's comments—it is not necessarily true that high values of *R* result in better stabilization. With many Zener diodes, including those

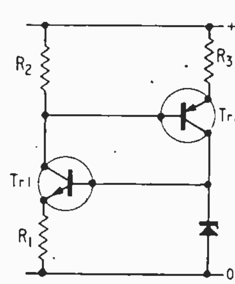


Fig. A. The circuit to which Mr. Williams refers.

breaking down around 6V, the slope resistance increases rapidly with falling current, largely nullifying the effect of an increased drive resistance. Should the slope resistance be inversely proportional to the current, then, to a first order at least, the stability factor of the circuit will only depend on the ratio of supply and breakdown voltages.

PETER WILLIAMS

Paisley College of Technology,
Renfrewshire.

Polarization and Local Broadcasting

IN the May issue Mr. R. S. Roberts proposed that vertical polarization be used for the new f.m. local sound broadcasting service on the grounds that (a) it would provide a better service to receivers in cars, and (b) it might enable existing local channels to be used again in the same area, if orthogonally polarized.

Simple rod type aerials, as used on cars and portable receivers, provide very little polarization protection particularly when used in congested surroundings. The practical improvement in service by using vertical polarization for local stations would therefore be small. Indeed, those listeners using fixed horizontal outside aerials, having good orthogonal polarization discrimination, would be penalized if the polarization of the new service differed from that now available in the area.

It is suggested that some 10-12 dB polarization protection together with "capture effect" would adequately separate two co-channel transmissions. Unfortunately the protection ratio necessary for satisfactory f.m. broadcast reception greatly exceeds the discrimination provided, even by carefully sited outdoor aerials, against orthogonally polarized signals of equal field strength.

R. A. DILWORTH

P.O. Engineering Dept.,
London, E.C.1.

Electronic Organs

I SHOULD like to take up one or two points from Mr. Douglas's letter in the April issue commenting on my article (Feb. 1967).

First, the omission of organs using magnetic and electric tone generators was deliberate, as I feel they cannot be regarded as true electronic organs since their only use of electronics is in the final amplifier, and I was concerned with what might be called "pure" electronic instruments.

With regard to complex wave oscillators I am still doubtful whether they can equal the stability of, say, a common-base Hartley or Colpitts circuit, operating in the pure sine mode, which can tolerate a voltage variation of at least 12% and a temperature change of up to 15°C without the frequency changing by more than one cycle in 1,000. Incidentally the most popular instrument of the Miller Co. uses dividers and not free phase generators.

Concerning wind noise, I have read Mr. Douglas's interesting article on "chiff" circuits (*Electronic Engineering*, Nov. 1963), and undoubtedly this is the ideal, albeit rather costly. I was, however, only proposing to modulate the main oscillators to produce the tonal effect of wind variation and not to introduce wind noise as such. The desired effect can also be produced by playing the twelve top octave notes from endless tapes, using the combined natural wow of player and recorder. This also is expensive and I was suggesting a cheaper compromise.

Since writing my article I have been able to investigate transistor keying and I agree that it is possible to key a sawtooth, with independently variable attack and decay rates, without any distortion; moreover this can be done using a very cheap simple divider circuit.

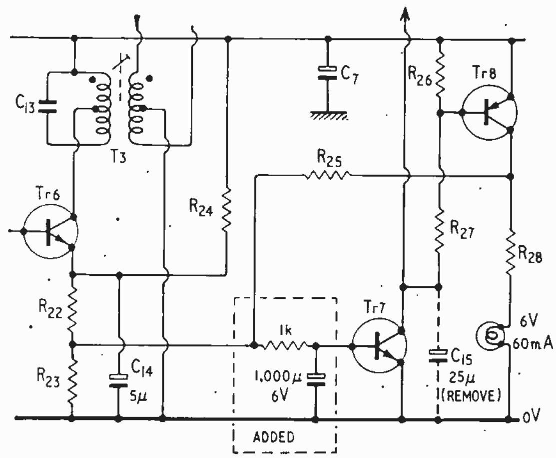
In conclusion and perhaps in answer to Mr. Douglas's charge of being less than just, may I remark that nearly all the faults I discussed have been observed from life in a commercial church-type instrument of reputation, which cost the better part of £1,000.

J. W. MACHIN

Stoke-on-Trent,
Staffs.

"Stereo Decoder"—A Modification

I HAVE been led, by queries received from readers who have built the stereo decoder I described in the January, 1967, issue, to devise a method of preventing a stray 19 kc/s transient, during the reception of a "mono" signal, from switching the decoding circuitry on. This is achieved by inserting a time constant of about one



The additions to the original circuit are shown boxed and the capacitor to be removed is dotted.

second in the feed to the base of Tr7 as shown in the diagram. This does not affect the performance with stereo reception but it does permit the signal input to the decoder to be increased by at least 12 dB without any fear of mono signals being marred by transients.

DAMER E. O'N. WADDINGTON

St. Albans,
Herts.

A Dis-ztreh-sing Business

THE answer to Mr. K. Smith's problem of what to do about frequencies of less than 1 Hz (see May, p. 228) is that a frequency of, say, one cycle in 1,000 seconds could be described as 1 milli-hertz (mHz). Similarly the rest of the normal decimal terms like pico and nano can be used. This is much neater and more consistent than the current usage although I admit I would be surprised to find gramophone records being described as 750 mHz 18 cm singles.

R. A. DERRY

London, W.10.

Simple Audio Indicator

Circuit described uses complementary multivibrators to produce a modulated pulse train. A novel method of producing printed circuits is briefly described.

By P. St. J. R. FRENCH, B.Sc.

THERE are many applications for an audio indicating device that can give a more attracting indication than an electro-mechanical or visual one, particularly if it can produce a strong note from a small transducer in a compact package. Experiments have produced this simple circuit which produces a cheerful yet commanding tone for use as a door bell or, for these days of high-speed motorway cruising, it can save that dreadful sensation on discovering that one has motored just too long at 70 mile/h with no oil pressure in the engine. A continuous sounding note in a noisy environment is very easily ascribed to some other source of sound unless its amplitude is much greater than any other sound and is only really noticeable at the instants of its commencement and cessation, because of human sensitivity to change of environmental conditions. If the note is made to fluctuate, it becomes instantly distinctive and can be identified even if its amplitude is lower than other circumfusing sources. The device therefore uses two oscillators, one to produce the tone and the other to produce low-frequency modulation.

BASIC CIRCUIT

Consider the circuit of Fig. 1, neglecting for the moment the base-emitter voltage of Tr2 (i.e. assuming this to be zero while the transistor conducts), and suppose that a variable test voltage be applied at the emitter of Tr2 which is decreasing from a high positive value so that at first Tr1 and Tr2 are both cut off. Tr2 remains off until the voltage has decreased to the base potential set by R_2, R_6 and R_7 (v_1) when it begins to conduct. Regenerative action then occurs through R_2 and both transistors bottom. If now the test voltage is increased again, the pair remain bottomed until the voltage reaches the new level determined by R_2, R_6 and R_7, after the change of voltage across R_2 (v_2), when they switch off. Thus the circuit has a triggering characteristic with a definite differential band. If the test voltage is varied in sympathy with the collector voltage of Tr1, but with a lag as provided by R_3 and C_1, the circuit will oscillate continuously to give the waveforms of Fig. 2. An important property

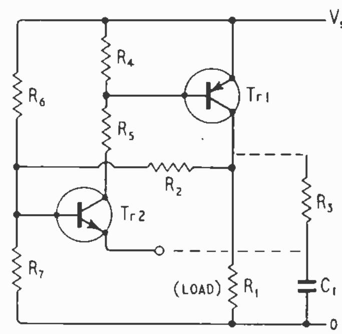


Fig. 1. Basic circuit of complementary astable multivibrator using single timing capacitor.

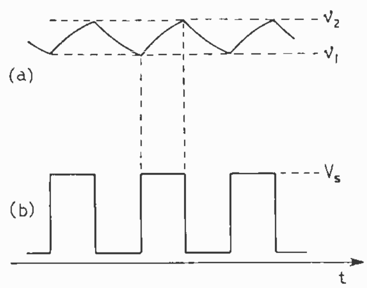


Fig. 2. (a) Voltage across C_1 (b) Voltage across load (R_1).

of this type of circuit is that no matter what the circuit conditions are at the moment of switch-on, the capacitor will always charge toward the correct switching level and the circuit will always begin to oscillate without the assistance of starting devices. In practice the current in C_1 is controlled solely by R_3 during discharge but during the charging half-cycle it is controlled by R_5 as well as R_3 and is also affected by R_6 and R_7. Allowance must be made for this in design to obtain the required mark to space ratio. The frequency of oscillation is principally controlled by the charging time of C_1 and coarse frequency control is made by selection of this component. Fine adjustment of frequency is given by changing the width of the differential band by small variations of R_2—Fig. 3 (a).

The mark to space ratio of the oscillator may be changed by variation of the average operating level of the base of Tr2 and so changing the relative charging and

P. St. J. R. French is a senior development engineer with Lancashire Dynamo and Electronic Products Ltd., at Rugeley, Staffs., which he joined in 1961 after studying for his degree at the Polytechnic, Regent St., London.

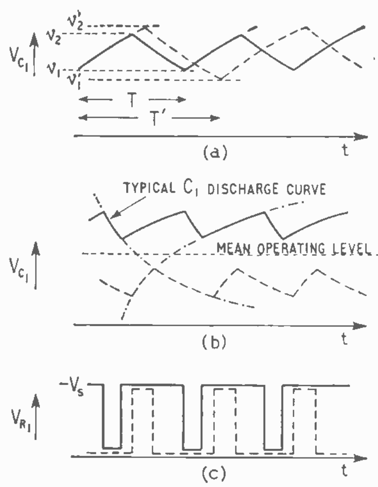


Fig. 3. (a) Variation of period with change of switching levels. (b) Waveform across C_1 resulting from displacement of operating level of Tr2 base. (c) Change in mark to space ratio corresponding to waveform shown at (b).

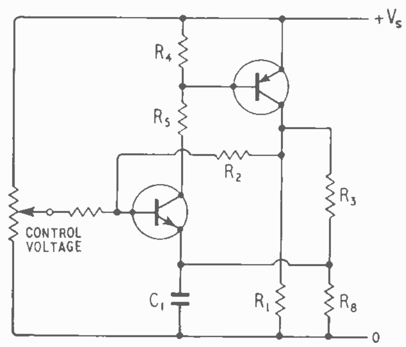


Fig. 4. Oscillator circuit arranged to give variable mark to space ratio.

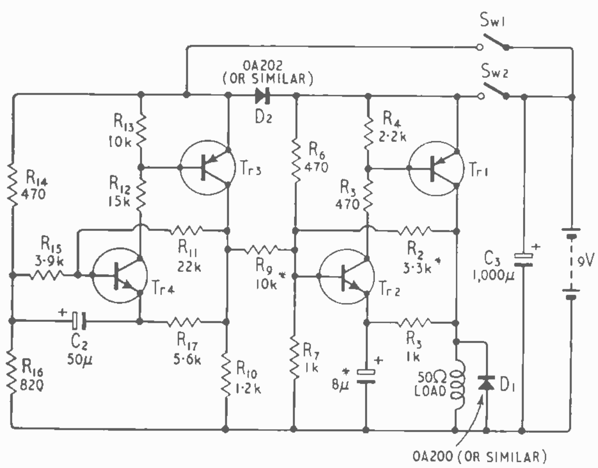


Fig. 5. Complete circuit of audible indicator. Closing Sw2 causes the tone generator to sound without modulation.

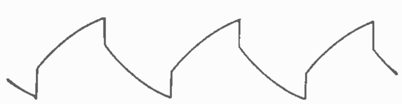


Fig. 6. Waveform of Fig. 2 (a) modified by use of poor quality electrolytic capacitor with high series resistance for C_1.

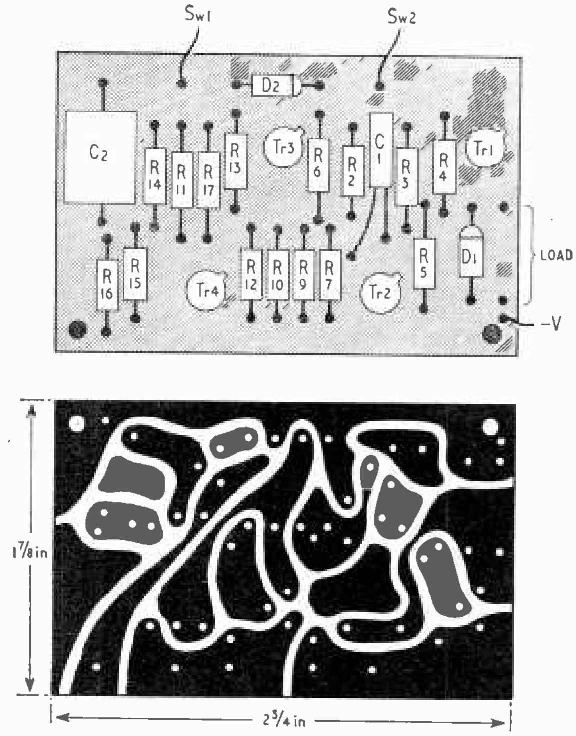


Fig. 7. Layout for novel printed circuit technique used.

discharging times of C_1 as in Fig. 3 (b) and (c). Extremes of mark to space ratio can be obtained by limiting the maximum charge of C_1 with a parallel resistor, and if continuous control of the ratio is required from 0 to ∞, as for example in a power controller, the circuit would become as that of Fig. 4. In this circuit, if the differential band is chosen to be small compared with the maximum control voltage, minimum output (short " on " time and long " off " time) is obtained with zero control voltage and maximum output when the control voltage is approximately equal to

$$\frac{R_8}{\dfrac{R_5 R_3}{R_5 + R_3} + R_8} \cdot V_s$$

As a practical detail, this voltage has to be chosen so that the voltage drop remaining across R_5 at maximum output still gives sufficient current in R_5 to bottom Tr1 well.

PRACTICAL ASPECTS

The rectangular output waveform has a pronounced set of harmonic components whose relative amplitudes depend on the mark to space ratio, and a small change in this ratio produces a very obvious change of quality of note. As mentioned previously the change of mark to space ratio may be obtained by changing the operating level of the base of Tr2, which is where the output from the modulating oscillator is applied through R_9 (which therefore controls modulation depth). Surprisingly little modulation is needed and too much can spoil the effect. The most commanding tone was found experimentally to be between 2 and 3 kc/s, depending on natural resonance, a most helpful phenomenon in boosting output, with modulation at 10 c/s.

The complete circuit (Fig. 5) has the additions of the overswing diode D1, and the diode D2 which allows the tone generator to sound alone without modulation by closing Sw2 if a secondary indication is required. The capacitor C_3 is an optional extra included so that the device may be powered from a compact 9 V battery but is not needed if larger batteries are used. It will be noted that the capacitor C_2 is not returned to 0 V as C_1; if it were there would be a significant delay after switch-on before the modulation began while it charged to the switching level.

The choice of capacitor for C_1 is simple in theory but it was found in practice that a certain oriental make of miniature electrolytic capacitor had such a high series resistance that the ideal waveform of Fig. 2 (a) was modified to that of Fig. 6 and 8 μF had to be used where only a high-quality 4 μF capacitor would have done. When choosing push-button switches for Sw1 or Sw2 it is well to consider the totally enclosed snap-action type which give the best reliability and the cleanest sounding attack. The type of transistors used is not critical at all except that the p-n-p ones should have current gains greater than 50, while for the n-p-n ones, silicon types are preferred and minimum gains of 15 at 1 mA are sufficient. Suitable types include the ACY18 and the 2S701 respectively. Advantage was taken of the base-emitter voltage of the silicon transistor used for Tr4 and the voltage drop across R_{15} to provide the polarizing voltage for C_2. If a germanium transistor is used here an extra bias resistor may be needed. In the prototype the transducer used was a moving-iron earphone insert and this made plenty of noise; in fact a small loudspeaker made rather too much. The volume can very easily be controlled by a resistor in series with the load of Tr1.

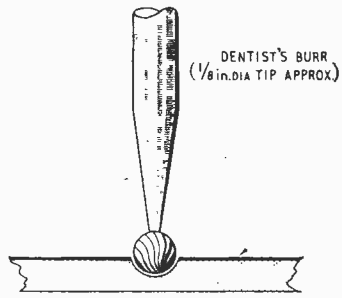


Fig. 8. Unwanted parts of copper laminate may be milled out with small burr.

Novel printed circuit technique. There is a very quick method of producing the layout of Fig. 7 on a copper-clad board.

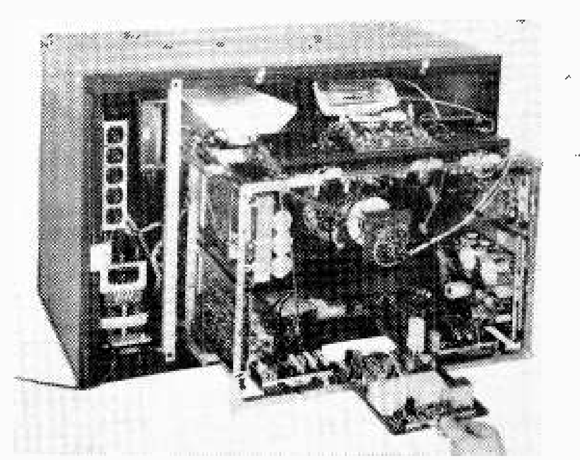
A dentist's burr may be used with a high-speed drill to mill out unwanted copper. The copper-clad board can be slid about on the work platform to obtain a constant depth cut while the burr follows the lines shown on Fig. 7 (b). A spherical burr (about ⅛ in tip dia.) is most suitable for this because it chamfers the edge of the cut copper and leaves no roughness or stray material to bridge the gap.

There are various intriguing noises which can be obtained from the device by experiment and elementary modifications, such as the startling effect when the modulator function is changed to direct on-off switching of the tone generator. Perhaps a good criterion of effectiveness of any particular arrangement is the number of curious colleagues or relations one can attract to a given place with that arrangement!

Solid-state Colour Receiver

THE chassis used in British Radio Corporation's recently announced range of 25-inch colour television sets (Ferguson "Colourstar," H.M.V. "Colourmaster" and Ultra "Bermuda Colour") is claimed by the makers to be the first all-transistor colour receiver in the world. The electronic design significance of this is, of course, that the company has now developd high power transistor circuits for line-scan/e.h.t., frame-scan and video output stages which have sufficient reliability and repeatability for mass-production in domestic equipment. The chassis uses 90 silicon transistors, of which only two are imported types. Designed to allow as much servicing in the home as possible, the set is principally made up from 10 replaceable printed-circuit modules—line timebase, e.h.t., convergence, field timebase and sound, chrominance, video, i.f., power supply, automatic degaussing, regulator—which are plugged into a rectangular chassis (no soldering is required) as shown in the illustration.

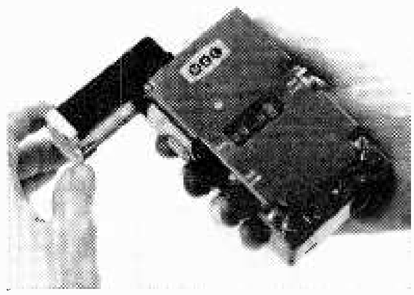
The 100 volts or so of video drive needed for each gun of the shadow-mask display tube (Thorn-A.E.I.) is given by an output stage using two transistors in cascade, while the 25 kV e.h.t. for the tube is provided by a "jelly pot" line output transformer and a voltage tripler (a technique based on that used in the company's recent monochrome sets). Regulation of the e.h.t. voltage, normally performed by a special shunt stabilizer valve, is here achieved by a series transistor in the h.t. current supply to the line output stage, controlled by a tapped sample of the e.h.t. voltage. Most colour receivers have only one extra viewer control compared with monochrome sets—saturation—but this chassis also provides what is called a "personal tint control." By differential adjustment of voltages applied to the red and blue guns of the c.r.t. it is, in fact, possible for the viewer to vary the colour temperature of white from bluish-white through Illuminant "C" to sepia-white, but the control also serves to take up tracking errors between the guns which may develop after a period of use—again facilitating maximum servicing in the home.



NEW PRODUCTS

POCKET RECEIVER

INTEGRATED and thin film circuits have been employed in the design and development of an M.E.L. pocket-sized communications receiver L.662 measuring $6 \times 3\frac{1}{4} \times 1\frac{1}{2}$in. Intended for a.m. and c.w. reception over the frequency range 40 kc/s to 30 Mc/s it can also be employed for s.s.b. Tuning is carried out by a digital frequency display, possessing the equivalent scale length of 300 inches over the above-mentioned range. Fine tuning is achieved with a continuously variable control knob. The first local oscillator is crystal locked at 1 Mc/s, the required harmonic being selected by an indexing mechanism geared to a precision variable capacitor in the oscillator circuit. The 1 Mc/s control also carries cams which by operating microswitches, automatically selects the necessary filters. The 100 kc/s steps are crystal controlled and selected by switching in one of ten crystals. Both the 1 Mc/s and 100 kc/s steps are selected by two indexing knobs. A crystal controlled b.f.o. is also built into this set. In addition to its function as a b.f.o. it can be used for calibrating the receiver. This is done by setting all controls to zero, disengaging a clutch on the fine tuning wheel, and tuning the oscillator for zero beat. The receiver is powered by two mercury cell batteries housed in a detachable plastic compartment which in very cold conditions can be placed in the operator's pocket. In addition to sockets for wire aerials, a telescopic rod aerial is provided, and high impedance dynamic earphones of the "hearing aid" type are employed. The set is housed in a sealed aluminium case with flush controls and terminals. M.E.L. Equipment Co. Ltd., Manor Royal, Crawley, Sussex.

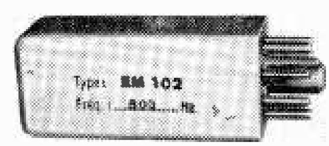


WW 301 for further details

TUNING FORK OSCILLATORS

AS an alternative to the crystal oscillator and divider, the Straumann precision tuning fork oscillator can provide reliability and temperature stability at low frequencies. Manufactured in Switzerland, as the EM101 series, they are available from 1 to 5 kc/s, with associated circuitry in a sealed steel can, overall dimensions 30 mm square by 51 mm above chassis, and 13 mm below chassis projection. Series EM102 oscillators are also enclosed in a steel can with international octal plug-in base. Frequencies available are 2 c/s to 5 kc/s. Both the above series contain associated electronic circuitry and provide an output of 4 V minimum pk-to-pk square waveform into a 10 kΩ load. The supply voltage required is 12 V d.c. The EM103 series are basic oscillators without electronics, mounted in crystal cans with solder spill connections. Available from 500 to 5 kc/s with dimensions of 18 mm × 8 mm, height 45 mm for 500-800 c/s units, and height 38 mm for units above 800 c/s. Prices start at £13 8s. Claude Lyons Ltd., Instruments Division, Hoddesdon, Herts.

WW 303 for further details



Miniature Audiometer

FOR screening tests of patients' hearing, the United Kingdom Atomic Energy Authority have produced a small, cheap, audiometer based on an idea from the Audiology Research Unit at the Royal Berkshire Hospital. The main unit is small enough ($5 \times 2\frac{5}{8} \times 1\frac{3}{8}$ in) to slip into the operator's pocket. The speaker unit is $2\frac{3}{8} \times 2\frac{1}{2} \times 1\frac{1}{4}$ in, and can be concealed in one of the operator's hands, thus fulfilling the requirements that a patient, especially a child, should not be distracted by the sight of the instrument. Three pure tones of 500 c/s, 2 kc/s, and 4 kc/s are generated. The intensity of each tone can be selected at levels of either 70 or 40 dB above normal threshold one foot from the patient's ear. Growth and decay rates of the tones are controllable, and these rates, frequency accuracy, harmonic content, and intensity levels conform to British Standard 2980. The unit is powered by two 3·9 V Mallory batteries. Patents Licensing Officer, U.K.A.E.A., 11 Charles II Street, London, S.W.1.

WW 302 for further details

Carbon Film Resistors

MINIATURE carbon film resistors manufactured by ISKRA, Yugoslavia, are available in the U.K. from Guest Electronics, Ltd., of 78-86 Brigstock Road, Thornton Heath, Surrey. These resistors of the type UPM comply with IEC (Publication 115) 55/125/21 type IB. Offered in the range 4.7 Ω to 10 MΩ, in two tolerances 5% and 10%, these resistors are available in 0.25, 0.5, 1 and 2 W ratings. The 0.25 and 0.5 W types are rated at 70°C and the 1 and 2 W types at 40°C. Body colour is red-brown, and the ohmic values are marked according to the colour code system. Noise level measured in the 0.25 W type rises to 0.6 μV/V at 10^7 Ω, is less than 0.8 μV/V at 10^7 Ω for the 0.5 W type, and is less than 1.2 μV/V at 10^7 Ω for the 2 W resistors. Prices per 100, range from 7s 9d to £1 3s 6d.

WW 304 for further details

Galvanometer

EACH of the moving coil galvanometers in the K100 series by Walden Precision Apparatus Ltd. possesses a scale length of 180 mm; magnetic and electrostatic screening; slow motion zero setting ($7\frac{1}{2}$ turns of the zero knob moves the light spot from one end of the scale to the other); and oil bead damping. This series employs a double reflecting optical system for increased sensitivity and linearity, the equivalent pointer length being 42 cm. The light source is a krypton low voltage 1A bulb, and the galvanometer mirror is a spherical type of 11 cm focal length. The pretwist of the suspension is said to be unique, offering zero stability. The coil is wound with non-magnetic or spectrographically pure copper wire, and is bonded in epoxy resin. Current, voltage and ballistic sensitivities vary according to the galvanometer selected; this is also true of the critical damping resistance, galvanometer resistance (direct and series), current and flux constants. Periodic time is 2 seconds for each model. Walden Precision Apparatus Ltd., Shire Hill, Saffron Walden, Essex.

WW 305 for further details

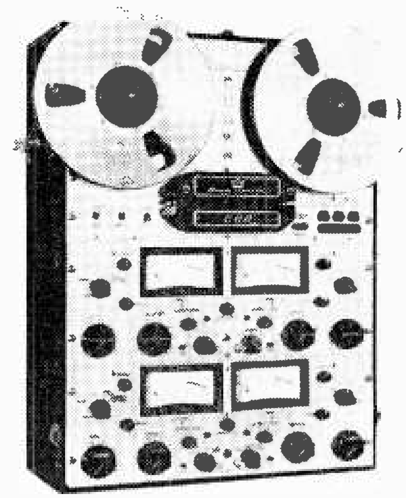
TAPE CONVERTER

CONVERSION of characters on paper tape to characters on magnetic tape can be carried out on the tape converter model 1720 by the Digi-Data Corporation, U.S.A. Stated to be capable of transcribing 2,500,000 characters in an eight hour shift, it converts any code on paper tape to magnetic tape written incrementally at 200 or 556 characters per inch. These code translations include any input character code to any output character code, translation of non b.c.d. codes such as Teletype, to IBM-BCD or similar codes, and checking for parity and error conditions. This instrument reads all types of punched tape, photo-electrically at 100 characters per second, and loading of fresh paper and magnetic tape reels takes less than 1 minute. Marketed by Scientific Furnishings Ltd., Terminus Road, Chichester, Sussex.

WW 306 for further details

TAPE RECORDERS

THE 800 series solid-state tape recorders from Crown International of Elkhart, Indiana, U.S.A. are now available in the U.K. from Carston Electronics Ltd., Oakley Rd., Chinnor, Oxfordshire. These recorders are available as full, half or quarter track models for mono or stereo operation and have been designed for use as either a professional audio-recorder or as an industrial instrumentation recorder, for which special low crosstalk heads can be supplied. Modular construction enables the playback panel to be offered as a separate self-contained unit for building into customers' systems. Three speeds—15, $7\frac{1}{2}$ and $3\frac{3}{4}$ i.p.s.—are standard but other speeds can be supplied to order. Typical performance figures at 15 i.p.s. for a 2-channel, half-track recorder include a frequency response of within ± 2 dB from 50 to 30,000 c/s, wow and flutter better than 0.06% and a signal-to-noise ratio better than 60 dB. Features of 800 series recorders are highly efficient, non-jerk brakes, photocell automatic stop, four input-mixing extended-range tone controls, a manual cue and edit control and comprehensive monitoring facilities. Accessories available include



a remote control unit for all transport functions, automatic repeat/rewind device and a floor console. Designed for free standing or 19in rack mounting, the 800 series Crown recorders have a power consumption of about 230 watts. Prices from £683 to £1,490.

WW 307 for further details

GaAs LASER

THE radiation source for the laser unit Type MLB1 by Photain Controls Ltd., is a gallium arsenide diode and this produces a pencil beam (16' wide), which is then collected and focused by a lens system. A transistor oscillator is used to generate 350 V d.c., which charges non-inductive capacitors. These discharge through the diode at a frequency which may be selected from between 10 to 300 c/s. The resultant infra-red pulsed beam (about 9000 Å) is directed onto a receiver unit and passes through a collector lens, to a tuned circuit via a solar cell. The tuned circuit is selected to respond only to the frequency of the oscillator in the projector unit. Should the beam be interrupted, a relay energized by the tuned circuit will relax, providing changeover of contacts for external control circuitry. Capable of projecting a beam up to 500 feet, this control system is intended for use as a burglar alarm and for industrial security, and to control installations in interior or exterior environments, since it is not affected by natural or artificial ambient lighting conditions, or by condensation or weather conditions. The price is £75 per set. Photain Controls Ltd., Randalls Road, Leatherhead, Surrey.

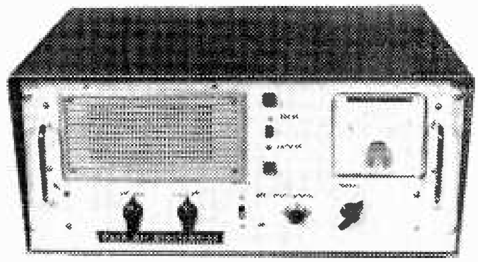
WW 308 for further details

Moving-coil Microphone

SAID to be the first microphone to use separate moving-coil systems for high and low frequencies, the A.K.G. D202 dynamic two-way instrument has the frequency range of 20 c/s to 18 kc/s, and it remains cardioid independent of frequency. It has a bass attenuation of 0 to 20 dB at 50 c/s, and a sensitivity of 0.18 mV/μbar. Impedance is 200 Ω +15 % and −30 %. It has a sintered metal front end for the rejection of dust, wind noise and magnetic particles. Available with DIN standard connector (D 202CS) or international Cannon connector (D 202ES). The price is £30. Politechna (London) Ltd., Eardley House, 182/4 Campden Hill Road, London, W.8.

WW 309 for further details

V.H.F. Transmitter/Receiver



FOR ground use in airline operations rooms, air traffic control, and business aircraft users' sites, the Park Air Electronics 50Z is a complete ground station installation, consisting of transmitter, receiver, aerial system and microphone. The crystal-controlled receiver and transmitter both conform to I.C.A.O. and I.T.U. 50 kc/s channelling requirements. The receiver is a double conversion superhet, with a single crystal controlled channel working over the frequency range 118 to 136 Mc/s, and it has a sensitivity which lifts the electronically adjustable squelch at 1 μV. Signal to noise ratio is better than 10 dB at 2 μV input over the frequency range. The output of 2 W fed into an 8 in loudspeaker has less than 10% distortion. All spurious responses are better than -65 dB. The a.m. transmitter is single channel, crystal controlled, amplitude modulated, with all stages metered including an r.f. output monitor. The r.f. output is 8 W maximum, and the frequency stability better than 0.005% over the range $-20°$ to $+70°$C. The modulation has automatic limiting at 80% on positive peaks. Hum and noise are better than -40 dB at 30% modulation. Complete with microphone, 60 ft of matched coaxial feeder cable with matching plugs and sockets the price is £128 10s. Park Air Electronics, 22a High Street, Stamford, Lincolnshire.

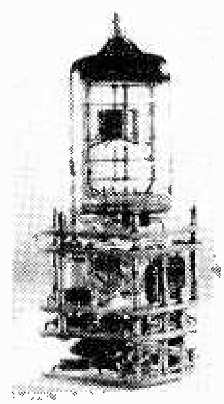
WW 310 for further details

LOW-POWER MINI-OSCILLATOR

NEW temperature stabilization techniques are employed in the Marconi Type F3180 miniature 1 in × 1 in × 3 in oscillator which has a short-term stability of 1 part in 10^8 averaged over 1 second. This unit is designed to operate over the temperature range -55 to $+90°$C and can be supplied preset to any frequency between 10 and 15 Mc/s. A quartz crystal $\frac{3}{16}$ in diameter is cold welded into a TO-5 transistor can, with a sensitive microcircuit heating element. This can is then placed in an evacuated glass envelope to insulate the circuit from environmental temperatures. Temperature stabilization is achieved by a micro-miniature amplifier controlled by a thermistor bridge input stage.

Thermal losses through the structure holding the can inside the tube have been reduced to a minimum, and the wires connecting the crystal to the rest of the oscillator circuit are made of platinum (which maintains good electrical conduction and rigidity even when fine drawn) to reduce thermal conduction. The oscillator circuit incorporating solid state devices, is constructed on printed circuits. A trimmer permits the frequency of the oscillator to be adjusted in order to compensate for ageing effects over 10 years.

Power consumption is 500 mW at -55°C (worst outside temperature condition). Long term stability is ± 5 parts in 10^6 over six months. The power supply required is 12V d.c. ± 5% and the F3180 will provide a sinusoidal output of 1 V pk to pk into a load impedance of 50Ω. Marconi Co. Ltd., Chelmsford, Essex.



WW 312 for further details

Contact Cleaner

A LOW toxic solvent CO contact cleaner by Corrosion Abolition Ltd., evaporates rapidly and is said to leave no residue. Intended for use with delicate, high precision electronic instruments, it will remove greases and oils, from metal, plastic, painted, varnished, and plated surfaces with little or no solvent action on the base material. Particularly recommended for use in regular maintenance and cleaning of low-voltage equipment this cleanser is non-flammable, and remains stable in the presence of alcohols already used for cleaning purposes. It will not decompose at temperatures up to 300°F. The toxicity is 1,000 p.p.m. Corrosion Abolition Ltd., Camey House, Horton Road, West Drayton, Middlesex.

WW 311 for further details

CROSSHATCH AND DOT GENERATOR

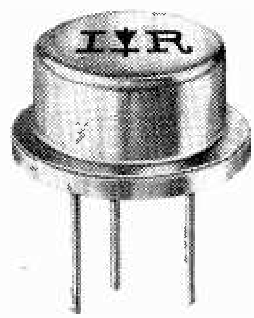
THE main application of the V75A pattern generator is that of convergence checking and correcting in colour television receivers, although the graticule or crosshatch pattern can be used to display linearity faults in the timebases of monochrome receivers. The output of this instrument may be directly connected to the aerial input of the receiver. A front panel switch selects 625 or 405 line generation, while the field frequency is triggered by the mains supply frequency. The r.f. output via a 75Ω coaxial lead, is continuously variable in frequencies from channels 6 to 13 in the v.h.f. band, and channels 29 to 43 in the u.h.f. band. By adjustment of front panel controls, the crosshatch can be varied from 5 to 25 lines, and dots are derived from the intersections of the crosshatch pattern. This instrument weighs 9lb, and costs 75 guineas. Video Circuits, 101 Salisbury Road, Barnet, Hertfordshire.

WW 313 for further details

Full-track Magnetic Heads

EXTERNAL dimensions of the Miniflux magnetic heads for use in professional studio and film equipment are identical to those for half-track operation. However to meet the more exacting requirements of broadcast authorities and others, the linearity of replay response at low frequencies has been improved, so that deviations from the expected 6 dB/octave straight line do not exceed 1 dB, even at a tape speed of 15 in/s. Record and replay heads FN5 and FM5 have inductances of 30 and 100 mH respectively at 10 kc/s and both heads have a gap of 5 μm. The FR10 record head has an inductance of 7 mH at 10 kc/s, and a gap of 10 μm. Two versions (the LF4VS and LF6V) of full-track erase heads have three and two field erase systems respectively. Erase currents are 125 and 70 mA, and maximum erasure is -78 dB and -70 dB respectively; this erasure relates to 330 c/s at 7·5 in/s. Miniflux Electronics Ltd., 8 Hale Lane, London, N.W.7.

WW 314 for further details



Low Current Thyristor

THYRISTORS designated IRC 20 to IRC 60 by International Rectifier, Hurst Green, Oxted, Surrey, are for use in low power applications such as logic switching, static relays and a.c. power supplies. They are rated at 1.3 A average (2 A r.m.s.) up to 60° C with a surge rating of 60 A for 10 ms. Available with PRV/PFV gradings of 200, 400, and 600 V. These devices are constructed to TO-8 outline and are hermetically sealed.

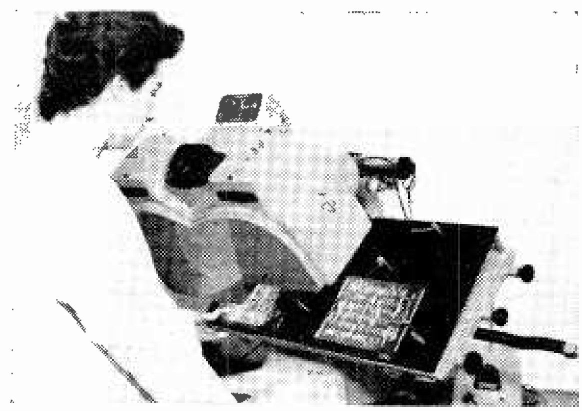
WW 315 for further details

PLUGS AND SOCKETS

SUB-MINIATURE plugs and sockets with p.t.f.e. insulation are available from Oxley Developments Co. Ltd., Ulverston, Lancashire. The plug and socket, known respectively as 30P/093 and 30S/093, have their metal components made of heavily silver-plated brass and the overall lengths of plug and socket are 0·440 in and 0·380 in, respectively. The bush for mounting the socket is inserted into a 0·093 in plain punched or drilled hole in the chassis, and the socket is then pressed firmly through the bush, expanding it. Working voltage is 1·8 kV d.c. with a breakdown voltage of 5 kV d.c. The current rating is 5 A with a corresponding 10°C rise in temperature. Insulation resistance is greater than 2×10^6 MΩ.

WW 316 for further details

Circuit Inspection Aid



STATED to be several times faster than any other known method for visual inspection processes, the Vision Comparascope has been designed specifically for inspecting assembled printed circuit boards for missing, reversed, misplaced or incorrectly assembled components, and checking that they are visually identical in all respects with an original. Images from both the master component, and the work to be inspected, are required by the operator through twin optical paths. Both images pass through polarizing filters, then through a rotating analysing disc. Thus the operator receives repeated images first of the master and then the work under inspection. This happens at a speed controllable by the operator, eliminating the need for successive eye transfer between two objects. Illumination is by fan-cooled quartz iodine lamps with a life of about 1,000 hours. The lights are collimated through a series of lenses, and offer shadow free illumination. Each lamp unit is fitted with independent rheostat so that the lights may be balanced to suit individual requirements. A binocular attachment is available with magnification of 5:1, and is intended for examining miniature and micro-miniature components. The maximum inspection area is 12in × 12in with standard co-ordinate table, and field size is 6in × 6in at any table position. Operation is from 240 V or 110 V a.c., the price is £875 and the binocular attachment complete with mounting facilities is £85. Vision Engineering Ltd., Send Road, Send, Woking, Surrey.

WW 317 for further details

AUTOMATIC LOADING TAPE RECORDER

EACH one of the solid state stereo recorders in the 1100 Series by Ampex is said to take only two seconds to load with a reel of tape, pull the tape through the head assembly and put it in the "magic slot" (automatic threading). The recorder is then ready for playing. Automatic reverse (another feature of these recorders) permitting a play-back of tape unattended for up to 9 hours, is achieved by the addition of inaudible reverse signals at any desired point on the track. There are three tape speeds $1\frac{7}{8}$, $3\frac{3}{4}$, and $7\frac{1}{2}$ in/s. Record level VU meters and controls are provided for each channel. Dual capstan drive is stated to reduce wow and flutter to inaudible levels even at $1\frac{7}{8}$ in/s. Wow and flutter measured to A.S.A. standards is 0.15 % at $7\frac{1}{2}$ in/s and 0.2 % at $3\frac{3}{4}$ in/s on all machines. The overall record/reproduce frequency response of the pre-amplifiers is 50 c/s to 15 kc/s ± 4 dB at $7\frac{1}{2}$ in/s and 50 c/s to 7.5 kc/s ± 4 dB at $3\frac{3}{4}$ in/s. Model 1150 is a deck version with pre-amplifiers only, Model 1160 is a portable deck with pre-amplifiers and power amplifiers, and is supplied with a microphone. The 1165 model is similar to 1160, except that this unit is mounted in an oiled walnut cabinet for bookcase or table display. Ampex International, 72 Berkeley Avenue, Reading. Berks.

WW 319 for further details

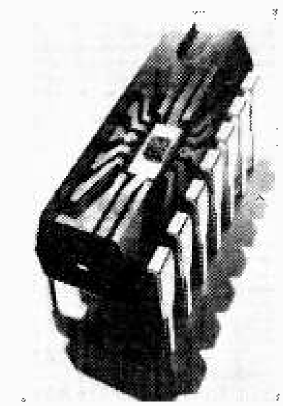
Silicon Planar Transistors

FERRANTI ZTX300 series are general purpose, silicon n-p-n planar transistors. Collector-emitter voltage ratings are from 20 to 45 V, typical gain-bandwidth product is 300 Mc/s, and a typical output capacitance is 4 pF. The ZTX310 series silicon n-p-n planar switching transistors are intended for high-speed, low-current logic applications. They possess collector current ratings in the range 1 to 100 mA. Typical storage times are from 8 to 15 ns. Operating temperatures for all types is -55 to $+125$°C with a power rating of 250 mW. These devices are epoxy encapsulated and meet the requirements of MIL-STD.202C. Ferranti Ltd., Gem Mill, Oldham, Lancs.

WW 318 for further details

DTL Integrated Circuits

INTEGRATED DTL circuits in the 930 range are now available from Texas Instruments Ltd. in a moulded plastic package. This series is intended for operation in the temperature range 0° to 75°C, and is designated Series 15830N. The complete group of eleven DTL circuits is available in the moulded package, including dual, triple, and quadruple gates, buffers, expanders, binary elements, and a one-shot. The transfer moulded plastic packages has 14 plug-in pins on 100-mil centres for fast, economical flow-soldering and wire-wrap techniques. The two rows of pins are 300 mils apart, providing sufficient space to run earth and power-supply strips directly under the body of the package. The rigid plug-in pins are adaptable to high-speed automatic or manual insertion techniques. The solid moulded construction provides maximum protection against shock and vibration. Good heat dissipation (70° C/W in free air) results from full contact of the moulding compound around the silicon bar. The package meets or exceeds MIL STD 202C, Method 106B for moisture protection. Typical gate propagation delay for Series 15830N



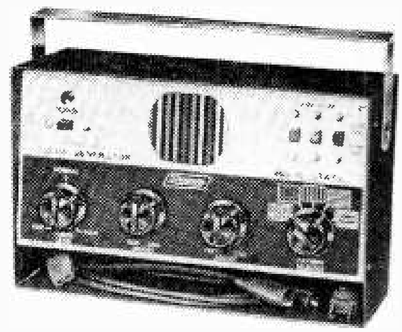
is 25 ns, power dissipation is 5 mW, there is a fan-out of 8, d-c noise margin is 750 mV, and supply voltage is 4.5 to 5.5 V. Integrated circuits in the 930-DTL configuration are also available in the standard TO-84 14-pin flat pack for operation over the full military temperature range of −55 to +125 C. Texas Instruments Ltd., Manton Lane. Bedford, England.

WW 320 for further details

COLOUR GENERATOR

MANUFACTURED in the U.S.A. by Mercury Test Instruments, the Model 1900 colour generator is intended for use in installing and servicing colour television receivers. Designed with solid state circuits, it provides line width adjustments, permitting selection of vertical and horizontal line thickness, or dot size. Separate horizontal and vertical bars indicate the area where there is inaccurate convergence, and a crystal controlled rainbow colour display enables colour circuits to be tested and adjusted. This unit can be connected directly to the aerial socket, so that most tests can be carried out without having to open the set. Department "E", Singer Products Company Inc., 95 Broad Street, New York, N.Y. 10004, U.S.A.

WW 322 for further details

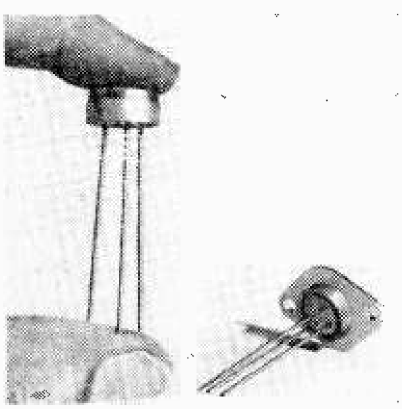


A.C. Thyristors

FOLLOWING a recent agreement with Electronic Control Corporation of Texas, a range of a.c. semiconductor switches is now available from Claude Lyons Ltd., of Valley Works, Hoddesdon, Herts. Known as Quadrac, the device is a multi-layer bi-directional switch with trigger and an optional built-in bi-directional trigger (negative resistance) diode. The devices are intended for application in a.c. power control circuits.

Current ratings (r.m.s.) of 3, 5, 10 and 15 A are available with breakover voltages of 200, 400 and 500 V. We understand, however, that a 7 A range has also been introduced and that the 3 A range has been up-rated to 4 A. Typical trigger diode breakover voltage is 45 ±5 V and the capacitor value required is 0.1 μF. Holding current for the low-current devices is 7 mA and 12 mA for the higher-current types. Trigger potential should be in phase (same polarity) as that across the device or, if this is not possible, the trigger potential should be negative. The switches are available in either a press-fit housing or TO-3 case. Typical price are: for a 500 V, 15 A type with trigger diode and in a TO-3 case—about 125s for 100 up; and for a 200 V, 3 A press-fit type without trigger diode—about 23s for 100 up.

WW 321 for further details



MUMETAL PERMEABILITY

MUMETAL manufactured by Telecon Metals of Crawley, Sussex, is now available in three different guaranteed minimum initial permeabilities. Standard Mumetal and Mumetal 40 (CT grade) both have a guaranteed m.i.p. of 40,000. Mumetal 60 has a m.i.p. of 60,000. The prefix "super" previously used for Mumetal 60 will in future be restricted to Mumetal having a guaranteed m.i.p. of 100,000, e.g. Supermumetal (100,000).

WW 323 for further details

Subminiature Indicator

NEON or incandescent lamps are employed in the TEC-LITE indicator (STL series) manufactured by the Transistor Electronics Corporation, U.S.A. Transistor controlled from low level signals present in discrete components or integrated circuits, it is intended for use where many indications are required in a small area, and the permanently wired-in neon or incandescent lamp will operate from signals as small as 0.5 V and a current of 0.7 mA. The overall length is $1\frac{1}{8}$ in, and the lamp, transistor, and related circuitry are contained in a case of 0.360 in diameter. U.K. agents Litton Precision Products, 503 Uxbridge Road, Hayes, Middlesex.

WW 324 for further details

STRAIN GAUGE POWER SUPPLY

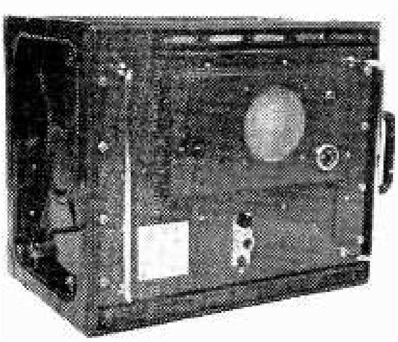
A POWER supply and bridge balance unit for strain gauges by Intersonde Ltd., The Forum, High Street, Edgware, Middlesex, is available in single- and six-channel form. It is intended to energize transducers such as resistive strain gauges connected either in half or full bridge configurations. It will provide stabilized d.c. excitation of up to 24 V. The six-channel version features six identical and fully floating d.c. supplies. These units also have controls in the form of high resolution multi-turn helical potentiometers for adjusting the span and zero of a transducer. Shunt calibration facilities are also provided, and enable a choice of two internal high-stability resistors to be switched across one transducer bridge-arm to produce a known amount of bridge unbalance, and hence transducer output. The units operate from 200/250 V, 40-60 c/s, and have an output voltage stability of better than 0.1% for a ±10% change in mains input. The units will produce an output current of up to 100 mA over the operating temperature range 0-60°C.

WW 325 for further details

Static Inverter

THE inverter 606/ST/1250/B by Industrial Instruments Ltd., is for use in energizing tape recorders, computers, outside broadcast and television equipment, oscilloscopes, power tools, and a variety of industrial and military equipment. This instrument, employing thyristors, inverts a d.c. input of 24 V to produce a mains-type output of 240 V a.c. stabilized at 50 c/s ±1%. Additional features include protection against short circuit and reversal of input polarity, and the ability to accept a wide input voltage swing (20 to 30 V d.c.). The power circuit is designed to enable satisfactory starting of motors of poor power factor. Dimensions are 21 in × 18 in × 14 in. Industrial Instruments Ltd., Stanley Road, Bromley, Kent.

WW 326 for further details



LITERATURE RECEIVED

Information on manufacturers of **semiconductors and valves** is tabulated in the nine-page guide from the Electronic Valve and Semiconductor Manufacturers' Association (V.A.S.C.A.), and the British Radio Valve Manufacturers' Association (B.V.A.). Valves and tubes range from backward-wave oscillators through gas-filled spark gaps to masers and gamma ray radiation detectors. Semiconductor devices are covered from avalanche diodes to thin film integrated circuits. Other electronic devices include dry reed switches, ferrite components, and strain gauge elements. Twenty-four manufacturers in the U.K. are cross referenced to these products. V.A.S.C.A., Mappin House, 156 Oxford Street, London, W.1.
WW 327 for further details

"Reliability of AEI Semiconductors," Publication 4450-257, is an eight-page report on **voltage reference diodes.** Descriptions of the types of environmental and life tests that these diodes undergo are supported by a series of nine graphs which plot the variations of reference voltage against time during these particular tests. Associated Electrical Industries Ltd., Electronic Apparatus Division, Semiconductor Department, Carholme Road, Lincoln.
WW 328 for further details

Neumann Condenser Microphones is the title of a catalogue of condenser microphones, accessories, calibrating standard microphones, microphone mixing transformers, filters, booms and overload protectors. This 25-page publication, and literature on other equipment such as transistor studio amplifiers, and disc-cutting lathes, are available from F. W. O. Bauch Ltd., Holbrook House, Cockfosters, Barnet, Herts.
WW 329 for further details

Design rules for employing Series US-0900 Unicircuit integrated circuits are now available from the Technical Literature Service, Sprague Electric Company, Marshall Street, North Adams, Massachusetts, U.S.A. These rules are included in the 20-page Sprague Engineering Bulletin 25075, which also gives a summary of mW resistor-transistor logic, noise margins, propagation delay, power consumption, and a description of various applications.
WW 330 for further details

Abridged data on valves and accessories is given in the English Electric Valve Company's 1967 brochure. These products include industrial thyristors, TR and TB cells, television camera tubes, image intensifiers, storage tubes, gas lasers and vacuum capacitors. Also included in the 72 pages is an equivalents index of all E.E.V. types, their CV numbers and other manufacturers' types which they may replace. This guide is obtainable by making a written application on company notepaper to the Press Officer, English Electric Valve Co., Ltd., Chelmsford, Essex.
WW 331 for further details

Bulletin C-121R on **solid-state choppers** in the Airpax series PM, gives their switching and drive characteristics. This information sheet also indicates typical applications of these phase modulation choppers—which employ toroidal transformers—and the environmental conditions in which these high-signal isolation devices operate. Airpax Electronics Incorporated, Cambridge Division, Cambridge, Maryland 21613, U.S.A.
WW 332 for further details

Quarndon Electronics (Semiconductors) Ltd., Slack Lane, Derby, have issued a summary of Texas Instruments **SILECT transistors** stocked by them. These include fast switching n-p-n and p-n-p devices, f.e.ts. and unijunction types.
WW 333 for further details

Electronic components manufactured by A. B. Metal Products Ltd. are described and illustrated in the 13-page "AB Short Form Catalogue." Products of the Wolsey Electronic and Smart & Brown Connector Divisions are included. Potentiometers, power resistors, a wide range of switches, miniature d.c. motors, television tuners, aerials and multipin connectors are all mentioned in this publication of which there is a French edition. A. B. Metal Products Ltd., Abercynon, Glamorgan, Wales.
WW 334 for further details

Silicon power transistors in complementary pairs—permitting designers to dispense with driver transformers and associated components in many applications—are fully described in the publication "Mounting Procedure and Thermal Aspects of Plastic Power Transistors" by Motorola Semiconductors, York House, Empire Way, Wembley, Middlesex.
WW 335 for further details

Training courses on circuit principles, recalibration procedures, and maintenance techniques are described in the four-page Tektronix brochure, Training Courses 1967. Information is provided on the booking procedures for the courses that are conducted throughout the year at the European marketing headquarters, Channel Islands. From Tektronix U.K. Ltd., Beaverton House, Harpenden, Herts.
WW 336 for further details

An introduction to, and an explanation of the SI units (Système International d'Unités) which are coming into international use, are explained in the new B.S.I. 21-page publication **The Use of SI Units,** (reference PD 5686) price 2s. It introduces the six basic SI units at a time when the U.K. is changing to the metric system, and when 23 countries have already, or are about to make the SI the only legal system of measurement. Conversion from imperial to metric units is briefly discussed, and appendix A has been specially prepared for British industry, since it covers and tabulates both SI and other units. Appendix B defines derived SI units with special names, appendices C, D, and E also offer much pertinent information. Also available is an improved and cheaper version of the inch/metre conversion slide marketed by B.S.I. With it, rapid conversions can be carried out from imperial to metric and metric to imperial units of length, area, volume, mass, force, pressure and stress, capacity and temperature. It also converts Birmingham, British Standard Wire and American wire gauge numbers to metric dimensions. All conversion factors are in accordance with BS 350 and they are correct to five significant figures. The price is 21s. in plastic case. B.S.I. Sales Branch, British Standards Institution, 2 Park Street, London, W.1.

Sound is the title of a new technical periodical to be published quarterly by the Royal National Institute for the Deaf. The first issue has articles on power requirements of inductive loops, hearing loss in the Indian population, justification for audiometer calibration check-ups, technical reports on hearing aids and on an audiometer. Issues cost 2s 6d or 10 shillings for a year from the R.N.I.D., 105 Gower Street, London, W.C.1.

Over 5,000 items—electronic components and equipment—are described and many illustrated in the 200-page 1967 catalogue from Henry's Radio Ltd., 303 Edgware Road, London, W.2. Price is 7s 6d.

The 1967-68 100-page mail order catalogue (No. 17) has been received from **Radio Control Ltd.,** 93 North Road, Brighton. It describes surplus electrical and radio equipment, components, semiconductors, plugs, relays, sockets and switches. Price is 3 shillings.