Wireless World

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MAY 1963

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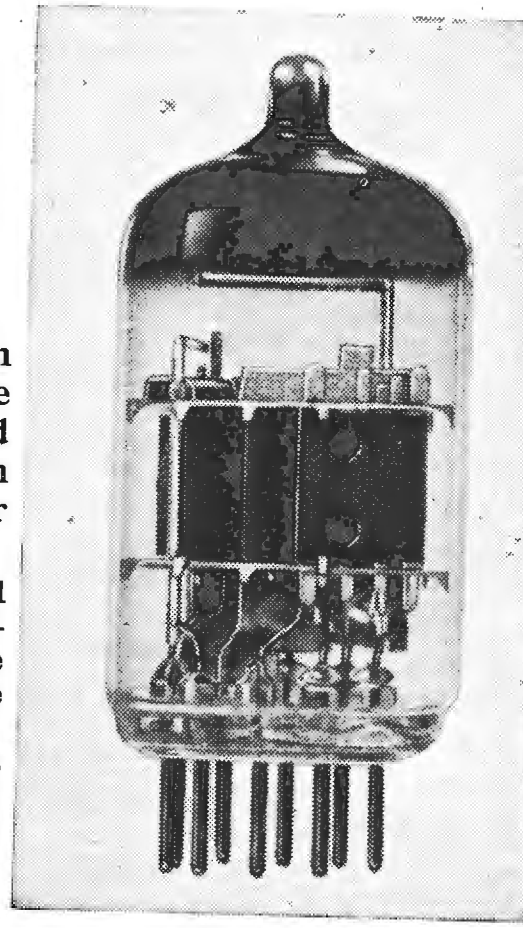
NEW TRIODE-PENTODE PCF801

FOR TV TUNERS AND I.F. AMPLIFIERS



THE PCF801 is a new Mullard triode-pentode for television tuners. The performance and versatility of the valve make it an excellent choice for television receivers designed for both v.h.f. and u.h.f. reception. It can function as an oscillator-mixer in v.h.f. tuners and as an i.f. amplifier following a u.h.f. tuner.

Two frame grids are incorporated in the valve: the triode grid and the pentode control grid, which has also been designed with a variable-mu characteristic. Outstanding properties of the PCF801 are small inter-electrode capacitances, a high conversion conductance and a remote cut-off characteristic.

As an oscillator mixer, the pentode section of the PCF801 operates as the mixer and the triode section as the oscillator. In the triode section, use of the frame grid ensures an oscillator performance that is largely independent of supply voltage variations. In the pentode section, a conversion conductance of 5mA/V is achieved with an r.m.s. oscillator signal amplitude of only 1·6V. Because of the small cross-capacitance between the triode anode and pentode control grid (<10mpF), the oscillator frequency shift when bias is applied to the mixer control grid is kept to a minimum.

Mullard will welcome visitors to
STAND 308
at the
R.E.C.M.F. EXHIBITION
Olympia, 21st-24th May

The control grid of the pentode section of the PCF801 has a variable-mu characteristic. This section is therefore very suitable for application as a controlled i.f. amplifier. Because of the remote cut-off characteristic, large i.f. signals from a u.h.f. tuner can be handled without risk of cross-modulation or overmodulation occurring. The small anode to control grid capacitance of the section (9mpF) eliminates feedback of the i.f. signal to the r.f. bandpass filter, so that difficulties in the adjustment of this filter are avoided.

AW59-91 23 in. SHORT-NECK PICTURE TUBE

The new Mullard picture tube, type AW59-91, has a rectangular screen with a 23-inch diagonal. The flatness of the screen offers a wide viewing angle and freedom from distortion when viewed obliquely.

The focusing lens is of the unipotential type, which prevents deflection defocusing and ensures good spot quality over the whole picture area. An ion-trap is unnecessary, so that interaction between the ion-trap magnet and the deflection coils is absent, and there is a consequent further improvement in spot quality.

The design of the electrode structure of the AW59-91 is such that a very short gun has been achieved. In addition to this, the sealing pip at the base of the gun is very small, so that the total length of the tube neck is only 110mm. This compares with a neck length of 130mm with the AW59-90. The overall reduction in the length of the AW59-91 resulting from the short-neck construction has made possible even greater reductions in the depth of television cabinets, leading to the more slender appearance of present-day sets.

AC107—JUNCTION TRANSISTOR FOR TAPE RECORDERS

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

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

MVE/CA 1092

Wireless World

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High-quality Transistor Amplifiers

FIFTEEN years ago, when the first phase of point-contact transistors were demonstrating, if somewhat noisily, their capability of small-signal amplification, it seemed unlikely that in the foreseeable future they would challenge valves for a place in high-quality audio amplifiers, though their possibilities in other directions were soon apparent. The transistor portable with its all too obviously non-linear response and noisy background has done little to encourage belief that the junction transistor of the second phase would be any more successful. Indeed, the transistor set has created a prejudice against the transistor among some sections of the audio fraternity which will need active argument and demonstration to remove.

That this prejudice is without foundation there can no longer be any doubt. Last autumn, during his presidential address to the British Sound Recording Association, H. J. Leak demonstrated a prototype high-quality transistor amplifier which gave results indistinguishable from those of his valve amplifiers, and more recently Mullard have demonstrated to the Press three designs which could not be faulted by the most critical listening tests, and in which measurement has shown the total harmonic distortion to be $\leqslant 0.06\%$.

Early attempts to improve the quality of transistor audio amplifiers were to some extent restricted by the available types of transistors, but more so by long-ingrained habits of thought associated with valve amplifier design. Thus for a time development halted at the Class-B complementary pair type of output stage with a transformer between driver and output stages to match the low input impedance. Crossover distortion was severe and even with negative feedback it proved difficult to reduce distortion below the 5% mark. Compared with that of a valve the equivalent circuit of a transistor is very much more complex and must be given the full treatment of network analysis before we can begin to understand, and therefore to exploit correctly, its inherent possibilities. We must eschew the short cut which the simplifying assumptions of treating the device like a valve temptingly offer and tread the steeper gradients marked out by our contributor O. Greiter in the series of articles now appearing in this journal. These are the ways which have been taken by leading amplifier designers and which are beginning to bear fruit. We shall be giving full details of the Mullard designs, starting with this issue, and it is possible that other firms may be disclosing their achievements at the London Audio Fair.

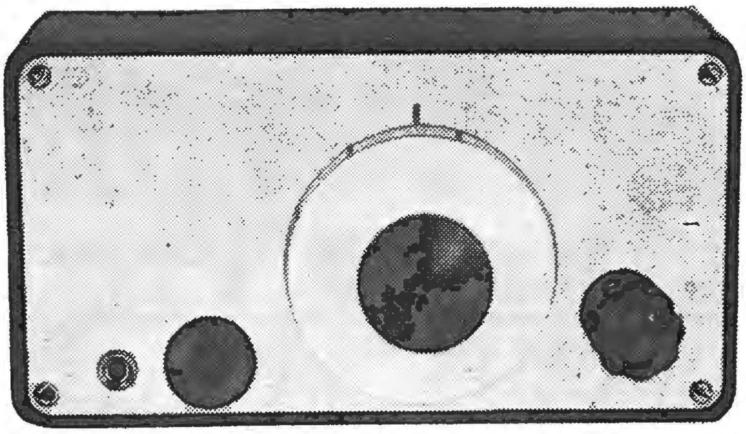
At present transistors cost more than valves but it does not necessarily follow that transistor amplifiers must be correspondingly more expensive. In valve amplifiers there is an output transformer which can be omitted when we use transistors.

People sometimes ask why there is any necessity to change to transistors. The elimination of the output transformer is, in our view, sufficient reason now that solutions of the problem of linearity in the response of the rest of the transistor circuit have been found. As additional bonuses we get smaller size, cooler running and the prospect of longer life.

P. P. Eckersley

EVERY broadcast listener of the early 1920s will be saddened to learn of the death, in March, of Capt. Eckersley, first Chief Engineer of the B.B.C. The irrepressible ebullience of his microphone performances in the early days at Writtle was the expression of a gay and charming personality, well atuned to the social manners of the period; but underlying an apparent irresponsibility was a serious concern that the potentialities of this new power of broadcasting should not be frittered away. He saw early and clearly that the diverse interests of humanity could not be adequately served by programmes of short duration, fed in succession through a few channels, and that the logical solution was simultaneous transmission on many channels. Although fundamentally a wireless man he did not shirk the conclusion that, with the limited wavelength spectrum available in the early 1930s, broadcasting should be supplemented by if not abandoned for a system of carrier-frequency distribution over the electricity supply mains. To this idea he bent all his talents for public persuasion, and it was a bitter disappointment that Parliament did not see fit to pass the necessary legislation to put the scheme into effect.

Although in recent years he had not been much in the public eye, he found a congenial atmosphere in the meetings of the I.E.E. where his original and mordant contributions to discussions will long be remembered with affection by his fellow members. For he was fundamentally a kind person who used the weapon of his wit to challenge rather than to wound.



REFLEX CIRCUIT

USING ONLY TWO TRANSISTORS

SIMPLE TRANSISTOR PORTABLE

By G. W. SHORT

THE receiver described here (Fig. 1) was designed to provide a simple means of receiving the Home, Light, and Third Programmes in the London area. Since it was intended to be used by a child, controls were kept down to two—tuning and volume. A signal of about 4 mV across the tuned circuit provides full output, with average transistors. The receiver was designed for use with headphones, but it is easy enough to add a standard output stage if it is required to use a loudspeaker.

General Considerations

The r.f. and detector circuit are of crucial importance in a receiver such as this. The detector must receive a signal large enough to enable it to work efficiently. If it does not, no amount of a.f. amplification will avail, because a.f. noise sets a definite lower limit to usable a.f. signals. Experience showed that three a.f. stages in cascade produce about as much noise as can be tolerated. The present design uses two, but the first stage employs an r.f. transistor which is not the quietest of a.f. input stages.

R.F. Circuits:—The designer is faced with a choice of three basic types of r.f. and detector arrangements:

1. Diode fed directly from tuned circuit. ("Crystal set" with a.f. amplification.) This is ruled out by a.f. noise except in areas of high signal strength and when large aerials can be used.
2. A reacting detector using an r.f. transistor. Here one can use either an "emitter bend" detector working at a low collector current (say 100μA) or a "collector bend" circuit working at a higher current. The first is preferable because the audio frequency noise output is smallest at low collector currents. Either type (and the hybrid between them) requires a base-emitter input of 10-20 mV peak to produce a reasonable a.f. output. This implies a voltage across the input tuned circuit of the order of 100 mV. To get this, using an aerial of moderate size, it is often necessary (except in the neighbourhood of a transmitter) to adjust the circuit so that it is on the threshold of oscillation. One then runs up against the difficulty that the reaction setting must be altered for each station. The arrangement is really only usable where fixed station selection is permissible. One can then provide a pre-set reaction control for each station, plus a common control which may be used to give the reaction a fine trim when a station is selected.
3. An r.f. stage feeding a detector. This enables the r.f. signal level to be raised, without using regeneration, to a point at which the detector becomes efficient. This is the arrangement used here.

Practical Considerations

A diode detector was decided upon partly because of its compactness and cheapness, and partly because it throws very little capacitance across the r.f. stage which feeds it. (This is very desirable with a broad-band collector load.)

At first sight, the ideal method of coupling the detector to the r.f. stage is to use a matching transformer. The reasoning goes like this. The detector will be feeding an a.f. stage with an input resistance of, say, 1 kΩ. So the r.f. impedance of the detector will be comparatively low—a few hundred ohms. The r.f. transistor, on the other hand, has an optimum load of the order of 20 kΩ. So a step down transformer should be used between the transistor and the detector.

Various transformers were constructed and tested, using a single diode as the detector. Then the primary of each transformer was used as an r.f. choke (like L_1 in Fig. 1) feeding a voltage-doubling detector. Detector load resistance and bias current were optimised in each test. The result was quite clear: in every case the choke-coupled circuit, with a high d.c. load for the detector, was more sensitive than the transformer-coupled circuit. What is wrong with the theory? Well, it ignores a basic fact. In a circuit like that of Fig. 1, the detector output current is amplified about 2,000 times by the transistors. The collector current of V2 is only about 2 mA, so the peak current required from the detector is only about a microampere. The question I should have asked myself before winding all those transformers and making all those tedious measurements was: what arrangement enables the smallest input signal to produce 1μA from the detector? I would then have remembered that, under low-level conditions, a germanium diode has a forward resistance of a few *thousand* ohms instead of a few hundred, so the transformer ratio would need to be drastically reduced. Subsequent tests showed that a step-down of about 2 produced equal sensitivities for both arrangements. This suggests that a small step down to a voltage doubler will give the best performance. But in view of the small improvement to be expected, and in view of the fact that suitable transformers are not standard components, while r.f. chokes are, the idea of using a transformer was dropped. One lives and learns.

Detector Bias:—This is applied by resistor R_4, which may require adjustment. For every combination of r.f. source impedance and detector load there is an optimum value of detector bias current. It is instructive to monitor the output of a receiver such as this on an oscilloscope, apply a small modulated r.f. signal, adjust the bias from zero upwards and watch the a.f. signal emerge from the noise. The bias is not particularly critical, but it is important to get it approximately right. This is not so easy to do by ear, listening to an incoming station. When in doubt, err on the side of applying too much rather than too little.

R.F. Collector Load:—The choke L_1 is chosen so that it tunes the stray capacitances (mainly the output capacitance of V1) to about the middle of the medium-wave band. It should be a small component and wave-wound to reduce self-capacitance. The collector circuit is heavily damped by the detector. To obtain reasonably level response over the medium-wave band the circuit Q has to be reduced to about unity. It follows that L_1 can have quite a high resistance without ill effects.

On the other hand, it is questionable whether one wants a level response. The input tuned circuit, if the coil is wound on a ferrite aerial rod, will be more selective near the l.f. end of the band than at the higher frequencies. So one can make use of a higher gain at the lower frequencies. This can be obtained, without much loss at higher frequencies, by making L_1 resonate the collector circuit at, say, 700 kc/s rather than 1 Mc/s.

Input Circuit:—We arrive, at last, at the beginning—the aerial tuned circuit. Not much need be said about it, as it is a straightforward and well-tried arrangement. The particular ferrite rod aerial used in the writer's son's receiver was made from the remains of a 10-inch rod which got broken into three bits of varying length. These were taped into a bundle and the tuned winding put round the middle. Constructors who wish to use a commercial rod aerial designed for use in a superhet should note that the base winding will have too many turns, because the input impedance of an OC44 as a mixer is much higher than as a straightforward amplifier. As a rough guide, use a turns ratio of about 15. But it is best to adjust the number of turns in the base winding by trial and error, starting with about 5 and reducing them until the output of the receiver just begins to fall off appreciably.

Audio Circuit:—This is a straightforward "d.c. feedback pair"* amplifier, in which V1, the r.f. transistor, doubles as first a.f. stage. It will be necessary to select R_2 (or make it adjustable—say 100 kΩ max) in order to set up the transistor operating currents, but once set up they should be little affected by supply-voltage fluctuations. The p.d. across R_5 is a good setting-up indicator. Temperature drifts may, however, be troublesome. To reduce them, R_2 could be fixed at a lower value (say 4.7 kΩ) and fed, not from the emitter of V2 but from a tap on R_5, which could in this case be a miniature pre-set "pot." Even better temperature stability can be obtained by giving V1 an emitter resistance (by-passed to a.f. and r.f.), but if this is done the emitter voltage of V2 must be raised, otherwise V1 will not have enough collector voltage. This will reduce the audio output power obtainable with a given collector current, but there is room for some reduction.

The value of the volume control potentiometer R_3 is not critical. Provided that R_4 is selected to maximise sensitivity, values of R_3 down to about 5 kΩ can be used. (The writer used 50 kΩ because a suitable "pot" was available: 50 kΩ is rather on the high side, and I would not recommend anything higher.)

The output transformer T_3 will not be necessary with some types of earphone. (If the earphone is to be used without a transformer but has a high d.c. resistance, reduce the current in V2 by an appropriate increase in R_5.)

Top-cut can be arranged by connecting a series RC network from the collector of V2 to "earth" (battery positive), and may be a useful way of reducing the annoyance value of the background

* "D.C Feedback Pair" p.636, December 1961

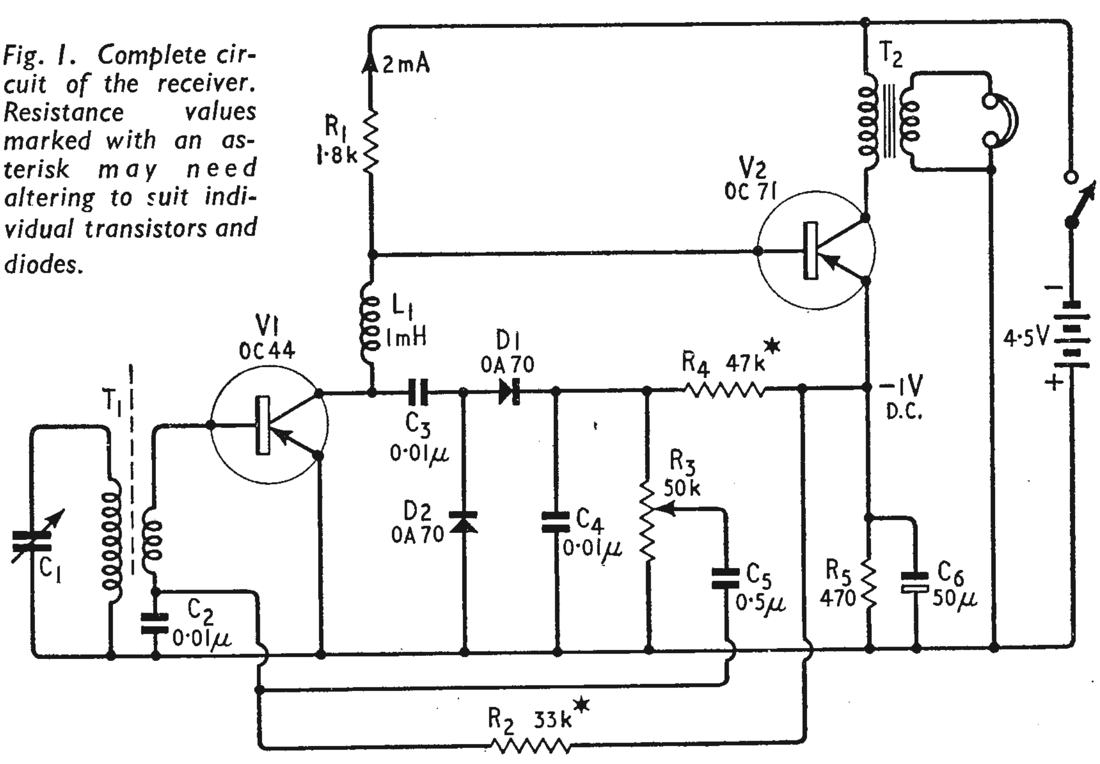
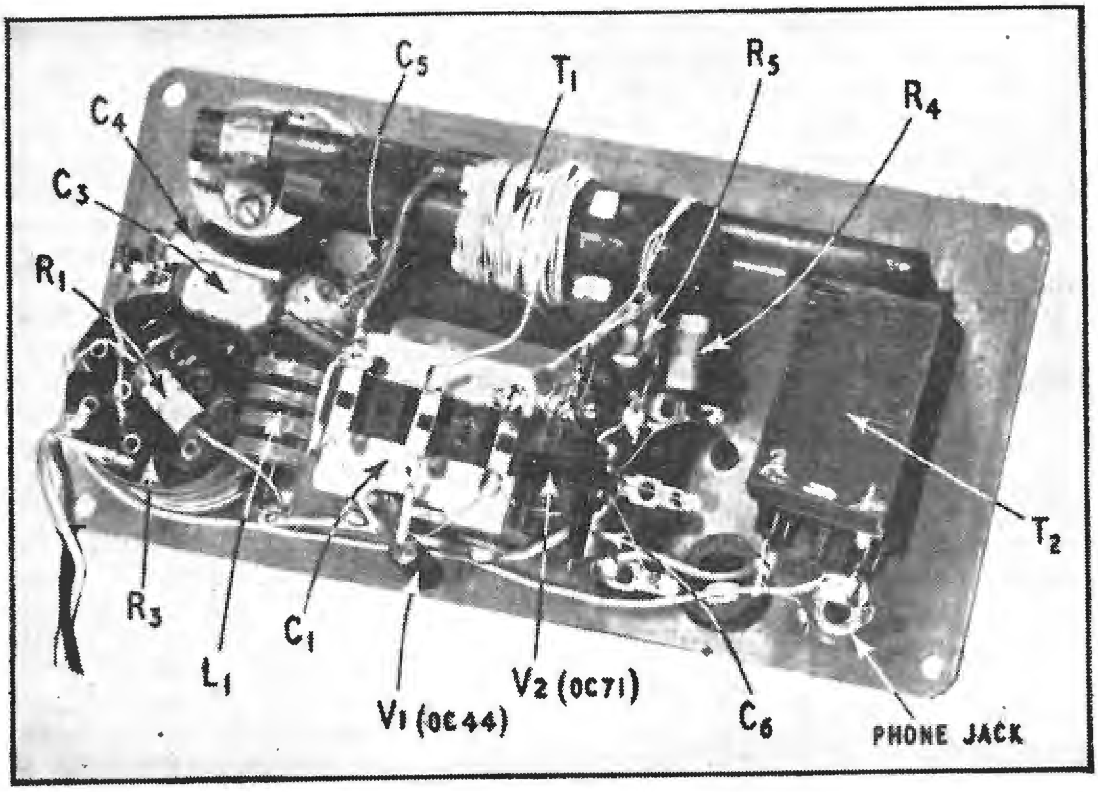


Fig. 1. Complete circuit of the receiver. Resistance values marked with an asterisk may need altering to suit individual transistors and diodes.



Interior of receiver, showing principal components. The panel is a piece of 'Formica'. Tag strips (for the transistors) and the output transformer (T_2) are stuck down with a rubbery adhesive ('Bostik 252'). Small components are suspended by their leads. The diodes are hidden by C_3.

hiss. A more elegant alternative is to apply negative feedback. The easiest way to do this is to remove C_6, but there will then be a drastic reduction in gain. Alternatively, one could connect a 1 kΩ variable resistance (log. law) in series with C_6, and use it as a negative feedback volume control. (R_3 would then be fixed.) It will not be possible to reduce volume to zero by this means, but the range of control may still be adequate.

Improvements

It is a good plan to incorporate *some* a.f. negative feedback embracing V1, because this reduces r.f. intermodulation noise and strong-signal break through as well as ordinary background hiss. The procedure just mentioned (resistance in series with C_6) does the trick, because a.f. signals are then fed back to the base of V1 via R_2. (A feedback resistance of about 30Ω is quite effective.) It may be worth while introducing some pre-set reaction (e.g. by positioning L_1 to couple with T_1) in order to throw away the extra gain by using negative feedback.

Sensitivity can be improved by using a better transistor for V1. "Better" in this context could mean (a) lower input capacitance and higher input resistance so that the step-down ratio of T_1 can be reduced, (b) higher cut-off frequency, (c) higher current amplification factor, (d) lower output capacitance. The logical choice is a transistor such as the Mullard AF117 or the Brush Crystal AF132. Reduced output capacitance means that a higher value of L_1 is permissible (say 2.5 mH).

Use of Other Supply Voltages

The 4.5 V flat torch battery used in the original circuit was chosen because it was cheap, easily fixed in place, and easy to make connections to (leads soldered to the brass contact strips). However, 4.5 V is on the low side, and improved sensitivity and output may be obtained by using a higher voltage. Raising the battery voltage has very little effect on the current taken by V2. The collector current of V1 increases in such a way as to keep its collector voltage constant. However, it is advantageous to operate V1 at a higher collector voltage. With a 9 V supply, for example, one could choose values for R_1 and R_5 such that the emitter of V2 is at -3 V. (The collector of V1 is at about the same potential.) For mains operation, the modest current required can be provided by a point-contact diode rectifier supplied with a.c. by an l.t. transformer. (A Woolworths' bell transformer, which has 3-V, 5-V and 8-V taps, is a suitable miniature component.)

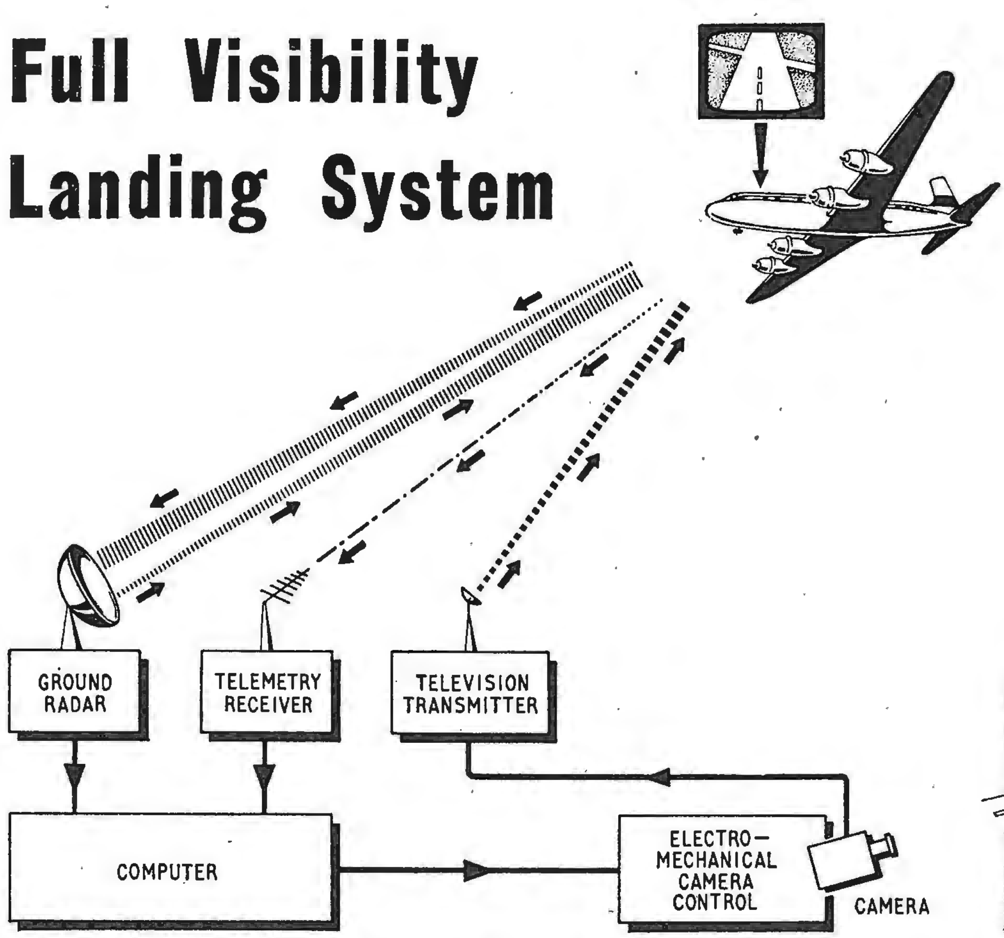
Reaction

The first model constructed turned out to be sensitive enough without reaction. The model shown in the photograph is less sensitive, so some fixed reaction is used. This is provided by two means, both of which are visible in the photograph. First, a "tickler" coil on the aerial rod (to the right of the main winding) is connected in the emitter lead of V1. Secondly, capacitive feedback from the collector of V1 to the tuned circuit is provided by a piece of insulated wire pushed under the "hot" end of the tuning coil. The tickler coil is most effective at the low-frequency end of the band, and the capacitance at the h.f. end. They are moved about until regeneration is about the same at high and low frequencies. (In practice, it is impossible to obtain constant reaction over the whole hand, and some sort of compromise is necessary.)

Construction

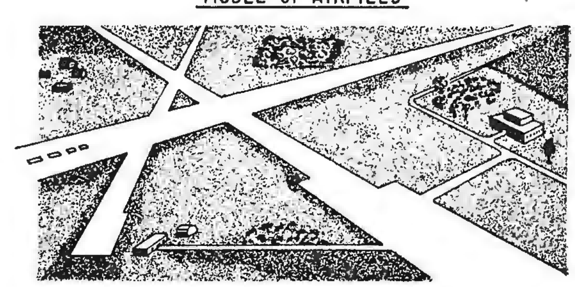
There are no special difficulties. Connections to the collector of V1 must be kept short to minimize stray capacitance. The only likely cause of r.f. instability is coupling between L_1 and T_1, and this can be cured by reversing the sense of winding of L_1 or the base winding of T_1.

Full Visibility Landing System



Diagrammatic plan of the Miles "visual" blind-landing system which employs television techniques for the presentation of information in the aircraft.

MODEL OF AIRFIELD



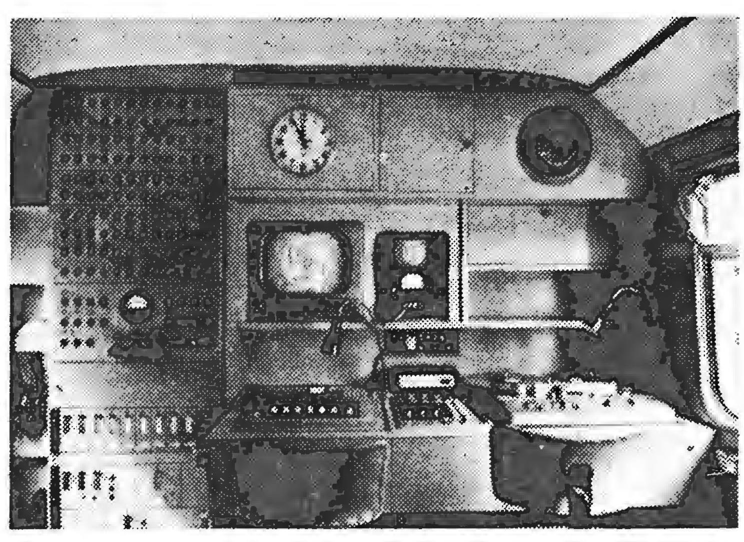
A NEW approach to the problem of blind landing, using television in conjunction with known electronic techniques, has been devised by F. G. Miles of Miles Electronics Limited, Shoreham, Sussex. The Miles system gives pilots a clear television picture, even with zero visibility, of what they would normally see when making a landing with good visibility. This is achieved by accurately scanning a scale-model of the airfield, and its surrounding countryside, with a small television camera and transmitting the information to a receiver in the aircraft. Presentation of the information can be effected either by using a simple monitor or using more elaborate methods such as projecting an image on to the pilot's windscreen.

As can be seen from the accompanying schematic two sets of information are required to direct the television camera. A search and lock-on radar installation, sited at any convenient spot on the airfield, is used to obtain azimuth, elevation and range of the aircraft. The standard aircraft instruments provide the rest of the information required—height, roll and pitch—which is transmitted from the aircraft using telemetry techniques. Both sets of information are fed into a programmed computer whose function is to control the television camera. A point worth noting is that the siting of the ground radar is not important, as allowances can be made in the computer, and a change of runways can be effected just by flicking a switch.

The video output of the camera is transmitted back to the aircraft using conventional techniques. A low power transmitter with a highly directional aerial, locked to the radar, is used to avoid interference to other services and to prevent another aircraft receiving the transmission.

There are numerous applications this system can be used for and considerable interest has been shown in using it for flight deck landings. So far, the landing system has only reached the " breadboard stage," but the principle has been applied very successfully in Army tank training by the Miles Group.

Eurovision Mobile Control Centre



WHEN commentaries in different languages are distributed to countries taking a Eurovision programme, portable soundproof booths are provided for each commentator with a monitor receiver showing the picture going out on the network. To co-ordinate the incoming and outgoing signals a mobile telecommunications exchange has been developed by the Westdeutsche Rundfunk in conjunction with Siemens and Halske. Here the normal background noises are mixed with each commentary and routed via the switchboard on the left to the appropriate landlines. The vehicle accommodates cable drums, etc., in forward compartments.

Wireless World OSCILLOSCOPE

3.—"No. 1" TIMEBASE UNIT

HAVING described, last month, the means of deflecting the c.r.t. spot in a vertical direction, we must now consider the circuitry we need to produce the second co-ordinate of the graph—the horizontal or (as the independent variable in our work will usually be time) time base.

Requirements

It was shown in the first article that the output of the timebase or sweep generator is of sawtooth form—a relatively slow rise or fall followed by a rapid "flyback." The main characteristics required are that the sweep (the slower part) should be as straight as possible and that the rate of change of the sweep should be sufficiently rapid to draw out the y signal over a reasonable amount of the screen. Most modern sweep generators produce a sawtooth which is virtually perfect as far as the eye is concerned, and the usual specification of sweep speed is that the timebase should be able to display the rise-time of the amplifier over about one-tenth of the screen. The flyback should be as fast as possible and during this time the circuit should produce a waveform which can be used to blank the c.r.t. and avoid meaningless information. A further requirement is that it should be easy to synchronize the timebase with the y signal.

All these requirements can be supplied by a number of timebase circuits, and it was originally intended to use one of the multivibrator family, the circuit of Fig. 14 in the March issue. However, a little delving into the reliability of this circuit has revealed that it is somewhat deficient in this respect and that the linearity, especially at very low speeds, is dependent on the quality of capacitors used. It was eventually decided to use instead the Miller-integrator screen-coupled phantastron, sometimes known as the Miller-transitron because of the connection of the g_2—g_3 circuit. A short description of this circuit was given in the first article, but a more comprehensive account of its operation is, we feel, called for.

There are several ways of looking at the circuit, and although they all amount to the same thing, it will be useful to examine one or two and see how they correspond. We can, for the time being, ignore the flyback mechanism and concentrate on the production of a linear sweep.

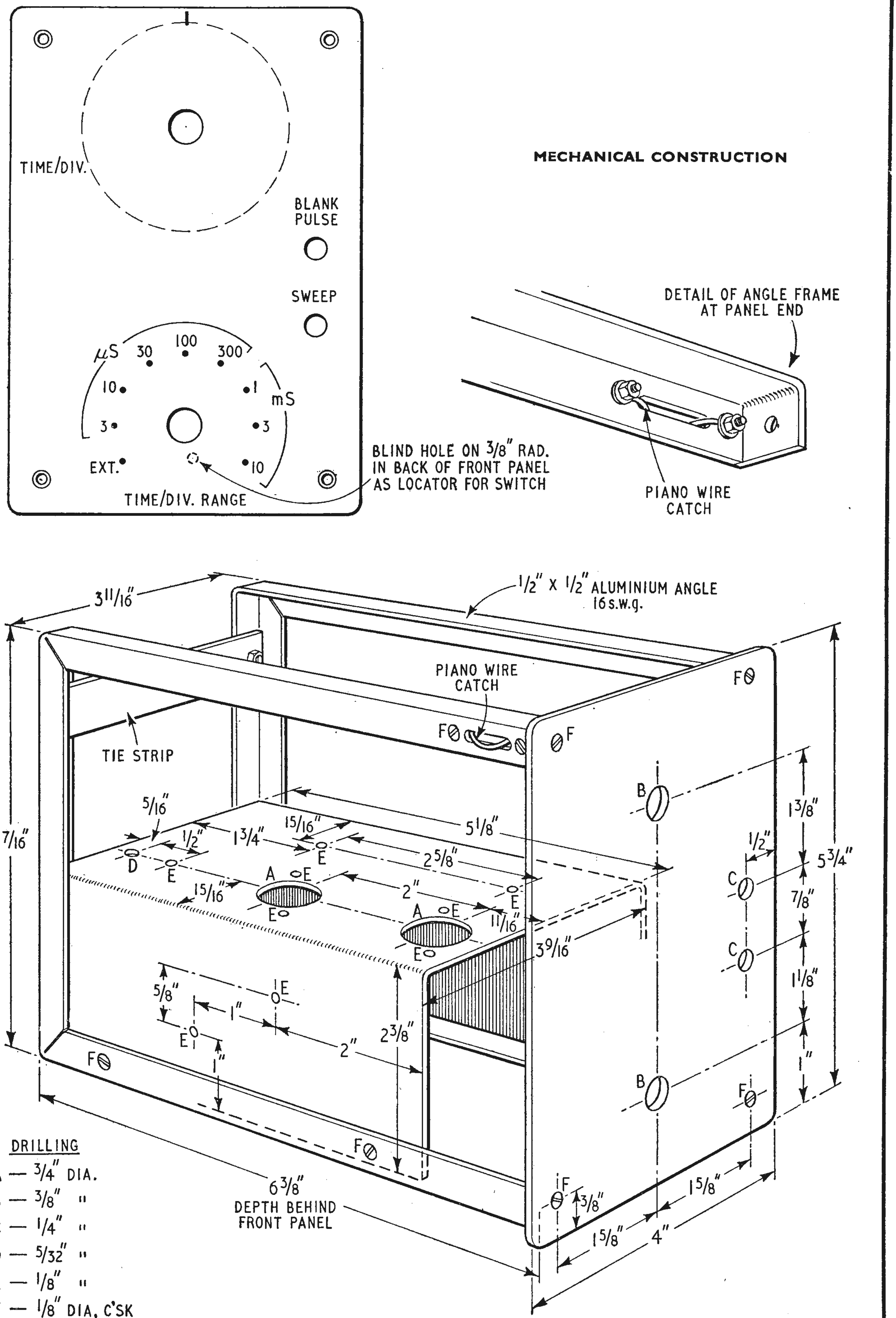
General Description

Sweep.—As we saw earlier (March) the general way of forming a linear ramp is to charge a capacitor through a resistor. Now, this process is subject to the law of organic growth in that the increase of voltage v across C in Fig. 1(a) is exponential. The rate of change of v is proportional to its instantaneous value, and the growth of v is shown in Fig. 1(b) (the current curve is the exact opposite). In a time CR, v increases to just over 60% of V in a fairly linear manner, but then begins to curve in a most alarming way. The capacitor voltage never, in theory, reaches V but is considered to have done so after about 5CR seconds. (In 5 seconds a 1μF capacitor will have been fully charged through a $1\text{M}\Omega$ resistor.) The only way to use this curve as a sweep is to extract a small part near the origin where it is still fairly straight. This, of course, means that we can only obtain a very small output or, alternatively, that C must "aim" at a high voltage. Small outputs need large amplifiers and tend to be fussy over the discharge circuit used, and it is therefore easier to simulate the effect of a large aiming voltage V. This is easily done by keeping the current through C and R as constant as possible. A diagram is needed here and Fig. 2 is the one we need.

One always has to start somewhere, and so we will assume that C is charged to V, without worrying about how it came by this charge. C now begins to discharge through R and v falls. The grid is affected initially by this sharp fall, but then begins to rise, the resistor R being taken to h.t. We now have the situation where the fall in anode voltage v is opposing the rise in grid voltage which causes it. If the gain of the valve is large, the change in grid voltage need only be very small, and the voltage across R remains almost constant. This, of course, means that the current in R is also constant, and this is the discharging current of C. The fall in v takes place at constant speed and the result is a beautifully linear sweep. The effect is the same as if C were initially charged to several kilovolts.

An alternative way of looking at the process is to consider the circuit as a feedback amplifier, with the voltage across the resistor as the input. Fig. 3 shows this arrangement in block form. The voltage across the capacitor C is v_c and is the sum of the resistor voltage v_r which is also the amplifier input signal, and the output voltage of the amplifier v_a. In other words, $v_c = v_a + v_r$.

However, v_a is A times v_r, where A is the amplification, so $v_c = v_r\ (A + 1)$, or $v_r = v_c/A + 1$. If now the voltage across v_c changes by, say, $0.1v_c$, the voltage across R will also change, not by $0.1v_c$ but by $0.1v_c/A + 1$. The change in amplifier input



MECHANICAL CONSTRUCTION

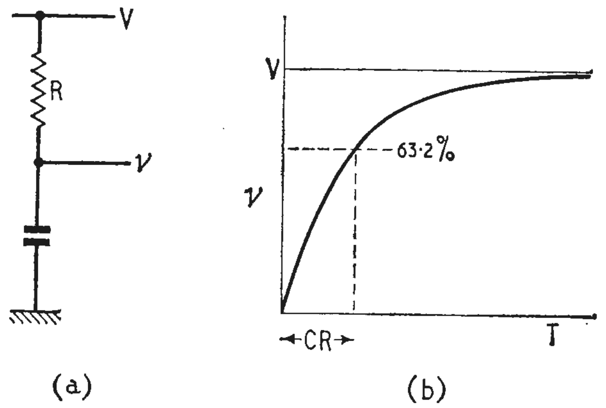


Fig. 1. The charging curve of a capacitor fed through a resistor. CR is called the "time constant."

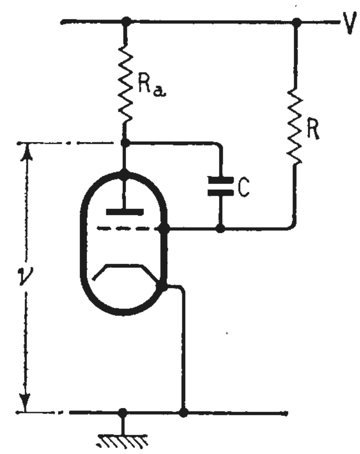


Fig. 2. The feedback capacitor C augments the Miller capacitance C_{ga} and is responsible for the name Miller-integrator.

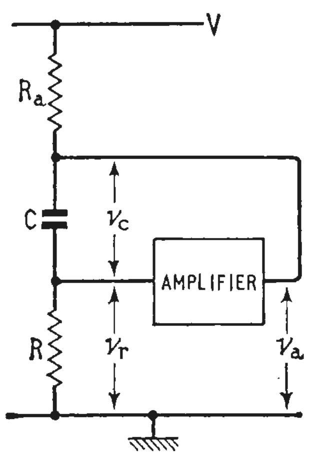


Fig. 3. Miller-integrator as feedback amplifier to provide constant charging current.

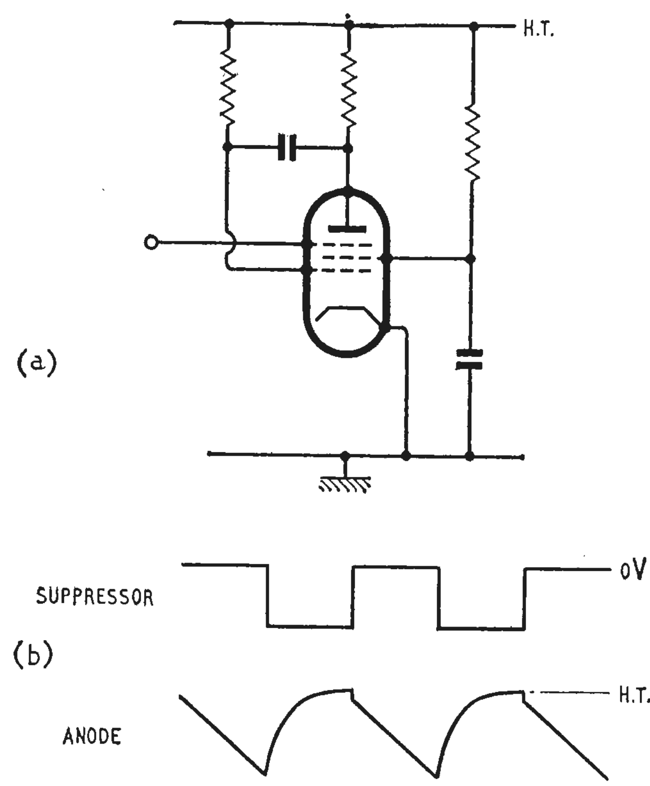


Fig. 4. (a) Circuit for suppressor-gated sweep generator to provide waveforms as at (b).

voltage, which is the same as saying the change in current in R, has been reduced by a factor of (A + 1). Once again, the capacitor current is held almost constant and a linear sweep is obtained.

Flyback. Having got the anode voltage to the end of its sweep in a linear manner, we are now faced with the problem of getting it back again without too much loss of time on the way. To do this, we abandon the triode and use the characteristics of a pentode to give us the flyback. If the suppressor is fed with a square wave, as in Fig. 4, the anode will perform the linear sweep when the suppressor is at or about cathode potential and will return towards h.t. when the suppressor goes negative to cathode, cutting off anode current. The modifications to this arrangement to make the circuit self oscillate are shown in Fig. 5. The circuit is made to generate its own square wave by the action of screen and suppressor. Assume that the anode is well on its way down the sweep, the screen voltage is high and the suppressor is at about cathode potential. The anode continues its linear way, glancing neither to right nor left, until the anode voltage is so low that it reaches the bend in the output characteristic—the familiar pentode "knee." At this point, two things happen. One is that the gain drops sharply, reducing feedback and therefore linearity, and the other, which follows so quickly that the non-linearity hardly makes an appearance, is that the screen begins to take more of the cathode current. This increase in screen current causes screen voltage to drop, and, as the screen is connected to the suppressor *via* a capacitor, the suppressor also falls. A multivibrator action now takes place as the suppressor, in falling, reduces anode current and diverts more cathode current to the screen. This "toggle" process is over in a very short space of time and ends in a quasi-stable condition where the anode current is nil, and the anode voltage is returning to h.t. in a time governed by the time-constant C_gR_a. The screen voltage is very low and the suppressor has been driven well below cathode potential. C_{supp} and R_{supp} form a differentiating circuit, which means that a square wave fed to them in series appears like Fig. 6 when viewed across the resistor. The square pulse from the screen is therefore differentiated and the suppressor voltage slowly increases towards cathode potential.

When it arrives at a point where anode current can flow once more, the screen relinquishes its claim to most of the cathode current and the anode falls, taking the grid with it. The grid has been sitting out of harm's way at the positive end of the grid base, prevented from going positive by a small amount of grid current in R_g. (The value of R_g is enormous compared with the grid-cathode resistance of the valve.) When the anode falls, the grid is pushed down to the active part of its operating region, feedback becomes effective and the linear sweep gets under way. The waveforms of the circuit are shown in Fig. 7.

The time the anode takes to reach h.t.—the flyback time—is governed by its time constant, and if it does not reach h.t. before anode current begins to flow once more, the amplitude of the sweep will decrease. Conversely, if it reaches h.t. before the suppressor reaches cut-off, it will sit there, rather tensely, wasting time which could be used more profitably in sweeping the spot. It is arranged, therefore, that the anode flyback time—about 3 or 4 times C_gR_a—is equal to the time required by the suppressor to return from its negative excursion to the cut-off value.

The variation of sweep time necessary for oscilloscope use is obtained by three methods. Large variations—range switching—are performed by switching different capacitors in the anode/grid position. For the reason set out above, it is also necessary to switch the screen/suppressor capacitors at the same time. Fine variation of the sweep time is obtained by either varying R_g or the voltage to which it is returned, this being our method.

Cathode-follower. At very low sweep speeds, large values of C_g are used, which means that the flyback time is very long indeed. This also means that large values of C_{supp} are needed. Both these effects are avoided by the use of a cathode-follower between the anode and grid, as in Fig. 8. The sweep time is as before, but when the anode current is cut off, the capacitor C_g charges not through R_a, but through the cathode impedance of the cathode-follower, which is typically about 200 Ω. As the value of R_a is commonly of the order of 100k Ω there is a considerable time-saving in the flyback period.

The main drawback of the circuit described is the initial step in the anode waveform. This is rather worse at the faster sweep speeds because stray capacitance from grid to earth forms a potential divider with the anode/grid capacitor, but it is considered that the performance is adequate. Later, more sophisticated units will contain circuitry for the sole purpose of avoiding this step, but this kind of thing can get out of hand and run the builder into another two or three pounds before he notices it.

Blanking. During the flyback, the screen should be blank. If not, one is confronted by the spectacle of the normal display and the display reversed at a different, inconstant speed all at the same time. This is not the most convenient type of picture to resolve, and steps are normally taken to get rid of the flyback. The screen waveform is just the right shape for this, if applied to the c.r.t. grid and, after the waveform has been squared by the action of the diode and potential divider, it is fed to a cathode-follower output stage for this purpose. It is taken from here to the tube, *via* a floating e.h.t. supply, to avoid the use of a blocking capacitor, which would cause sag during the sweep time and vary the brightness.

Calibration of the timebase is by switched ranges

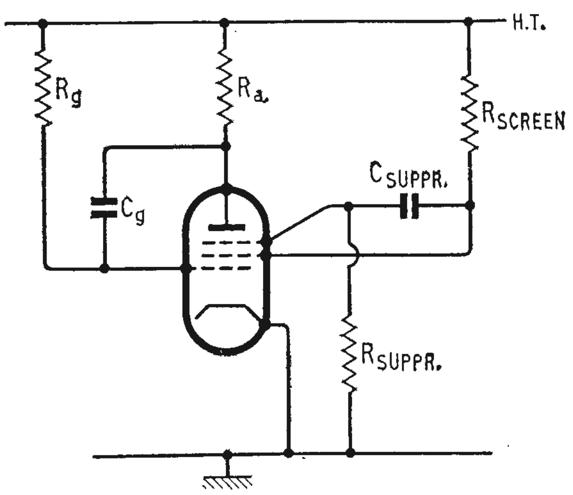


Fig. 5. Screen and suppressor components produce internal gating waveform.

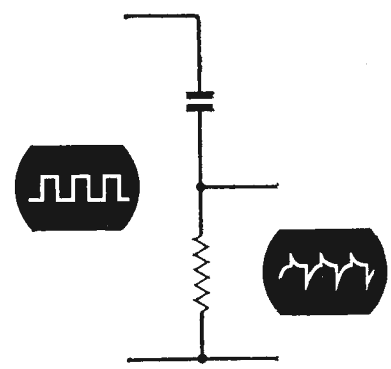


Fig. 6. Differentiating circuit.

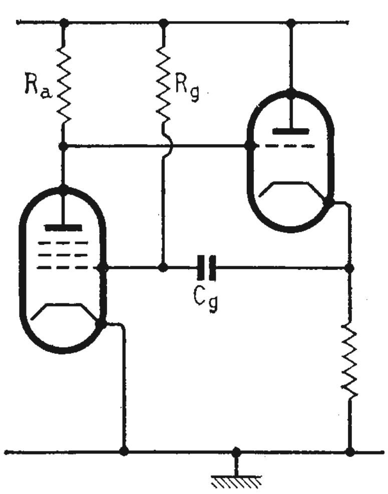


Fig. 7. Waveforms for circuit of Fig. 5. Grid waveform slope is exaggerated.

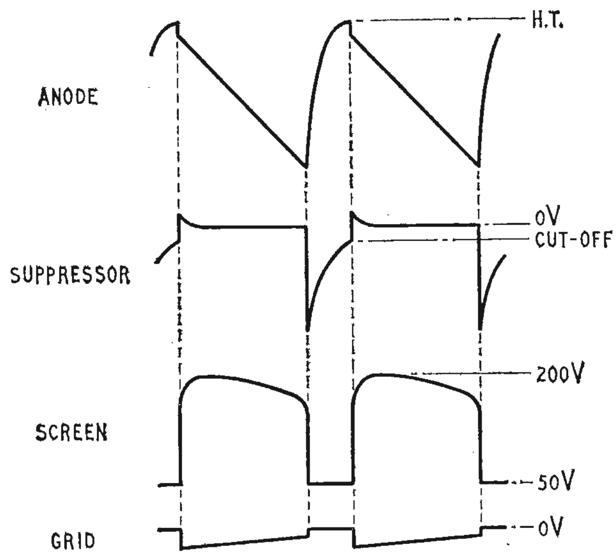
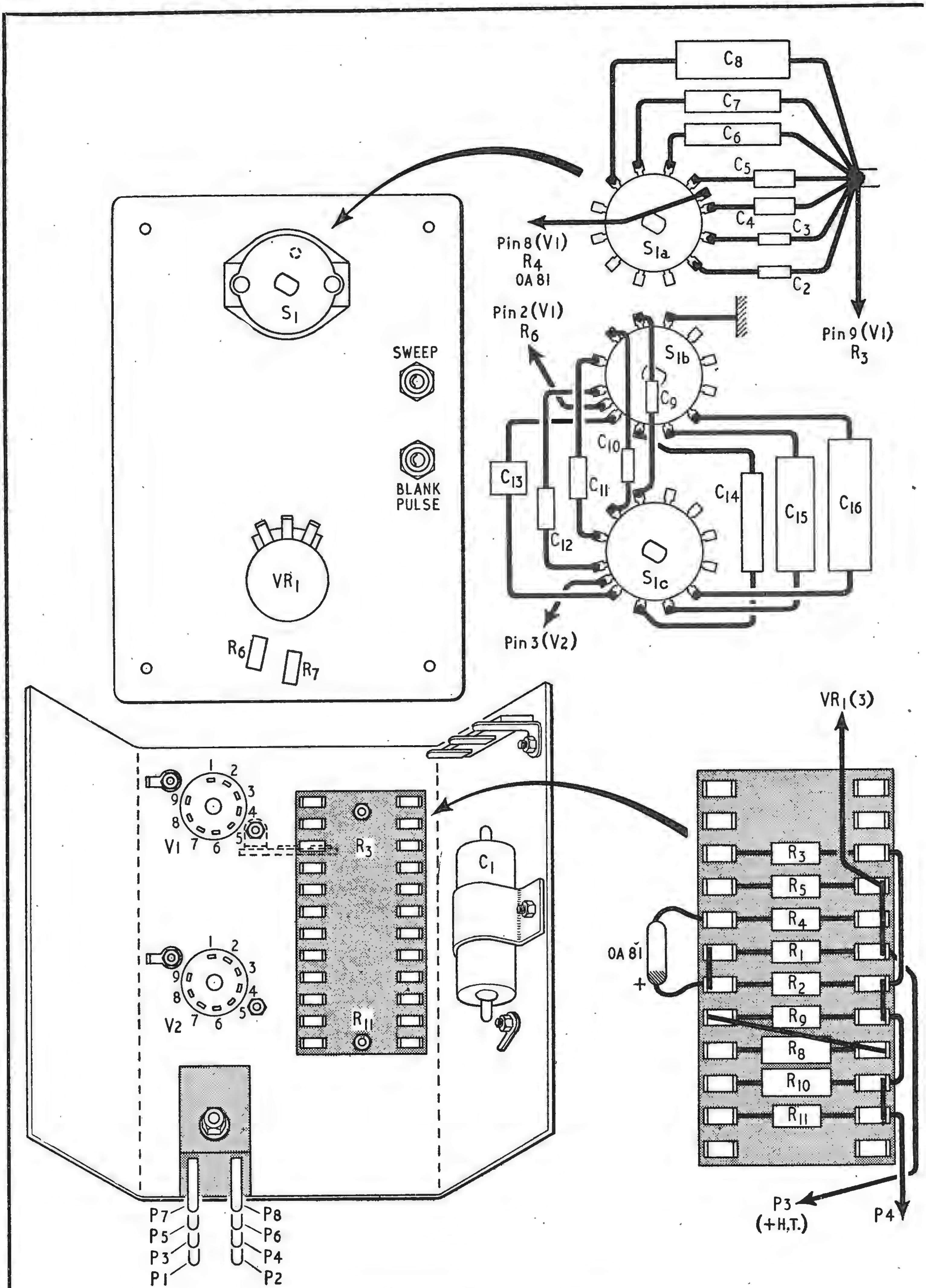


Fig. 8. Addition of cathode-follower reduces charging time of Cg.



LAYOUT OF COMPONENTS

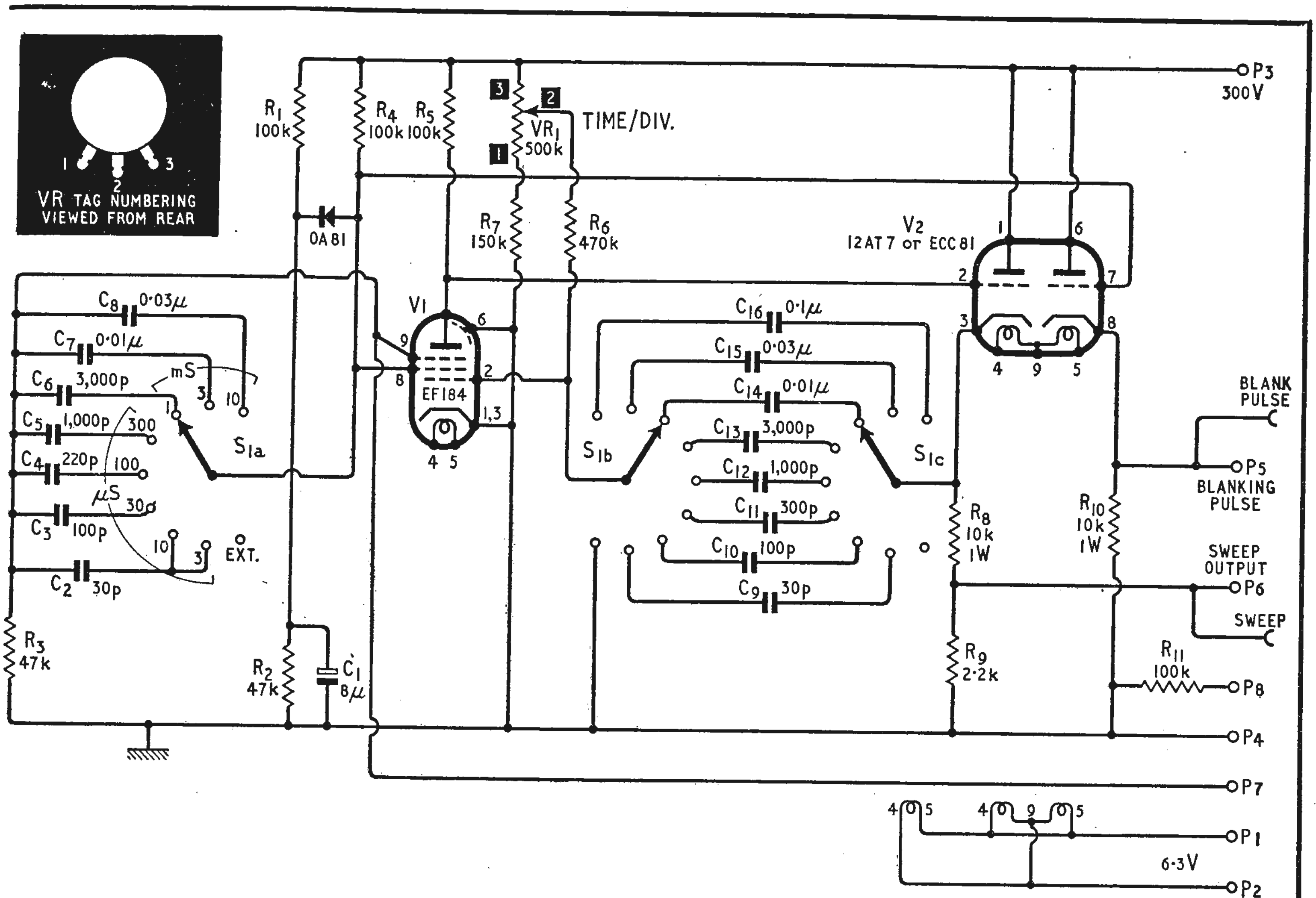


Fig. 9. CIRCUIT DIAGRAM OF "No. 1" TIMEBASE UNIT AND COMPONENT LIST

Capacitors

C_1	8μ	150V	electrolytic
C_2	30p ± 2p	350V	plastic film (Salford Type PF)
C_3	100p ± 5%	350V	„ „ „
C_4	220p ± 5%	350V	„ „ „
C_5	1000p ± 5%	350V	„ „ „
C_6	3000p ± 5%	350V	„ „ „
C_7	0.01μ	350V	paper (Dubilier Bluecon)
C_8	0.03μ	350V	„ „
C_9	30p ± 2p	350V	plastic film (Salford Type PF)
C_{10}	100p ± 5%	350V	„ „ „
C_{11}	300p ± 5%	350V	„ „ „
C_{12}	1000p ± 5%	350V	„ „ „
C_{13}	3000p ± 5%	350V	„ „ „
C_{14}	0.01μ ± 10%	350V	paper (Dubilier Bluecon)
C_{15}	0.03μ ± 10%	350V	„ „
C_{16}	0.1μ ± 10%	350V	„ „

Resistors

R_1	100k	½W	
R_2	47k	½W	
R_3	47k	½W	
R_4	100k	½W	
R_5	100k	½W	
R_6	470k	½W	high-stability
R_7	150k	½W	„ „
R_8	10k	1W	
R_9	2.2k	½W	
R_{10}	10k	1W	
R_{11}	100k	½W	
VR_1	500k	½W	linear

Miscellaneous

OA81	germanium diode
V1	EF184
V2	12AT7 or ECC81
S_1	3-pole, 9-way " Makaswitch " (Radiospares)

Wander-plug sockets
P_1,P_8 " Domina " plugs P490 Bulgin

and a continuous " fill-in " control and is to a certain extent dependent on the tolerance of the capacitors used in the anode/grid position. The ranges are switched in a 1-3-10 sequence to cover sweep speeds between 1μsec and 10msec per screen division, the continuous control giving a 3 : 1 coverage. Calibration is best left until the whole instrument is completed, when the screen an be used as a calibration aid.

Synchronization is effected by the injection of a negative-going pulse, derived from the trigger stage in the main unit.

Outputs from the sweep and brightening-blanking circuits are taken to the front panel, where they can be used to drive external equipment such as swept oscillators.

Construction is identical to the *y* amplifier described last month except that the front panel drilling is different. Apart from this identical metalwork can be used.

Errata

In the article on the *y* amplifier in the April issue, the component values in the circuit diagram and component list do not correspond completely. The values of VR1-3 and C13 are correctly shown on the circuit diagram.

WORLD OF WIRELESS

Communications Satellite

THE Government has decided to carry out a detailed design study for a communications satellite which could be launched within the next six years. Julian Amery, Minister of Aviation, said in the Commons recently that the study, which is expected to be completed by this autumn, will be carried out under the general guidance of the Royal Aircraft Establishment at Farnborough and the Signals Research and Development Establishment at Christchurch, with suitable firms being invited to attach members of their staffs to these establishments to work on the study. R.A.E. will be concerned with the satellite and its launcher and S.R.D.E. with the telecommunications and ground stations side of the project.

Speaking at the annual dinner of the Radar & Electronics Association on April 5th, Air Marshal Sir Edouard Grundy (Controller of Guided Weapons & Electronics in the Ministry of Aviation) stated that the information resulting from the study will be made available to companies not participating in the initial investigation. The study is aimed at deciding on the type of satellite and launcher to be used and on the most suitable orbit to meet both civil and potential military requirements.

Sir Edouard, outlining some of the problems being encountered in "going into space," mentioned the multiplicity of Government committees of which the four most directly concerned are:—the Official Committee on Communications Electronics in Space, Launchers and Vehicles for Space Committee, Combined Communications Electronics Committee, and the Steering Group on Space Research.

Radio-Microphone—P.O. Approval

THE Post Office has recently given approval to a radio-microphone and the P.M.G. is prepared to grant a licence for its use. Manufactured by Lustraphone it operates in the frequency range 174.6-175 Mc/s, which is at the lower end of Band III, and has a range of about 200-300 yards. A five-year licence costs £2 and it is understood that about half a dozen have already been granted. Further particulars regarding the licensing of radio-microphones are obtainable from the Radio Services Department, Radio Branch, G.P.O., St. Martin's-le-Grand, London, E.C.1.

Car Radiotelephone Service

THE public car radiotelephone service, inaugurated as a pilot scheme in the southern half of Lancashire in November 1959 and reported in *Wireless World* at the time, is to be introduced in the London area. The service will come into operation next year and at first cover a radius of 25 to 30 miles from central London. It will operate in the 160 Mc/s band using f.m. Subscribers to the service will have to pay a licence fee of £30 a year and a radio charge of 1s per three minutes, plus the standard local and trunk rates. The subscriber will have to buy or rent the necessary mobile equipment from an approved supplier.

Standard Frequency Transmissions

AS a result of international agreement on time-sharing between standard frequency stations in the European area the programme of the MSF (Rugby) high-frequency transmissions was altered on March 1st. The station now broadcasts only in alternate 5-minute periods during each hour according to the following schedule:—0.5min, carrier plus second and minute pulses; 5-9½min, no transmission; 9½-10min, call sign and amount of frequency deviation* given three times in slow morse. The above cycle is repeated six times during the hour. The new schedule means that, on 5 Mc/s MSF and HBN (Neuchâtel, Switzerland) effectively share the available time, the latter operating in the periods when MSF is silent, except for the last five minutes in each hour which is left free for the transmissions of time signals from RWM-RES (Moscow) on 5 and 10 Mc/s. Both HBN and MSF participate in the international co-ordination of time and frequency and the time of emission of their signals is the same to within one millisecond: they may, therefore, be used interchangeably after making due allowance for propagation delay.

It is hoped that it will be possible ultimately to extend this basic pattern of time-sharing to other standard frequency stations in Europe.

*Expressed in parts in 10,000 million

Components Show

BRITISH manufacturers of some 3,000 million components a year valued at about £140M will be showing their wares at the biennial Radio and Electronic Components Show which opens at Olympia, London, on May 21st for four days. There will be a total of some 280 exhibitors occupying over 220 stands in the Grand Hall. Admission to the show, which is sponsored by the Radio and Electronic Component Manufacturers' Federation, costs 5s.

As announced elsewhere we shall be including in our next issue, to be published on May 20th, an alphabetical survey of the manufacturers' exhibits and in the following issue a review of the trends shown at the Exhibition.

Engineering Exhibition.—Both Olympia and Earls Court are being used for the International Engineering Exhibition which opens on April 23rd and continues until May 2nd. Only a small number of the exhibitors are in the radio and electronics industry but electronic techniques are employed in so many branches of engineering that there will be much of interest to the industry as a whole. Over 20% of the 750 or more exhibitors are from abroad.

The Greek Government has decided to introduce f.m. broadcasting, employing 38 stations to serve 98% of the population. A TV service will be established using a central transmitter and 17 repeater stations. It is also planned to build a 100-kW short-wave transmitter for overseas transmissions of the National Broadcasting Corporation.

New York Decca Chain, the first to be built in the U.S.A., has now been brought into service. The chain of four stations operates on the "multipulse" system (employed in the latest Decca Navigator marine receiver) which reduces the effect of skywave interference on the accuracy of lane identification.

Asynchronous operation has been adopted by the B.B.C. for all television trade test transmissions from March 25th. The fact that these transmissions are not locked to the mains is of particular interest in view of the suggestion referred to in our last issue that we should adopt a field frequency different from that of the mains.

R.E.C.M.F. Council.—At the annual general meeting of the Radio and Electronic Component Manufacturers' Federation, the following were elected to the council: N. D. Bryce (Belling & Lee), R. A. Bulgin (A. F. Bulgin & Co.), S. H. Brewell (A. H. Hunt), J. Thomson (Morganite Resistors), R. Arbib (Multicore Solders), C. M. Benham (Painton & Co.), L. T. Hinton (S.T.C.), G. A. V. Sowter (Telcon Metals), G. J. Taylor (Bakelite), E. G. Lennard (Cosmocord) and K. G. Smith (N.S.F.). The new chairman is J. Thomson and vice-chairman, S. H. Brewell.

B.E.A.M.A.—Following the March 21st a.g.m. of the British Electrical and Allied Manufacturers' Association, Arnold L. G. Lindley (chairman of G.E.C.) was elected the new president and Edward B. Banks (joint managing director of English Electric) deputy president.

A.P.A.E.—The president of the Association of Public Address Engineers for 1963 is Cecil Clarabut, of Bedford, who has been chairman of the association since its foundation. The new chairman is Frank Poperwell, manager of Reslosound Ltd., and the vice-chairman, S. W. Lewis, of Theydon Bois, Essex.

Instrument Show.—The seventh International Instrument Show to be organized by B. & K. Laboratories opens at the company's offices, 4 Tilney Street, London, W.1, on May 27th for five days. Instruments from over 60 manufacturers in 10 countries will be on show. Invitation tickets are available free from the organizers.

Next year's **international components show** (*Salon International des Composants Electroniques*) in Paris will be held from February 7th-11th.

A new pamphlet "**Teaching in Technical Colleges**" has been prepared by the Ministry of Education and the Central Office of Information. It outlines career prospects in full-time technical teaching and is available from local education authorities or from the Ministry of Education, Curzon Street, London, W.1.

Tape-controlled Routing.—In the April issue of our associate journal *Production Technology* there is an informative article on the economic advantages of numerically controlled machining, as compared with conventional machining, for heavy-duty, routing of light-alloy parts.

Students of four nationalities were the recipients of the prizes for the "**Best Student Members Of The Year**" presented at the seventeenth annual dinner of the Radar & Electronics Association on April 5th. The prizes, consisting of textbooks, were presented by the president, Sir Robert Renwick, to A. Bhattacharya (India), J. J. Jacobs (Israel), S. G. Chamberlain (Cyprus) and I. Richards (U.K.), who are all taking the Brit.I.R.E. graduate course at the Northern Polytechnic, London.

Reliability.—A three-day full-time course on General Concepts of Electronic Equipment Reliability "planned to give a general understanding of all the factors which influence the reliability of electronic equipment" will commence at the Borough Polytechnic, London, S.E.1, on June 11th. The fee, including meals, is £6.

A five-day residential course, starting May 20th, on "**Printed Circuit Techniques**" is to be held at the Twickenham College of Technology. Enrolment forms are obtainable from the College, Egerton Road, Twickenham, Middx. Fee is 8 gn (16 gn residential).

***"Shape of things to come . . ."**—Colour television receivers (left) and monitors (right) in the Chiswick, London, factory of Rank-Bush Murphy who are producing them for the B.B.C. colour trials.*

A course of eight lectures on "**Technical Writing**" is to be held at the Borough Polytechnic, starting May 3rd. The fee is £1 and further details can be obtained from the secretary, Borough Polytechnic, Borough Road, London, S.E.1.

A two-day symposium, starting on June 12th, "**Electronics, Instrumentation and Production**" is to be held at the Bristol College of Science and Technology. Further details, including registration forms, may be obtained from the secretary of the South Western Section of Brit.I.R.E., at 3 Northwick Road, Bristol 7.

CLUB NEWS

Birmingham.—A lecture-demonstration on amateur television will be given to members of the Slade Radio Society by B. W. Smith (G3LGJ/T) on May 3rd at 7.45 at The Church House, High Street, Erdington.

Derby.—A series of three lectures on "Safety in the Shack and Home" will be given to the members of the Derby and District Amateur Radio Society on May 8th, 15th and 22nd. Weekly meetings are held at 7.30 at 119 Green Lane.

Edinburgh.—R. McInnes (GM3LNE) will talk about "Railway Communications" at the May 9th meeting of the Lothians Radio Society to be held at 7.30 at the Y.M.C.A., 14 South Saint Andrew Street.

Melton Mowbray.—"Wired Television" is the title of the talk to be given by L. Root at the meeting of the Melton Mowbray Amateur Radio Society on May 18th at 7.30 at the St. John Ambulance Hall, Asfordby Hill.

Mitcham.—"This is the B.B.C.," the film showing a typical day in the life of the Corporation, will be shown at the May 24th meeting of the Mitcham & District Radio Society. Meetings are held at 7.0 at "The Canons," Madeira Road.

Spen Valley.—The problems involved in conversion to 625 lines will be discussed by a representative of Baird Television at the May 2nd meeting of the Spen Valley Amateur Radio Society. A fortnight later M. A. Browne will talk on "Guided Missiles." Both meetings will be held at 7.15 at the Grammar School, Heckmondwike.

Thanet Mobile Rally, organized by the Thanet Radio Society, will be held at Cliffsend, Ramsgate, on Sunday, May 5th. Talk-in stations will be G3DOE/P on 160 metres and G3BAC/P on 2 metres. Further details are obtainable from R. A. Bastow, 31 Canterbury Road East, Ramsgate.

News from Industry

Telefusion Ltd., the radio and television rental specialists, have announced that they have taken a holding in British Telemeter Home Viewing Ltd., formed in 1960 to operate pay-as-you-view television services in the U.K. J. Evans, a director of Teleng Ltd., a manufacturing subsidiary company of the group, has joined the board of British Telemeter Home Viewing, as the Telefusion representative.

Toll TV Ltd., registered by British Relay Wireless & Television Ltd., is being re-formed as a joint company by B.R.W. and British Home Entertainment Ltd. to foster pay-television.

English Electric-Leo Computers Ltd. has been registered as the name of the recently announced English Electric and J. Lyons joint computer company.

Advance Components have acquired the small company **Pentechnique,** of Cheltenham, who specialize in electronic measurement, counting and control techniques. The name of the acquired company is to be changed to Advance Controls Ltd. and is to continue producing the same line of products. The board of the new company will consist of E. A. J. Miles, managing director, A. W. Piercey, A.M.Brit. I.R.E., and E. G. Wakeling, A.M.I.E.E.

Ether Langham Thompson Ltd. announced, at their fortieth annual general meeting, that their profit for the year was £183,993. This is a drop of £113,438 on last year's figure and is said to be "due primarily to reduced level of Government expenditure in the military field and to the uncertain conditions in industry generally."

The Telegraph Condenser Company group profit on trading for the past year was £447,375; a drop of over £225,000 on the previous year.

A. H. Hunt (Capacitors) experienced a further setback last year, with trading profits down from £401,888 to £305,144, leaving net profits at £79,372, compared with £156,223 a year earlier.

Zenith Radio Corporation of Chicago, Illinois, have announced that their net consolidated earnings for 1962 amounted to $19,637,068 after provision for income taxes of $21,300,000. This represents a 9% increase over 1961 and a 140% increase on 1957 earnings.

Amplivox Ltd. have been awarded a Ministry of Aviation development contract for a miniature magnetic throat microphone for use in the R.A.F. and the Navy.

Newmatic (Electrical) Ltd., car radio manufacturers, are moving their works and offices to new premises on 1st May, 1963. The new address will be Argyle House, 22 Parnell Road, London, E.3. (Tel.: ADVance 5257.)

Armstrong Whitworth Equipment, the Gloucester unit of Whitworth Gloster Aircraft Ltd., has recently changed its name to **Whitworth Gloster Equipment.**

The Pye Group have recently introduced a **rental-maintenance scheme** for boat owners who wish to have radiotelephone facilities. The scheme includes installation of the "Hamble" radiotelephone and subscribers will be entitled to service facilities from Pye Marine agents.

British Insulated Callender's Construction Company Ltd. has received an order valued at £48,000 from the B.B.C. for the supply and erection of a 620ft TV mast at Wenvoe, near Cardiff. The new mast will carry a Band III aerial, for the future Welsh National Programme, and is sited only 160 feet away from the existing 750 foot Band I/II mast. Owing to height restrictions it is not permissible to extend the present mast to carry the new array.

A reciprocal licence agreement has been signed between Moore Reed and Co. Ltd., of London, S.W.19, and the Vernitron Corporation, of New York, U.S.A. Under the terms of the agreement Moore Reed will manufacture the Vernitron range of servo components in the U.K. Similarly, Moore Reed products will be manufactured in the States.

Bendix Ericsson U.K. Ltd., of New Basford, Nottingham, have signed an agreement with M. C. Jones Electronic Co., Inc., of Bristol, Connecticut, U.S.A., to act as their U.K. agents and distributors. Under this agreement Bendix Ericsson are to market a wide range of equipment for measuring and monitoring r.f. and v.s.w.r. on coaxial lines and waveguides. Marketing will at first be by importation, but the agreement includes provision for the equipment to be manufactured under licence by Bendix Ericsson if required.

Cleveland Agents.—T. J. Sas & Son Ltd. have recently announced that they are now U.K. agents for Cleveland Electronics Inc., of America, who manufacture orthicon and vidicon deflection components and assemblies.

Measuring Instruments (Pullin) have appointed Curtiss-Wright Limited of Toronto to be sole concessionaires for all their products in Canada. They will also handle U.S.A. enquiries. Two new overseas agency appointments have also been announced by Measuring Instruments. These are, N. V. Vema, of Arnhem, Holland; and Instrumentation Oy, of Helsinki, Finland.

The M-O Valve Company has received an order from the G.P.O. to supply six high-power travelling wave tubes for use in satellite communication systems. These tubes were developed by Dr. M. O. Bryant of the Services Electronic Research Laboratories at Harlow, and one was used to provide the r.f. output power for the Goonhilly Down transmitter in the recent Telstar communication experiments. They operate at a frequency of 6,000 Mc/s and have an output of about 4kW.

The new head office building of **Marconi International Marine** at Elettra House, Westway, Chelmsford was opened officially by Sir Edward Wilshaw last month. Since its formation in April 1900, M.I.M. has administered its many service depots from the same premises as the three-years-older Marconi's Wireless Telegraph Company, but expansion of both companies has necessitated a removal from Marconi House, Chelmsford. As Lord Nelson of Stafford said in his introductory speech, the Marconi Marine Company has now attained its triple majority and is thrice worthy of the key to its own door. The new building has been designed specifically for the Company's special needs with large stores, and offices wired to a central control audio-typing room.

The English Electric Valve Company has received an order from Pye T.V.T. Limited for twenty-four high-power klystron circuit assemblies. These assemblies comprise the mechanical mounting for the klystron, with associated focusing coils, resonators, and other ancillary fittings, the whole being designed as a withdrawable unit. They will be used in the final stages of the Band IV and V television transmitters recently ordered by the B.B.C. Pye T.V.T. has also ordered two 25kW E.E.V. klystrons, for testing purposes in connection with these transmitters.

In last month's commercial literature we inadvertently stated that the ten **sealed terminals** described in a leaflet from Royal Worcester Industrial Ceramics Ltd. were approved by the Ministry of Defence. They have, in fact, been submitted to the Ministry, but not yet approved.

Aveley Electric Ltd., which was formed by J. Brown (managing director) in 1954 at Aveley, Essex, has now moved to larger premises in the same locality. The Company markets and services test and measuring instruments made by several overseas companies including Rohde and Schwarz (Germany), Narda and Fairchild-DuMont (U.S.A.), and Bach-Simpson (Canada). The audio division handles such well-known equipment as Bang & Olufsen's (Denmark). The old factory has been taken over by the associated company Avel Products which has specialized in toroidal windings but is now also producing equipment for the parent company.

The controlling interests of the **Nottingham Electronic Valve Company,** which were held by the Granada Group of Companies, have been purchased by the directors of N.E.V. The company have also announced that their subsidiary Flow Developments Ltd. has been sold to Rockwell International Inc., of Pittsburgh, America. N.E.V. are to continue manufacturing closed circuit television equipment, but have transferred the production of apparatus for the repair of cathode ray tubes to another company.

Marconi aircraft radio equipment has been specified for the new transport aircraft due to be supplied to R.A.F. Transport Command in their latest re-equipment programme. The specification includes v.h.f. communications, v.h.f. navigation and automatic direction finding equipment.

OVERSEAS TRADE

The German Ministry of Defence has awarded a contract to Standard Telephones and Cables Ltd. for the supply of about £6M worth of radio communications equipment. For security reasons, S.T.C. are not releasing information regarding the type of equipment to be supplied.

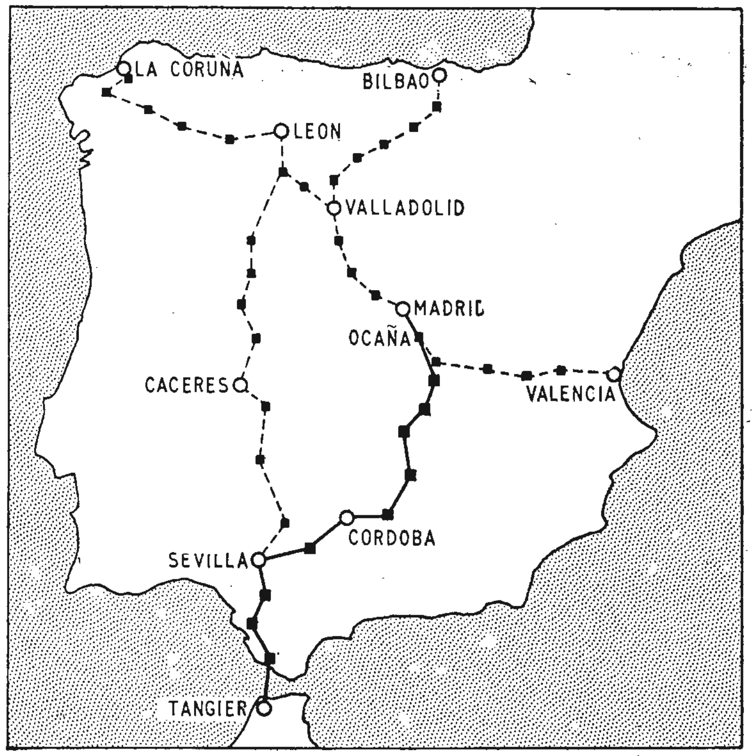
A.T. & E. (Bridgnorth) Ltd. have recently supplied v.h.f. radiotelephone equipment for the **Hong Kong harbourphone system,** which is owned and operated by Cable and Wireless Ltd. The new equipment operates in the 160-180 Mc/s band using frequency modulation with tone signalling for dialing and supervisory functions. The equipment supplied for the ship-shore section includes six 4-channel exchanges complete with radio, signalling and supply units. Twelve shore radio terminals have also been supplied to extend the system catering for tugs, launches and the off-shore island subscribers, and 24 battery operated radiotelephones are available for ships in transit.

£50,000 contract for **portable transceivers,** to equip Malayan troops, has been placed with the Murphy Electronics Division of the Rank Organisation by the Government of the Federation of Malaya.

Magyar Radio es Televizio, the Hungarian broadcasting authority, has ordered a second television outside broadcast unit from E.M.I. Electronics, through Elektroimpex, Budapest. The vehicle will be equipped with four E.M.I. $4\frac{1}{2}$in image orthicon cameras.

Orders worth more than £2,200,000 have been placed with Standard Telephones and Cables Ltd. for **four complete submarine cable systems** (which includes 81 repeaters and six equalizers) across the North Sea. Each cable will be capable of carrying 120 telephone circuits. These orders have been placed by the G.P.O. in conjunction with its partners in Germany, Denmark and the Netherlands.

Vidiaids industrial closed circuit television equipment, produced by Automatic Information and Data Service Ltd., of Richmond, Surrey, has been approved by the University of Gothenburg, Sweden's central electrical engineering authority.



MICROWAVE EQUIPMENT worth £1.75M has been ordered by the Compania Telefonica Nacional de Espana, to extend the existing (full line) long-distance radiotelephone circuits in Spain. The equipment is to be supplied by Standard Telephones and Cables Ltd., of London, and its associated company Standard Electrica, S.A., of Spain.

TV Cameras.—The Ampex Corporation of America has placed an order with the Marconi Company for a further twenty-eight $4\frac{1}{2}$in image orthicon camera channels, complete with English Electric camera pick-up tubes. This contract brings the total number of sales of these cameras in the Americas to 323, of which 184 have been sold to the U.S.A.; world sales approach the 600 mark.

A contract has been placed with **Solartron Electronic Group** for a 160-channel pressure measuring installation to be used on the primary gas circuit and the clean-up system of the Dragon reactor now under construction at the Atomic Energy Research Establishment at Winfrith, Dorset. Dragon is a joint venture of the O.E.C.D. (Organization for Economic Co-operation and Development).

The Parliament buildings in Kuala Lumpur, Malaya, are to be fitted with a comprehensive sound amplification system by Trix Electronics, a member of the Ultra Group of Companies. The system covers both Houses and adjoining offices, and includes more than 200 microphones, together with low-level speakers. In addition, a four-channel radiated translation system is to be installed and will provide two language channels in each of the two Houses.

JUNE ISSUE

Next month's issue will be on sale a week earlier than usual—on May 20th—and will include a guide to the exhibitors and the products which they will be showing at the Components Exhibition which opens at Olympia, London, on the following day. The 20-page show guide will be in addition to the normal quota of pages devoted to regular features and constructional and technical articles. In the following issue we hope to review some of the trends in components as exemplified at the show which is sponsored by the Radio and Electronic Component Manufacturers' Federation.

Personalities

W. H. Lidstone, since 1942 engineer-in-charge at Bush House, London, the headquarters of the B.B.C.'s external services, retired on April 10th. He joined the B.B.C. in 1924 as an assistant maintenance engineer in the London Control Room at Savoy Hill. In 1929 he was appointed supervising engineer and in 1936 assistant engineer-in-charge of the London Control Room. **R. H. Bullen,** who was appointed assistant engineer-in-charge in 1942, has taken over the duties of W. H. Lidstone. Mr. Bullen joined the Corporation in 1928 as an assistant maintenance engineer in the London Control Room.

Dr. Bernard Y. Mills, Senior Principal Scientific Officer in the Division of Radiophysics of the Commonwealth Scientific and Industrial Research Organization, Sydney, has been elected a Fellow of the Royal Society. The citation refers to "his contributions to radio astronomy and especially the development of a novel form of high-resolution radio telescope."

B. H. Venning, B.Sc. (Eng.), A.M.I.E.E., A.M.Brit.-I.R.E., is to be senior lecturer in the Department of Electronics at Southampton University. He joined the staff at the University in 1955 after spending three years as lecturer in electronics at the Manchester College of Technology. After war service in the Royal Signals he took his degree at the City and Guilds Engineering College following which he was, from 1949-1952, at what is now known as the Admiralty Underwater Weapons Establishment.

W. H. Thorneycroft, B.Sc., A.M.I.E.E., is now engineer-in-charge of the B.B.C.'s short-wave station at Rampisham, Dorset, in succession to **D. Hamilton-Schaschke** who has retired after 36 years' service with the Corporation. Mr. Thorneycroft joined the B.B.C. in 1936 and has been engineer-in-charge of the medium-wave transmitting station at Moorside Edge, Yorks, since 1958. Mr. Hamilton-Schaschke was engineer-in-charge of the engineering training school from 1941-1948 and for two years from 1954 was resident engineer of the British Far Eastern Broadcasting Service in Malaya. He has been e.-in-c. at Rampisham since 1958.

Grp. Capt. Raymond J. Lewis, B.Sc., Coastal Command's Signals Officer, transferred to a similar post in Transport Command on 18th March. Grp. Capt. Lewis was commissioned in the R.A.F. in 1940 and has held several posts in signals including overseas duties in the Middle East, Japan and the U.S.A. He became Coastal Command's Signals Officer in 1962; prior to this he was at the headquarters of 90 Group.

Wing Cdr. John Scott-Taggart has asked us to point out that he was S.T.O. (Senior Technical Officer), not C.O. of No. 73 Wing R.A.F. as was stated in last month's issue.

J. S. Johnston, B.Sc., A.R.C.S., A.Inst.P., A.M.Brit.-I.R.E., has become chief development engineer of Research & Engineering Controls Ltd., of Bognor Regis. He joined the company from Decca Radar in 1961.

OUR AUTHORS

R. Osborne, B.Sc., who with P. **Tharma,** B.Sc.(Hons.), contributes on page 221 the first part of an article on the construction of a transistor amplifier, joined the Mullard Radio Valve Company in 1959 as a graduate apprentice after graduating in physics at Leeds University. After serving his apprenticeship he joined the audio section of the Mullard Applications Research Laboratory. Mr. Tharma, who took an external London University degree in Ceylon, joined the Mullard laboratories in 1955. He had previously spent several years on the design of hearing aids and instruments, and was for some time in the Post Office Engineering Department.

D. Singh, who came to this country in 1958 to study at Faraday House Engineering College, London, and returned to India last August, writes in this issue on the design of a transistor millivoltmeter. During vacations he has received practical experience in West Germany as well as with Joseph Lucas, Birmingham, where he worked on the assembly and testing of silicon power diodes and transistors.

OBITUARY

Peter Pendleton Eckersley died on 17th March, aged 71. His association with wireless began in 1906, when he conducted experiments with spark apparatus at Bedales School. There followed a period of training in electrical engineering at Manchester and in 1914 he joined the R.F.C. as a Wireless Experimental Officer and saw service in the Near East. He joined the Marconi Company in 1919 and in an army hut at Writtle worked with a small team on the development of a radio-telephone transmitter for Croydon Aerodrome. It was with equipment based on this design that the first experimental broadcasts were made from Writtle in 1922, and it was largely due to Eckersley's wit and flair for the use of the microphone that station 2MT attracted a wide audience. With the official start of broadcasting later in that year, "P.P." was appointed Chief Engineer of the B.B.C., a post which he held until 1929. He was the protagonist of the B.B.C. Regional Scheme and it was his uncompromising insistence on the highest possible quality of reproduction that helped to give British broadcasting a leading position in the world. On leaving the B.B.C. in 1929 he became interested in wire distribution of programmes, in particular over the electricity supply mains, but he was unable to obtain the necessary legislation to bring his scheme to fruition. In recent years he was with the Telephone Manufacturing Company where his duties included the editorship of the *T.M.C. Technical Journal.*

Thomas William Bennington, for many years a regular contributor to *Wireless World* on ionospheric propagation, died in Cromer on March 13th at the age of 63. His radio career started in the Navy in which he was a wireless operator from 1919-22. He then spent six years in the Merchant Navy as an operator, followed by several years in the radio industry, before joining the B.B.C. in 1934 as assistant maintenance engineer at the Moorside Edge transmitting station. "T.W.B." transferred to the Overseas Engineering and Information Department two years later and was concerned with propogation problems for the major part of his service with the Corporation. He was seconded (part time) to the Inter-Services Ionosphere Bureau at Chelmsford in 1942 and from 1953 was in the B.B.C. Research Department at Kingswood Warren. For many years he contributed our notes on "Short Wave Conditions" and his book "Short-Wave Radio and the Ionosphere" is well known.

Edouard Belin, whose name is synonymous with photo-telegraphy transmission, died in Montreux in March at the age of 87. Born in Alsace he took out his first patent for the transmission of photographs over wire in 1904.

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Heater Current	I_h 0·3	or	0·15A

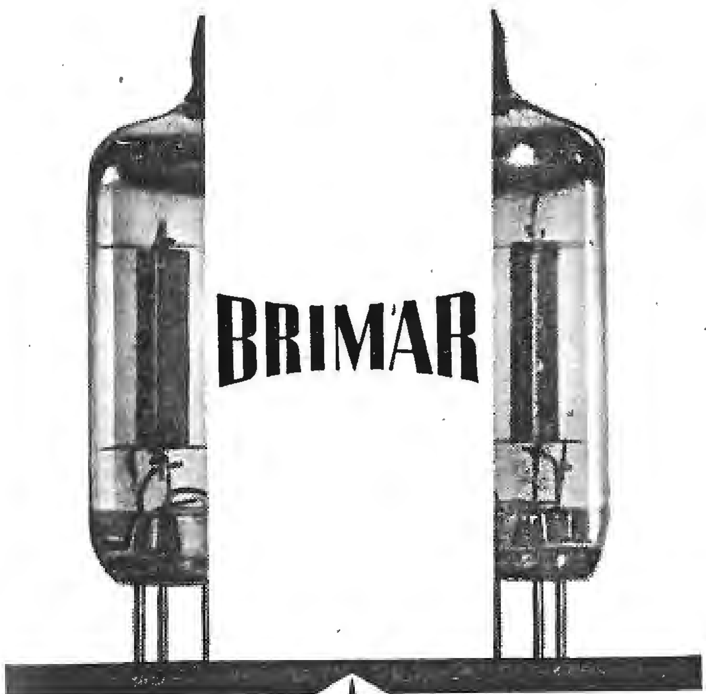
OPERATING CHARACTERISTICS
(EACH SECTION)

V_a =250 V, V_g = −8·5 V, V_h =12·6 V (Series Connection)

Anode Current	I_a	10·5	mA
Anode Resistance ($\delta V_a/\delta I_a$)	r_a	7·7	kΩ
Mutual Conductance	g_m	2·2	mA/V
Amplification Factor	μ	17	—
Anode Current Balance Between Sections	$I_a' - I_a''$	<±1·5	mA

OPERATION AS RESISTANCE COUPLED AMPLIFIER

Anode Supply Voltage	$V_{a(b)}$	100	250	V
Anode Load Resistor	R_a	0·1	0·1	MΩ
Cathode Bias Resistor	R_k	3·9	2·7	kΩ
Peak Output	$v_{a(pk)}$	17	50	V
Stage Gain	—	11	12	—



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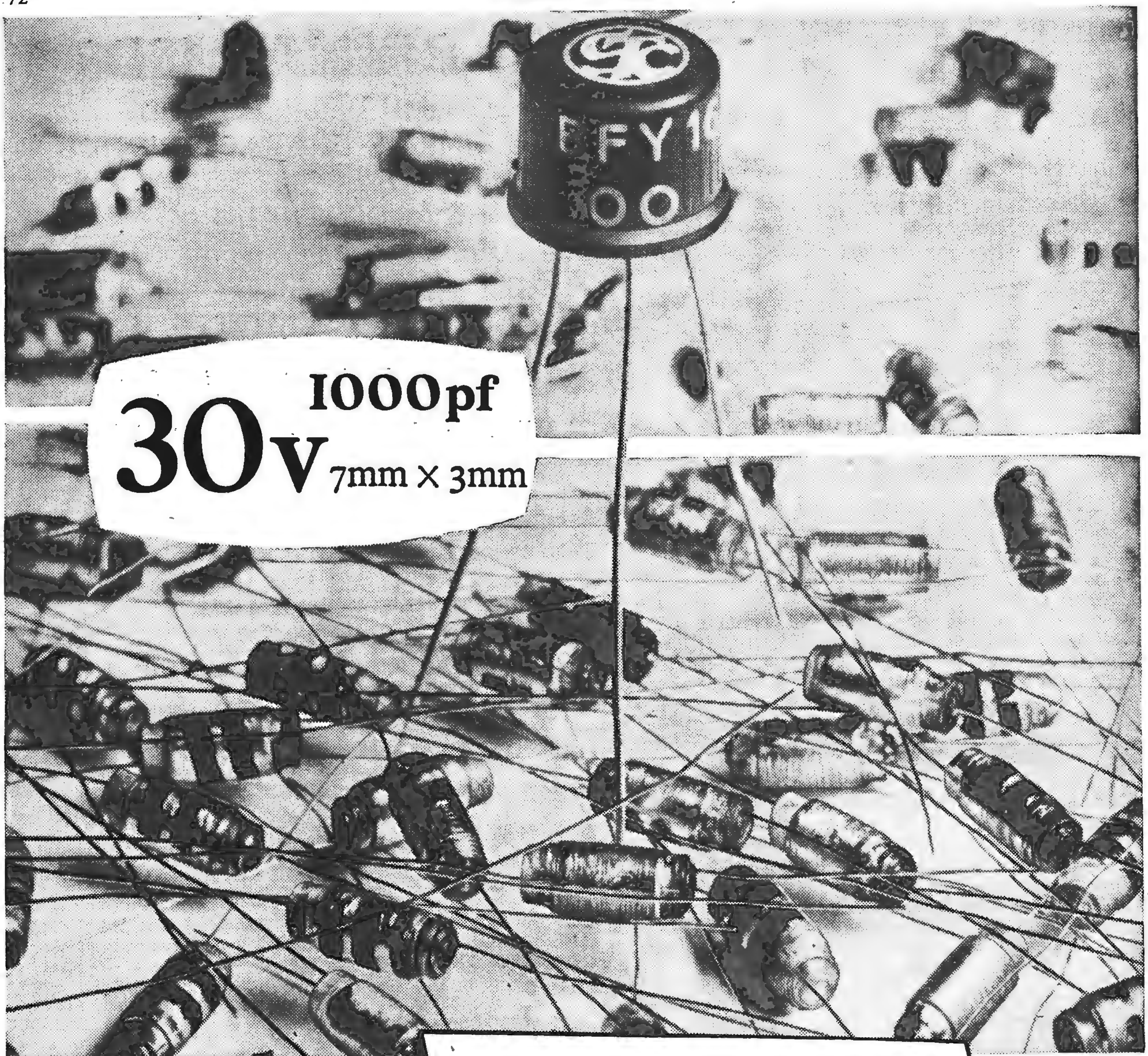

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Transistor High-quality Amplifiers

1.—GENERAL DESIGN CONSIDERATIONS

By R. OSBORNE,* B.Sc. and P. THARMA,* B.Sc.(Hons.)

IN this series of articles designs for three-high-quality amplifiers and a pre-amplifier will be described. A 10-watt amplifier using the output transistors in a new Class-AB mode of operation, referred to as the "π mode" Class AB will be described in next month's issue. Subsequently a 10W amplifier with a Class-B output stage, a 5W amplifier with a Class-A output stage, and a pre-amplifier suitable for all three amplifiers will be described.

The three designs represent different approaches to transistor high-quality amplifier design. The individual merits of the amplifiers will be obvious from the description of the circuits. Extensive listening tests, in which these amplifiers were compared with established high-quality valve amplifiers such as the Mullard 5-10 and the more recent ECL86 10W amplifier, did not show any difference, except, of course, that a 5W design will overload earlier than a 10W design.

A particular feature of these designs is that readily available low-frequency power transistors, with common-emitter cut-off frequencies of 4 kc/s, are used in the output stages.

Performance Requirements of High-quality Amplifiers

Broadly speaking, high-quality amplifiers should not introduce audible deterioration of the quality of the programme material. Deterioration of the quality of reproduction can be due to one or more of several causes, the important ones being:—

(a) Distortion due to non-linearity: harmonic distortion and intermodulation distortion.
(b) Inadequate frequency response.
(c) Poor transient response, indicating low-frequency or high-frequency instability.

The above factors will now be examined. In particular, it has been found that present methods of measuring distortion due to non-linearity (e.g. harmonic distortion and S.M.P.T.E. and C.C.I.R. intermodulation distortion measurements) correlate poorly with the subjective unpleasantness of distortion. New methods of measurement, with better correlation, are proposed.

Distortion due to non-linearity is generally measured as harmonic distortion or intermodulation distortion by the S.M.P.T.E. and C.C.I.R. methods. These methods of measurement do not correlate with the unpleasantness of "crossover distortion" of under- or overbiased Class-B amplifiers. A particular modification of the S.M.P T.E. method has been found to give better correlation. In this method the variation of gain along the transfer characteristic is measured. This is done by applying a 10 kc/s signal and a 100 c/s signal, the amplitudes of which are in the ratio of 1 : 10, to the amplifier. From the output the 100 c/s is filtered out, and the 10 kc/s signal observed on an oscilloscope. The variation of amplitude of the 10 kc/s signal corresponds to the variation of gain along the transfer characteristic. The maximum variation of gain henceforth referred to as "maximum gain deviation" correlates well with the unpleasantness of crossover distortion. Extensive tests show that the "maximum gain deviation" concept can be extended to all forms of non-linearity distortion, provided the transfer characteristic is not frequency dependent.

When the transfer characteristic is frequency dependent (e.g. when the negative feedback is less at high frequencies than at low frequencies) some method of measuring the high-frequency intermodulation distortion is necessary. A sensitive method is to pass white noise confined to the high-frequency band, e.g. 16 kc/s to 20 kc/s through the amplifier and measure the resultant noise below the h.f. band, e.g. below 10 kc/s. This measurement is particularly important with transistor amplifiers designed around low-frequency transistors.

In the amplifiers described later, the overall feedback has been chosen to reduce the "gain deviation" and h.f. intermodulation distortion to acceptable levels. The harmonic distortion in the mid and low frequencies has also become extremely low: the Class AB-amplifier has 0.06% total harmonic distortion at 10 watts output at a frequency of 1 kc/s. It must be emphasized that such extremely low levels of harmonic distortion are not an essential requirement of high-quality amplifiers, for it has been shown by Olson[1] that in a wide-range system (40 c/s to 14 kc/s) odd or even harmonic distortion levels of 0.7% were just detectable.

Frequency Response:—In reference 2 the performance of the human hearing system is discussed in detail. It is shown (page 66) that if the frequency range of the reproducing system is from 30 c/s to 15 kc/s (−3dB point) the quality of reproduction is in no way impaired. This gives the minimum bandwidth requirement for high-quality amplifiers. Also, the peak power of musical instruments is in the low and mid frequencies (reference 2, page 14). Therefore the upper −3dB point of the power response need not be better than about 10 kc/s.

A frequency response very much above 15 kc/s

*Mullard Applications Research Laboratory.

[1] *Elements of Acoustical Engineering*, 2nd Edn., pp. 488-491 (Van Nostrand).

[2] *High Quality Sound Reproduction*, by James Moir, 2nd Edn. (Chapman & Hall).

can impair the quality of reproduction. Some musical instruments produce frequencies well above the audible range but at low levels. These frequencies, together with undesirable high-frequency noise produced as a result of limitations of recording techniques etc., can produce intermodulation products within the audible range. These can be detected as an unpleasant harshness. This effect can be removed by limiting the upper frequency response of the amplifier to about 15 kc/s—20 kc/s. The quality of reproduction is in no way impaired by this.

Transient Response and H.F. and L.F. Stability:—An important requirement is that the amplifier shall have a good margin of stability. The high-frequency stability can be conveniently checked by observing the pulse response of the amplifier. The pulse should show very little ringing with resistive, resistive and capacitive, and inductive and capacitive loads.

The low-frequency stability can be checked by applying a 1 cycle/sec square wave to the amplifier. The resultant pulse should ideally be a simple differentiation of the square wave. An amplifier with poor stability will, instead of a simple decay, show an oscillating decay.

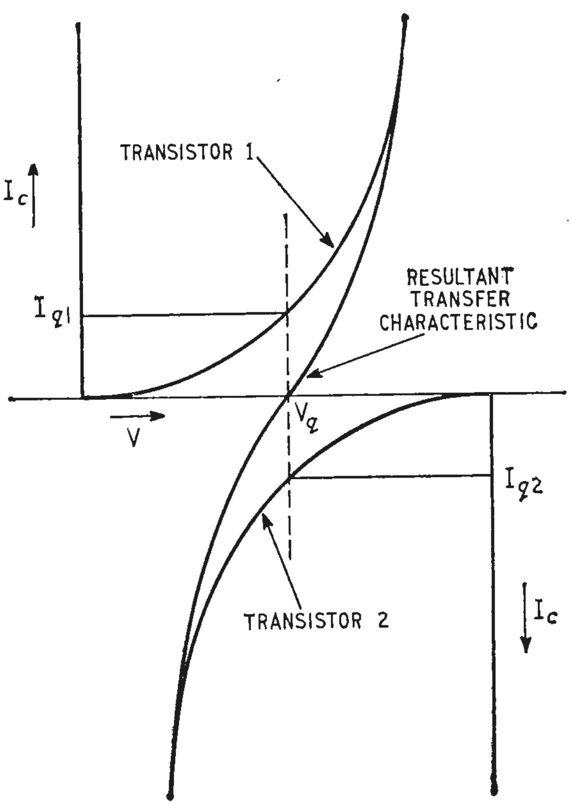


Fig. 1. Combined transfer characteristic of two ideal transistors.

Power Transistors in High-quality Amplifiers

Power transistors which are readily available at economical prices have common-emitter cut-off frequencies of the order of 4 kc/s but these transistors can be used in high-quality amplifiers provided certain requirements are met in the design of the amplifier.

The power output from an output stage fed from a constant-current source falls with increase of frequency, the −3dB point being given by the common-emitter cut-off frequency, f_β, of the transistor.

The cut-off frequency in circuit, f_x, will however be considerably higher than f_β if the source resistance is low compared to the input resistance of the stage; the improvement depending on the relative values of the resistances. This condition is readily achieved by emitter degeneration.

If the drive current can be increased, with increase of frequency, to compensate for the fall-off of gain, then full power can be obtained from the output stage at all frequencies. Overall negative feedback (if sufficient) will do this automatically but the driver stage design should be such that it can deliver the extra power without distortion. The amount of extra power the driver stage has to deliver will depend on the amplitude of the high-frequency components expected in the signal source which determines the power *versus* frequency response required from the amplifier.

At frequencies near and beyond f_x there will be an increasing phase shift with increase of frequency. In Class-AB and Class-B output stages the conduction angle also increases. This is accompanied by a reversal of base current during part of the cycle. This reversal of base current is due to the stored charge in the base region, which has to be removed before the transistor can be cut off. In circuits where the driver stage is direct-coupled to the output stage, the driver stage should allow this reversal of base current of the output transistor, otherwise the waveform will be distorted. In the case of an emitter-follower driver stage, the reversal of base current can be accommodated by returning the emitter of the driver transistor to a positive potential with respect to the output transistor emitter and operating the driver transistor at a substantial quiescent current.

With Class-B and Class-AB output stages certain steps are necessary to minimize distortion at high voltages due to "softening." As the collector voltage is increased, with the transistor cut off, the leakage current of the transistor increases. This increase of leakage current largely depends on the base-emitter impedance and the bias voltage. The softening can result in distortion at high levels; thus to ensure low leakage currents the base-emitter impedances should be as low as possible. In addition, small amounts of reverse bias can decrease the softening considerably. If the output transistors are driven from a symmetrical drive source, then undecoupled emitter resistors (1 ohm is sufficient) can ensure that the output transistors are reverse biased when cut off.

Output Transistor Dissipations and Heat Sink Requirements

With Class-A and "π mode" Class-AB output stages, the output transistors operate at constant levels of dissipation. The heat sinks on which the output transistors are mounted should ensure that the maximum junction temperature ratings are never exceeded. In calculating the temperature ratings, variations of mains voltage and the effect of component tolerances should be considered.

The mains voltage can be higher than nominal by 6% due to mains variations. Also, a mains transformer with three primary taps (205V, 225V, and 245V) can contribute to an increase of 2½% because of the difference between the nominal supply voltage and the nearest tap voltage, and a similar contribution may be made by the tolerances of the power supply components. These mains voltage variations to-

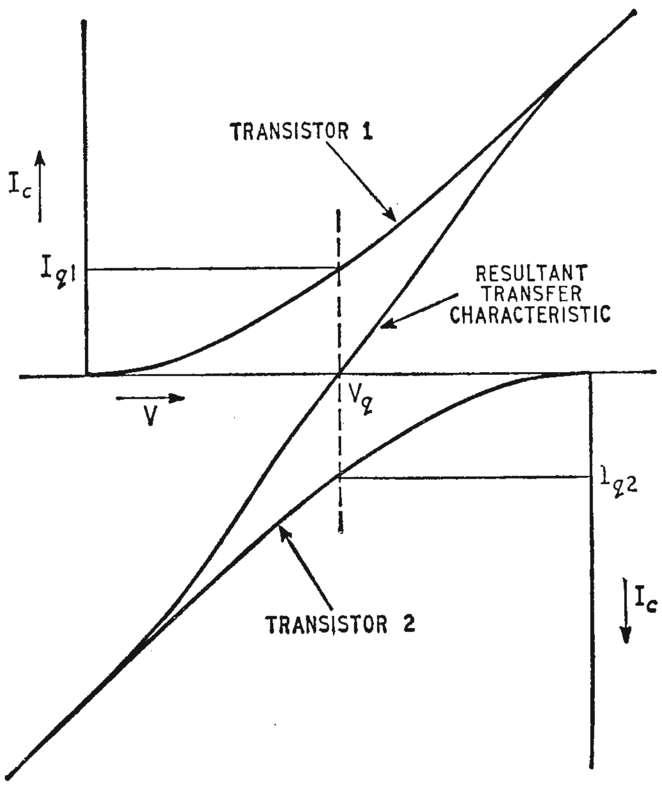


Fig. 2. Combined transfer characteristic of two transistors with $r_{bb'}$ and r_s.

gether with the spread due to circuit resistor tolerances in the circuits described give an effective maximum increase in power dissipation (all spreads unfavourable) of about 33%.

The output transistor, AD 140, has two maximum junction temperature ratings—the maximum *continuous* junction temperature is 90°C, but *intermittent* operation (total duration 200 hrs.) up to 100°C is permissible. The junction temperature T_j, ambient temperature T_a, and the power dissipation P_c are related by

$$T_j - T_a = P_c \cdot \theta_{j-a}$$

where θ_{j-a} is the thermal resistance from the junction of the transistor to ambient.

The temperature ratings and spreads in dissipation can be interpreted as follows. Suppose the thermal resistance is such that the junction temperature rise above ambient at normal dissipation is 40°C. Then with maximum dissipation (all spreads unfavourable) the temperature rise is 53.3°C, and the corresponding ambient temperature ratings are:

Max. continuous ambient temperature 36.7°C (for T_j = 90°C.)

Max. intermittent ambient temperature 46.7°C (for T_j = 100°C).

A great majority of circuits will be safe at ambient temperatures higher than the above, as, with nominal dissipations, the maximum continous ambient temperature can be 50°C (for T_j = 90°C) and maximum intermittent ambient temperature, 60°C (for T_j = 100°C).

In the above discussion, the variation of transistor dissipation with temperature has been ignored. This is valid because of the excellent stability of the circuits described.

With Class-B amplifiers, the heat sink requirements are determined mainly by thermal stability considerations. Thermal stability of Class-B amplifiers is discussed in *Mullard Technical Communications*, Vol. 3 No. 29 March 1958.

Class-AB Operation of Transistors

The amplifier which will be discussed in detail later is a 10-watt Class-AB high-quality amplifier. As the Class-AB mode of operation of transistors may be unfamiliar to many, it is considered worthwhile discussing in some detail the underlying concepts. A pair of transistors in Class B push pull can be operated in Class AB simply by increasing the quiescent currents in the transistors. This method is similar to the operation of valves in Class AB, but with transistors such operation leads to excessive distortion because they do not have the valve's lengthy region of gradually decreasing slope. Also, the direct current would vary with drive.

A new method of Class-AB operation with transistors referred to as the "π mode" Class AB where the total d.c. remains constant irrespective of drive will be described. The advantages are as follows:

(1) Absence of the crossover distortion associated with Class-B operation.

(2) Constant current drain from the power supply. Therefore, regulation is not of any importance. Adequate smoothing of the power supply can be obtained by simple R-C filtering.

(3) Short circuit of output terminals does not damage the transistors (Class-B output stages are vulnerable in this respect).

(4) Very low distortion at normal listening levels as the transistors operate in Class A push pull at low levels.

(5) With the use of emitter-loaded operation, the distortion of the amplifier over the full power range can be controlled to specific limits by suitable choice of driver stage source impedance.

If the forward bias of two transistors operating in normal Class-B mode is increased and the intrinsic base resistance $r_{bb'}$ of the transistor and the drive source impedance be zero, then the overall transfer characteristic will be the result of two exponential characteristics as shown in Fig. 1.

The base resistance $r_{bb'}$ and the drive source resistance, however, modify the transfer characteristic of each transistor to a nearly linear characteristic with a very short transition region to zero gain. The combined transfer characteristic of a pair of overbiased transistors now consists of three linear portions (assuming constant current gain β) as shown in Fig. 2. The centre portion of the transfer characteristic has twice the slope of the ends of the characteristic. This change of slope results in excessive distortion. The distortion can be reduced by decreasing the total resistance in series with the exponential characteristic, but here the limit is set by the base resistance $r_{bb'}$ of the transistor. A method of reducing

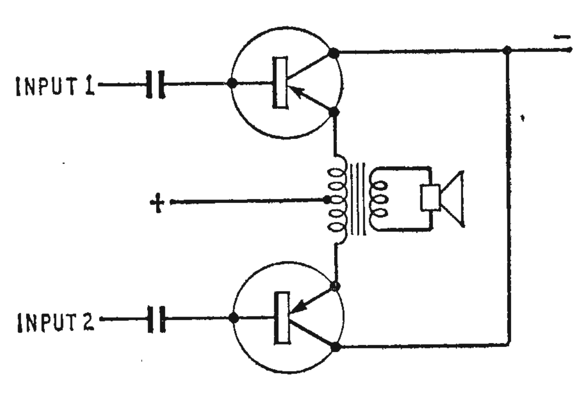


Fig. 3. Basic emitter-loaded output stage.

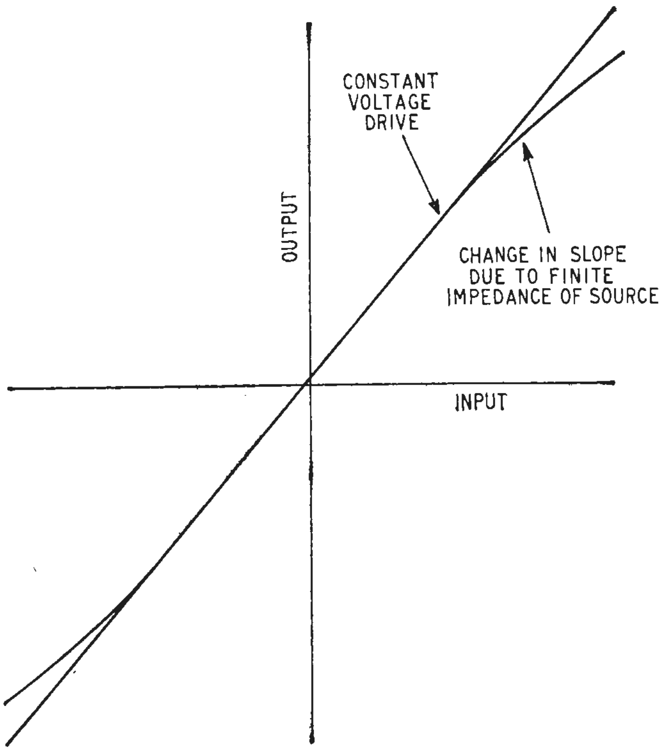


Fig. 4. Transfer characteristic of Class AB operation showing effect of finite source impedance.

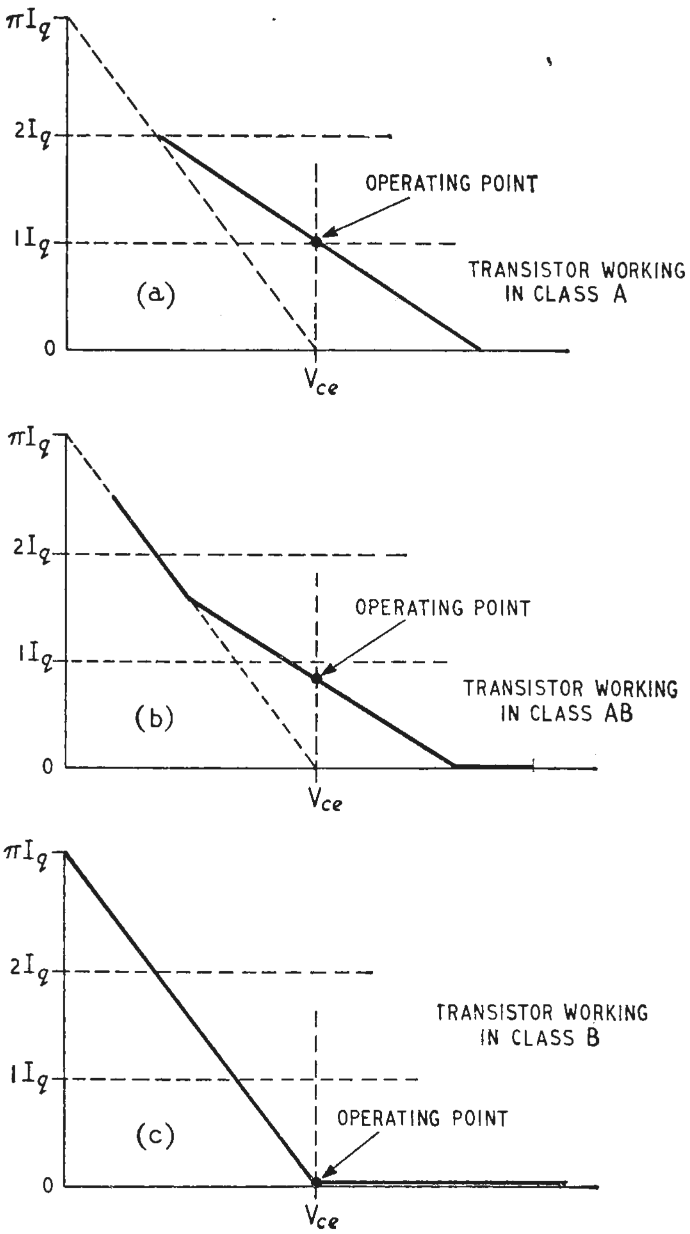


Fig. 5. Diagram showing nature of load line of a transistor working in "π mode" Class AB for various output powers. (a) Up to 0.4 x full output. (b) Between 0.4 and full output. (c) Full output.

this effect of source resistance is to operate the transistors with the load in the emitter circuit.

Fig. 3 shows the collector load transferred to the emitter circuit, the load being transformer coupled for simplicity. If the transistors are driven from a push-pull voltage source, then the voltage across the load will be the input voltage minus the voltage drop across the transistors. If the transistor voltage drops are small compared with the output voltage, then the transfer characteristic will be linear, irrespective of bias conditions. Both transistors will conduct over the middle portion of the transfer characteristic while one or the other conducts over the end portions, the changeover being determined by bias conditions.

During the centre portion of the transfer characteristic each transistor contributes half the load current, while during the end portions, the conducting transistor provides the full current. The variation of current demand from each transistor causes a change of slope at the changeover point when fed from a finite source resistance, as shown in Fig. 4. This change of slope, which is primarily determined by source resistance, can be defined and arranged to be small by circuit conditions.

In general an emitter resistance is always used to stabilize the operating conditions. If the emitter resistance (decoupled by a suitable capacitor) is made large enough so that the direct current is well defined, then the dynamic bias condition of the transistor has to adjust itself with drive so as to maintain constant d.c. The load lines for various levels of drive are shown in Fig. 5. Up to a certain power level both transistors operate in Class A push pull. Beyond this point each transistor is cut off for part of the cycle. Also each transistor sees half the Class-A load for that part of the cycle during which its partner is cut off. As the drive is increased beyond this point the total current will also tend to increase. The operating point will, however, shift so as to return the overall d.c. consumption to its previous value. With the increasing drive the operation shifts to Class-B and then to Class-C conditions. For audio amplifier applications, the design should be such that the Class-B condition is just reached at maximum power output. For this case the quiescent current I_q, the peak current I_{pk}, the collector voltage V_c and the load resistance R_L are related by $I_q = \frac{I_{pk}}{\pi} = \frac{V_c}{\pi R_L}$

when I_{pk} is the peak current at maximum output, and R_L is the load seen by each collector independently.

The design of the output stages is the same as for a Class-B stage delivering the same power but the quiescent current is $\frac{I_{pk}}{\pi}$ and $P_{out} = \frac{I_{cpk} \cdot V_{cpk}}{2}$

Provided the load does not at any frequency fall below $R_L = \frac{V_c}{\pi I_q}$ crossover distortion cannot appear.

With this particular method of Class-AB operation, which has already been referred to as "π mode" Class AB, the collector dissipation is maximum under no drive conditions, and the dissipation per transistor with no drive is given by

$$P_c = \frac{V_c I_{cpk}}{\pi} \approx 2/3 \, P_{out} \, (\max)$$

For comparison the respective dissipation per transistor of a pure Class-A push-pull stage of the same output is approximately equal to the maximum output power whereas for a comparable pure Class-B stage it is approximately one-fifth of the maximum output power. It must be pointed out that the heat sink requirements for a Class-B stage are in most cases dictated by thermal stability considerations and not by power dissipation, so the heat sink for Class-AB is nevertheless comparable with that required for Class-B operation.

The changeover from Class-A to Class-AB operation occurs at 0.4 P_{out} (max).

(To be continued)

Commercial Literature

Microwave Associates.—A brochure giving general and design information on varactor harmonic generation and a series of leaflets on their made-up units are available from Microwave Associates Ltd., Cradock Road, Luton, Beds. A leaflet is also available on silicon video diodes with cartridge case and subminiature glass style bases. **(301)**

F. C. Robinson and Partners Ltd. (FCR) have issued a loose-leaf catalogue giving details of their products. It includes various types of laboratory and test equipment, power supply units, industrial and operational recording equipment, analogue computers, and is available from either Councillor Lane, Cheadle, Cheshire, or Davies House, 181 Arthur Road, Wimbledon, London, S.W.19. **(302)**

Transformers.—An information sheet listing standard ratings and sizes of transformers made by the Raven Transformer Company, is available from 7 Kelso Lodge, Primrose Road, London, E.18. Incidentally, this company can supply transformers to customers' requirements. **(303)**

A new edition of the **High Fidelity Loudspeaker Manual** is available from Goodmans Industries Ltd., Axiom Works, Wembley, Middlesex. In addition to information on their products it includes an explanation of stereo sound reproduction and detailed data on enclosure construction. **(304)**

Valve Equivalents.—English Electric's equivalents index, listing valves of various manufacturers for which E.E. valves may be used as replacements, is available from the English Electric Valve Company, Chelmsford, Essex. Service type numbers are also given. **(305)**

The **Pure Elements** Division of L. Light and Co. Ltd., Colnbrook, Bucks, have recently published a new catalogue (M-4) of their products. New items include organometallic compounds, stable isotopes, and pure gases. **(306)**

Relays.—A broad sheet giving brief specifications of some of S.T.C. relays is available from Standard Telephones and Cables Limited, Electro-Mechanical Division, Harlow, Essex. **(307)**

Magnetics Inc., of Butler, Pennsylvania, U.S.A., have recently released two design manuals featuring tape wound cores and permalloy powder cores. These manuals are available in the U.K. from A. Dunkley, 14 Wellington Road, Ashford, Middlesex. **(308)**

A **combined v.h.f. radio and intercom. system** is described in a leaflet available from Newlyn Electronics Limited, The Star Hotel Buildings, New Street, Penzance, Cornwall. **(309)**

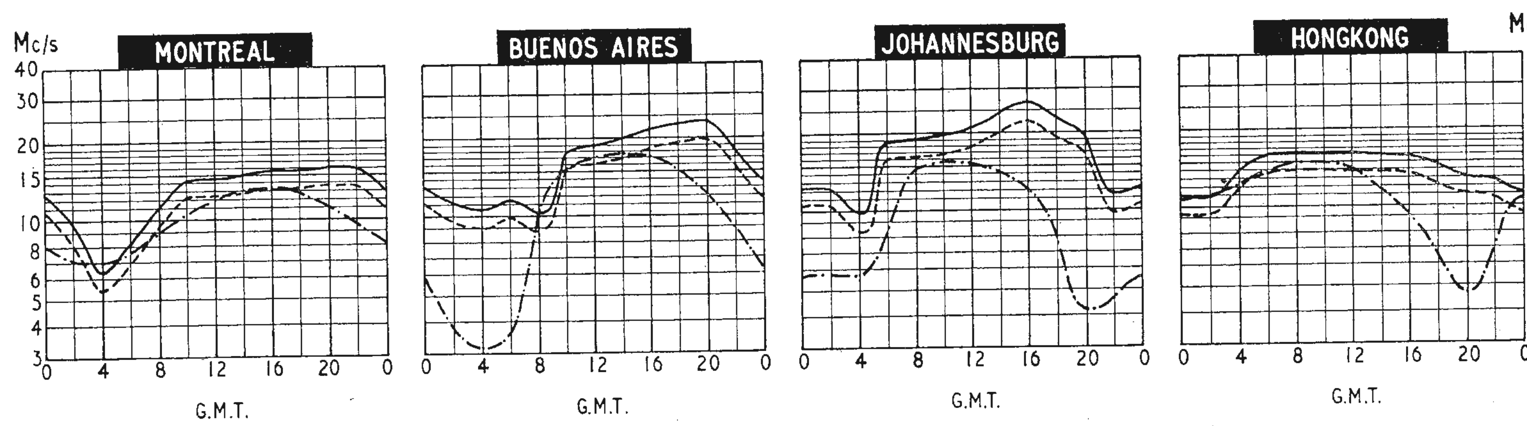
Wideband voltmeter—300μV-300V and 0.2c/s to 4 Mc/s—manufactured by Siemens & Halske, is described in a leaflet available from their U.K. agents, R. H. Cole (Overseas) Limited, 26-32 Caxton Street, London, S.W.1. **(310)**

Rectifiers.—A brochure describing the complete range of Brimar/SenTerCel silicon and selenium rectifiers is available through Brimar representatives or from the Thorn-A.E.I. Publicity Department, 155 Charing Cross Road, London, W.C.2. **(311)**

Machine Tool Control.—A leaflet, titled B100 Positionier-Steuerungs-System, describes, in German, the EMICON B100 position control system which is capable of controlling machine movements driven by electric or hydraulic servo systems. A technical specification is given and copies of this leaflet are available from the Publicity Department, E.M.I. Electronics Limited, Hayes, Middlesex. **(312)**

For the convenience of readers a number has been appended to each of the above items so that when applying for literature all that is necessary is to circle the appropriate number on the Information Service form at the back of this issue.

H. F. PREDICTIONS—MAY



MEDIAN STANDARD MUF
OPTIMUM TRAFFIC FREQUENCY
LOWEST USABLE HF

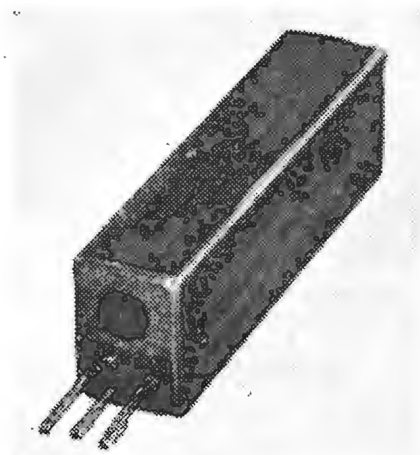
The prediction curves now show the median standard MUF, optimum traffic frequency and the lowest usable high frequency (LUF) for reception in this country. Unlike the MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, local noise level and the type of modulation: it should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

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Miniature Potentiometer

OXIDE film resistors are noted for their low inductance and self-capacitance properties. A miniature potentiometer using an oxide film as its resistive element is announced by Ancillary Developments Ltd., of Camberley, Surrey. The resistive element, which in



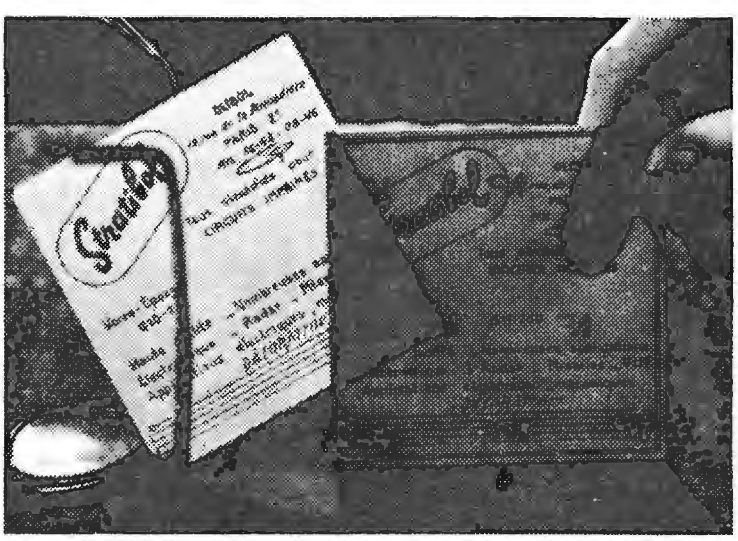
Ancillary Developments miniature potentiometer.

the present size of the component, can be made in values up to 3 MΩ, consists of a metal oxide film fired on to a glass substrate. This in turn is cemented to a mica glass moulding. Adjustment of the wiper is made by a 32-turn lead screw sealed by two silicone rubber O-rings. The power rating is 0.1 W and the overall resistance tolerance is 20%. The unit is claimed to be stable over an ambient temperature range of $-50°$ to $+150°$C. Dimensions $1.25 \times 0.275 \times 0.40$in, weight—$5\frac{1}{2}$ grammes.

For further information circle 313 on Service Card.

Glass/Epoxy Copper Clad Laminates

TWO new glass/epoxy copper clad laminates are announced by Stratibol. One is a very fine regular glass weave, the other is almost translucent. It is claimed that instead of printing component legends on



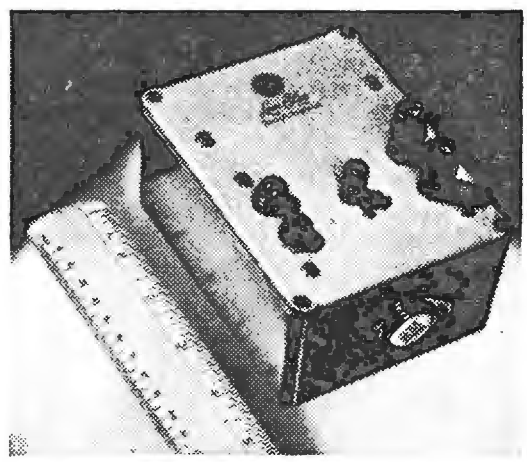
Stratibol glass/epoxy copper clad laminates.

printed boards for ease of location, the connections may be observed through the laminate. The fineness of the glass weave is said to give cleaner punching and cutting whilst at the same time it adds to the strength and transparency of the product. Stratibol G.10-710 and G.11-760 material is distributed by Oswald E. Boll, Ltd., London House, Duke Street, Woking.

For further information circle 314 on Service Card.

D.C. Power Supply

A SMALL d.c. power supply unit capable of providing a continuously variable output from 7.5 to 12V at 0.5A has been produced by Lan-Elec Ltd., 9, Farnham Road, Slough. These units may be connected in series to give higher outputs. Ripple and noise is claimed to be less



Lan-Elec miniature d.c. power supply.

than 1mV, peak-to-peak. The stability is better than 1,000:1 for supply variations of $\pm 10\%$, and the output resistance is not more than 60mΩ. Transistors are used throughout and the unit is protected from overload. It can be used up to 40°C. The power supply operates from a mains supply of 200/250V 50 to 400c/s. The dimensions are $4\frac{3}{4} \times 3\frac{5}{8} \times 2\frac{1}{4}$ inches. The price is £18.

For further information circle 315 on Service Card.

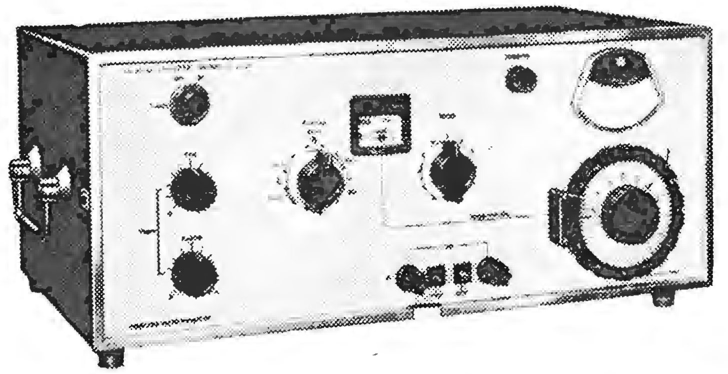
High-voltage Rectifiers

A NEW cartridge-type high-voltage silicon rectifier is announced by the International Rectifier Company. Called the Type 35CR2 the rectifier is rated at 200V (r.m.s.), 35mA and is about 3.5in long. The forward voltage drop is low (10V at 35mA). It is designed to operate up to 10kc/s at ambient temperatures up to 100°C.

For further information circle 316 on Service Card.

Universal Bridge

A TRANSFORMER ratio-arm bridge for measurement of capacitors, resistors and inductors is announced by Marconi Instruments. In addition to the normal facilities the bridge can be used for measuring capacitors with substantial shunt resistive loading, resistors with a shunt capacitive loading and components which form one arm of a three-terminal network. For many *in situ* measurements long connecting leads can be used with



Marconi Instruments "in situ" Universal Bridge Type TF2701.

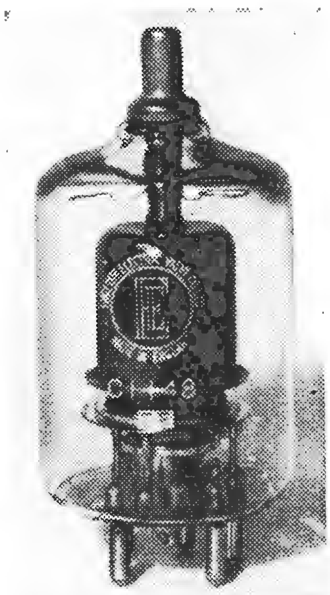
negligible effect on accuracy. The measurement ranges of the TF2701 Universal Bridge extend from 0.002pF to 11,000μF in eleven ranges, 1μH to 110kH in ten ranges and from 0.01Ω to 110MΩ in nine ranges. An internal oscillator enables measurements to be made at 80c/s and 1kc/s. The detector circuit includes an automatic gain control, which is so arranged that the direction of unbalance is indicated. Transistors are used throughout. Two internal 9V batteries provide the power supply for the bridge. The price of the instrument is £170.
For further information circle 318 on Service Card.

Pulse Modulator

A RADIAL beam pulse tetrode (C1148) for use as a modulator in radar equipments having peak power outputs in the range 10 to 25kW has been developed by the English Electric Valve Co., Ltd. The heater consumption is 31 watts; peak output powers of 150kW are attainable. A short grid base permits relatively low grid drive requirements to provide full output power.
For further information circle 318 on Service Card.

Combined Switch, Fuse, Pilot Light

MOST electronic equipment contains an on/off switch, fuse and pilot light. The Rowan Type F.C. Controller is a single device combining all three components. The unit is mounted through any ½in diameter round hole by two mounting nuts. The switch is in the form of a push button incorporating the pilot lamp. Overall length in the "off" position is 2.665in reducing to 2.5in in the "on" position. The contacts are sintered silver cadmium oxide. The Rowan agents in the U.K. are G. S. Westbrook, Ltd., Hersham Factory Estate,



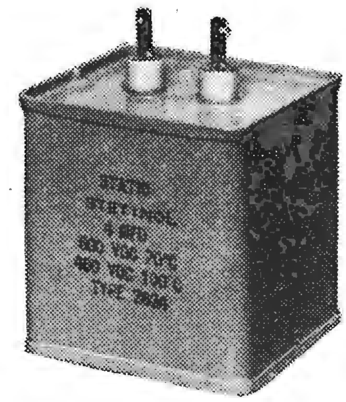
English Electric C1148 pulse modulator valve.

Rowan combined switch, fuse and pilot light.

Lyon Road, Walton-on-Thames. The complete unit costs 12s.
For further information circle 319 on Service Card.

Impregnated Paper-dielectric Capacitors

SIXTEEN types of capacitors are offered by The Static Condenser Co. Ltd., of Wokingham, Berkshire, in their new Stetinol range. Values are available in the 0.25 to 8.0μF range with working voltages of 200, 600, 800 and 1,000V. All the capacitors have ceramic



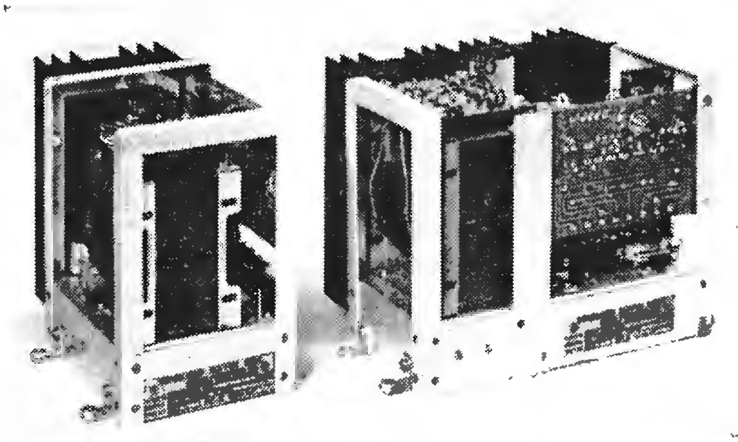
Stetinol sealed paper capacitor.

bushes with soldering tags and are fully sealed in steel cases.

The Stetinol range meets the full requirements of the Joint Services specification DEF.5131 AO/100 Class H.1.
For further information circle 320 on Service Card.

Transistor Power Units

TWO new transistor power units designed and constructed on the open-chassis principle so that they can be incorporated into other equipments, are announced by Advance Components Ltd. They are Power Units Types DCT1 and DCT2. The output voltage of the

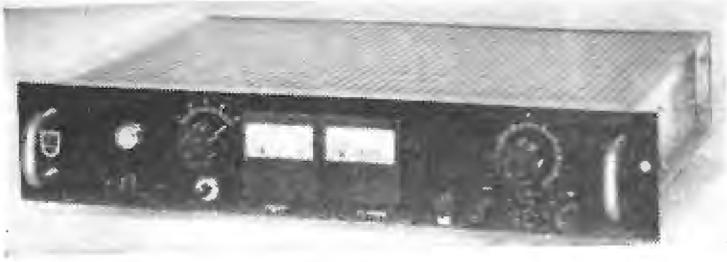


Advance transistor Power Units Types DCT1 and DCT2.

DCT1 may be varied from 5 to 30V, that of the DCT2 from 25 to 50V. Both instruments have a maximum current of 1A and a stability ratio of better than 500:1 at maximum output for a ±10% mains variation. The output resistance is claimed to be less than 20mΩ. An electronically operated cut-out is designed to operate at 110% ±5% of full-load current. Any number of units of either type may be connected in series to obtain higher output voltages. The outputs may be connected to any potential within the limits ±500V with respect to chassis.
For further information circle 321 on Service Card.

Stabilized Power Unit

A NEW power supply Type PE4805/00 with separate voltage and current output meters has been announced. The unit which makes use of transistors has a maxi-



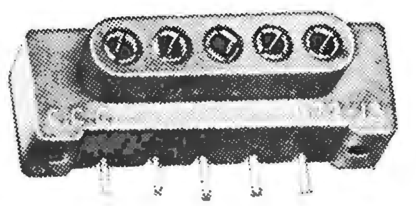
Philips Stabilizer Unit Type PE4805/00. Available for rack mounting or as a cabinet version.

mum current output rating of 1A. The voltage is adjustable from 0-35V in five ranges. The output is "floating": thus either positive or negative terminals can be connected to the earth terminal on the front panel. The manufacturers, Philips, represented in the U.K. by Research and Control Instruments Ltd., claim that for supply voltage variations of 10% the maximum change in output is well within 0.1%. Hum is less 1mV and the output resistance is 0.02Ω. The unit has a relay overload protection circuit.

For further information circle 322 on Service Card.

Test Point Connectors

A SERIES of printed circuit test point connectors in 4, 5, 6, 8, 16, 42 and 63 contact arrangements is available from Continental Connectors, Industrial Estate, Long Drive, Greenford, Middlesex. Each socket is designed to accept a standard 0.08in test probe. The unit, due to its moulded construction, can be used as a grip for the insertion and withdrawal of the printed boards. The test sockets are recessed. The pin



Printed circuit test point connectorf rom Continental Connectors 672 series.

terminals are mounted at right angles to the test sockets and can be aligned with ease for soldering to printed and etched-wired boards. Current rating on all types is 3A continuous (4A maximum).

For further information circle 323 on Service Card.

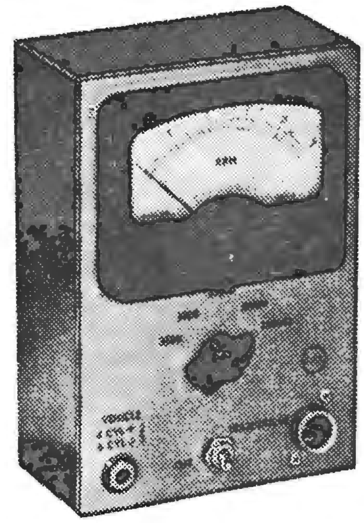
Electrometer Valve

AMPLIFICATION of electrical outputs of ion chambers, photomultipliers, proportional counters and biological sensors presents considerable difficulty due to the very low outputs. The Raytheon electrometer valve type CK587 permits low noise amplification of signals equivalent to as little as 5×10^{-14}A. An unusual feature of the tube is its low power requirement. It draws 0.0075W under typical operating conditions. The European and U.K. agents for Raytheon are Raytheon-Elsi, S.p.A., Piazza Cavour 1, Milano, Italy.

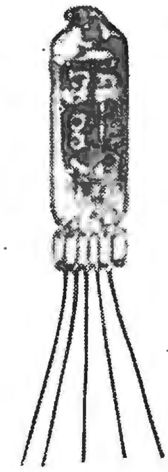
For further information circle 324 on Service Card.

Electronic Tachometer

WITH the use of a suitable transducer the measurement of speed of rotation of machinery shafts is possible to within ±2% with the E.K.E. tachometer, Type TT8. Five ranges are provided 2,500, 5,000, 25,000, 50,000 and 250,000 r.p.m. An interesting feature is the vehicle engine input. The meter reading derived from ignition pulses is divided by two for four-cylinder engines and by three for six-cylinder types. The instrument is



E.K.E. Model TT8 tachometer.



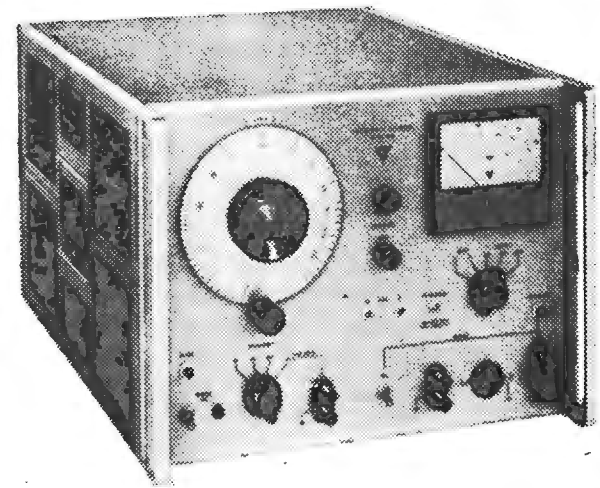
Raytheon electrometer valve Type - CK587 (actual size).

claimed to be completely free from needle flicker on all ranges above 1,500 r.p.m. The tachometer will respond to a pulse rate as low as seven per second. Printed board circuitry is used and the instrument is powered by an internal 12V battery. The price is £19 15s and the instrument is manufactured by E.K. Electronics Ltd., Brotherton, Nr. Knottingley, Yorks. Suitable transducers for use with the instrument can be obtained for £4 4s.

For further information circle 325 on Service Card.

Variable-frequency Power Supply

MANUFACTURERS of electronic equipment are sometimes faced with the problem of testing at a mains frequency or frequencies other than that of their normal supply. The Hewlett-Packard company have produced an oscillator-amplifier Model 4310A which is an RC oscillator feeding a sine wave into a low distortion amplifier. The frequency range extends from 40c/s to 2kc/s with a maximum tuning error of ±1% and a stability within ±1%. The harmonic distortion is less than 1.5% for resistive loads and is less than 5% for reactive loads with power factors up to 0.7. The output voltage may be adjusted from 0-130V at a maximum current of 2A, or from 0-260V at 1A maximum. A front panel regulation control allows adjustment of output impedance for any given load so that



Hewlett-Packard variable frequency power supply Model 4301A.

the output voltage remains constant for both full-load and no-load conditions. An external frequency source may be used with the instrument. The manufacturers are represented in the U.K. by Livingston Laboratories Ltd. The model 4301A will be sold in the U.K. for £564.

For further information circle 326 on Service Card.

LETTERS TO THE EDITOR

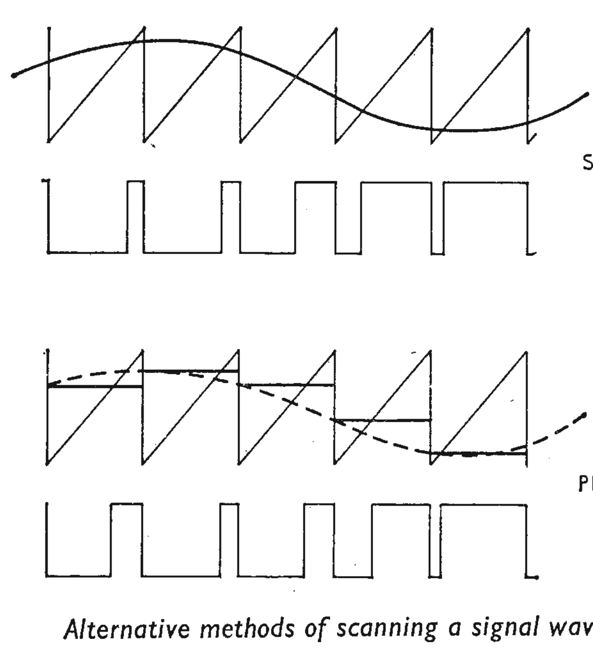
The Editor does not necessarily endorse opinions expressed by his correspondents

Pulse-modulated A.F. Amplifiers

MR. Birt and Mr. Johnson are to be congratulated on doing something about a system which some of us have been muttering about for years. My own interest in the subject was revived by the Ettinger-Cooper paper at the I.E.E. Transistor Conference and the possible application to audio amplification is discussed in a book which went to the publisher in the middle of 1962. I have one question for Mr. Johnson: does he keep dogs? Some time ago an ultrasonic garage door opener came into service in America and was followed by reports that all the dogs in the parish would begin to bark whenever the users arrived home. There is a large 50 kc/s signal before the low-pass mechanism of this kind of amplifier and it may be desirable to use better filtering.

There are some other rather interesting aspects which should help to fill out the picture. In 1947 ± 2 years, an audio frequency amplifier consisting of a magnetic amplifier with a 20 kc/s drive was shown in London, probably at the Physical Society Exhibition. A magnetic amplifier is, of course, simply a pulse length modulator. At that time, of course, the carrier generator was necessarily a valve oscillator and was probably a sine-wave generator. We now have the possibility of using transistor square wave generators of high efficiency, and we have improved square loop materials. This line of development could be of special interest where a group of amplifiers can be operated from a single oscillator, because the whole group would then need only two active devices and we could contemplate the provision of a square oscillator with comparative calm.

A good many years ago I described in these columns a discriminator for f.m. of what is sometimes, I think, called the diode pump type. I prefer to call it a pulse counter. The principle is now quite well known. The signal is brought to a low i.f., centred on something in the 150-250 kc/s region, and may be limited solid, if you see what I mean, by a Schmitt trigger circuit. The output of this is differentiated and one side is clipped, leaving us with a pulse-frequency modulated signal. Standard procedure is to take this through a low-pass filter and then amplify. There is no reason why we should not amplify first and then filter, and no reason why the pulse amplifier should not be a pulse standardizing circuit to give us a square pulse of convenient length. Feedback may be taken to the second local oscillator to reduce the modulation index, and thus the maximum pulse rate.



Alternative methods of scanning a signal waveform.

Mr. Johnson's circuit appears to give modulation of both edges of the pulse, and this gives very much smaller sidebands than we get with the single-edge modulation described by Mr. Birt. Readers who are interested should compare the graphs, Figs 3 and 4, in E. Fitch's paper at the Radiocommunication Convention, *J.I.E.E.* 94, III A, 13, 1947, page 560.

The closer you look, the worse it gets. It was pointed out by Parks and Moss, also at the I.E.E. Radiocommunication Convention (p. 511 *et seq*), that periodic length-modulated pulses can be used at a much lower recurrence frequency than synchronously scanned length-modulated pulses. The difference between the two is indicated in the accompanying diagram, which is based on Fig. 1 of the paper by Parks and Moss. The periodic scanning technique transmits information about the signal amplitude at regular intervals, while synchronous scanning varies the spacing between the test points. Valve circuits are described by Parks and Moss, and offer plenty of scope for ingenuity if any readers wish to convert them for transistor working.

Underlying all the possibilities there is, I suspect, a general principle. The discussion of this would occupy more space than the correspondence columns will bear, but I shall be exploring this in the near future.

A minor error has been detected in Mr. Birt's discussion of the regenerative output stage. He states that there is no audio component in phase-modulated pulses. There is, in fact, such a component which is almost proportioned to the modulating frequency. The amplitude is given by Fitch (eqn. (7) *loc. cit*).

London, W.8. THOMAS RODDAM

The author replies:

I have to confess I don't own a dog, but I do have two cats, and for what it's worth, neither seems to have registered any abnormal protest against my working with pulse amplifiers!

On the topic of reducing the h.f. energy, one could, perhaps, subtract an unmodulated square wave from the modulated waveform, so that with no audio input signal there would then be substantially no output from the amplifier. (I have resolved to be more careful in using the word "no"!) In the interests of economy one could no doubt do this prior to the output stage, in which case neither output switch would conduct in the absence of an audio signal.

In practice there would, I think, be some danger of introducing a threshold signal level below which the amplifier would cease to operate. This would produce an effect exactly like crossover distortion in Class B amplifiers. Indeed, this mode of operation is very similar to Class B, as each switch conducts only during alternate half cycles of the audio signal; but it is a further avenue to explore.

There is an important distinction between synchronous and periodic sampling (otherwise known as "natural" and "regular," respectively) to which H. S. Black draws attention in his book "Modulation Theory." This is that, whereas synchronous sampling (which I discussed in the February issue) provides a linear system which does not introduce either harmonics of audio frequencies or intermodulation products between differing audio frequencies; periodic sampling *does* introduce harmonic and intermodulation distortion. If one takes a really big piece of squared paper and draws out the waveforms assuming a *sawtooth* audio modulating waveform, one can see that the transfer characteristic is curved.

In a communication system one can, as Black shows, overcome this by converting to pulse amplitude modulation prior to demodulation; and it is interesting that the equipment described in the paper by Parks and Moss, to which Mr. Roddam refers, does, in fact, do this.

However, the major benefit of pulse modulation as a means of audio power amplification would be lost in an amplitude modulated system, since one would again require linear amplifying devices capable of considerable power dissipation.

The idea of a high-power pulse-counting discriminator is interesting. Maybe one could more easily control the volume by varying the h.t. to the output stage and be spared the task of designing a linear reactance modulator!

D. R. BIRT

Addenda from Thomas Roddam:

Although we can only get linear behaviour by converting to p.a.m., we should expect to correct the linearity by negative feedback, and might be able to avoid the conversion.

The last paragraph of Mr. Birt's reply reveals that I had not considered how to change the level!

Non-linearity Distortion Measurement

THE article on this subject by Murray and Richards suffers the misfortune of beginning with some false statements and assumptions:

1. It is stated that under normal operation the higher-order terms of the transfer characteristic are increasingly less important, and all those above the third can be neglected. However, it is well known that small amounts of high-order distortion can produce more unpleasant aural effects than relatively large amounts of low-order distortion. For this reason various systems of weighting them have been proposed. One thinks of such causes as transistor crossover, and peak clipping due to grid current and cut-off (which are sharpened by negative feedback). It might, perhaps, be argued that the proviso "normal operation" was entered to exclude these. But surely the main point of measuring distortion is to investigate all causes and especially those that are most undesirable in their effects?

2. Some rather startling figures ("astronomical" is the description used) are quoted for the strengths of intermodulation products in a multi-tone test relative to that of the harmonics in a single-tone test. In the first place, these figures are inflated by making the comparison on a *power* basis, for which there is no justification, since what matters is the amplitude, and distortion figures are invariably given on that basis. But an even more unjustifiable feature of the comparison is that each tone in the two-tone test is assumed to be equal in amplitude to the single tone with which results are compared. For fair comparison obviously the overall peak amplitude should be the same in each case. This appears to have been allowed for in the white-noise method described later on.

Rewriting Appendix 1 on this basis we find that each of the two second-order intermodulation tones in the two-tone case is—so far from being greater as stated—half the amplitude and one-quarter the power of the second harmonic in the single-tone case. Consequently, it is not true, as stated, that a two-tone test has the advantage over a single-tone test that lower levels of disortion can be measured. If many tones are used, the intermodulation products are correspondingly smaller still.

3. It is assumed that the transfer characteristic is independent of frequency. While this simplifies calculation it is liable to be seriously misleading in practice. Consider, for example, the iron-cored output transformer. A test was made* using a single 60 c/s tone, and the odd-order harmonics were measured to assess the distortion. An intermodulation test was then performed using 60 c/s and 400 c/s having the same combined amplitude, but 4:1 ratio to maintain a large sweep at 60 c/s. The odd-order intermodulation products, expressed as percentages of the 400 c/s signal, were less than half those of the corresponding harmonics in the first test, and 5 times smaller still in actual amplitude. The impedance of the coil was varying over the 60 c/s cycle, causing distortion of the waveform at that frequency. But at 400 c/s the impedance of the coil was much higher, consequently the 400 c/s was not modulated in proportion to the 60 c/s distortion.

Bromley, Kent. M. G. SCROGGIE

* See "Measurement of Non-linearity Distortion," *Wireless World*, July, 1955, pp. 317-323.

Intuition and Instability

IT is commonly supposed that intuition breaks down when a feedback system is met which, at the frequency where the loop phase shift is zero or a whole number of cycles, is stable when the loop gain is greater than one and unstable when less than one. This letter seeks to show that by considering feedback systems on the brink of instability with sufficient care, physical arguments can be adduced which not only remove the difficulty when intuition seems to fail, but also shed more light on the situation when it doesn't. For brevity we restrict ourselves to loops containing exponential lags or integrators, but the arguments apply equally to loops comprising leads and/or differentiators. It is necessary to bear in mind that

$$\int e^{(a+j\omega)t} = \frac{a - j\omega}{a^2 + \omega^2} e^{(a+j\omega)t} + C$$

or in words, that a sine wave undergoes a phase shift of less than 90° lagging when passed through an integrator

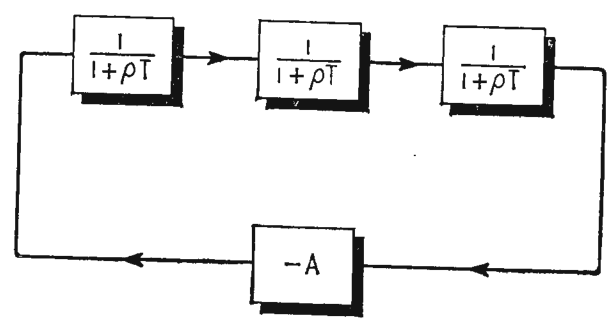


Fig. 1. Three lags of time constant T, and a gain of −A.

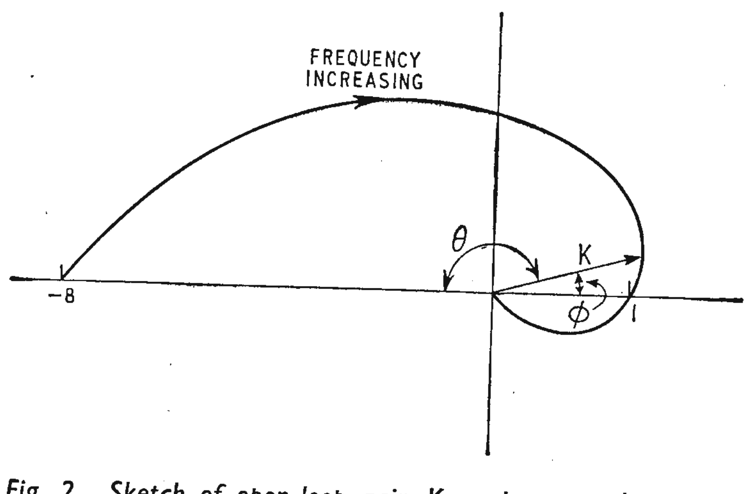


Fig. 2. Sketch of open-loop gain K against open-loop phase shift φ when on the verge of instability (A=8). θ is the filter phase shift.

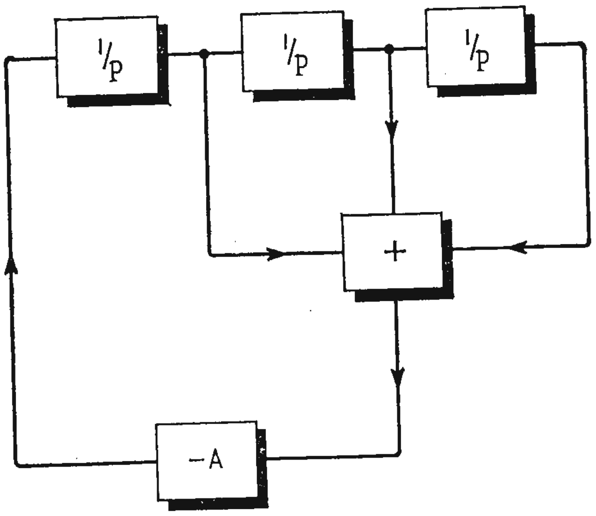


Fig. 3. Three integrators, an adder, and a gain of −A.

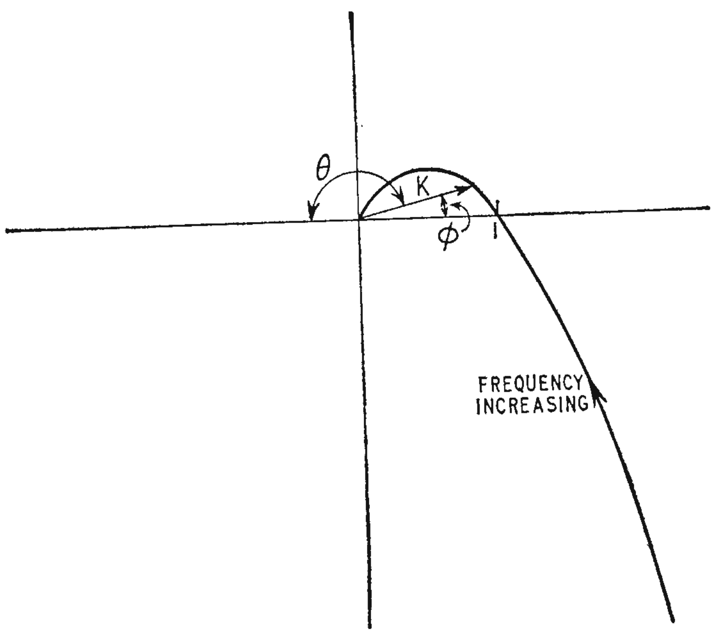


Fig. 4. Sketch of open-loop gain K against open-loop phase shift φ when on verge of instability (A=1). θ is the filter phase shift.

if it is exponentially growing in amplitude, and of more than 90° if it exponentially declining. We call the first case " compensatory lead " and the second " compensatory lag ".

Consider a case where intuition works, containing three equal exponential lags, Figs. 1 and 2, on the brink of instability, and suppose the gain A to be reduced slightly. Rather than saying " the oscillations die away because there is not enough gain to keep them going ", the writer suggests the following treatment:

1. Since the loop is closed, the loop gain must equal unity; if A is reduced, the gain of the filter must increase.
2. For the filter gain to increase, the frequency must fall (Fig. 2).
3. If this were all that happened, the filter phase lag would decrease (Fig. 2).
4. But the filter phase shift cannot decrease, because the loop is closed, which locks the loop phase shift.
5. Therefore compensating lag must come from the filter sections.
6. Hence the amplitude of oscillation declines.

At first sight the argument might seem tortuous. But consider now a case which seems to flout the intuition (Figs. 3 and 4). It is easily shown by Routh's, Nyquist's or some other criterion that the system is unstable if $A<1$. If $A = 1$ and is then reduced slightly, we can say:

1. Since A has been reduced, the filter gain must increase.
2. For this to happen, the frequency must fall (Fig. 4).
3. If this were all that happened, the filter phase lag would increase (Fig. 4).
4. But it can't.
5. Therefore compensating lead must come from the filter sections (integrators in this case).
6. Hence the amplitude of oscillation increases.

Physiological Laboratory,
Cambridge — P. E. K. DONALDSON

Oscillator Analysis

I AM a little confused by Mr. Brodie's statement that "Pritchard suggests a three-terminal approach, subject to the view that a two-port view may be more convenient." Does Pritchard reject the two-terminal approach completely? Surely there are few circuits which require a three-terminal approach, unless the 3-T is merely a degenerate two-port. The object of working with two-ports is to enable us to use a simple routine for manipulation.

Comments on the wider implications would be welcome. I am inclined to believe that most texts are produced by people with tough-minded temperaments. To a greater or lesser degree they set out their material in a tree, following the rules for writing informative English described, for example, by I. J. Good (" The Scientist Speculates," p. 41 *et seq*, Heinemann 1962). Twigs that upset the pattern must be pruned. The material itself, however, is a field, established by the work of the tender-minded. The reader who wishes to apply the material may also be tender-minded. There is thus a double translation process between the original worker and the student: the latter can't see the field for the tree.

The tree appears as a screen in many management problems. Subjective managers will only accept the simplest tree presentations and cannot use any of the critical path techniques, so that their trees, like Cody's tree, become merely monuments. An interesting variant on this theme is the way in which the economists ignore phase shift, or delay, in their studies of the stabilizer and then wonder why the economy oscillates.

There is a problem of communications here which is of considerable importance. We are in the middle of it, with our computors and teaching machines encouraging the tough-minded in their formality, while the real advances depend on a supply of ideas which only the tender-minded can produce.

In short, Sir, we need more highly qualified men organizing a muddle, and fewer highly paid men muddling in organization.

London, W.8. — THOMAS RODDAM

Transistor Parameters

SOME time ago discussion centred on the possible use of mutual conductance and input conductance as parameters in the design of transistor amplifiers. The justification for this is that, if internal feedback and capacitances can be neglected, the transistor equivalent circuit can for practical purposes be reduced to that of Fig.1.

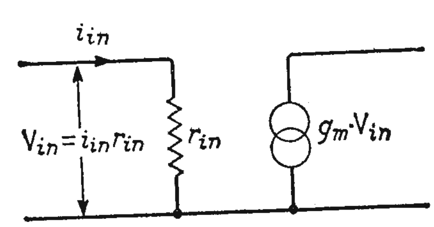


Fig. 1.

This equivalent circuit has the advantage of being exactly the same as that for a valve when the latter's input resistance is finite. Unfortunately, the mutual conductance of a transistor varies rather wildly with the operating point, and so does the input resistance. " Cathode Ray " (Sept. 1961, p.489) tabulates variations of mutual conductance, input resistance, voltage amplification factor, and current amplification factor for an OC45, and shows that, over the range of collector current 0.18—3.7 mA, mutual conductance varies in the ratio 20, and input resistance in the ratio 12. Current amplification, on the other hand, varies only by a factor of 1.5.

The purpose of this letter is to point out that the product $g_m.r_{in}$ varies much less than either factor taken by itself. For example, the ratio of $g_m.r_{in}$, maximum to minimum, for "Cathode Ray's" OC45 is 1.7, while for the particular C111 transistor whose characteristics are given here it is less than seven for a collector current ratio of 1000.

TABLE

I_c	10mA	3mA	1mA	200μA	50μA	10μA
g_m (mA/V)	190	77	35	7	1.6	0.4
r_{in}	700Ω	1200Ω	2500Ω	10kΩ	20kΩ	50kΩ
$g_m.r_{in}$	133	93	88	70	32	20

Now, $g_m.r_{in}$ is a dimensionless number, and readers will already have observed that it bears a strong resemblance to the valve parameter $\mu = g_m.r_a$. It is, in fact, the voltage amplification factor, not of a transistor taken by itself, but of one transistor in a chain of identical capacitance-coupled stages (Fig. 2).

Here the stage gain is: $\frac{g_m.r_{in}.R_c}{r_{in} + R_c}$, and this can be compared with the stage gain of a valve amplifier: $\frac{g_m.r_a.R_a}{r_a + R_a}$.

In the past, the voltage gain of a transistor amplifier stage has not entered much into design procedure, but it may do so in future. One obvious case is a multi-stage video amplifier, where collector loads must often be reduced to values comparable with the input resistance of the following transistor in order to get enough bandwidth. With modern transistors, it is possible to achieve quite useful stage gains with bandwidths of 20Mc/s or more, and under these conditions a radar receiver of the "crystal-video" type may be an attractive poposition, since there are no i.f. circuits to align. The coming of v.h.f. transistors with input and output capacitances the same as those of valves will presumably make possible the design of wide-band i.f. stages like Fig. 3, where r_{in} provides most of the required damping.

Croydon. G. W. SHORT

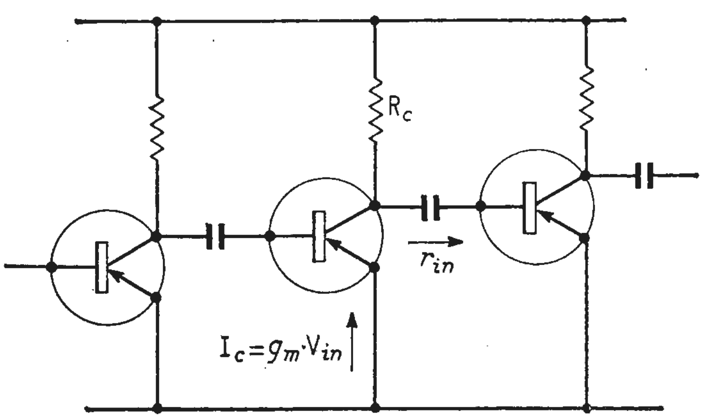


Fig. 2.

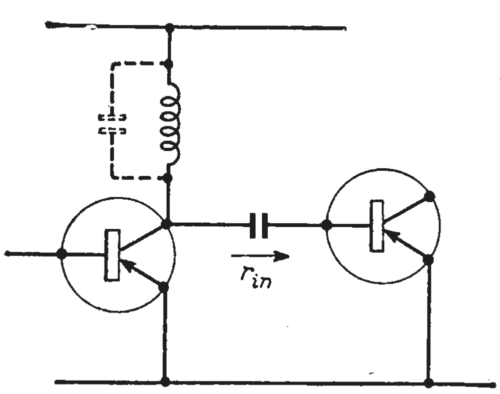


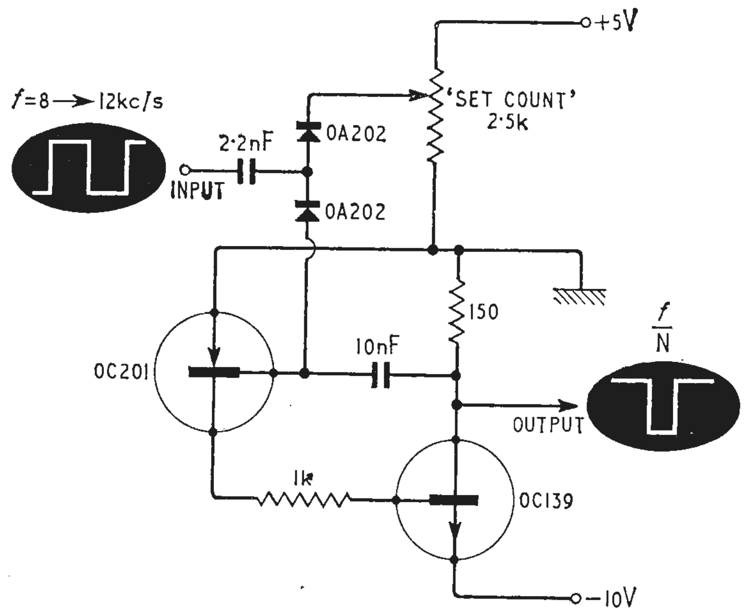
Fig. 3.

Complementary Mono-stable Circuit

PLEASE permit me to qualify the rather sweeping dismissal of the complementary mono-stable circuit in my article in the August 1962 issue.

Below is an application for this circuit as a diode-pump frequency divider.

Besides possessing the same advantages and limitations as other "staircase" dividers, this circuit shows the



superior current and component economies that are characteristic of the use of complementary transistors.

Hayes, Middlesex. J. C. RUDGE, E.M.I. Electronics Ltd.

Radio

IN the March issue, "Free Grid" asks for references to the early use of the word "radio." As this word, in Latin, means a ray or radiation, it was natural for Professor Sir William Crookes to use it for the radiometer which he demonstrated to the Royal Society on 7 April 1875, which although worked by radiation, was not used for the communication of intelligence.

Mercadier's radio-phone, however, was used for telephony, and was reported in *Comptes Rendus*, Vol. 91, p. 929, in 1889. Professor Graham Bell and Sumner-Tainter also worked with this type of equipment, but did not describe it similarly.

Probably in view of these prior uses of the word, J. Munro wrote to *The Electrician* in December 1898, suggesting the term "radio" in lieu of "space telegraphy" which had previously been adopted by Sir Oliver Lodge.

In America, the term radio was popularly used to describe sound broadcasting soon after World War I, and is now in common use in this country, too, and it is probably for this reason that engineers prefer to adhere to the term wireless for instances other than broadcasting, and it is a source of gratification to them that your journal retains its original title and has not succumbed to the modern jargon. Many engineers abhor the now popular combination "radio and tele-

(*Continued on page* 233)

BY APPOINTMENT TO
H.R.H. THE DUKE OF EDINBURGH

SUPPLIERS OF MOBILE
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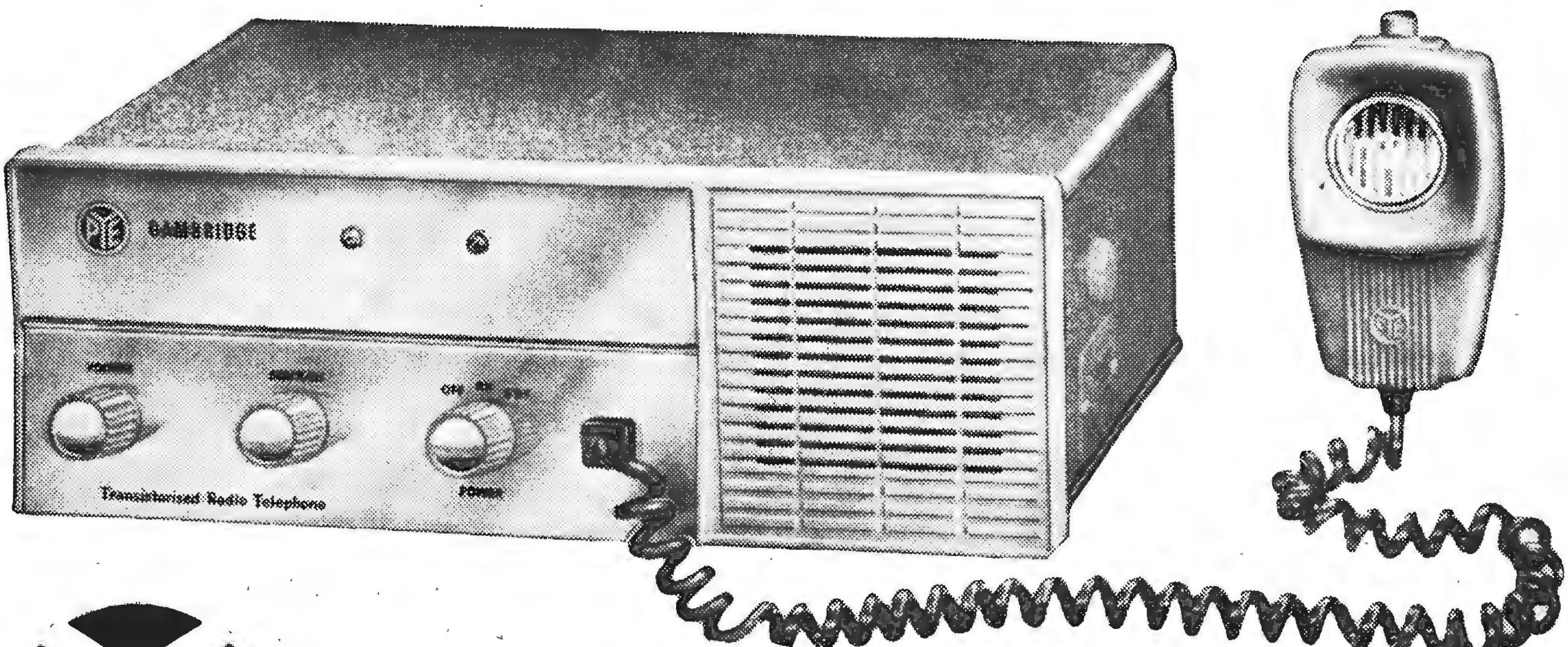

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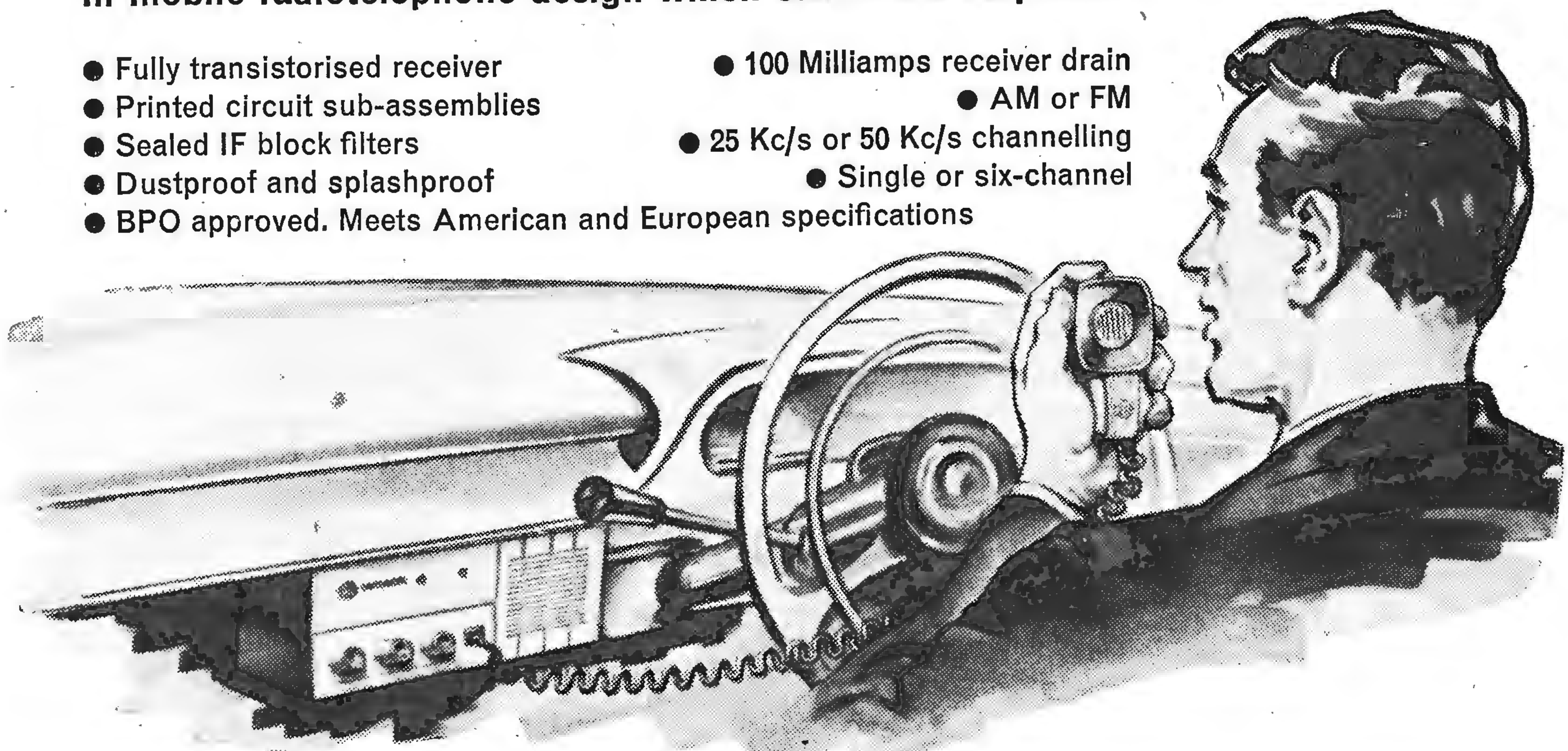

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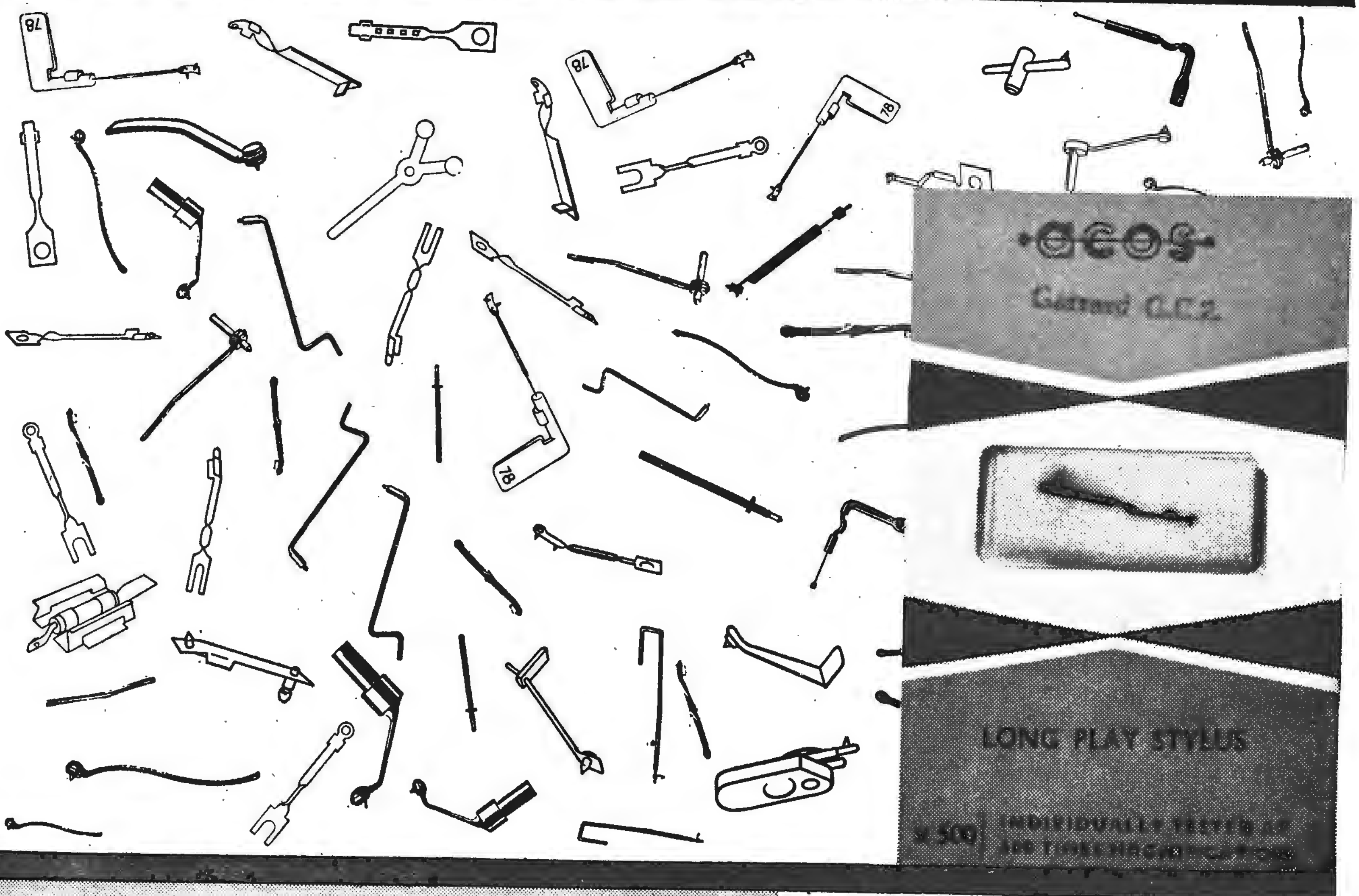

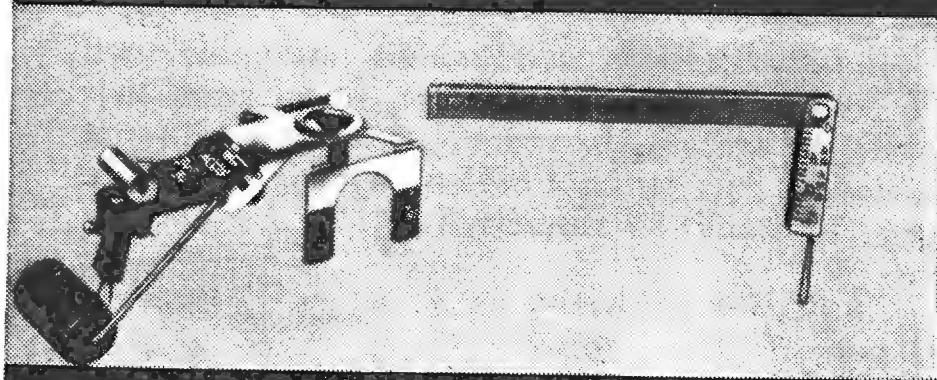

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COSMOCORD LTD, WALTHAM CROSS, HERTS. TEL: WALTHAM CROSS 27331 vision," because what is television if not a branch of radio? It is tantamount to a restaurant advertising "meals and luncheons"!

Little Baddow, Essex. E. A. PAYNE

Agnoia Waves

AS far back as October 1955 "Free Grid" was seeking to impress us with his antiquity. But I doubt whether any of us realized even then that his interest in radio went back to the period before the existence of what I prefer to call æther (to avoid confusion with an anæsthetic fluid) was disproved, as it was by the Michelson-Morley experiment in 1881. His note under the above heading not only implies this, but joins us all with him in the same age group, which I for one must modestly disclaim.

Possibly his extreme old age is responsible for some slight confusion on his part as to what I actually did deal with in your November 1958 issue. I did not say that *radio* waves travelled *in* nobody knows what, but that *electrons* were waves *of* what nobody knows, so, to avoid embarrassment, they are called ψ waves.

Going back to electromagnetic waves, it was suggested more than 50 years ago, and is now generally accepted, that they consist of photons, which are minute particles possessing energy and momentum. They therefore need no æther nor anything else to carry them. Electromagnetic radiation is still called waves, however, because the distribution of photons can be calculated by the same mathematical forms as apply to waves. But this does not necessarily mean that they actually are literal waves, i.e., disturbances in a medium. It happens that the particle aspect of radiation is most pronounced at the highest frequencies (e.g., X-rays) and the wave aspect at the lowest frequencies (radio), so photons are naturally less prominent in our vocabulary.

There remains the problem of how electric fields operate across empty space, and it has been suggested that they, too, are due to photons, which are continuously being exchanged between electric charges. But as far as I know this is still rather speculative.

Any agnostic words "Free Grid" may care to invent might perhaps be applied to ψ waves, if something better than a Greek letter is desired; but they, too, are waves only in a mathematical sense. We are usually more interested in their particle aspect and don't feel the need for any medium to carry them from cathode to anode. I never have, anyway, in spite of being, yours sincerely,

"CATHODE RAY"

New Phase Splitter

MR. Arthur R. Bailey (March issue, p. 134) has tried to prove the superiority of the long-tailed pair phase inverter over the split load, or concertina, phase inverter. He claims that the unequal driving impedances will have adverse effect on the output valves under conditions of overload. I contend that this can happen only if the designer has neglected to observe some simple precautions.

Use of minimum values of grid resistors for the output stage will, of course, minimize grid leak bias. If minimum values of anode and cathode resistors are used in the phase inverter, the effects of unbalanced impedances will be reduced. Further, each of these expedients will reduce the available output voltages from the phase inverter and thus prevent overdriving the output valves.

Limitation of drive signal to the output is a certain way to avoid overload grid bias shifts. In practice, the designer must compromise his signal levels in the circuit to have adequate drive at moderate distortion without having excessive drive. Admittedly, the compromise between distortion near maximum and what we refer to as "overload distortion" is not a simple one. However, this compromise can be rather independent of the type of phase inverter used. The split load inverter cannot furnish as much drive as the long-tailed pair which gives it some freedom from overload distortion problems, but this may not permit as low a distortion level near maximum drive.

One of the finest advantages of the split load inverter, and one seldom mentioned, is the fact that its inversion capabilities are dependent solely on two resistors, without dependence on age of the valve. This is not true for other circuits.

Philadelphia, U.S.A. DAVID HAFLER,
Dynaco, Inc.

Transistor Bias Networks

REFERRING to Mr. Ormond's paper on page 106 of your March issue, there appears to be a point of confusion in the first equation,

$$I_c = \beta I_b + SI'_{co}$$

The American stability factor S is defined as the ratio of the incremental change in the total collector current to the incremental change in the zero-emitter collector current or $S = \frac{dI_c}{dI_{co}}$ ("Electronic Designer's Handbook," Landee, Davis and Albrecht, 2–71) and is greater than unity.

In this equation however we need the English stability factor, K, which is the ratio of the change in the total collector current in the stabilized circuit to the change in the total current in the unstabilized circuit

$$K = \frac{dI_c}{dI'_{co}}$$

("Principles of Transistor Circuits," Amos, page 81) and for the common-emitter circuit

$$K = \frac{1}{1 + \alpha' R_e/(R_b + R_e)} \text{ (ditto, page 88)}$$

which is $\beta + 1$ or $1/1-\alpha'$ times S given in equation (2) of the paper, and is always less than unity.

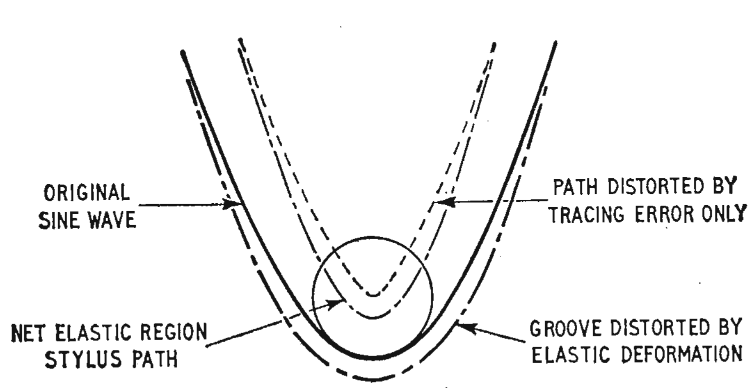
So $I_c = \beta . I_b + K . I'_{co}$ or $B . I_b + S/(1 - \alpha' . I'_{co})$ or $\beta . I_b + S . I_{co}$ (undashed).

As S and K are a constant multiple of one another this does not alter the arguments in the paper, but the point may have confused others as it did me.

Lausanne, Switzerland. R. H. WILLIAMS

"Stylus Mass and Distortion"

The author wishes to correct the impression, given by Fig. 5 (a), in the above article in the April issue, of the *addition* of tracing and stylus inertia distortion.



(a)

Accordingly Fig. 5(a) is here redrawn to demonstrate that the final reproduced waveform can be *more* sinusoidal as a result of groove deformation (which follows a non-linear law as described).

Also the expression in line 5, right-hand column of page 176 should read $z \propto f^{\frac{5}{3}}$(as in the full expression for stylus inertia distortion $z = \phi k_3[m^{\frac{2}{3}}.f^{\frac{5}{3}}.V^{-\frac{1}{3}}]$).

TRANSISTOR AMPLIFIER OUTPUT STAGES

5.—DESIGN OF COMPOUND PAIR CIRCUITS

By O. GREITER

IN preceding articles we have seen that in the design of transistor power stages we can take advantage of a flexibility of structure which is very much greater than anything we have encountered in the design of valve stages. We are faced, however, with device limitations of performance. These are of a kind which involves decisions. In valve circuits it is usually possible to tailor the supply to the performance, so that decisions of valve types are made on the broadest possible basis. Transistors introduce the frequency response limitation with a price and power premium to be paid for improved performance.

When we look back we can see that broadly similar situations heve existed in other parts of our field in the past. We can see that the first phase, once a circuit of any kind is established, is the development of a whole range of different circuits, each of which is claimed to have some advantage over the others. This is followed by a shaking-down phase, in which many of these circuits die quietly. It is often difficult to see why one circuit survives and another remains only a note in a yellowing textbook. The circuit which fails was designed in good faith, its users were competent engineers who believed in its virtues.

It is tempting, when surveying the field, to seek to find a circuit trend, to offer the reader a winner for the big race. At very least the reader might expect to be told which is favourite. Unfortunately there seems to be no real trend in the design of output stages for high quality transistor audio frequency amplifiers. In structures there seems to be some indication that transformerless stages are in, but for the rest the field is wide open. Some evidence of a trend in driver design can be found but it is not very reliable because it reflects merely the several outlets of a single designer's views. The Baby Austin is not a confirmation of the desirability of the Mini Minor.

The reader may expect to find that the available circuits will be classified, reviewed and given some kind of objective ratings so that he, or a simple decision-making logical device, can select the best combination of structure, drive circuit, device characteristic for a particular application. Objectivity is the problem. The only objective decision the author can see in the industry is the decision to cut down teams and rely on the designs produced by the device manufacturers. The author can see no reason why he should be able to avoid the human error of claiming objectivity for his own prejudices.

One feature of output stage design is to be observed. Many of the circuits used commercially, and by many we must mean a majority of the rather small total, are rather complicated. There are, for example, several combinations of the Darlington compound pair in use. The theoretical behaviour of this structure was examined in *Wireless World*, Aug. 1962 (When reading this please note that Figs. 2 and 3 should be transposed). The analysis here deals particularly with the small-signal linear behaviour of a compound pair. It shows how the internal feedback in each transistor limits the validity of the very simple approximate result which we can write down so quickly and easily.

This approximate result may lead us to the conclusion that a power stage can be built in which the drive is about 1V, 2mA peak. From this conclusion we proceed in the belief that a stage based on an element of this kind is easily driven from a simple phase-splitter. There are, in any practical system, some difficulties to be surmounted. For the designer, however, the first stage will be the determination of the stage characteristics. Since the compound transistor pair is, from a user standpoint, a three-terminal semiconductor device the first step will be to obtain a device characteristic. It seems likely that the load applied will be fairly small and that the drive will be applied to the base from a low-impedance source. The first consideration will then be the linearity of the system. We may work in terms of the mutual conductance characteristic and we can generate this on a point-by-point basis from the individual device characteristics. This has been done rather rapidly for a combination of OC84 and OC28 in the table below, which follows the order of the operation.

OC28 I_c I_b $-V_{be}$	0 0 160	1 32 530	2 71 630	3 113 710	4 160 800	5A 210mA 850mV
OC84 $-V_{be}$ for $I_c = I_b$ (OC84) (OC28)	110	260	310	345	385	420mV
$-V_B$ $= V_{be} + V_{be}$ (OC84) (OC28)	0.270	0.790	0.940	1.055	1.185	1.270V

The critical reader may note that it would be prudent to re-examine some of these values in order to smooth out the differences. However, the last row indicates the voltage needed between the base of the OC84 and the emitter of the OC28 in order to produce the integral values of OC28 current in the first row, and thus the compound collector current which is the sum of the first two rows. The result is plotted in Fig. 20.

If we wish to use this compound pair as an element in a class-B stage we shall bias it to the point VB = −0.8 volts, where the mutual conductance is one-half its high-current value. The standing current will then be a little over 1 amp in each of the two (or four) transistor units of the output stage. We have been through this before and we know that we must add an emitter resistance R_E to give, for example, the characteristics dotted in on Fig. 20, which shows the effect of the rather high value of 1 ohm. With this value of emitter feedback we find that in a suitable quiescent current is somewhere below 0.25 amp. We shall need to plot out this region in detail to find just where we should work and we shall do better to set up a physical experiment and measure real transistors. The half-g_m bias is easily found if we apply a small signal in series with a variable bias voltage and observe the signal current by monitoring the voltage across R_E.

We can construct other characteristics for this compound pair in the same way. In particular we shall find that we require an input current of 2mA to the OC84 to bring the total collector current to 5.2amps, so that the overall current gain is some 2,600 times. With the 1-ohm emitter resistance which calls for some 6 volts of drive, the apparent input resistance will be 3,000 ohms, so that a relatively low impedance drive is certainly easy to provide.

A problem which seems to have been largely ignored is that of the temperature stability of compound pairs. It is, indeed, a problem of great complexity. To begin with we cannot assume that the two transistors will be at the same temperature, for it will not usually be convenient for them to share a heat sink, and even if they do so the internal thermal resistance of the OC84 is high. It is not specified but the data suggests that it may be of the order of 50-100°C/watt.

We could embark on a full analaysis with the certainty that the result would be almost impossible to use in everyday design. Let us consider the rather simpler conditions which might seem ideal. We can fix the bias voltage V_B by using a very low impedance bias circuit. If we have an emitter resistance which is of the order of 0.5-1 ohm this will exercise rather tight control of the total emitter current, for even at the quiescent bias point the transistor mutual conductance is about 5 A/V. Probably the main problem will be changes in V_{be}, perhaps 5mV/°C if both transistors are allowed to get hot, and with a 1-ohm emitter resistance we shall get about 5mA/°C shift in emitter current. We know well how to compensate this by using a resistance with positive temperature coefficient for R_E. Then as the value of V_{be} falls the value of R_E I_c will rise to compensate it at a constant value of R_E.

The difficulty of this treatment is that much of the temperature rise is due to transistor dissipation in the immediate past and we have no easy way of matching the temperature of the emitter resistor to the junction temperature. All these compensation systems appear to suffer from this kind of defect which we can easily conceal from ourselves in a normal test procedure. Indeed, the more painstaking our testing, the longer we allow the system to settle into a steady-state condition.

The circuit we have considered looks very satisfactory from the point of view of protection against collector leakage current drift. This is the biggest fallacy. Consider our typical pair operated with a quiescent current of 250 mA and an emitter resistance of 1 ohm. The required base current of the OC28 will be about 8-10mA. This current can be supplied very happily by the OC84. Now raise the temperature of the OC28 to 100°C with a supply voltage of −14V, and we shall get a collector-base leakage current of 20mA. This will completely swamp the effort of the OC84 to supply its 8-10mA and will, with the aid of R_E, drive the OC84 well beyond cut-off.

This effect can be considered from another aspect. Although the base of the OC84 is supplied from a very low impedance, the base of the OC28 is supplied from the emitter of the OC84. This is not a low impedance when compared with the value of $\bar{\alpha}'$ (OC28). R_E, which is about 30 ohms. Unfortunately the data is not available, but for the GET114 we have h_{ib} = 28 ohms at a collector current of 1mA and at the higher currents it appears to fall to perhaps 10 ohms. Notice that this is, in a way, an explosive situation. As the leakage current increases the current through the OC84 will fall and, in consequence, the impedance in the base of the OC28 will increase and thus reduce the stability of the system.

The reader will notice that there are two obstacles

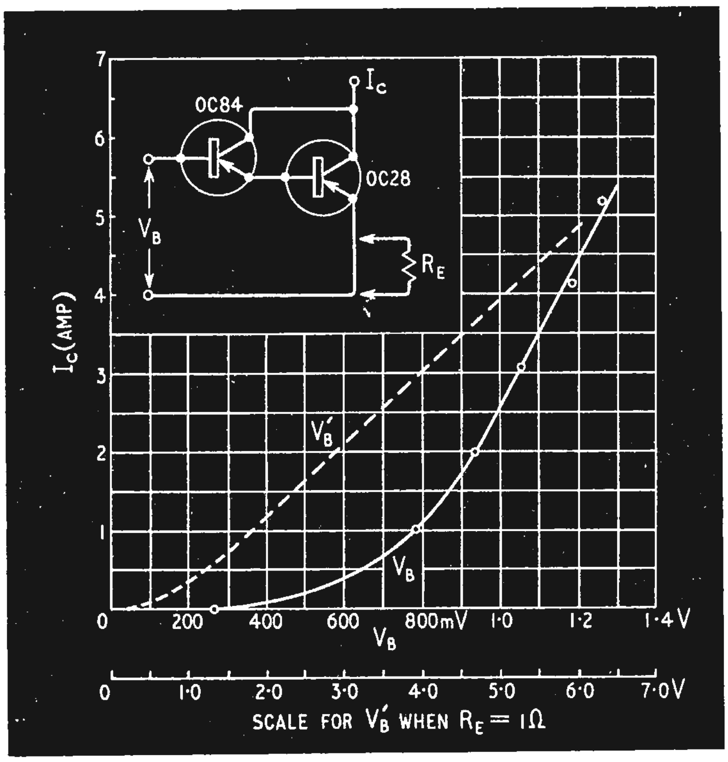


Fig. 20. Characteristics of OC28 and OC84 connected as a compound-pair.

to a theoretical study. The analysis, already complicated in a linear region of operation, is further elaborated by the non-linearity of the emitter input resistance of the OC84 (or transistor 1) and to add to our difficulties we shall find that we must use particular types of transistor in order to have data for our calculations, not because they are the most suitable types.

In practice the difficulties are evaded. One method used is shown in Fig. 21. The added resistance R_1 can be thought of as a drain down which some of the emitter current of Tr 1 can flow, so that Tr 1 operates at a higher current level than would be required if the only outlet were the base of Tr 2. We can now allow a higher level of I_{co} in Tr 2 before the working point of Tr 1 is disturbed. Another view is that R_1 acts to reduce the amount of I_{co} which flows back into Tr 2. It also might be thought that the presence of R_1 will help to stabilize Tr 2, but the effect here is probably very small.

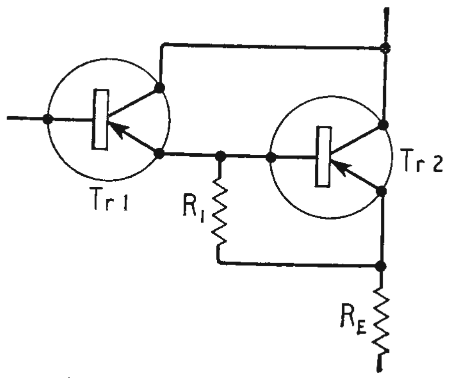


Fig.21

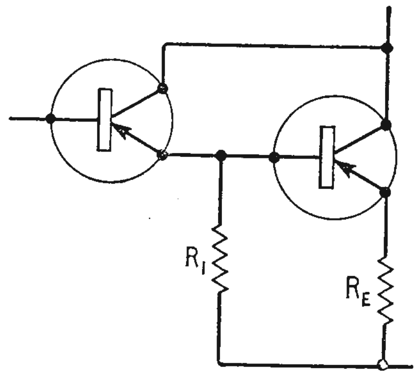
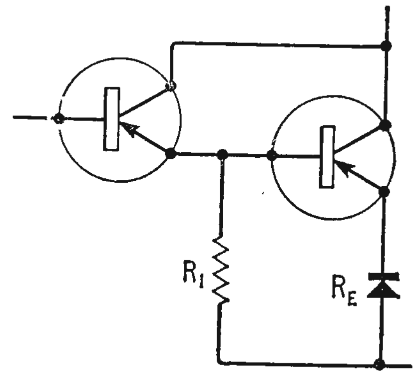


Fig.22



Figs. 21-23. Variants of the basic compound pair.

We have connected R_1 between base and emitter, so that R_E offers no help in the stabilization to which R_1 contributes: Only the internal resistance r'_e is involved. Equally the value we can use for R_1 is comparable with the input impedance of the transistor itself, not the transistor with emitter feedback.

Once we introduce R_1 we must redraw Fig. 20, for the extra drain of current from Tr 1 means that the curvature of the characteristic will come mainly from Tr 2. Even a graphical approach will be rather tedious, because the voltage across R_1 is the roughly exponential V_{be} of Tr 2.

An alternative approach which has been used is the one shown in Fig. 22. Here R_1 can be determined for stability alone in its relationship to Tr 2 and R_E. This circuit is a good deal more tractable theoretically provided that we are prepared to over-design by neglecting Tr 1 altogether in our determination of stability. Again Tr 1 will be lifted up into the nearly linear region by the extra current which flows in R_1.

The circuit shown in Fig. 23 is used in an American commercial high-quality amplifier. This resembles the form shown in Fig. 22, except that now the emitter resistance has been replaced by a diode. We can regard this diode as a rather small value of R_E with a built-in bias battery. With all these circuits the author is tempted to the view that point-by-point plotting of graphs from data sheets is not a satisfactory procedure. We must select a couple of reasonably typical transistors and set up an experiment to draw the curves on the face of an oscillograph. Where we have the variable R_1 and R_E we can explore a whole range of values relatively quickly in this way. An experienced engineer can judge at a glance the characteristics produced in this way. If he cannot, the laboriously drawn graphs will be useless too. Probable solutions can then be tested for temperature effects, an experiment for which a hair-dryer is invaluable. Since one object of the procedure is to obtain at the end an impressive report, photographs may be taken and in addition the numbers obtained in this way may be substituted in the methematical analysis. The guess of 1 ohm used (to save work) in producing Fig. 20 is replaced by the selection made after twisting the knobs of a resistance box.

Although we have given up the struggle to analyse these circuits we have only touched the fringe of the permissible variations. We might consider, for example, using a thermistor for R_1 and returning it to a tap on R_E. Then as I_{co} increases so we provide an easier path down which it can leak. We can use a thermistor or some other temperature-sensitive system to alter the bias to Tr 1 so that it will reset itself to deal with changes in I_{co}. Most designers seem at the moment to be sitting quietly on the fence waiting for someone else to shout "They went thataway."

In this article we are assuming that a compound pair will be used and we must think a little about the frequency behaviour. We know, by looking in the appropriate textbook, that in the common-base connection the current-gain:bandwidth product is a good deal higher than that of the individual transistors. A treatment sometimes adopted regards Tr 1 as a unit which simply provides an error signal to try to restore the common-base current gain to unity. In this view the base current of the main transistor, Tr 2, is "lost" current and is piped back (at least $(1-\alpha)$ of it is piped back) by Tr 1. Even if Tr 2 has a lower cut-off frequency than Tr 1 the overall cut-off is found to be above that of Tr 1.

The delays in the transistors produce an over-compensation and the overall current gain at some frequencies will rise above unity. Typical graphs are given by Cattermole ("Transistor Circuits," Heywood, 1959, Fig. 8. 31. The scale for $|\alpha_p|$ in this figure is to my eye suspect and should probably read 0.15, 0.25 etc.). The unwary designer may be delighted to feel that in using a composite pair he has gained in frequency response. He has, of course, done no such thing. The analysis given in the August 1962 issue of *Wireless World*, pp. 397-9, can be applied by using the frequency-dependent h-parameters. Some simplification is obtained if low-frequency parameters are used for Tr 1 and medium-frequency parameters for Tr 2 to accord with the use of a transistor of good frequency response in the low-level part of the circuit. Even so the analysis is extremely tedious.

A purely physical approach reveals much of the story. If an impulse is applied suddenly to the base of Tr 1 and Tr 1 is an ideal or infinitely fast transistor it will produce at its emitter an emitter current which will flow into the base of Tr 2. This slow transistor can be regarded as a diode or as a capacitance, but not as a transistor. From a circuit viewpoint we have lost the feedback due to the $\beta_2 R_E$ effect in Tr 2, and the emitter degeneration in the circuit of Tr 1 will be small. The unfortunate

(*Continued on page 237*)

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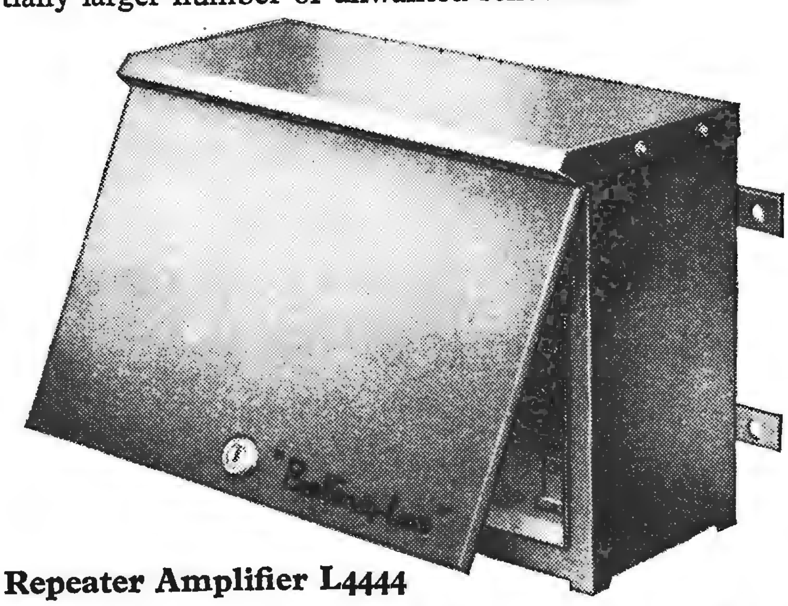

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Tr 1 will then, since we have assumed a voltage drive, be heavily overdriven.

Looked at from the error signal viewpoint, until Tr 2 collector comes into action the total demanded collector current must be produced by the error mechanism, that is by Tr 1. There appears to be no way in which we can avoid this rather simple result, that the only place we can get, in terms of Fig. 20, the 5 amps we need except by overloading a small transistor or by waiting until the big transistor is ready to deliver it. If we use a big transistor with a very low cut-off frequency we can get a good high-frequency response only for signals which can be fitted into the unused available current region of the small transistor.

Our difficulties are by no means ended. We find that a rather popular, if we dare use this term, arrangement is the one shown in Fig. 24. We must now repeat all our studies for the n-p-n/p-n-p, circuit and we must consider how the different properties of the n-p-n unit will affect the overall situation. The n-p-n/p-n-p combination shown here is not the one shown as Fig. 4 in the August 1962 paper but may be drawn in the form usually adopted for compound pairs as Fig. 25. The analysis of this circuit, starting with unit emitter current on the left, is carried out on the diagram itself. The overall current gain from base to collector is found to be

$$(1-\alpha_1+\alpha_1\alpha_2)/(1-\alpha_1)(1-\alpha_2)$$
$$=\frac{1}{(1-\alpha_1)(1-\alpha_2)}-\frac{\alpha_1}{(1-\alpha_1)}$$

so that it is rather smaller than the corresponding figure for the conventional p-n-p/p-n-p form. The

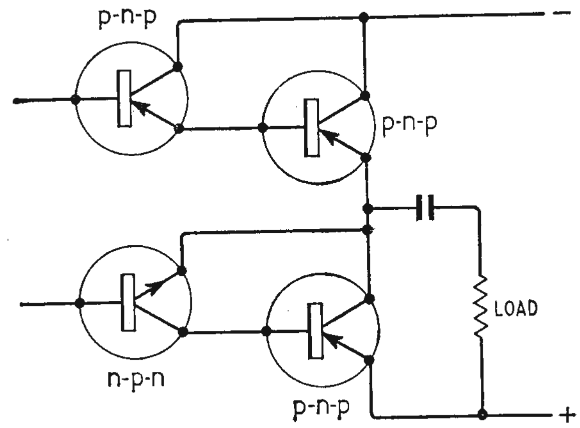


Fig. 24. A "popular" output stage configuration.

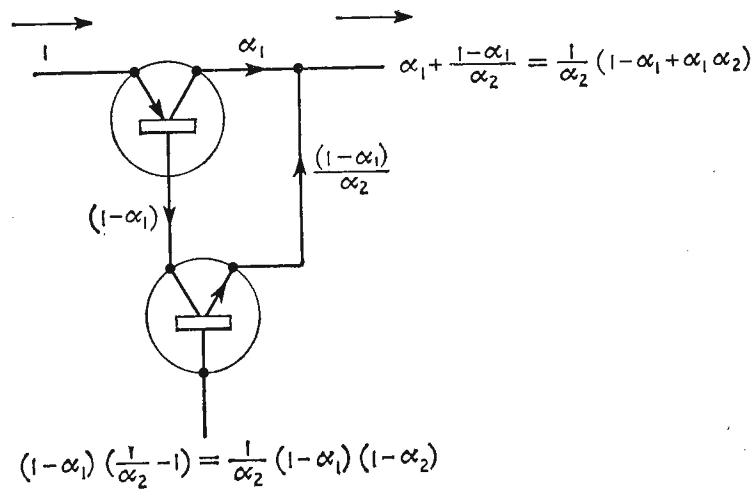


Fig. 25. Rearrangement of circuit of Fig. 24 for convenience of analysis.

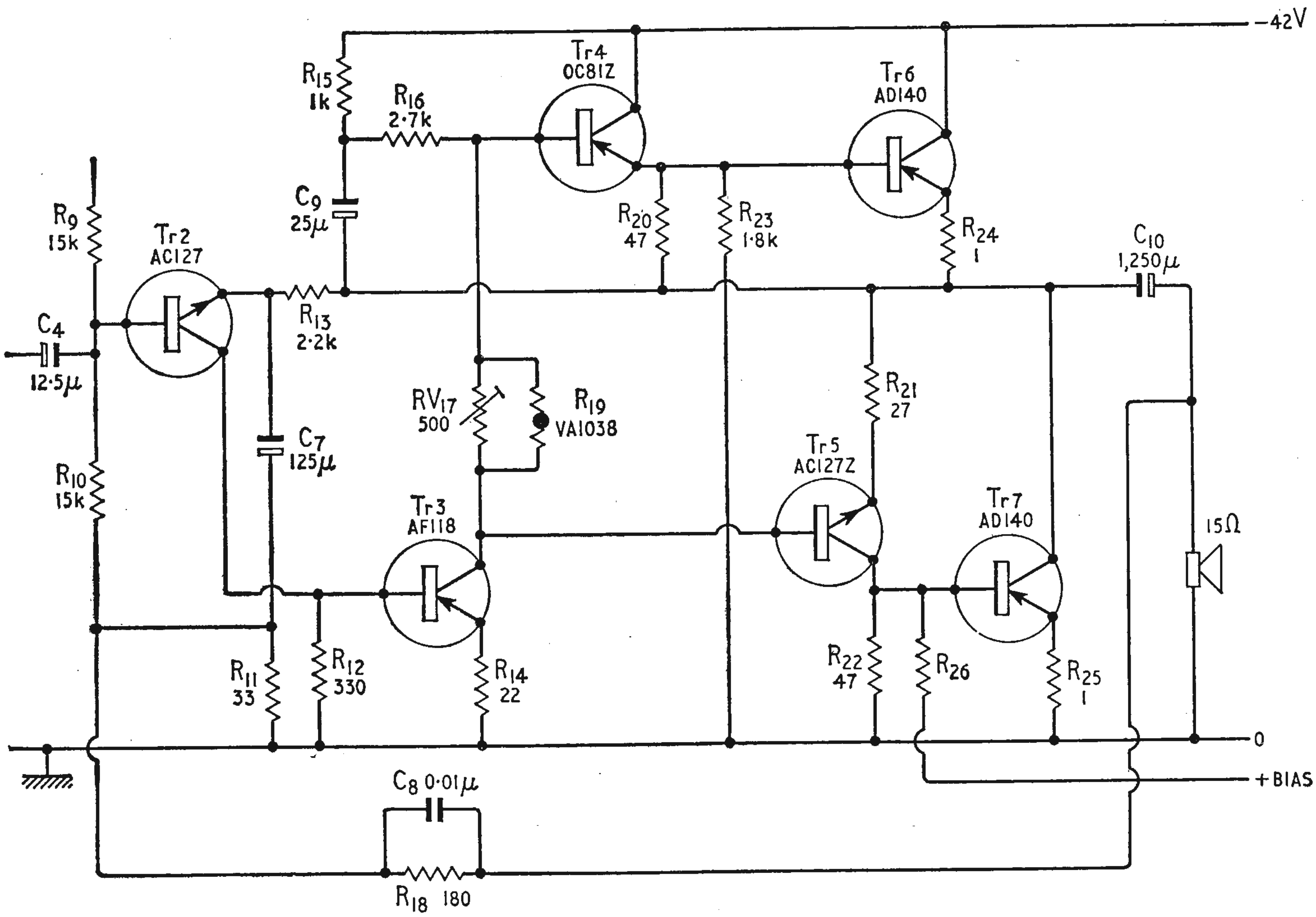


Fig. 26. Circuit of Mullard (Osborne and Tharma) amplifier.

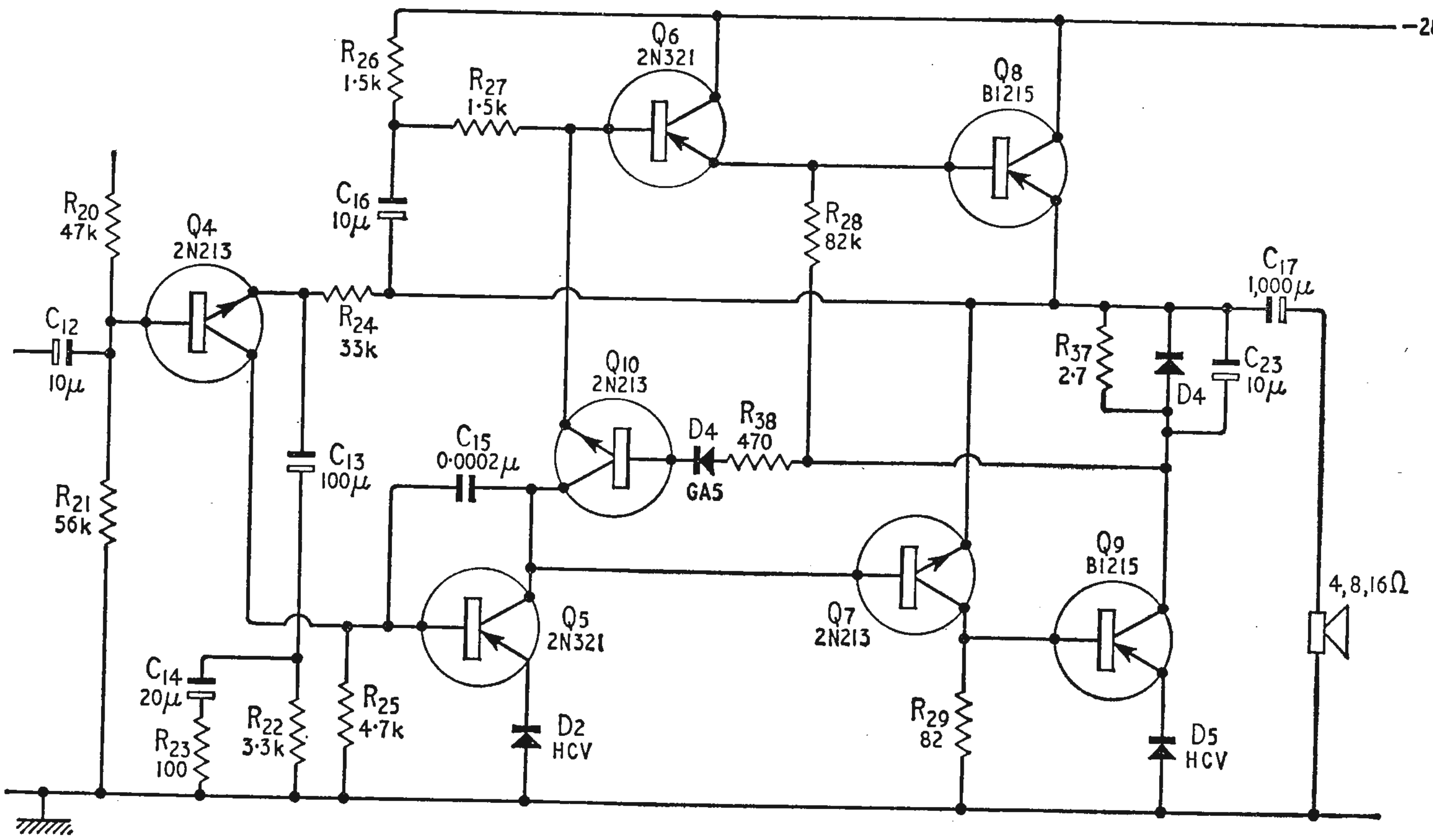


Fig. 27. Circuit of Transistronics Type TEC S-15 amplifier.

form shown in Fig. 25 shares with the conventional form the relatively high collector voltage for the first transistor (i.e. the one having gain α_2). The form shown previously needs some circuit elaboration, for the V_{ce} for the small transistor in only the V_{cb} of the main transistor. On the other hand it is not too easy to see just how we should use the circuit of Fig. 25 since the collector load will play havoc with the base-emitter voltage of the small transistor if a conventional common-emitter connection is adopted.

The British designer may find his style rather cramped by the very limited supply of cheap n-p-n transistors and the fact that most of them are restricted to rather low operating voltages. As we have seen, we must take some account of reactive loads and of the voltage over-swings which they produce.

The problem has been partly resolved for us by a report which has only just reached the author, and which will be published soon after this part of our study reaches the reader. Our starvation has not been that of Buridan's ass but rather that of a dog offered a selection of tinned dog-foods, poised in a balance of repulsion. A circuit described by Mr. Tharma of Mullards must be of particular interest because we can be sure that it will be a circuit which, in the jargon of this day and age, is device-orientated. In rather less fashionable language, they are not going to publish this circuit unless they can sell you the transistor to go into it. There are, indeed, two circuits offered to us at this time, one a class-AB circuit, which operates in something called the " π-mode ", and one a straight class-B circuit. There are a number of interesting features in the class-AB circuit, which uses conventional p-n-p/p-n-p Darlington pairs driven by a long-tailed pair phase splitter. The class-B amplifier, however, is all we can spare room for, especially as it ties in with the circuit which was already planned to form the tail-piece of this section before Mr. Tharma's report was issued.

The circuit shown in Fig. 26 shows all except a common-emitter OC44 input stage. We see the quasi-complementary Darlington structure of Tr 4, Tr 6, a p-n-p/p-n-p pair, and Tr 5, Tr 7 an n-p-/p-n-p pair connected in the model of Fig. 25. Component values are chosen to give equal input impedances at the bases of Tr 4 and Tr 5 (choice of R_{21}) and to give equal current sharing between the resistance and the base at the main transistors. There is some asymmetry in the overall frequency performance of the two sides of the power stage.

It will be seen that R_{20} and R_{22} will bleed a fair standing current so that Tr 4 and Tr 5 will not be operating too near the bend in their characteristics. The two resistors R_{23} and R_{26} return to points which are well positive with respect to the transistor bases to which they are connected. This provides a reverse bias so that the base current can reverse to sweep away the stored charge and to hold down the leakage current when the output transistors are cut off.

We must now compare this circuit with that shown in Fig. 27. This is the arrangement used in an American amplifier, the Transistronics TEC S-15. Positive bias here is applied to the base through the bleed resistors R_{28} and R_{29}, although it is only the relatively small amount produced by the diodes D4 and D5. The same configuration has been adopted for the output stage.

The drive to this type of output stage is, of course, just a push-push drive, for the fact that one of the Darlington minor transistors is in common-emitter and one in common-collector provides the necessary phase reversal. We see then the drivers Tr 3 and Q5, quite ordinary common-emitter stages, directly coupled to their respective power stages. In the circuit of Fig. 26, however, the thermistor R_{19} will make a compensation for ambient temperature variations in the overall separation of the base potentials as the values of V_{be} vary and it would appear that this is the function of Q10 and D3.

Both circuits have a further directly-coupled input stage, Tr 2 and Q4, using an n-p-n transistor. This acts, by virtue of the large decoupling capacitor at the emitter, as a common emitter amplifier to drive the p-n-p transistor which follows. It also has another function. The base potential is fixed by the bias potentiometer, roughly R_9, R_{10} in Fig. 26 and R_{20}, R_{21} in Fig. 27. The emitter is supplied through a decoupling resistance (R_{13}, R_{24}) from the bridge centre point to which the load capacitor is connected. As we have seen, this point should float at one-half the supply voltage. Any errors in the power transistors can cause this point to drift away, and the available power output will then be limited. Any such drift, however, will cause a change in the standing current through Tr 2 on Q4 and, by virtue of the direct coupling, will pull the whole system back to a d.c. condition fixed by the bias at the input base. This is an overall negative feedback loop quite distinct from the signal frequency path R_{18} in Fig. 26 and omitted in Fig. 27.

It looks as though this sort of circuit is to be the answer. It is in commercial production on one side of the Atlantic and is well sponsored on the other. A detailed account will be given in the Mullard report when it is published. There is, however, one more circuit which needs to be considered and that will be the topic for what is hoped to be a concluding article.

MASERS

POINTS FROM AN I.E.E. LECTURE BY DR. K. HOSELITZ

A CONVINCING demonstration of the capabilities of the maser took place when the first tests of Telstar were carried out with such spectacular success. One of the most far-reaching of these capabilities is the almost noise-free operation of the modern wide band maser.

Dr. Hoselitz threw new light on the underlying principles of the device, and particularly on the low-noise attribute, in his lecture before the Electronics Division of the Institution of Electrical Engineers on the 16th January. Both the lecture and the ensuing discussion were maintained in the context of satellite communication, and restricted to the solid state form of maser.

Dr. Hoselitz showed that the performance demanded from a maser as part of a low-noise receiving system can be assessed by reference to the Telstar or similar link. In the Telstar case, with a satellite repeater gain of some 80dB and a transmitted power of $2\frac{1}{4}$ watts, the power received at the ground station is of the order of 10^{-12} watts. Nevertheless a signal/noise ratio of 50:1 is achieved with a bandwidth of 20-30 Mc/s available for communication channels.

Microwave amplification by stimulated emission of radiation (from which the term maser derives) can be obtained from a system of atoms or molecules in which these atoms or molecules exist in several discrete energy states, and in which a difference between two energy states corresponds to a certain radiation frequency. In the solid state maser system paramagnetic atoms are embedded in a crystal of non-magnetic or diamagnetic atoms or ions, and thus it is a system in which paramagnetic resonance can occur.

The phenomenon of paramagnetic resonance is the main key to the understanding of the maser action, and is itself a function of the angular momentum of the atoms or ions concerned. This overall angular momentum is the vector sum of the angular momenta arising from the orbital and spin motions of the electrons within the specific "shell" which they occupy. With completely filled shells of electrons the overall angular momenta compensate each other, and a substance is non-magnetic. When the shells are incomplete, there is a resultant angular momentum taken over the whole atom which therefore behaves as a magnetic dipole. (Using the accepted quantum number designations, L and S when compounded give the overall quantum number J, which is the angular momentum.)

It is fundamental to the behaviour of the maser that the spins of the electrons do not interact with the electrostatic field of the crystal. Thus the spin axes are not subject to constraint and can take up different orientations depending on the spin moments, i.e., they are paramagnetic.

In the absence of an applied magnetic field all the energy states are at the same level unless there is an internal field acting which can split them up, a condition which is called "ground-state splitting."

The crystal which is in general use for solid state masers is the ruby (chromium atoms in a non-magnetic matrix of aluminium oxide, Al_2O_3) in which the energy states can be made to split up and take different levels by applying an external magnetic field. The splitting action is proportional to the applied magnetic field, and the energy of separation corresponds with a frequency of a few kilomegacycles per sec., i.e., centimetre wavelengths, with fields of the order of 2,000 to 3,000 gauss.

Paramagnetic Resonance

Actual paramagnetic resonance occurs when the interaction between magnetic field and rotating particle results in precession about the applied field (a processing torque has been set up); and in the resonance condition power can be absorbed. The familiar precession torque effect takes place in that the precession angle tends to increase, so that the angular momentum vector can finally reverse and be opposed to the applied field. When this takes place the power which has been absorbed has to be given up to the surroundings.

There are two main forms of interaction which are associated with the resonance condition. The first is known as "spin-lattice" coupling in which there is spin/orbit interaction and the orbits get disturbed. This means that the atoms vibrate and that heat is generated, that is, spin-lattice coupling results in dissipation of power.

In the other form—"spin-spin" coupling—only a small amount of power can be dissipated. In this case the interacting components are magnetic dipoles which are inherently short range in their effect. The spin-spin interaction is independent of temperature and usually corresponds to a very short relaxation time, in other words it gives a very sharp resonance line.

The spin-lattice interaction is temperature dependent, and at high temperatures can be so intense that the resonance line is not observed. It is therefore necessary to bring the temperature to a sufficiently low value in order to detect resonance.

Stimulated and Spontaneous Emission of Radiation

One of the most outstanding points made by Dr. Hoselitz was that Einstein had laid down the basic principles of the maser and similar devices in an original paper in 1916.

Einstein's treatment was non-atomic, and involved the introduction of the "coefficient of stimulated emission" into what has become known as Planck's radiation law. Planck's formula was shown by Einstein to be applicable to the interaction of a system of atoms or molecules with a radiation field in which this system of atoms or molecules existed in discrete energy states occupied accordings to the Maxwell-Boltzmann distribution law.

Earlier still, in 1905, Einstein had postulated that such a system with two energy levels E_2 and E_1 interacting with a radiation field of frequency F, could either absorb or emit quanta of light of frequency F, where F was dependent upon the difference between E_2 and E_1.

In his extension of this work, Einstein employed the concept of effective temperature to cover the non-equilibrium condition where the Maxwell-Boltzmann law does not apply directly; and he also related each energy state to the number of electrons corresponding to it, i.e., to the "population."

Einstein brought out the way in which absorption and emission of radiation occurs. Thus absorption is proportional to the number (of electrons) N_1 "lifted" to the higher state, to the intensity of the radiation field ρ, and to a transition probability. Emission is proportional to the upper level population N_2, to ρ again, and to a transition probability which is negative. He also showed that the ratio:

$$\frac{\text{Probability of spontaneous emission}}{\text{Probability of stimulated emission}}$$

was dependent upon the frequency F of the radiation field and the temperature T (absolute).

For microwave frequencies and the normal range of temperatures, the ratio of probabilities becomes proportional to F/T; and at 3 cm, and even with a temperature as low as 3°K, the ratio is equal to 0.1, so that nearly all the emission is stimulated and little is spontaneous. (At higher temperatures the proportion of stimulated emission obviously becomes greater.)

At light wavelengths, however, the frequency is so high that the ratio exceeds 100 and the emission is almost entirely spontaneous.

Taking the two-energy-level case, for microwave frequencies, with N_1 greater than N_2 absorption occurs; with N_1 smaller than N_2, stimulated emission. As emission is proportional to the radiation field, amplification is taking place in a linear manner—it is possible to amplify a field linearly by this means.

This principle is used in the maser together with ground state splitting. The remaining requirement for obtaining maser action is to achieve the condition of N_2 being greater than N_1 usually called an "inverted population."

To effect this inversion it is necessary to reverse the magnetic field. This will consequently reverse the position of any given momentum vector, and the energy level, which it occupied relative to the magnetic field.

Although an inverse population can be produced by rapid reversal of the "d.c." magnetic field, such a method cannot be used in practice. This is because the ions relax to their equilibrium state after reversal, and therefore the inverted population would only exist for the duration of one relaxation time. Thus for continuous operation the large magnetic field would have to be reversed in a period shorter than the relaxation time, which is extremely difficult with a field of several thousand gauss.

However, it is much more practicable to sweep the frequency of paramagnetic resonance through the actual resonance condition; and the method which suggests itself is to adopt a frequency sweep speed which is slow enough to allow interaction to take place with the spins during the passage through the resonance line, yet fast enough to go through it in less than one relaxation time. This mode of operation is known as "adiabatic fast passage"—adiabatic because temperature equilibrium is not reached although an inverse population has been achieved. The major disadvantage of this method, which rules it out for most applications, is that—as with field reversal—operation is intermittent because the spins are only in a non-equilibrium position during the relaxation period.

The Three-level Maser

The ultimate goal is clearly to devise a method of operation which gives continuous inversion of population, and this was achieved with the invention of the three-level maser. In such a maser a very strong microwave signal—the pump field—is applied between levels 1 and 3 so that N_1 and N_3 are almost equal, but level 1 is occupied less than level 2, i.e. $N_2 > N_1$. Thus there is an inverted population between levels 2 and 1, emission of radiation can take place between them, and power can be emitted from the system. This power is proportional to the population density, to the population difference, and to the probability of signal transition. The last term is given by the Einstein probability multiplied by the microwave field. The power emitted is also dependent on the pump efficiency η which can take values of up to unity.

The Cavity Maser

The cavity maser represents the first type of three-level operation. The microwave cavity which is filled with the ruby crystal is made to be resonant at both the pump and signal frequencies, and is immersed in a low temperature bath.

A strong pump signal is fed directly in to the cavity to give the reversal of population between levels 2 and 1. The incoming signal is fed in to the cavity through a circulator and, after amplification, via the circulator system to the next stage of amplification.

The power emitted (or absorbed) is proportional to the cavity filling factor and inversely proportional to the Q factor of the cavity. Thus for high emitted power Q should be as small as possible at the signal frequency cavity, and the filling factor as high as possible. The atter can be made to approach unity, and is not less han $\frac{1}{2}$ in practical cavity masers.

The performance of the maser is also affected by he value given to D, the density of the active magnetic ons in the crystal. If the ions are too close together—) is too high—they relax too easily in a spin/spin mode. f D is too low the ions are so far from each other ınd relaxation is not free enough. In practice a com- ›romise is made in the value of D, which with ruby :rystals corresponds with a proportion of chromium of).1% for the extremely low working temperatures which ıre adopted.

As far as the cavity is concerned, the pump efficiency should be as high as possible and the Q of the cavity ıt the pump frequency correspondingly high. The pump resonance line should be narrow, which demands a low ambient temperature, while the transition proba- bility is made as high as possible by arranging for the maximum admixture of quantum states. The latter is achieved by crystal field splitting which means that an impure quantum state exists on the pump transition.

The gain-bandwidth product of a cavity maser is a constant—increased gain is obtained at the expense of bandwidth and vice versa. A typical value of this product is 80 Mc/s (obtained at "S" band); this is insufficient for a satellite communication link such as that provided by Telstar.

The Travelling-wave Maser

In order to provide the requisite gain-bandwidth product for satellite communication the travelling-wave maser is employed. In this type of maser the active material is placed in a length of waveguide to form a slow wave structure, so that the maximum possible interaction takes place between the incoming signal field and the resonating ions. The factor by which the microwave field is slowed down is of the order of 100, i.e. its group velocity is reduced to 1/100th of its phase velocity.

Advantage is taken of the fact that the field in the waveguide is circularly polarized, and that there is a symmetrical geometrical separation of the regions of right and left hand polarization. The waveguide can be made into unidirectional device by filling that half of the waveguide which contains the correctly "handed" polarization to drive the spin in the active material. Thus the circulator can de dispensed with and efficiency increased. A further improvement can be effected by filling the virtually redundant half of the waveguide with absorbing material such as yttrium-iron garnet to absorb the unwanted power and to give a better standing-wave ratio in the guide.

Effective Noise of a Maser

One of the most valuable contributions made by Dr. Hoselitz during his lecture was in the clarification of the principles underlying maser noise.

The primary reason for lowering the temperature of a maser is to ensure that an inversion of population takes place, and through this process to obtain a low noise temperature, which is not produced by the direct effect of low temperature.

The effective noise of the maser can be shown to be the noise temperature which is achieved by the inverted population with $N_2 > N_1$. Thus if the temperature is high N_2 and N_1 become equal (this is explained purely by the statistical conditions) and inversion cannot take place.

As the temperature is lowered, so the degree of inversion is increased and the noise temperature reduced. The actual effective noise temperature is given by the ratio: $\frac{\text{Temperature of operation}}{\text{Degree of inversion}}$ Thus even with a large degree of inversion the noise temperature remains high unless the operating temperature is low.

However, it will be seen that it is possible to get an extremely low noise temperature of the order of 1°K with an operating temperature of 2°K and an inversion factor of 2, which, combined with the wide bandwidth of the maser, makes it an almost ideal amplifier.

Maser Techniques

In the discussion period Dr. H. N. Daglish gave the background to the operation and maintenance of the maser installation at Goonhilly Downs, while Dr. J. C. Walling described some of the developments in superconducting magnets which have reached fruition.

At Goonhilly the travelling-wave maser is mounted at the back of the aerial dish in order to avoid long waveguide runs and consequent losses. This introduces certain difficulties in operation, particularly with regard to "helium filling" of the maser cooling system (liquid helium has to be transferred to this system at regular intervals). The large permanent magnet, which is undesirably heavy, also has the disadvantage of being extremely susceptible to temperature changes which cause the maser to go off tune. Dr. Daglish indicated that the receiving system was not yet on a 24-hour service basis. In order to reach this the maser would have to be supplied continuously with liquid helium, while some way would have to be found of producing a magnetic field which would be unaffected by temperature changes.

In dealing with superconducting magnets Dr. Walling showed that they were particularly suited to use with masers. Thus the 280 lb permanent magnet employed at present at Goonhilly could be replaced by an equivalent superconducting one weighing about 15 lb. Such a magnet could be placed at the focus of the dish and the waveguide run to the back of the dish eliminated.

The prime advantage of the superconducting magnet is that the field stability is "built-in." This means that an improvement is obtained in three directions:—

(i) Peak gain is maintained—this is a function of the applied field, viz. a typical figure is a change of $2\frac{1}{2}$ Mc/s per oersted for the peak.

(ii) The gain at the operating frequency is held constant—this changes with change of field.

(iii) The phase change through the maser is held constant in the same way as (ii).

Although phase change may not be unduly important for ordinary communication channels, it is vital for stellar interferometry where two travelling-wave masers are involved. In this case an agreement in phase of better than 2·5° is required, which means a field stability better than 0·1 oersted, on the basis of the phase shift of 25° per oersted which is experienced with travelling-wave masers. Tests with superconducting magnets had shown that they possessed a field stability better than 1 part in 10,000 over a period of 5 days.

A design problem is to produce fields of adequate uniformity, but this has been done to 1 part in 2,000 over the volume occupied by a typical ruby—about $5\text{in} \times \frac{1}{2}\text{in} \times \frac{1}{4}\text{in}$. The solution lies in the combination of the superconducting coils and the shields which are necessary to stop magnetic leakage. Another design quoted by Dr. Walling gave a field of 3,250 oersteds with a uniformity better than 1 part in 1,000 over a volume of approximately $7\text{in} \times 1\text{in} \times 1\frac{1}{2}\text{in}$. R. E. Y.

Electronic Aids to
Translating, Abstracting and Editing

By H. DAGNALL, M.A.

THE mechanical process of printing is the link between two human beings, the originator of the text and the reader. It has been estimated that the number of scientific publications doubles every ten years, with little or no diminution in the amount published in other fields, and there are signs that this increase is causing embarrassment to writers and readers alike. The printing industry has expanded to cope with this increase but in the future it may consider the adoption of electronic devices in an attempt to increase production still further. If this were to happen there is a danger that the printing industry would outstrip the present capabilities both of the writer to produce material to be printed and of the reader to assimilate the books and periodicals produced.

The object of this article is to examine ways in which electronic techniques—especially those developed for digital computers—could be used in machines which would take over some of the work now performed more slowly by human translators, abstractors and editors.* This would assist the writer by making his work available more quickly and to a greater number of potential readers; it would also help the specialist reader by providing him with the abstracts and indexes which would be essential for him to make efficient use of the voluminous information at his disposal. The field is vast and this article does not attempt to provide a comprehensive review, it only suggests a few of the possible applications, the problems involved, and some of the solutions that have been proposed.

Authorship:—When discussing the machine processing of linguistic material it is important to distinguish between two types of publication; the original work (a novel or research report, for example) and work based on a previously written or printed text (e.g., a translation, abstract, index, bibliography or summary). The distinction is important, because the preparation of entirely original material, based on the ideas and experiences of an individual, is obviously a human accomplishement which cannot be carried out by a machine which has no access to those ideas or experience. This article will, therefore, overlook the love-poems reputed to have been written by a computer and will only deal with the second type of publication, that obtained from an already-existent text by an operation that will be referred to as processing.

Input Devices:—Common to all the equipment mentioned below is the need to feed into the machine a text in a form that the machine can accept, usually coded electrical pulses, e.g., an alpha-numeric binary code. Typical input media would be magnetic tape, punched cards, or paper tape, but whichever is used a keyboard operation is necessary as the first step. Since the only input considered in this article is that based on an existing text, much time would be saved if the machine could be made to accept it without the intervention of a human transcriber.

* The author wishes to make it quite clear that he does not, as yet, advocate replacing the occupant of the editorial chair of *Wireless World* by a chassis of printed circuit boards.

Automatic Character Recognition

The history of automatic character recognition is over thirty-five years old[1], but in most cases the early attempts were made on specially designed characters. Digit shapes in which the area of black print was proportional to the digit value were proposed, and an alphabet was designed such that a single scan of a character would generate its Morse Code equivalent. Other early inventors in this field attempted to recognize normally shaped characters by projecting an image of the character on to templates of successive characters in the alphabet, so that when a match was obtained all light from a photocell was obscured[2]. This method is simple, but relies on perfect alignment of images and on printed characters which conform exactly to those of the template, both requirements being difficult to achieve in practice.

Modern character recognition systems[3] are usually based on the relationship existing between various parts of a character, a relationship which is unaltered by a change in either the position or size of a character and which remains relatively unchanged by blurring or other defects in the outline associated with poor quality printing. The character is scanned and the positions of the black areas coded, the resulting group of codes is then compared with groups of codes held in a store and the best match accepted[4]. Other systems use the contours of a character either as criteria for coding[5] or for obtaining auto-correlation of waveforms.

Automatic Speech Recognition

Many attempts have been made to build speech recognition systems which would enable an electronic machine to operate from the spoken word. AUDREY, the Automatic Digit Recognizer developed in the Bell Laboratories, can recognize the ten decimal digits when spoken clearly by a male voice[7]. We can construct a machine to recognize the different classes of speech sounds, such as sibilants, the puff of air accompanying a *p* or the fricatives *f* and *th*, and from them derive codes representative of the words they form. We do not, however, speak in letters but in groups of sounds which cannot easily be broken down and, although attempts have been made to analyse speech waveforms into identifiable parts, [8, 9] it would seem that the variety of human speech and speakers is a formidable barrier in the quest for a successful universal speech input device.

Output:—The final product is that of conventional printing presses and the link between them and the linguistic processor could be an output device using a c.r.t. character display combined with photographic or xerographic production[10] of printing plates. Alternatively the output from the processor could be in the form of the punched tape now extensively used to control conventional typesetting machinery. Page layout instructions could be included in the programme, and if error detecting and error correcting circuits were incorporated in the processor, the need for the slow human process of proof reading would be eliminated.

Automatic Translation

One of the most interesting ways—and certainly the one on which most work has been carried out—in which digital computing techniques have been applied to linguistic processing is automatic translation[11]. Translation is becoming of increasing importance in the fields of pure and applied science and the results of mechanizing this human function could be very rewarding. The problems, however, are immense, but not necessarily insoluble.

The aim of automatic translation is to produce a text in another language (called the target language) which conveys the same concepts as the original (the source language), with equal clarity and with no additional ambiguity. Moreover, the style of the translation must not be obtrusive or foreign to the target language. For example, if the German word order were to be retained in an English translation, the style would be most obstrusive and would detract from the ease with which the translation could be understood.

The ideal translation just depicted may never be reached but the progress so far achieved is encouraging and leads one to hope for a practical outcome in the near future. The results may indeed be devoid of literary merit but they will at least be understandable to those familiar with the subject, which is probably sufficient.

Automatic translation has been tackled at several levels which roughly correspond with the historical development of the subject. The simplest, and earliest, system to be tried was a word-for-word translation using a simple dictionary look-up operation. This approach may be one hundred per cent successful for selected short passages ("la plume de ma tante" for example) but, as every schoolboy knows, is unacceptable when the translation of extended passages is attempted. The requirements for this system are simple; the input and output devices, and a large permanent store with its address selector. The dictionary is initially entered into the store, one target word for every single source word, and it is thereafter available for use by the address selector.

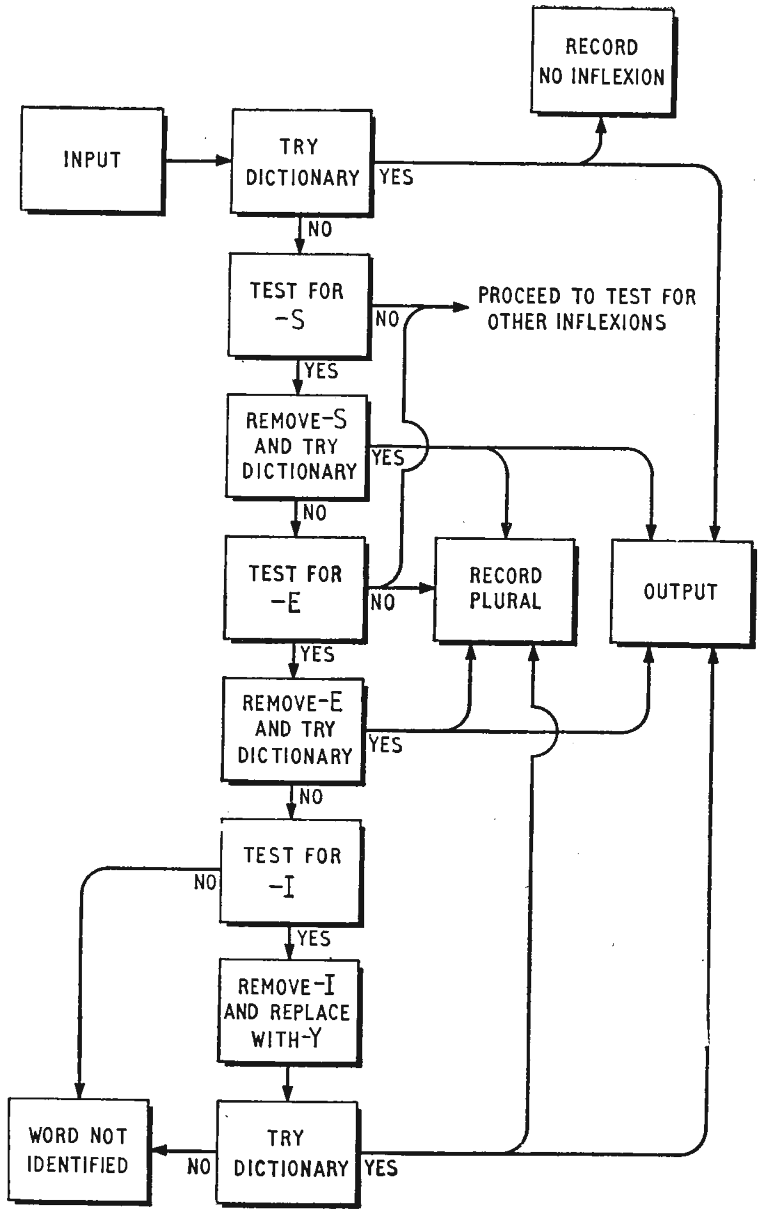
The development of large-scale storage devices, with the promise of even larger stores in the future, makes it possible to provide a comparatively large dictionary for the use of the automatic translator. This is obviously a prerequisite for any system of automatic translation, so before more complicated systems are described, the use of the dictionary will be considered.

In the dictionary required for translation at the lowest level described above, one word of the source language, in coded form of course, acts as the address, and at that address is stored the equivalent word of the target language. One disadvantage of this scheme will be apparent. If all storage locations have consecutively numbered addresses, as they must have if a random access store is used, the addresses in alphabetical form will run from AAAAA to ZZZZZ for a five-letter address. While all different source words with five or fewer letters form different valid addresses, a very large number of storage addresses do not represent any word in the source language and must remain unused. Thus the advantage of rapid reference afforded by random access to a stored dictionary is offset by inefficient use of the storage capacity.

Since an automatic dictionary has to be searched in much the same way as a human translator searches to find the word he requires, a store with part random and part serial access is the most suitable. In searching for a word beginning with the letter S, a human translator does not begin at page one and then steadily search through every word. He selects pages at random, each opening being a guide to where the next attempt will be made; thus he gets nearer and nearer to the page he requires by a series of trials. The method of searching an automatic dictionary is similar.

A suitable dictionary store is a magnetic drum or disc which allows random access to a track which then has to be searched sequentially. One procedure for dictionary look-up using this type of store is as follows. The words, in strictly alphabetical order, are grouped into "pages" (which may be tracks on the drum); the middle "page" is first selected and any word on it, or a specific index word, is compared with the source word to determine if the source word lies in a higher or lower "page"; a "page" halfway along the appropriate half is selected and another comparison made. This continues until a "page" is found in which the lowest storage address contains a word of lower alphabetical position than the source word, and the highest storage address one of higher alphabetical position. That "page" is searched sequentially until the source word is found and the corresponding target word is then read out from that location. Although searching is carried out at high speed, with a large dictionary the time necessary for each reference is rather long compared with other computer functions. Searching is, however, a function much used in commercial applications of digital computers and considerable work is being done to develop improved searching techniques from which automatic translation will benefit.

For translation at the lowest level the dictionary must contain inflected forms as well as the root form of all words; thus weld, welds, welded, welding, welder and welders, must all be included. In a more complex system the demands on the dictionary are less severe because inflections are usually stripped from the root before the dictionary is consulted and only root forms need be stored. This is the next level of translation and is one which gives greatly improved results. The prefixes and suffixes of a word are identified and from them is derived syntactical information. Only the root form of the word is found in the dictionary and consequently inflected forms cannot be matched. When this



Arrangement for testing for the English plurals -s, -es and -ies.

occurs, the word is tested for various endings (e.g., in English, -ing, -ed, -s, -es, -'s, -s', -est, -er) and if one is found, it is stripped from the word and an attempt is made to find the remaining letters in the dictionary. At the same time the syntactical information denoted by the suffix is added, in coded form, to the dictionary equivalent. A decoder takes the root target word obtained from the dictionary and, using the syntactical information, produces the correct inflected form. The process for deriving plural information from an English word is illustrated in the figure.

Refinements in Translation

The system just described will produce a better target text, but it will still retain any ambiguity due to ambiguous words in the source text, which can only be resolved by reference to the context—for example, "matches" may be detected as the plural of a noun, whereas it could be the third person singular, present tense, of the verb "to match". Resolving this ambiguity by limited reference to the context is the next level of translation. It permits correct identification of syntax; nouns, verbs, pronouns, prepositions and participles are identified as such, and enable "to" plus a verb, for example, to be labelled as infinitive and "to" plus a noun as dative. This kind of information is also necessary to obtain the word order information required when translating at a still more advanced level.

Ambiguity of meaning is a difficulty for human translators as well as for the machine, but both resolve it in the same way, namely by reference to the context. This requires highly sophisticated programming, the ability to be able to label words with a subject identification code and, besides the dictionary store, a large working store capable of holding one or more sentences. Details of programming are too involved to go into here, but briefly the method consists of finding the subject to which the sentence or neighbouring sentences refers, and picking the appropriate alternative target word from the dictionary. Thus the French word "arbre" would produce the English target word "mast" if the machine found that the sentences examined contained nautical terms, the word "shaft" if they contained mechanical terms, or "tree" if the subject was either botanical or general.

When translating an aeronautical text, dictionary words referring to chemistry are not required and to search them fruitlessly would be a waste of time, consequently the idea of micro-glossaries was evolved. Instead of all words of all subjects being placed in one alphabetical sequence in a single large dictionary, the store is divided into a general dictionary and a number of micro-glossaries. Words used only in a selected subject are grouped together in alphabetical order in one micro-glossary and when the most likely subject of the text has been determined, the most appropriate micro-glossary is searched first. This not only gives a more accurate translation by resolving ambiguity, but also saves considerable time, particularly as automatic translation is likely, in practice, to be used chiefly for scientific and technological articles, the subjects of which can be defined in advance. Another advantage is that only one micro-glossary need be held in the machine, the store being filled prior to a translating run by a transfer of the appropriate words from an external store such as a magnetic tape.

Other refinements for improving the quality of translation include means for determining the word order, for the translation of idioms, and for dealing with words which should not (e.g. proper names) or cannot (e.g. words not found in the dictionary) be translated. These points are very important and have a large effect on the style of the finished translation and the ease with which it can be understood.

Word order can be the subject of fairly precise rules which relate word position to syntactical information. Thus in English we can lay down the following rules: firstly, put the subject first, then the verb, then the object, then the indirect object; secondly, put adjectives, adverbs and auxiliary verbs before the words they qualify; and thirdly, in a question, reverse the order of the subject and the following auxiliary verb.

Idioms and phrases which occupy several words in the source language but are represented by one word or an unrelated group of words in the target language are dealt with by the principle of the longest match. The dictionary contains phrases arranged in order of length within their alphabetical sequence

(*Continued on page 245*)

and an attempt is made to match a whole phrase or part of a phrase before the individual words are looked up. The improvement in quality of translation is considerable, but it makes greater demands on storage space and on the programmer who has to decide in the first place what to put into the dictionary.

Proper names, which in English are identified by an initial capital letter, are simply transliterated and not translated. Words which cannot be found in the dictionary must be transliterated and left for the attention of a human post-editor.

One advantage of machine translation over human translation should be mentioned, namely the ease with which the same source text can be translated into a number of different target languages. If this is required, it is best done in two stages. In the first stage the source text is translated into a machine language, which is an artificial language with precise rules devoid of alternatives and exceptions, a language designed to be of maximum use in the machine. The machine language text is then recorded on tape and run through the input device whenever a different target language translation is required. Programming would be much simplified because, for example, a single Russian-to-machine-language programme would suffice for all translations having Russian as the source language and a single machine-language-to-English programme would be used for all English target language translations, whatever the source language.

It is hoped that enough has been said about automatic translation to show the truth of the statement made at the outset, that the problems are immense but not necessarily insoluble. In so far as any language structure can be defined by a limited number of rules and a finite number of exceptions, it is possible to programme it, but the more elaborate the programme is, the more storage space is required and the longer it takes to process the information.

Automatic Abstracting

Electronic digital computers have been used for the creation of abstracts[12]. The text is read in and statistical information is derived for word frequency and distribution. This information is then used by the computer as a measure of significance, first for individual words and then for sentences; scoring is not only for each occurrence, but the number of non-significant words between and around significant words is also taken into consideration. After the whole text has been examined, the sentences scoring the highest significance are printed out and become the auto-abstract.

The purpose of an abstract is to provide a rapid and accurate identification of the subject matter of the article in order that the reader may judge its relevance to his interests. The type of auto-abstract just described would seem to be adequate for this purpose and it would be interesting to see the results of an extended trial.

Automatic Classification and Indexing

An essential adjunct to a publication, if the information it contains is to be readily retrievable, is a classification of the contents. This can be carried out by a computer using a simple programme[13, 14]. The text is examined for given key words or phrases and if they are found the corresponding code in the classification list is recorded. By including a document reference in each entry, a full index is available for future retrieval of the document under subject headings.

Preparation of Concordances:—A concordance is an alphabetical collection of the individual words used by an author in a given work, citing every passage in which the word occurs. It is a useful tool for the student and research worker and is much used in theological, philosophical and philological studies. A major project which has been undertaken is the automatic production of a complete analytical index and concordance of the Summa Theologica of St. Thomas Aquinas[15], which contains approximately 13 million words. Carried out manually, this would have occupied 50 scholars for 14 years; it was actually done on punched cards by 10 scholars in 4 years with greater accuracy; if it had been done by means of a computer it would have been completed in less than a year.

A card was punched for each word giving its position in the text (its address), its semantic classification, and any interesting physical association of the word with others in the text which could be useful for research. These cards formed the basis of several lists—the complete concordance with a quotation of each passage in which a word occurs, literary statistics (such as occurrences of groups of letters, suffixes, roots, accents), and a list of words according to their structure.

Using the experience gained in this project, the Dead Sea Scrolls are being similarly indexed using an I.B.M. 705 computer with punched card input and magnetic tape storage[15]. In the text of the Scrolls many words are either missing or undecipherable, and the computer has, in many cases, been more successful than the scholar in indicating the probable original word.

Compression and Expansion of Text:—The application of communications theory and coding systems to problems in the communications field is of proved value and similar developments could be applied to the processing of linguistic texts.

Many news items are transmitted in "telegraphese" or condensed form, that is with redundant words omitted at the transmitting end and added at the receiving end. Words and phrases are redundant if their existence in the text can be predicted without any information other than that contained in the compressed message; there does not seem any reason, therefore, why the processor who turns running English into "telegraphese" at the transmitting end and in turn reconstitutes the running English text at the receiving end, should be a human one.

Shannon[16] has proposed a scheme which utilizes the probabilities of printed English (e.g., *q* is nearly always followed by *u*; *h* has a strong tendency to follow *t*; a letter is more likely to be *e* than any other) to determine redundancy. A predictor attempts to determine the next character, this prediction is compared with the actual character and if they are alike—indicating redundancy—the character is removed from the message before transmission. At the receiving end a similar predictor determines what redundant characters are to be added to the condensed text to produce a text having the same redundancy as the original, to within the degree of probability fixed by the probability criteria of the predictors. Such a system could equally well be extended to handle words as the basic unit.

Processing Music:—The publishing of music, like the publishing of books and periodicals, entails much slow editing and sub-editing work before the printed pages come from the press, but here again electronic devices could be helpful.

Original composition will not be considered, for although music is based on mathematical relationships, it is also subjective. A computer could turn out music—and has done so—which obeys all the text-book rules, but it could never, except by a rare coincidence, be æsthetically pleasing or satisfying. There are, however, two human occupations which can be taken over by a machine—transcribing and transposing.

The composer has to put his thoughts into written notation and a machine could be constructed to identify a note played, for example, on a violin, and print it on paper in the correct notation determined by its frequency and duration. Something similar has already been done mechanically in the production of Pianola rolls in which a paper strip is punched directly as a result of a performance on a specially equipped pianoforte.

The transcription of music from one key to another is a simple, but useful, task that can be readily processed on a computer; it has no subjective features and can be programmed as a mathematical problem. J. W. Granholm[17] in conjunction with the principal cor anglais player of the Seattle Symphony Orchestra, gives the following method. The twelve musical notes are numbered consecutively from 1 to 12 thus:

Note	C	C♯	D	D♯	E	F	F♯	G	G♯	A	A♯	B
Number	1	2	3	4	5	6	7	8	9	10	11	12

with D♭, E♭, G♭, A♭, B♭, equalling C♯, D♯, F♯, G♯, A♯, respectively. To transpose from key X to key Y, the difference of the key numbers is added, modulus 12, to each note in key X to get the corresponding note in key Y, a carry indicating a note in the next octave.

Transposition is the basis of the much larger subject of arrangement and orchestration, and mechanization of these things could free the composer from much drudgery.

Conclusion:—This article opened by stating that the printer was the link between the writer and the reader; it has suggested ways in which certain types of text can be processed by machines, but what of the reader? If the reader spends a long time locating the information he requires or if it is in a language unknown to him, his time is wasted. Mechanical translation, the automatic creation of adequate abstracts and indexes, and efficient information retrieval systems can help. If, however, the reader cannot assimilate all the printed information on his subject—and this is becoming a pressing problem—then the work of the writer and printer is rendered less availing. Much research has been done and ways are being developed to teach people to read faster, to instil knowledge into them while they are engaged on other tasks, or even while they are asleep. This problem should not be neglected in any discussion of increasing the output of printed matter but, being chiefly psychological, it is another story.

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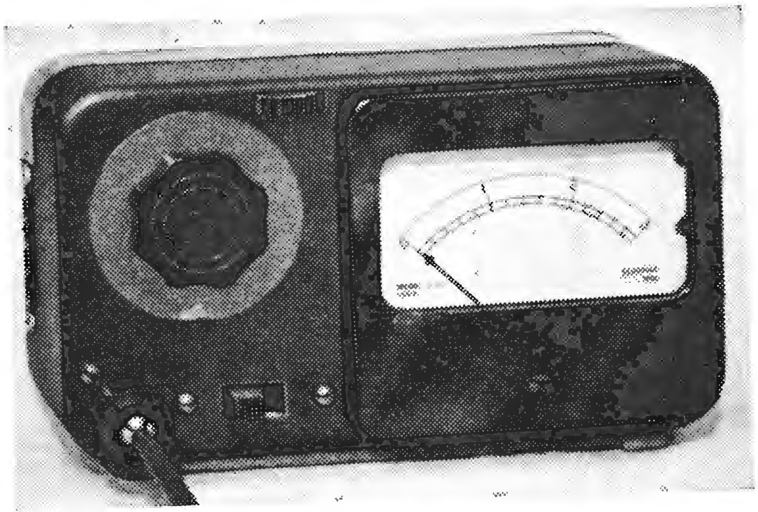


Front view of complete instrument.

The design and construction of a bridge-type voltmeter employing cross-coupled silicon transistor amplifiers is described. The circuit employed results in an input impedance of 1·3 MΩ/V and a usable full-scale-sensitivity of 30 mV with quite stable temperature characteristics.

TRANSISTOR MILLIVOLTMETER

USE OF CROSS-COUPLED AMPLIFIERS IN A BRIDGE CIRCUIT

By D. SINGH

SOME experiments on photoelectricity gave rise to the need for a millivoltmeter capable of reading about 50 mV full scale. It was decided to construct a suitable instrument, and reference to available literature showed that either a direct-coupled d.c. amplifier could be used to operate a meter, or the original d.c. signal could be fed to a "chopper", converting it to an a.c. signal, which could be amplified in the ordinary way, rectified through a bridge rectifier and again applied to a meter. The advantage of the chopper-amplifier system over the d.c. amplifier is complete freedom from drift due to temperature changes and small variations in the supply voltage. But the chopper circuit requires a square-wave generator, two transistors in the chopping circuit, a stable and sensitive a.c. amplifier, and a bridge rectifier circuit, as may be seen in Fig. 1. Consequent power requirements and complexity ruled out a really portable instrument as desired. For this reason it was decided to design the instrument around a transistorized d.c. amplifier.

The main problems of sensitive direct-coupled d.c. amplifiers using transistors are thermal drift and drift due to variations in supply voltage, as mentioned above. These both cause the meter pointer to creep about the scale quite independently of any input signal, so requiring frequent readjustment to set zero and making continuous voltage measurement inaccurate and difficult. In the case of a portable instrument, variations in supply voltage may be greatly reduced but not altogether eliminated by using mercury cells instead of the ordinary zinc-carbon type. The effect of voltage variations may be further reduced by using a bridge circuit with two adjacent arms composed of two independent amplifiers. Provided they have equal gains, any variation in supply voltage will affect them both equally, and the change will not register on a meter connected between them. The signal is, of course, applied to their inputs in push-pull.

Thermal drift occurs because of the characteristics of the transistors themselves which are used in the amplifiers. The net effect of heat on transistors is to cause an increase in collector current, as is well

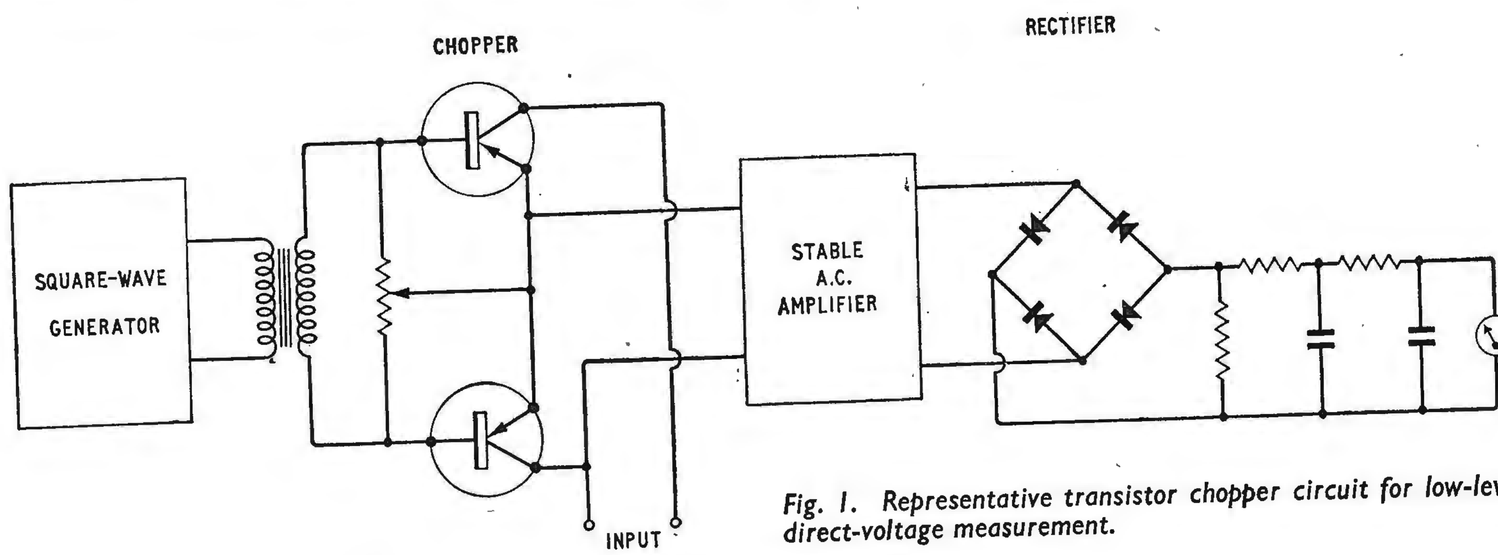


Fig. 1. Representative transistor chopper circuit for low-level direct-voltage measurement.

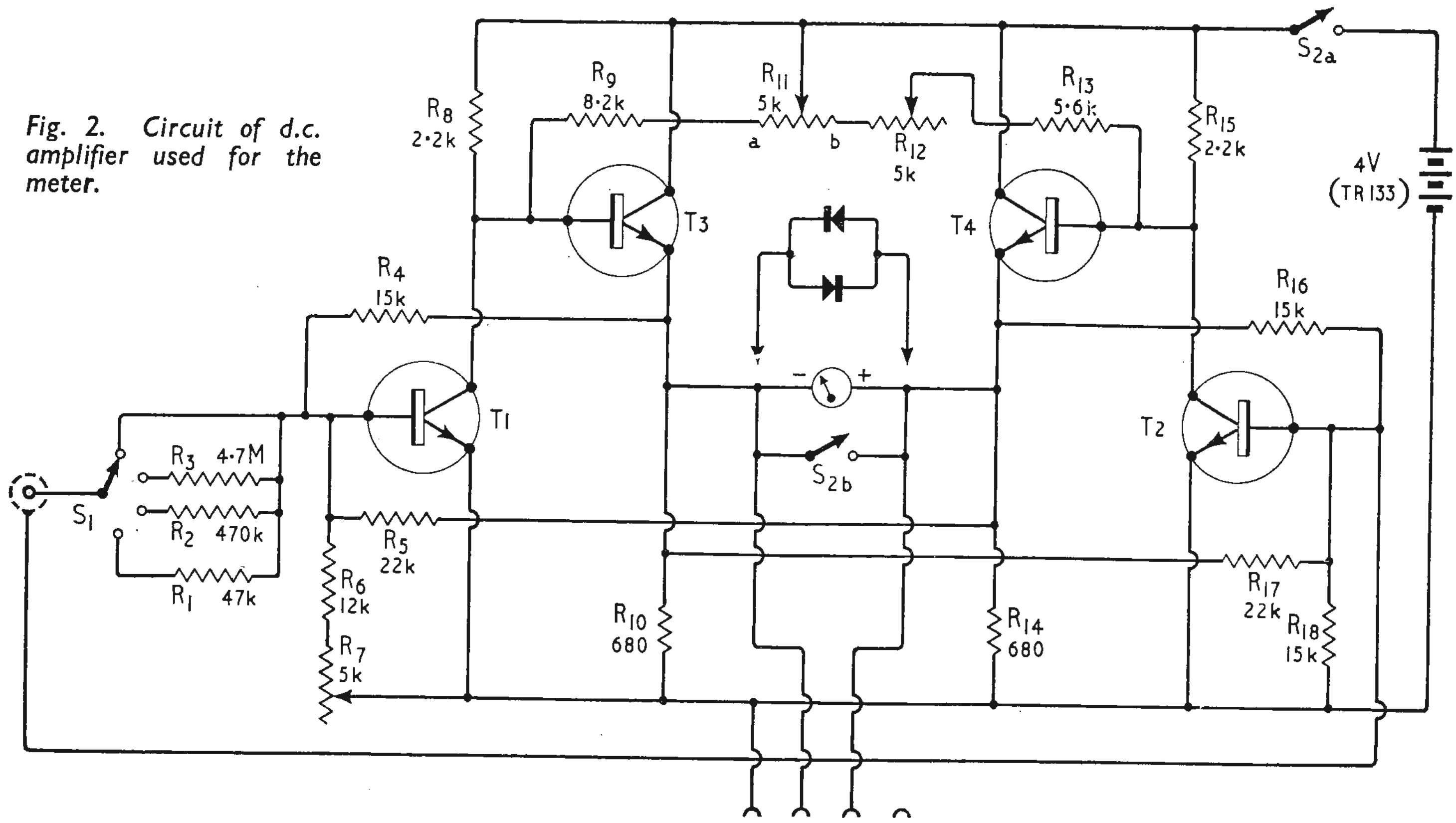


Fig. 2. Circuit of d.c. amplifier used for the meter.

known. This is due to three reasons. Firstly, the base-emitter voltage, which controls the base current and, therefore, the collector current, varies directly with temperature; secondly, the collector leakage current I_{co} varies exponentially with temperature, and lastly the gain of the transistor varies directly with temperature. The second effect mentioned above, i.e., the change of collector leakage current, is very much more marked in germanium than in silicon transistors, and if the latter are used may be neglected altogether over a practical working range of about 35°C. The effect of variation of gain with temperature may be rendered negligible by the use of heavy overall negative feedback, the gain then becoming a function of the relatively-stable passive feedback network rather than of the transistor. The variation of V_{be} with temperature remains and this is of the order of -2 mV/°C. It is usually dealt with by including a temperature-sensitive resistor in the potential divider chain used to set the base bias.

In the case of a bridge with amplifiers in two adjacent arms operating in push-pull, a better way of temperature compensation has been outlined by Nambiar*. In this the amplifiers are provided with as much negative feedback as the design will allow and then the outputs of the amplifiers are cross-coupled to the opposite inputs. This results in further negative feedback in the parallel or " drift " mode, but positive feedback in the push-pull or " signal " mode. This may be seen from Fig. 2. So for the wanted signal in push-pull the positive and negative feedbacks tend to cancel each other, while for drift they are mutually aiding. Thus unequal voltages at the outputs of the amplifiers caused by unequal drifts are greatly reduced. It can be shown that the positive feedback does not lead to instability so long as $R_5 \geqslant R_4$. The original circuit required an auxiliary negative supply in order that sufficient feedback could be applied while maintaining correct base bias. This is not necessary in the circuit used here as a common-emitter stage is coupled to a common-collector stage, the quiescent output voltage point of which is only about ½ V above the base of the input. Only a small dropping resistor need be used, and this provides the large amount of feedback required.

Yet another possibility is the cathode-coupled d.c. amplifier, but this requires a comparatively large bias below earth in order that the common-cathode resistor may be large enough to couple the two push-pull stages together, and also its temperature stability is known to be inferior to the Nambiar circuit.

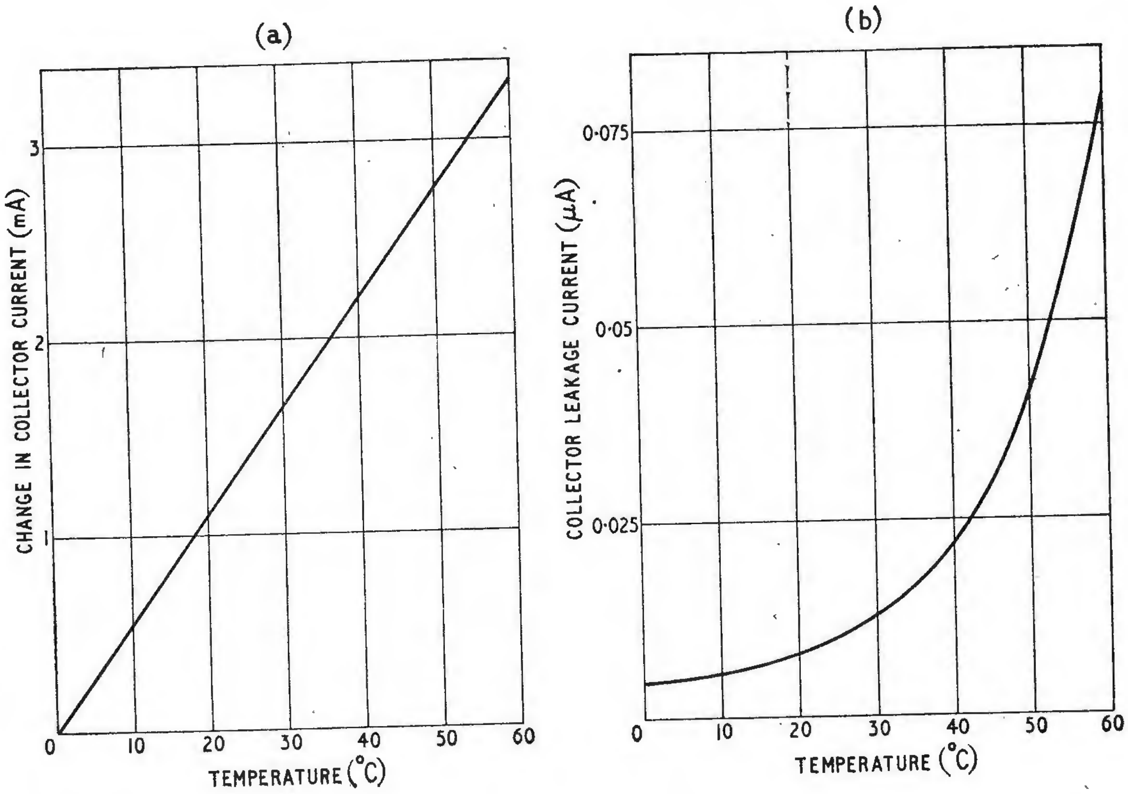
Design:—From the constructional point of view the design falls into the following: (a) selection of transistors, (b) deciding total battery drain and consequent operating points for the transistors, and (c) selection of meter, which determines the series input resistor.

Silicon transistors intended for small-signal operation would be the most suitable but, in fact, the particular transistors used were Lucas Type DT 1120. These are n-p-n large-signal transistors intended for switching purposes, but they are quite suitable as they have a β of over 100 at 30 mA and quite a usable gain down to about 1 mA. Curves are given (see Fig. 3) of collector leakage current I_{co}, and also of variations of I_c as a result of increased forward conductance of the base-emitter diode with an increase in temperature, and it may be seen that the second effect completely overshadows the first in the case of silicon transistors.

The DT 1120 has a knee voltage of 0.4 V, so allowing a minimum V_{eb} of 1 V, approximately 1.5 V per transistor is required. Thus for two direct-coupled stages about 3 V would be required. Allowing an extra volt for thermal effects, etc., a power supply of 4 V would be needed. Mallory make several mercury batteries of this voltage and the TR 133 was chosen as it is rated at 1,000 mAH,

* Transistor Differential Amplifier by K.P.P. Nambiar (*Electronic Technology*, April 1962, p.147).

Fig. 3. Curves for the Lucas DT1120 silicon transistor showing the variation with temperature of (a) the collector current I_c for V_{ce} = 4V (caused by changes in V_{be}) and (b) the collector leakage current (I_{co}).



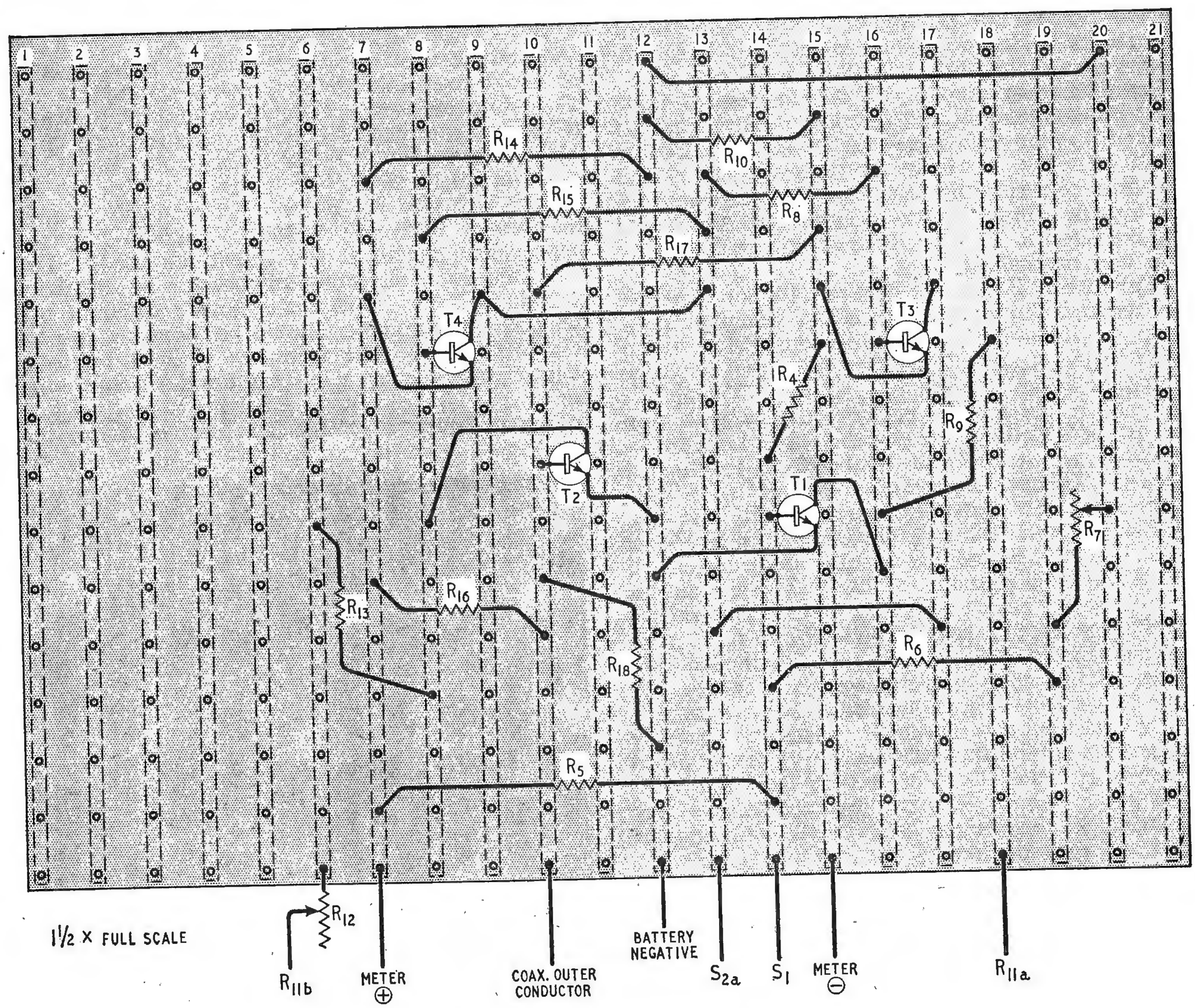
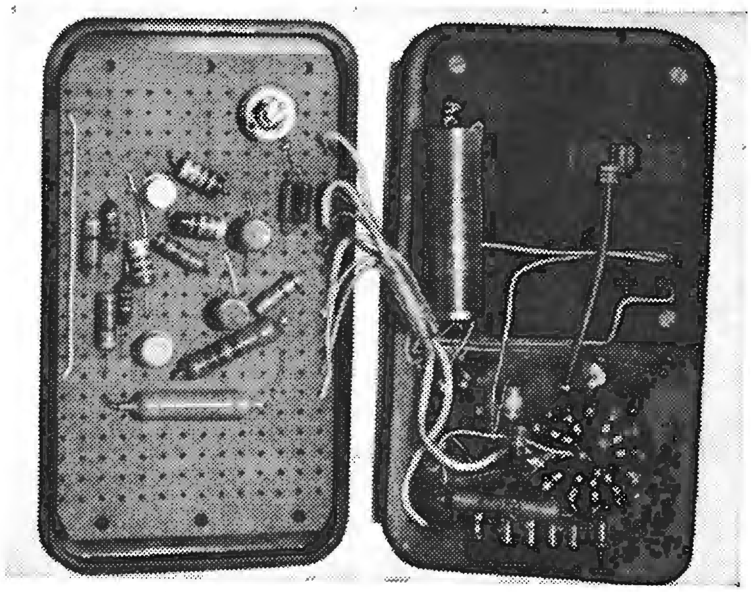


Fig. 4. View of Veroboard showing placing of components.



Rear view of instrument with lid opened.

which, for a total current drain of about 5 mA, permits a useful life of 200 hrs.

Designing initially for the emitters of the output transistors to be held at +1 V, at a collector current of 1.5 mA, $R_{10} = R_{14} = 1/1.5 \times 10^{-3} = 666\,\Omega$. The closest commercial value is 680 Ω. At 1.5 mA, the β was known to be about 25 and the input transistors begin to conduct when their bases are 0.45 V above the emitters. Therefore, R_4 and R_5 in parallel must drop 0.55 V at a current of $1.5 \times 10^{-3}/25 = 0.060$ mA, and so must equal 9.2 kΩ. If R_4 and R_5 were made equal, each would have a value of 18 kΩ. But this is on the limit of stability and also leads to perceptible differences in voltage between the inputs. Thus R_4 was decreased to 15 kΩ and R_5 increased to 22 kΩ. Adequate thermal stability was still maintained.

The base of T2 must be held at 1.4 V and therefore the resistors R_8, R_9 and part of R_{11} combined must drop $4-1.4 = 2.6$ V at an approximate current of 1.5 mA (I_{eT1}). Therefore the total effective resistance $= 2.6 / 1.5 \times 10^{-3} = 1.7$ kΩ. Taking R_{11} as being in the median position, the network then consists of 2.2 kΩ in parallel with 8.2 kΩ + 2.5 kΩ = 10.7 kΩ, which gives a total effective value of 1.8 kΩ. This is close enough to permit final adjustments with the preset potentiometers R_7 and R_{12}.

The meter chosen is a Sangamo-Weston Model S145.1.20 (1953) and has a full-scale-deflection of 50 μA and a coil resistance of 980 Ω. This is a surplus type currently advertised at £1 and thus represents excellent value. Its scale is divided into three main divisions, which are each further subdivided into fifths. Thus each division represents 6.7% full scale and this is considered rather large, 2 or 3% being a more suitable figure. The meter has a moving range scale behind the scale face which is connected to a spring-loaded lever protruding from the back. This may be connected to the range switch via a lever or string; in the present case a lever connection is used and may be seen in the rear view.

The circuit is laid out on one half of a 4¾ in × 5¾ in Veroboard and Fig. 4 shows the layout. It is preferable that the two input transistors be close together and on the same level in order that they should be at exactly the same temperature. The warmth of a finger on only one of the transistors sends the needle right across the scale. In order that the circuit should not be subjected to sharp temperature gradients, it is preferable to mount the instrument in a plastic case with foil shielding of the inside, or, if a metal case is used, then some form of thermal insulation such as polystyrene foam or even cotton wool should be provided. The box actually used is a plastic lunch box measuring 5½ in × 3 in × 2⅜ in, the bottom forming the front and the lid the back. The Veroboard circuit board is made a press fit into the inside of the lid: the mounting of the other components may be seen in the photograph. A four-pin unit or plug is provided on the side of the case, and the output of the amplifier is brought to this in case it is ever required for further amplification or for an oscilloscope, etc. The clear plastic box was painted with Dulux paint which was given a grainy finish by pressing polyurethane foam against it for an instant just before it was completely dry.

Once the circuit is wired up and the whole assembled together, it is better to let the instrument stand overnight before any adjustments are made. It is recommended that two silicon diodes be connected across the meter as shown, so that the voltage across it is not allowed to rise above about 0.6 V should something be wrong. The meter will be pinned quite firmly but it will not burn out if there is a fault.

Adjustment consists in bringing R_{11} to a middle position and then varying R_{12} to bring the meter to zero. Then the input is short circuited and R_7 is adjusted for zero reading once more, a discrepancy of about one scale division being allowable here. The two potentiometers should be adjusted back and forth until the needle indicates zero on both open and short circuit. Final adjustments should be made at about 20°C. In order to determine the correct values of R_1, R_2 and R_3, necessary to give the ranges 0–30 mV, 0–300 mV and 0–3 V, the approximate values shown should be used. The final values will correct for any changes in sensitivity introduced by a 50 μA meter with a different coil resistance. The meter should be connected in parallel with an accurate voltmeter across a variable-voltage supply which may consist of a 4 V accumulator and a 50 Ω rheostat. Knowing the actual and indicated values of voltage (at about midscale) the

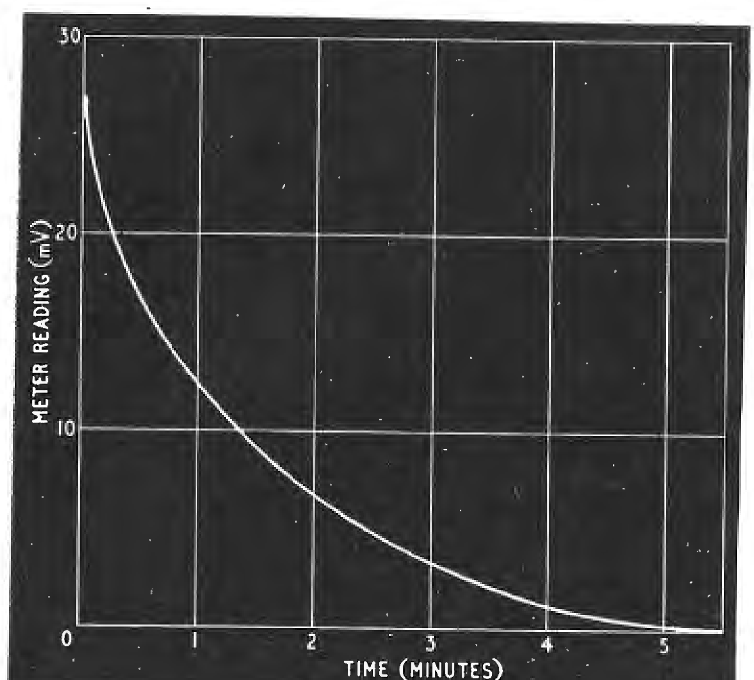


Fig. 5. Drift of instrument from switching on (at 20° C).

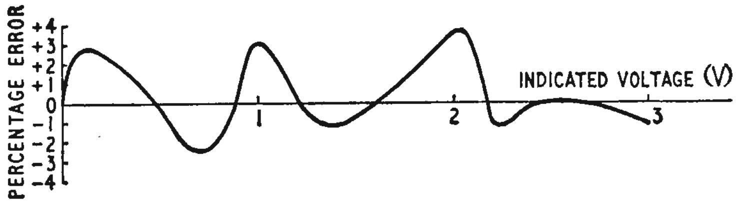


Fig. 6. Variation of percentage error with indicated value (at 20°C).

factor of error may be calculated. This is in turn applied to the input resistor, and with the new value installed, a comparison again made. The procedure is carried out once more. The relationship between indicated error and input resistor is not quite linear but by doing the procedure about thrice, the accuracy should be within 2%. The resistors used throughout the instrument should be ½W,1%, high-stability types.

Performance:—The instrument undergoes a steady drift from switch on (see Fig. 5) but almost completely settles down in about 5 minutes; the calibration curve (see Fig. 6) shows a maximum error of $\pm 3\%$ which is considered adequate for most purposes.

The temperature-dependent drift shown in Fig. 7 is for the whole instrument including batteries. The mercury cells used have a falling voltage characteristic below about 20°C and this showed itself rather clearly on the graph of thermal drift. Over the normal range of room temperatures the drift was not great and easily corrected by adjusting R_{11} from the front panel. The meter was found to be quite satisfactory in operation and the circuit is versatile in that it may be used just as a d.c. amplifier alone. In the case of temperature measurement with a

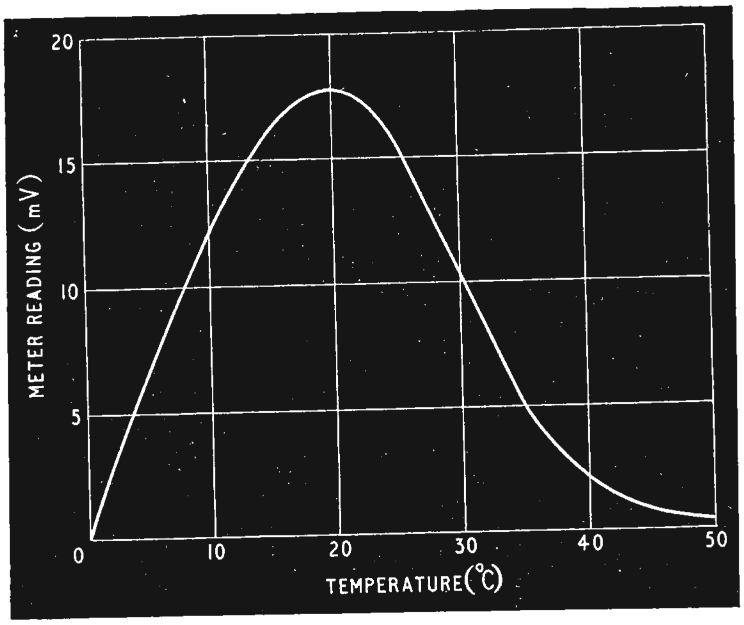


Fig. 7. Thermal drift for complete instrument including batteries.

thermal junction, copper may be made one of the metals and constantan the other, in which case it is only necessary to substitute the constantan for either the inner or outer conductor of the coax lead in, and a junction made at the far end, the end nearest to the instrument automatically forming a control junction. The copper/constantan pair gives approximately 1 mV/20°C at room temperatures and, using the instrument on its most sensitive range, a calibration chart may be drawn up.

Thanks are due to Joseph Lucas Ltd. for permission to publish the graph of the collector leakage current of their DT 1120 transistor (see Fig. 3).

BOOKS RECEIVED

Modulation and Coding in Information Systems, by Gordon M. Russell. The modern engineering curriculum emphasizes fundamental engineering theory more than the study of particular devices and routine methods of analysis. This book is concerned more with the information conversion processes applicable to the fields of industrial control, data transmission, power-system control and kindred subjects. Of special interest are the chapters on modulation, coding and multiplex transmission. Exercises are included at the end of each chapter. The reader is assumed to have a knowledge of electronic circuitry and advanced calculus. Pp. 260. Prentice-Hall International Inc., 28 Welbeck St., London, W.1. Price 42s.

More About Loudspeakers, by G. A. Briggs. An entertaining and instructive corollary to the author's previous book "Loudspeakers," in which developments during the past four years are recorded and discussed. Subjects dealt with include magnets, cabinet design, measurements of selective absorption of loudspeaker fret materials, and there is an intriguing chapter taking the form of replies by six well-known authorities to a questionnaire on stereo posed by the author. Pp. 136. Wharfedale Wireless Works Ltd., Idle, Bradford, Yorks. Price 8s 6d (9s 6d by post).

Graphical Symbols for Telecommunications, Supplement No. 7, Symbols for Semiconductor Devices. 12 page booklet published by British Standards Institution, British Standards House, 2 Park Street, London, W.1. Price 4s.

Electromagnetic Waves in Stratified Media, by J. R. Wait, F.I.R.E. Generalized theory of propagation in any number of parallel homogeneous layers, leads to a more detailed analysis of the propagation of very low frequency waves around the earth's surface and in particular the waveguide mode theory of propagation on which the author is a recognized authority. Pp. 372. Pergamon Press, Headington Hill Hall, Oxford. Price £5.

Medical Electronics Equipment Handbook, by Donald A. Smith. Provides information on electronic instruments used in medical and biological fields. As well as dealing with functions and applications of each instrument, operation of the device is discussed. Circuit theory for each main section of the instrument under review is considered. A section of each chapter is devoted to preventive maintenance and repair. Equipments reviewed fall into three main categories, laboratory instruments, diagnostic equipment and treatment devices. Pp. 254. Howard W. Sams & Co. Inc., Indianapolis 6, Indiana. Price $6.95.

B.B.C. Engineering Monograph No. 45. Vertical Resolution and Line Broadening, by G. D. Monteath, B.Sc., F.Inst.P., A.M.I.E.E., is concerned with the effects of scanning in lines on a television picture. Methods of broadening the scanning lines to reduce or eliminate these effects are considered. Pp. 22. B.B.C. Publications, 35 Marylebone High Street, London, W.1. Price 5s.

CONFERENCES AND EXHIBITIONS

Latest information on events during the second half of the year both in the U.K. and abroad is given below. Further details are obtainable from the addresses in parentheses.

LONDON

June 6-7 — West Ham College
Solid Circuits & Microminiaturization
(West Ham College of Technology, Romford Road, E.15)

June 12-22 — Olympia
International Plastics Exhibition and Convention
(*British Plastics*, Dorset House, Stamford Street, S.E.1)

Sept. 9-13 — Church House
Non-Destructive Testing Conference
(Institution of Mechanical Engs., 1 Birdcage Walk, S.W.1)

Sept. 9-13 — Imperial College
The Liquid State
(Inst. of Physics & Phys. Soc., 47 Belgrave Square, S.W.1)

Sept. 23-27 — Savoy Place
International Telemetering Conference
(I.E.E., Savoy Place, W.C.2)

Oct. 1-4 — Savoy Place
Electronics Research & Development for Civil Aviation
(I.E.E., Savoy Place, W.C.2)

Oct. 16-18 — Savoy Place
Design and Use of Microwave Valves
(I.E.E., Savoy Place, W.C.2)

Oct. 24-25 — Savoy Place
Automatic Production in Electrical and Electronic Engineering Symposium
(I.E.E., Savoy Place, W.C.2)

Nov. 11-16 — Earls Court
Industrial Photographic & Television Exhibition
(Industrial & Trade Fairs, Commonwealth House, New Oxford Street, W.C.1)

ABERDEEN

Aug. 28-Sept 4
British Association Annual Meeting
(Brit. Assoc. for the Advancement of Science, 3 Sanctuary Bldgs., Great Smith Street, London, S.W.1)

GLENEAGLES

Oct. 1-4
Wire Broadcasting Conference
(Alliance Internationale de la Difussion par fil, van Stopenberghestraat 3, Ghent, Belgium)

OXFORD

July 10-12 — The University
High Magnetic Fields
(Inst. of Physics & Phys. Soc., 47 Belgrave Square, London, S.W.1)

OVERSEAS

May 25-June 9 — Genoa
"Intercom" International Fair
(Fiera Internazionale di Genova, Viale Brigate Partigiane, 18-2 S.S., Genova)

June 4-5 — Philadelphia
Radio Frequency Interference Symposium
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

June 11-13 — Los Angeles
Space Telecommunications
(J. R. Kauke, 1632 Euclid Street, Santa Monica)

June 17-18 — Chicago
Broadcast & Television Receivers Conference
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

June 19-21 — Minneapolis
Automatic Control Conference
(Prof. O. L. Updike, Department of Chemical Engineering, University of Virginia, Charlottesville, Virginia)

July 9-11 — Boulder
Space Telecommunications
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

July 22-25 — Liège
Medical Electronics Conference
(Dr. A. Nightingale, St. Thomas's Hospital, London, S.E.1)

July 26-Aug. 10 — Sydney
Sydney Trade Fair
(Industrial & Trade Fairs, Commonwealth House, New Oxford Street, London, W.C.1)

Aug. 4-9 — Washington
Aerospace Support Systems Conference
(E. Halas, Box 6635, Washington 9, D.C.)

Aug. 20-23 — San Francisco
Western Electronics Show & Conference
(WESCON, 3600 Wilshire Blvd., Los Angeles)

Aug. 27-Sept. 4 — Basle
Automatic Control International Congress
(British Conference on Automation & Computation, c/o I.E.E., Savoy Place, London, W.C.2)

Aug. 30-Sept. 8 — Berlin
German Radio Exhibition
(Berliner Ausstellungen, Charlottenburg 9, Berlin)

Sept. 2-7 — Basle
Industrial Electronics Exhibition
(Swiss Industries Fair, Postfach, Basle 21)

Sept. 2-14 — Zurich
British Industrial Fair
(British Overseas Fairs, 21 Tothill St., London, S.W.1)

Sept. 5-15 — Paris
International Radio and TV Exhibition
(F.N.I.E., 23 rue de Lübeck, Paris 16e)

Sept. 9-11 — Washington
Military Electronics Convention
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

Sept. 13-22 — Amsterdam
Firato International Exhibition
(RAI Gebouw N.V., Europaplein 8, Amsterdam)

Sept. 15-19 — Tokyo
International Scientific Radio Union General Assembly
(U.R.S.I., 7 place Emile Danco, Uccle, Brussels)

Sept. 18-19 — East Lansing
Industrial Electronics Symposium
(L.J. Giacaletto, Michigan State Univ., E. Lansing, Mich.)

Sept. 30-Oct. 2 — Toronto
Canadian Electronics Conference
(I.E.E.E., 1819 Yonge Street, Toronto 7)

Oct. 1-3 — Miami Beach
Space Electronics Symposium
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

Oct. 7-9 — Utica
Communications Symposium
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

Oct. 8-17 — Utrecht
Instrument Exhibition
(Utrecht Trade Fair, Utrecht)

Oct. 28-30 — Chicago
National Electronics Conference
(N.E.C., 228 N. La Salle Street, Chicago)

Nov. 4-6 — Boston
N.E. Electronics Research & Engineering Meeting
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

Nov. 10-15 — Atlantic City
Magnetism & Magnetic Materials Conference
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

Nov. 12-14 — Los Angeles
Computer Conference
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

Nov. 14-21 — Paris
Mesucora Exhibition & Congress
(Secretariat, 40 rue du Colisée, Paris 8e)

Nov. 18-20 — Baltimore
Engineering in Medicine & Biology
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

Dec. 4-6 — Washington
Ultrasonics Symposium
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

Dec. 5-6 — Dallas
Vehicular Communications
(I.E.E.E., Box A, Lennox Hill Station, N.Y.21)

MAY MEETINGS

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

LONDON

1st. I.E.E.—" Radio astronomy and the electrical engineer " by Dr. F. Graham-Smith at 5.30 at Savoy Place, W.C.2.

1st. Brit.I.R.E.—" Electronic melody instruments " by K. A. Macfadyen at 6.0 at the London School of Hygiene, Keppel Street, W.C.1.

2nd. Brit.I.R.E.—Discussion on " Some outstanding technical questions on the N.T.S.C. and SECAM colour television systems which have not yet been satisfactorily answered " at 6.0 at the London School of Hygiene, Keppel Street, W.C.1.

2nd & 3rd. Royal Society.—Discussion on " Results from the first Anglo-American satellite Ariel 1 " at 10.30 at Burlington House, Piccadilly, W.1.

6th. I.E.E. and R.Ae.S.—Discussion on " The case for digital computers in aircraft " at 6.0 at the Royal Aeronautical Society, 4 Hamilton Place, W.1.

7th. I.E.E.—" Scientific research in space " by Professor Sir Harrie Massey at 5.30 at Savoy Place, W.C.2.

8th. Brit.I.R.E.—Contributions on " Techniques of semiconductor-controlled power supplies in data processing " at 6.0 at the London School of Hygiene, Keppel Street, W.C.1.

13th. I.E.E.—" Time-compression multiplex transmission " by Dr. J. E. Flood and D. J. Urquhart-Pullen at 5.30 at Savoy Place, W.C.2.

15th. Brit.I.R.E. and I.E.E.—Discussion on " Special requirements for medical electronic operators " at 6.0 at the London School of Hygiene, Keppel Street, W.C.1.

16th. Brit.I.R.E.—Symposium on " Processing and display of radar data " at 11.0 at the London School of Hygiene, Keppel Street, W.C.1. (Registration fee 30s.)

17th. Institute of Navigation.—" Compound air navigation systems " by C. Powell and M. Pearson at 5.30 at the Royal Institution of Naval Architects, 10 Upper Belgrave Street, S.W.1.

29th. Brit.I.R.E.—Symposium on " The technical features of pay-television systems " at 6.0 at the London School of Hygiene, Keppel Street, W.C.1.

LEICESTER

21st. Television Society.—" Recent developments in dry cells " by C. J. Weeks at 7.30 at the New Vaughan College, St. Nicholas Street.

MANCHESTER

7th. I.E.E.—" The Anglo-Canadian transatlantic telephone cable " by R. J. Halsey and Dr. R. A. Brockbank at 6.15 at the Engineers' Club.

NEWCASTLE

16th. Society of Instrument Technology.—" The analogue computor in engineering research and design " by G. Pearson at 7.0 at the Conference Room, Roadway House, Oxford Street.

SHEFFIELD

1st. I.E.E. Graduates and Students. —" Aspects of telecommunication progress " by J. W. Spooner at 7.0 at the University, Mappin Street.

UNBIASED

By "FREE GRID"

Home Acoustics

A CORRESPONDENT who was interested in my views on hi-fi and ni-fi in the March issue, wrote me a very informative letter on this matter. He is engaged professionally in the audio field and reminds me that the weakest link in the hi-fi chain is still the loudspeaker. However, my correspondent has made me realize that although the loudspeaker has many failings, it really does not constitute the end of the chain as we have often loosely supposed. The final link to our ears is provided by the acoustics of the room in which we are listening. This usually has a far more baneful effect than the loudspeaker.

No doubt a lot could be done towards improving these acoustics if we arranged to do our listening in one particular room, and called a conference of acoustic experts and designers of furnishings to provide the ideal listening room which exerted no distorting effect on what comes out of the loudspeaker.

I can well imagine, however, that such a room would be thoroughly uncomfortable to sit in, and its æsthetic disharmonies would far outweigh any acoustic advantages it gave. Of course, there are people whose love and appreciation of music is so great that fleshly comforts mean nothing to them. They would gladly suffer any mortification of the flesh if such were necessary to hear unsullied Schumann or Bach at his best. I am certainly not one of them but am, I fear, a bit of a sybarite where corporeal comforts are concerned.

Fortunately, as my correspondent reminds me, it is not necessary to throw our aspidistras and other archaic furnishings out of the window as there is a system of listening in which the acoustics of the room are not so important. This system is stereo. At present this is only applicable to recorded music, but eventually we shall most certainly have some kind of broadcast stereo service.

My correspondent puts the case for the relative imperviousness to room acoustics quite strongly. In his own words "mono in a 'dead' room is terrible but stereo is largely unaffected." I have been carrying out some experiments in the matter, as a result of which I agree to a great extent, but not entirely.

No doubt many people will say that my results and conclusions are largely psychological effects because I expected stereo to be better. Even if this were true it would not nullify my results. After all, having a tooth drilled to music seems to make the pain less, but does it really matter if the pain only seems to be less? That gives me an idea. If stereo instead of mono were used in the dentist's surgery, I wonder if it would make the pain disappear—or seem to disappear—altogether? Any volunteers?*

* My dentist feeds me stereo through headphones; the pain does *not* disappear.—ED.

Shame on Us

ENGLISH people have always been noted for an almost indifferent attitude to the day of their patron saint, St. George, on April 23rd. This is in great contrast to the Scots, Irish and Welsh on their respective patron saints' days.

The same attitude of lofty indifference which English people adopt on St. George's day, seems also to be found among members of the wireless industry towards the day of its own patron saint, St. Gabriel, who was appointed in 1951. On March 18th, St. Gabriel's day, I looked for the flag of St. Gabriel on the flagstaffs of many radio firms both large and small, but I looked in vain. I have mislaid my *W.W.* Diary, and so cannot look to see if the day of our patron saint was noted in its pages, but there was certainly no mention of the day by the B.B.C. or I.T.A.

I mentioned this to a radio personality to whom I happened to be talking on March 18th, but to my astonishment he shook his head and then said: "What is the emblem of St. Gabriel anyhow"? This question made me feel very foolish indeed, as I realized that either the heraldic authorities had not designed one, or, if they had, I was ignorant of it. I am more than willing to be corrected but frankly I don't think there is one. I feel, therefore, we ought to start at once getting together a few suggestions to forward to the heraldic authorities.

Neither hagiology nor heraldry can be said to be numbered among my academic attainments and so I must leave it to you. I do think, however, that something simple and striking is required, and I shall be glad to receive your suggestions for forwarding to the proper quarter.

Morse and Music

A FEW weeks ago on the B.B.C.'s "Monitor" programme, there was a very interesting item in which a well-known Russian pianist was demonstrating to two of his fellow craftsmen, who hailed from this side of the iron curtain, the particular way in which his fellow countrymen are taught to play this instrument.

I couldn't follow a lot of what he was talking about, although he spoke fluent English, but it seemed to me that he used not only his fingers, wrists and arms but his whole body in his attack on the piano; indeed, one of the other pianists questioned him about it. In view of his vigour and the resultant noise which he produced, I think the word "attack" is *le mot juste* for his effort, and I don't use it in the mere technical sense in which one of his fellow pianists did in the discussion.

There was one thing which did strike me at once when the Russian pianist was giving a detailed demonstration of wrist and forearm movement without actually playing the piano, but with his fingers merely resting on the edge of the keyboard. This thing was that he was instructing us to do exactly the same thing as does H. F. Smith, the author of the *W.W.* booklet "Learning Morse." The similarity was truly astonishing, and it struck me at once that an expert morse sender ought, with little trouble, to make a first-rate pianist and vice versa.

I am definitely not trying to say because of H. F. Smith's exposition of the correct method of morse keying, he must, therefore, also be a pianist of outstanding merit. Indeed, I don't think he is, but my point is that if he did decide to tackle the piano, his attack on it would certainly be attention-compelling.

As for expert pianists making expert morse readers, I cannot think there would be any doubt about it. To be really expert at morse one must have a sese of rhythm. In my opinion, every letter in morse must be learned as a rhythmic sound.

Speed of Electricity

THE figure of one-tenth of an inch per second as the speed of a strong electric current through copper wire, given by "Cathode Ray" in the March issue is liable to make some people think at first that the electricity which lights and heats our houses is virtually motionless. In the case of our 50 c/s mains, each electron can't get very far before it has to do an about turn. Yet this seemingly slow to and fro shuffle of the electrons in our heater elements creates enough friction to make them red hot.

Of course, compared with its own diameter each electron moves quite a considerable distance and it is not so virtually motionless after all. Even when we come to the realm of megacycles, the electrons travel quite a few diameters in each to and fro shuffle. It is, therefore, not true to say as I once saw it picturesquely put in a popular journal that each electron merely shifts its weight from one foot to another.