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APRIL 1976 35p

Valve audio output–transistor drive

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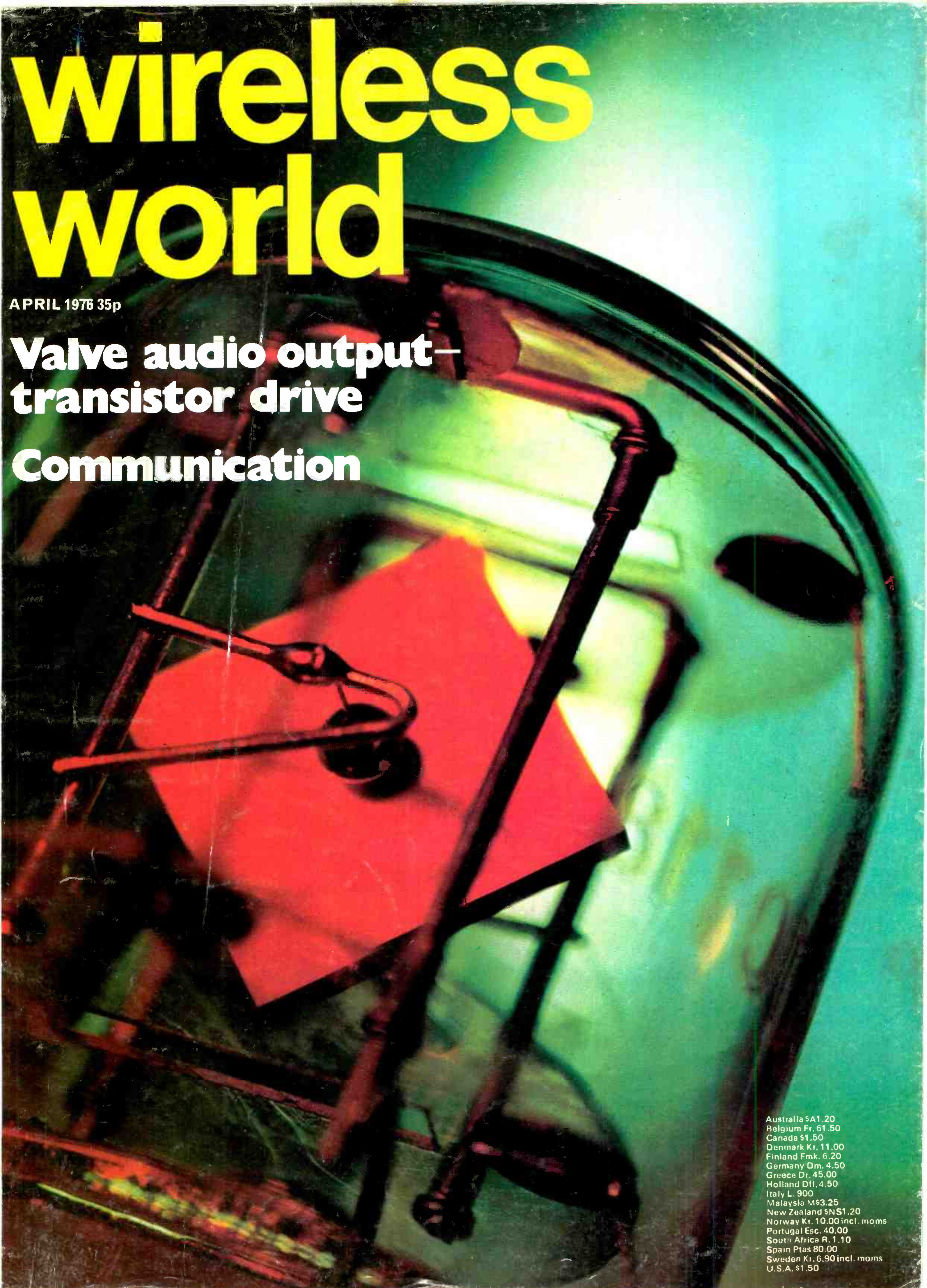

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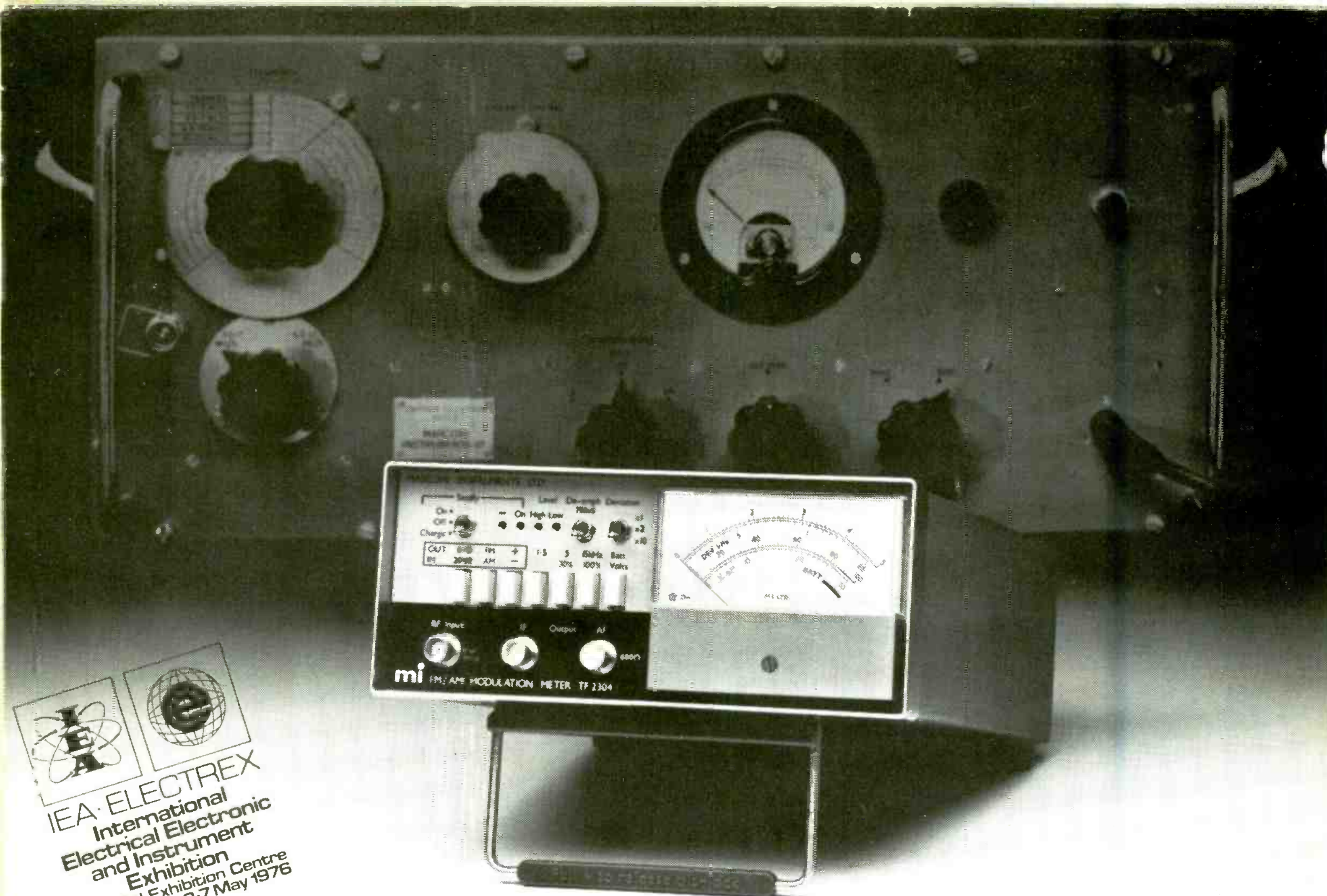

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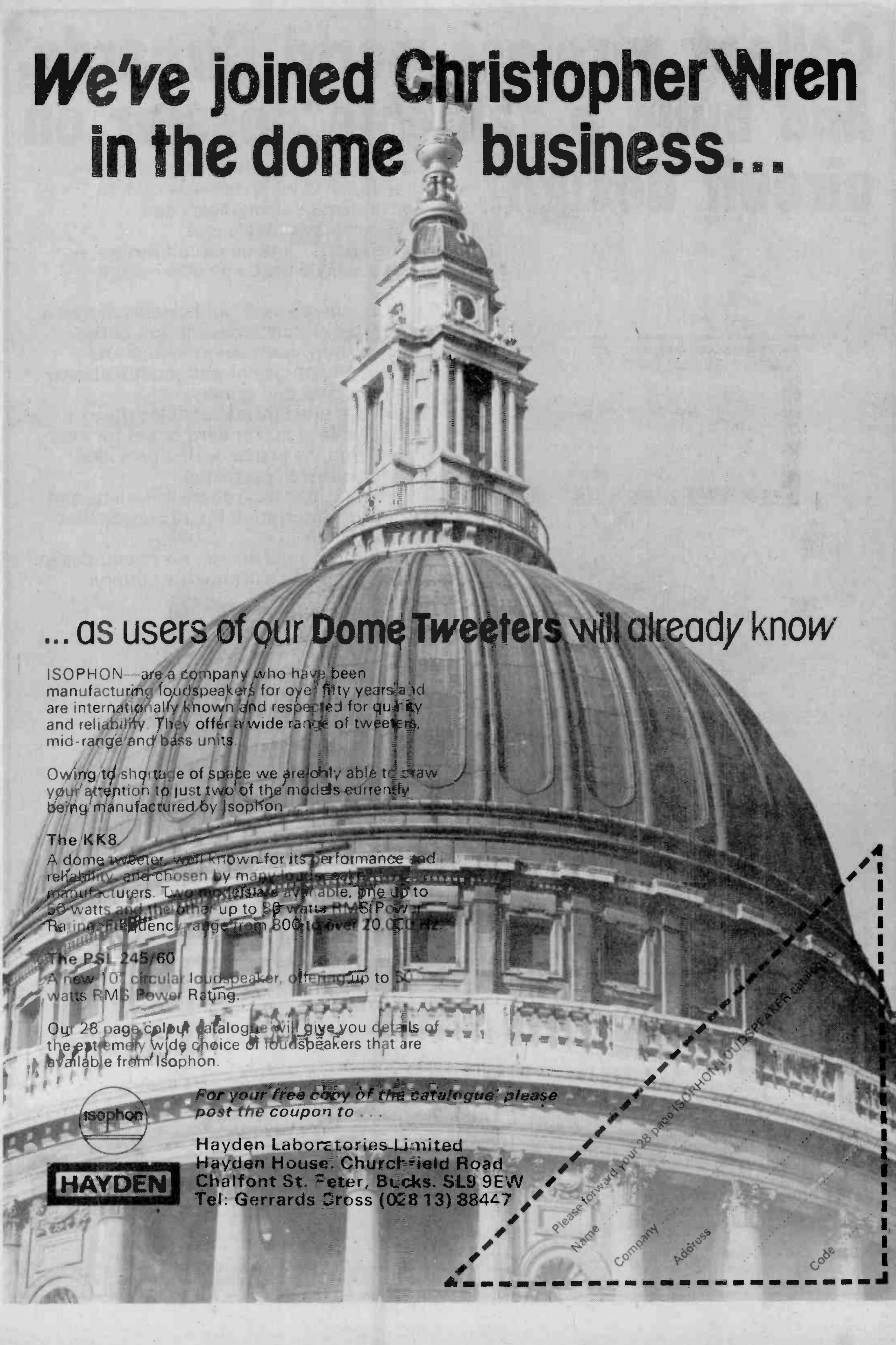
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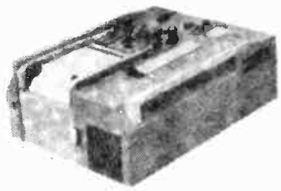

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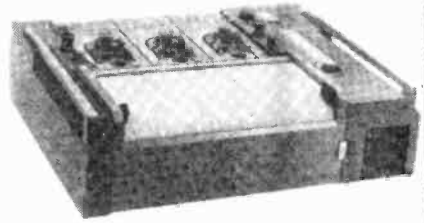

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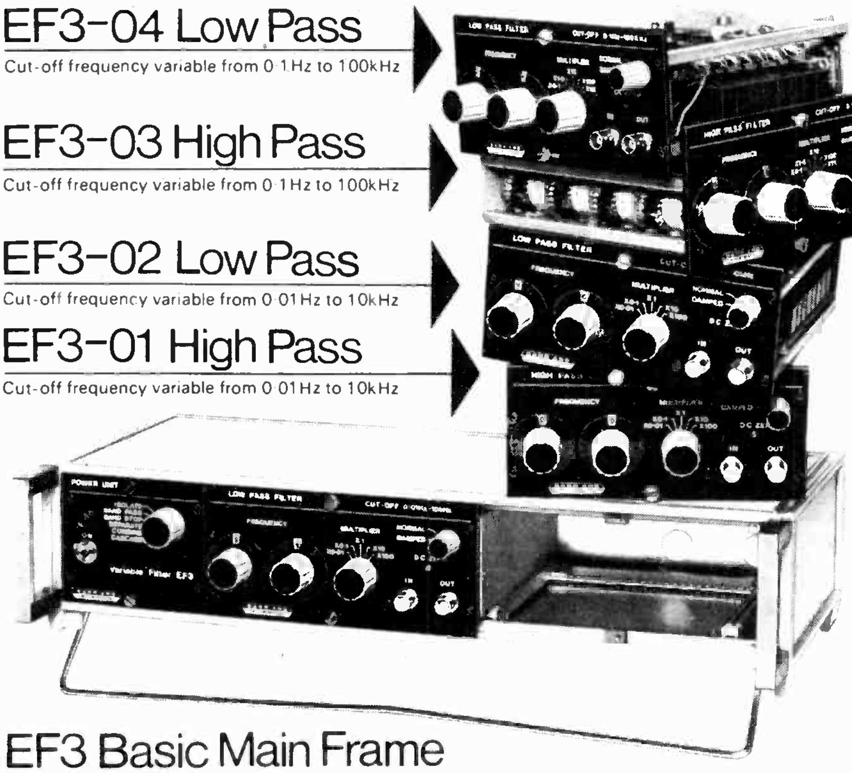

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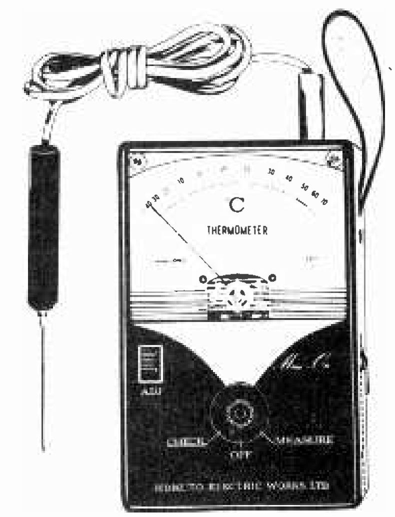

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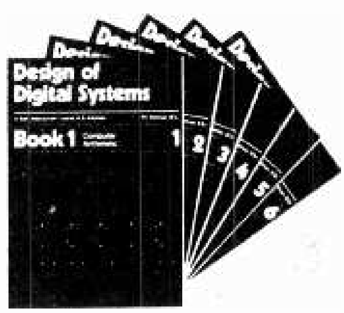

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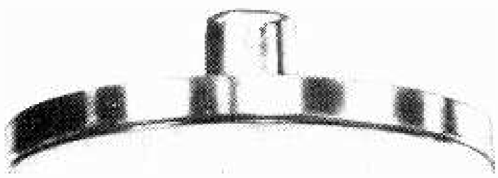

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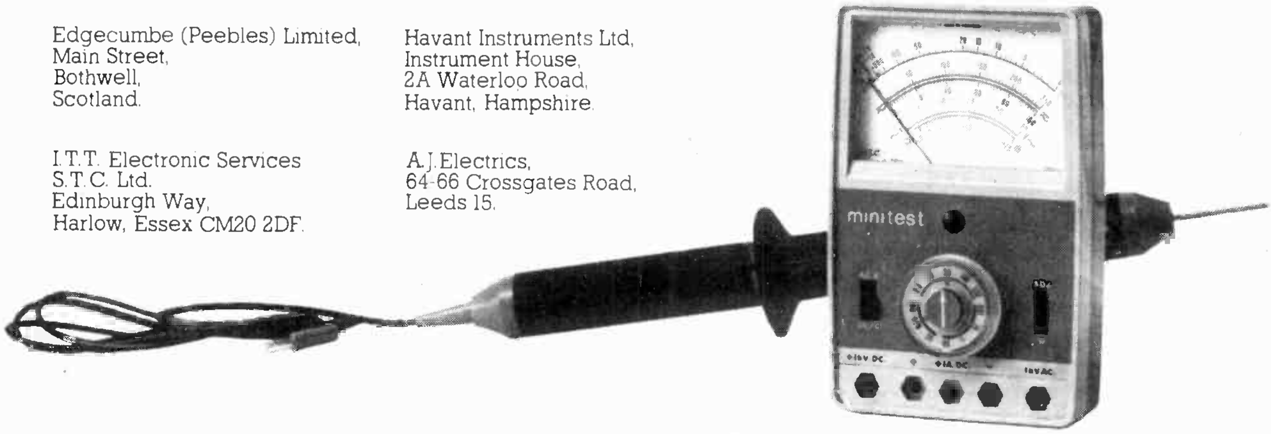

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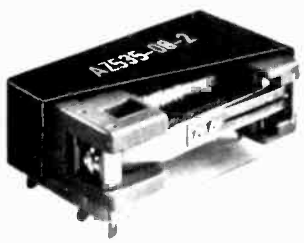

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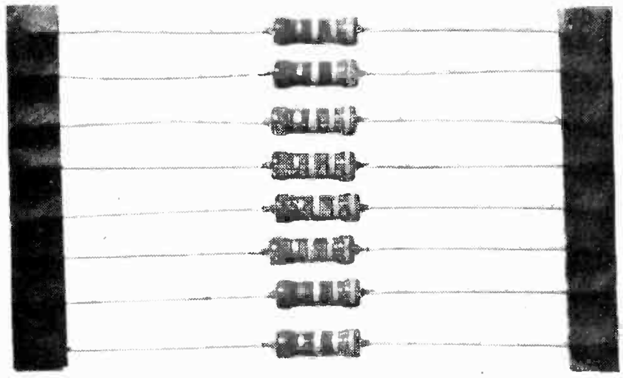

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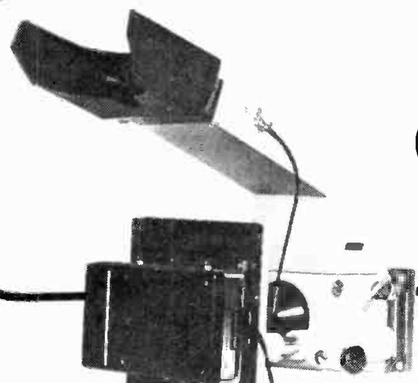

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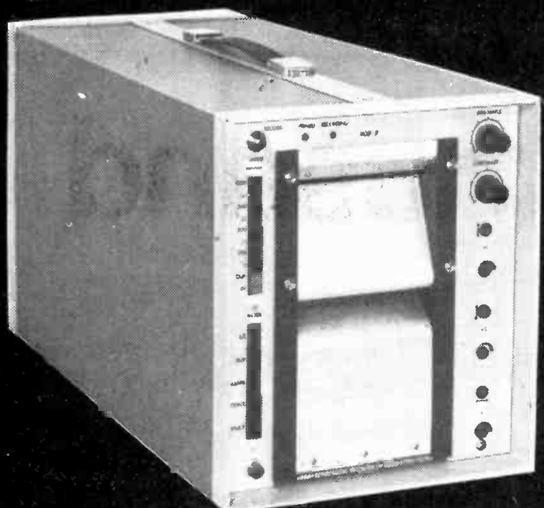

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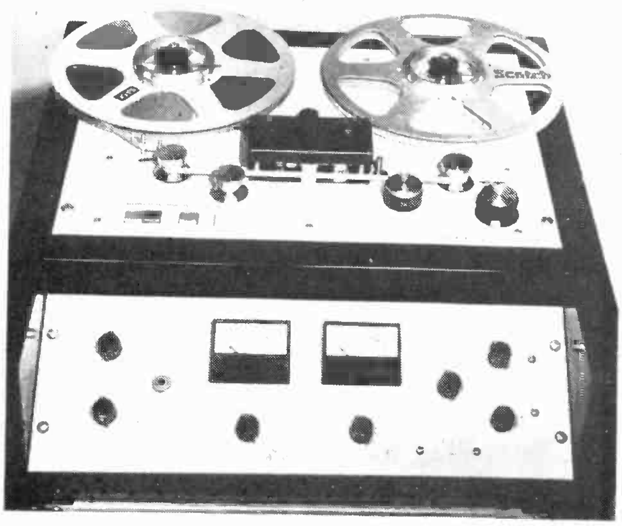

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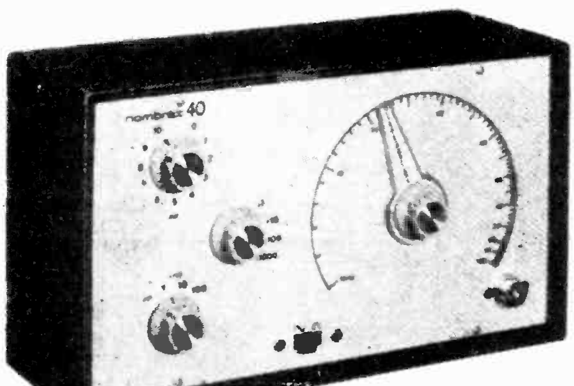

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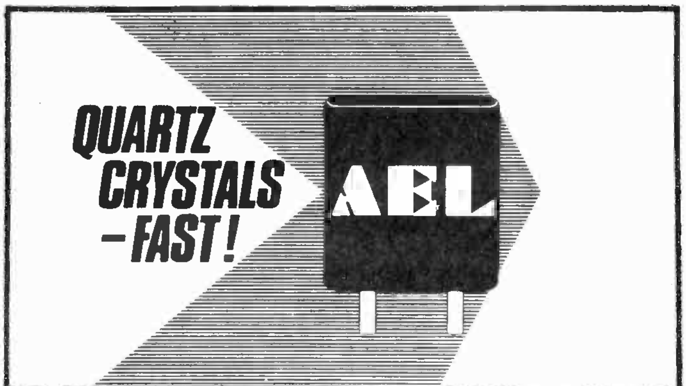

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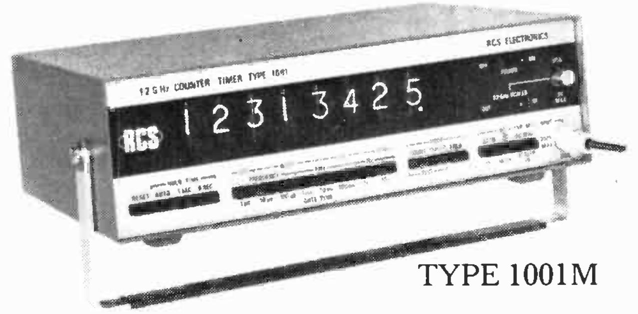

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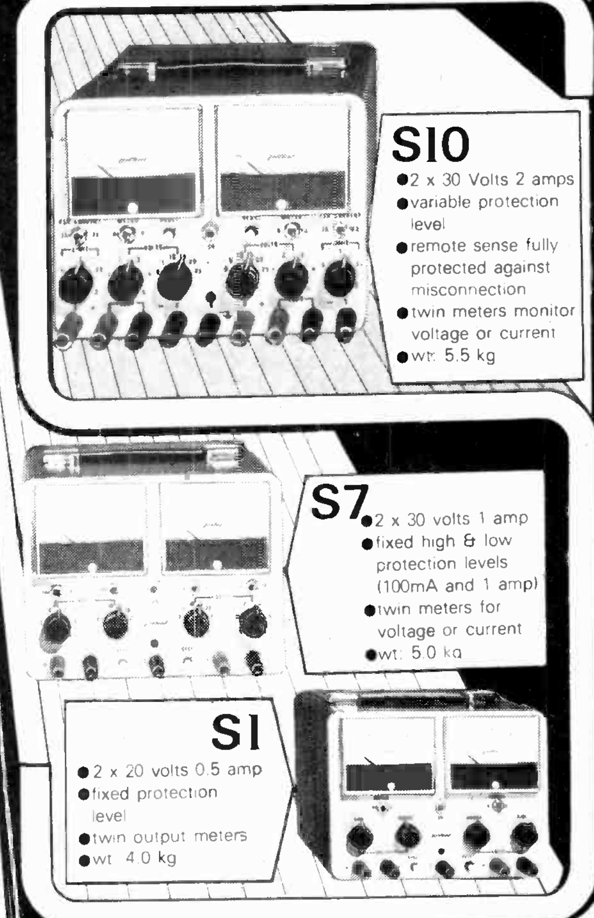

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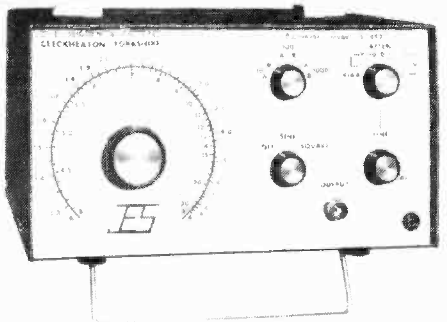

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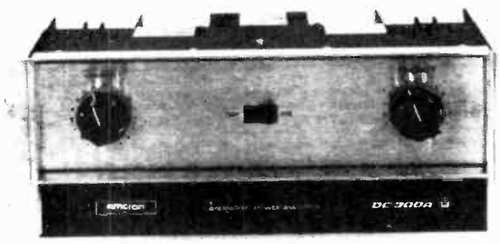

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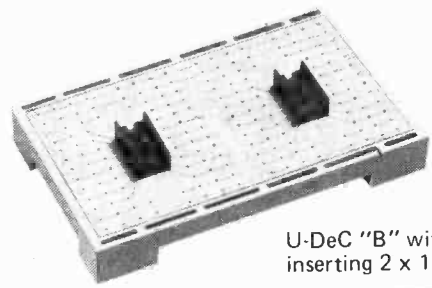

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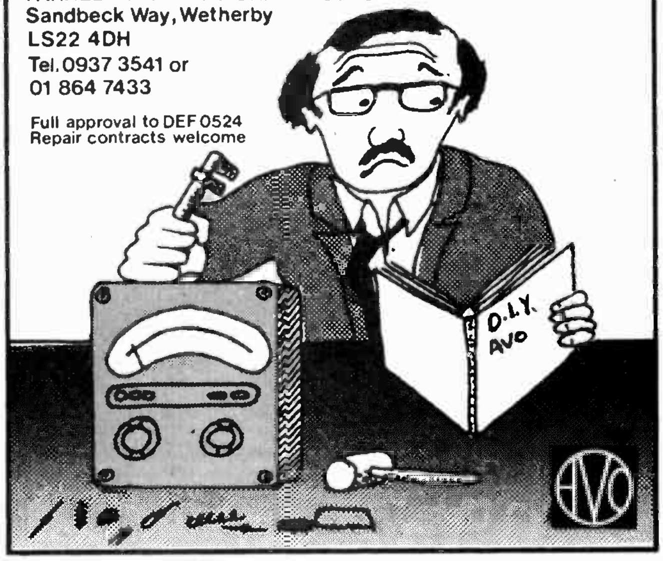

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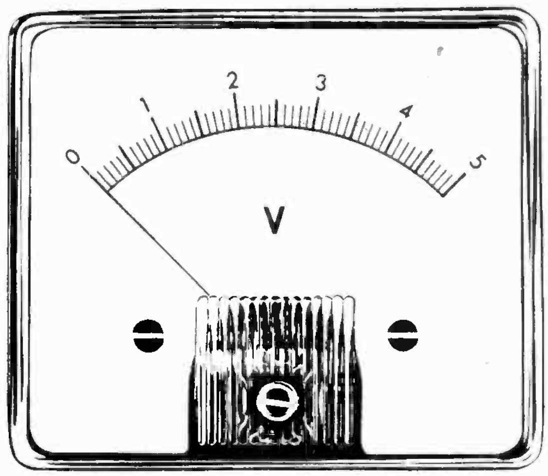

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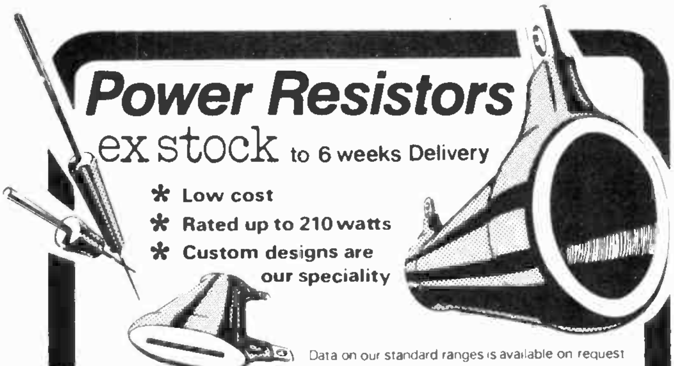

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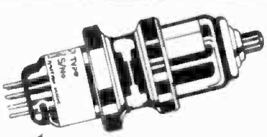

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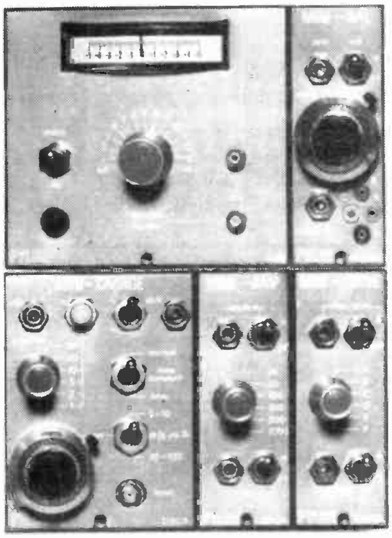

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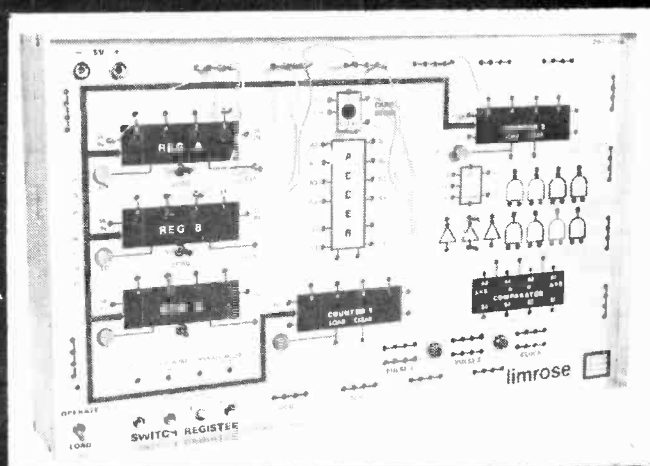

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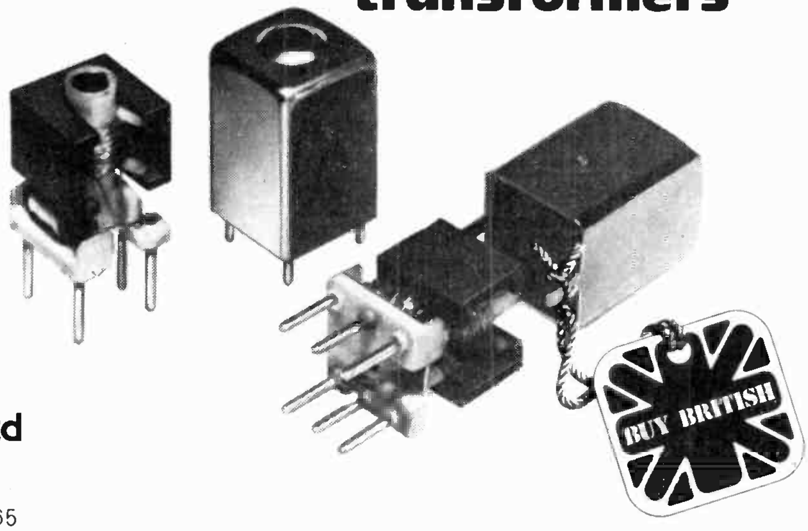

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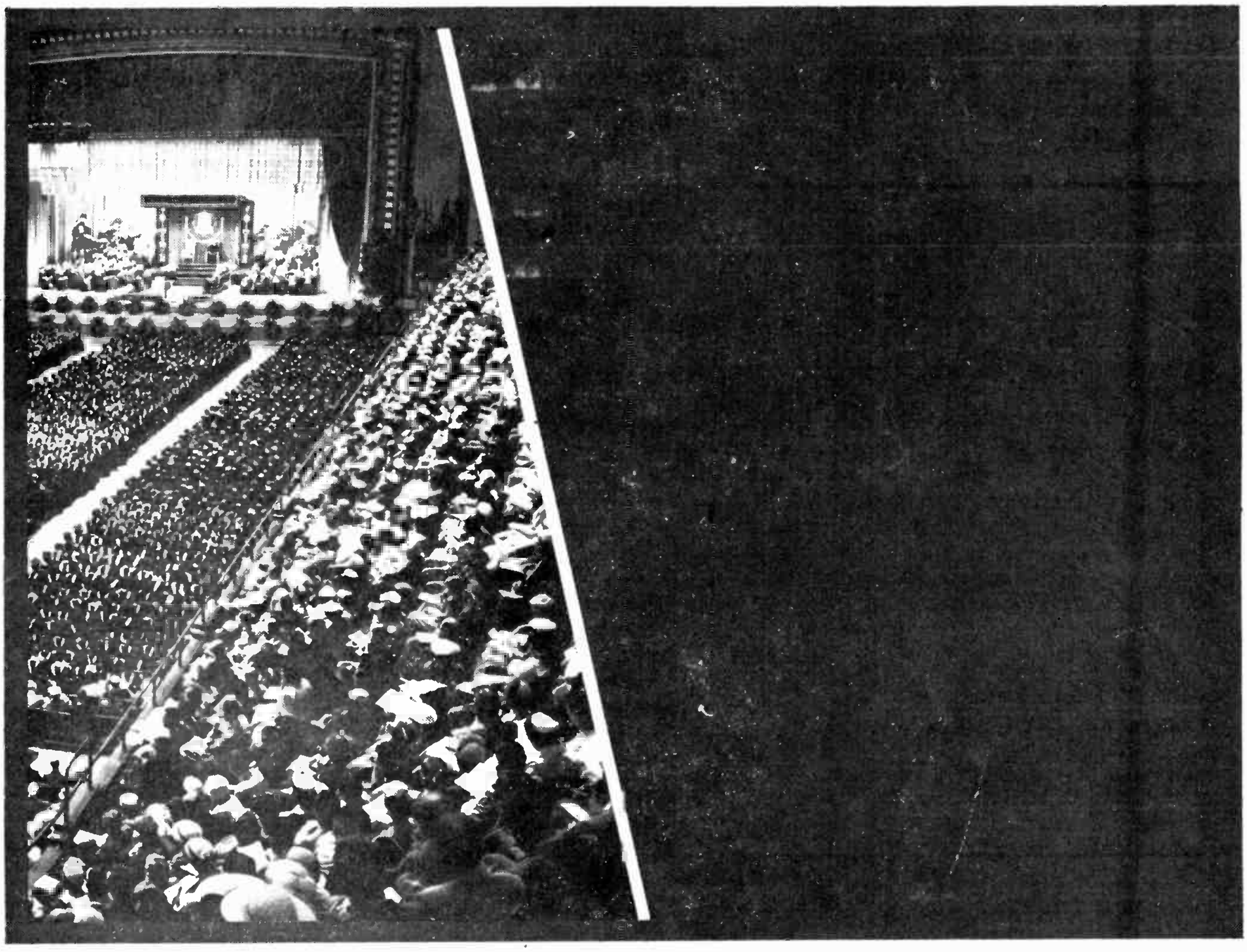

wireless world

Electronics, Television, Radio, Audio

APRIL 1976 Vol 82 No 1484

Contents

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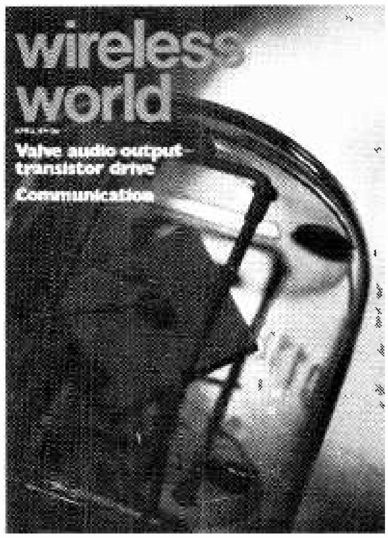

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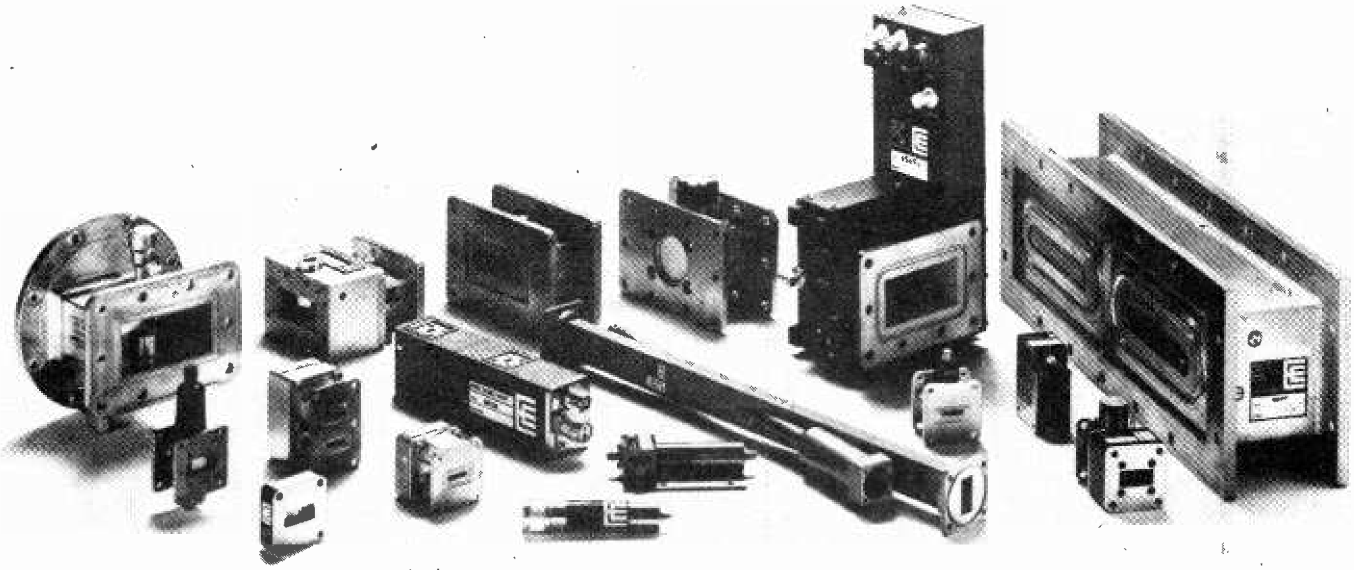

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wireless world

Approach to microwave landing

If your holiday beach last year lay at the end of a journey by air the chances are that the last few miles were flown along a narrow radio beam known as ILS – instrument landing system. This has become the standard international approach aid to airfields, and its performance has been steadily improved to the extent that it enables suitably equipped aircraft to be landed in virtually zero visibility. In no other function is the pilot required to put so much trust in the accuracy and reliability of electronics. But a new development known as MLS – microwave landing system – now holds the attention of the policy makers in the International Civil Aviation Organisation. Interest in the possibility of a new approach aid developed in the late 1960s when communications engineers realised that microwaves, digital computing and advanced cockpit displays could be brought together to produce a more accurate and versatile system.

ICAO produced in 1972 a set of technical requirements, and five countries responded: the USA, Britain, France, West Germany and Australia. Their proposals are now being studied, and a decision is expected next year. The schemes fall into two categories: Doppler and scanning beam. Britain, along with two US companies, ITT Gilfillan and Hazeltine, has put forward a Doppler-based system (see March 1974 issue, pp. 25-26) which, supported by the UK Government in collaboration with Plessey, has already been successfully demonstrated in flight tests at the Royal Aircraft Establishment, Bedford. Two other American companies, Texas Instruments and Bendix, pinned their faith on the alternative technique. Last year the US Federal Aviation Administration, in a controversial decision which was hotly contested by Britain and the two losing US companies, chose the scanning-beam system as its proposal to ICAO. The reasons given for this decision – there was no airborne experience of scanning-beam equipment to the technical standard specified by ICAO available for comparison – are not convincing, particularly since the scanning-beam system as it stands probably cannot provide the accuracy needed to level the aircraft and reduce its rate of sink just before it touches the runway. This, of course, is a critical manoeuvre.

America's choice cannot but influence the ICAO's committee, the All Weather Operations Panel, in its deliberations. If it pleads more time for practical experiments, the FAA is likely to go ahead anyway and introduce scanning-beam MLS into some US airfields which cannot be served by ILS. Such a *fait accompli* may very well capture the majority vote of the ICAO's eleven-man AWOP group which will choose one of the five entries as the basis of its recommendation for an international standard.

Apart from the rights and wrongs of the decision, the companies involved stand to make money handsomely. Even those firms which backed the losing method will have the edge over those which have no experience, because the C-band techniques, aerial design, data-processing and many other aspects are similar in both systems. This particularly applies to Britain, whose Government has spent £3.5 million in developing and demonstrating the so far only workable MLS.

Michael Wilson,
Technical Editor, *Flight International*

Transistor driver for valve amplifiers

Design for Williamson and other output stages

by Seth Berglund
Lunds University, Sweden

There are certainly a lot of valve audio amplifiers still in use, and many of them have an inherent quality of performance that makes it reasonable to give them a thorough repair, with or without an accompanying modernization. The work needed for repair may tend to grow, however, since it may not be sufficient to replace valves and a few electrolytic capacitors. A general degradation of components may have taken place, and in nearly all instances of modernization it should be advantageous to replace the rectifying valve by silicon or maybe selenium rectifiers. So there may be some doubt as to what is really needed and what is worthwhile.

For those who are interested in giving their valve amplifier a positive modernization that will result in obvious improvements, a description is here given of a transistor driving amplifier that can replace the voltage amplifying stages of many existing power amplifiers. The Williamson amplifier[1] has been chosen as a typical example for the discussion that follows, because it is a well-known design. Other amplifier designs that have been used for comparison are those designs by Mullard[2] and by GEC[3].

The original idea was to design an amplifier with a bandwidth sufficiently in excess of the output transformer bandwidth, so that the only phase shift to take account of should be that of the transformer. A d.c. amplifier with a bandwidth of about 1MHz was thought to be sufficient. Direct coupling from the input stage to the signal grids of the output valves leaves the output transformer as the only cause of phase shift at the low frequency end, and the shift tends to only 90°. So there are no problems of instability from negative feedback at the low frequency end, provided that the usual precautions as to supply line filtering are taken.

At the high frequency end of the transformer passband there is usually one main resonant frequency, often at about 100kHz, around which the phase shift passes 90° by a considerable amount but does not reach 180°. It was thought therefore that with a bandwidth of at least 1MHz for the driver, the normal amount of 20dB frequency-independent feedback should be allowable without instability. This was found to be the case for several output transformers, at least with a resistive load. With the Williamson transformer and output stage according to the original design, an essentially flat amplitude-frequency response was obtained up to 1MHz, and there was some stability margin.

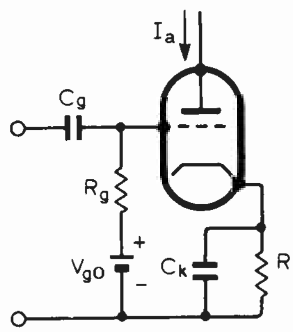


Fig. 1. A constant voltage V_{go} is in this circuit added to a normal cathode bias.

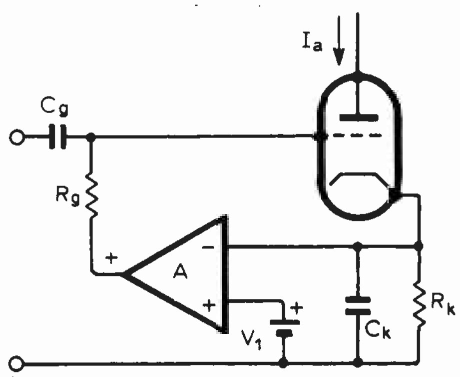


Fig. 2. Further development of the circuit in Fig. 1 by means of a gain function A.

If a loudspeaker or some load of a complex nature is inserted, the phase shift tends to become too large, and the only way to stability is then to reduce the closed-loop gain. So extended bandwidth is no radical solution for stability at the high frequency end in the same way as direct coupling is for low frequencies. And after all, the aim should not be amplification up to radio frequencies, but an l.f. amplifier with a defined upper frequency limit. This does not mean that it is a wasted effort to start with a large bandwidth for the driver. On the contrary, by starting with a bandwidth of 1MHz, the high-frequency response can be exactly formed up to this frequency, using simple operational amplifier techniques, and so it can easily be changed to suit different output transformers. The output voltage of the driver is sufficient even for large output tubes such as the KT88; they are assumed to work in class A or AB in the design that follows.

Output valve biasing

When direct coupling to the output valves is used, the grids can still be kept at zero potential for the quiescent point, with a normal cathode bias for class A or AB operation. But this is not necessary and in my opinion not at all the best way. Let us therefore look at other ways of biasing. For the sake of simplicity, single valve biasing is discussed first, and the valves shown as triodes with the usual assumption of zero grid current, i.e. anode and cathode currents are identical. If thus I_a is the anode current of a triode and R_k the outer cathode resistance, the negative grid voltage with a normal cathode bias is $V_{gk} = I_aR_k$.

It is possible, although not often used in practise, to modify the influence of the anode current on this bias voltage by the addition of a constant voltage to the circuit, either in series with the cathode or, normally with less effort, in the grid circuit, shown as the voltage V_{go} in Fig. 1. The grid bias voltage is now $V_{gh} = V_{go} - I_aR_k$.

It is important to note that V_{go} may be positive as indicated in the figure, or negative. In the first case a larger resistance R_k is required than for simple cathode bias, which makes the grid voltage more dependent on the anode current, i.e. there is a better stabilization of the quiescent point. In the case of negative polarity for V_{go}, the grid voltage becomes less dependent on the anode current, as R_k must be diminished. For growing negative values of V_{go}, it becomes in the limit equal to the desired grid voltage. Then R_k must go to zero and the result is a constant grid voltage.

A grid bias that has exactly the same dependence on the combination of a constant voltage and the anode current as that of Fig. 1, but with improved means for the choice, can be obtained by a circuit as shown in Fig. 2. With the notations according to this figure, and provided that the operational amplifier of voltage gain A has zero offset, the constant part of the grid bias is $V_{go} = AV_l$, and the total grid bias becomes

$$V_{gk} = AV_l - (1+A)I_aR_k$$

In this circuit R_k can be a small resistance, which is an advantage for large output tubes where the power dissipated in R_k for a normal bias may be considerable. Most important is, however, the ease of adjustment to a desired bias.

The bypass capacitor C_k has retained its function, and the time constant R_kC_k is chosen as for normal cathode bias. However, if R_k is small, so that it causes only negligable feedback by itself, the bias time-constant may be introduced by a separate RC-link, either before or after the amplifier.

In the foregoing figures the bias and signal voltages have been mixed in the usual way by a grid resistor R_g and a coupling capacitor C_g. If a full signal feedback from R_k is wanted, corresponding to an unbypassed cathode resistance in Fig.1, some other type of mixing circuit is needed. This also holds, if direct coupling of the signal to the valve grid is used.

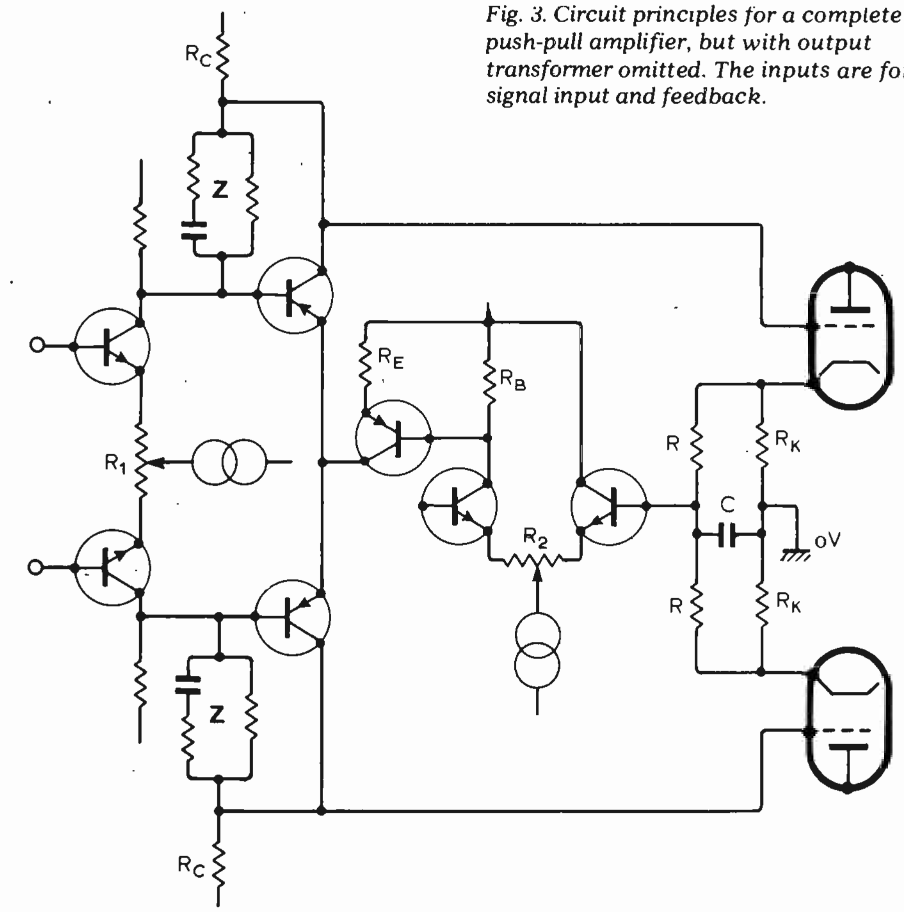


Fig. 3. Circuit principles for a complete push-pull amplifier, but with output transformer omitted. The inputs are for signal input and feedback.

Arrangement of amplifier

To explain the main features of the complete push-pull amplifier, its layout is first shown by the simplified circuit of Fig. 3. The circuit comprises three differential stages, namely a signal input stage, a biasing stage for the sensing of the currents in the output valves, and between these a mixing and amplifying stage that drives the valves. It is a symmetrical circuit throughout for the input signals, and the necessary d.c. balance is obtained at the emitter side of the input stage, in the figure by means of the potentiometer R_1. Another important feature is that the differential stages are all supplied by a current source at the emitter side, instead of just by a common emitter resistor. A high common-mode rejection ratio is thereby obtained, which means that the input signal and the negative feedback around the amplifier can be fed differentially to the input stage without danger of adverse secondary effects.

The current source for the mixing stage, a single transistor in Fig.3, acts with the differential pair as a common-mode amplifier for the signals from the preceding biasing stage, so that the two stages together give a common-mode voltage gain from cathodes to grids that corresponds to the gain function denoted by A in Fig. 2. The gain to a sufficiently good approximation is

$$|A| = \frac{R_B}{R_2} \cdot \frac{R_C}{2R_E} \cdot$$

Resistance R_2 is selectable for choice of voltage gain.

As the amplified part of the bias is a common-mode one, it corresponds to a common cathode resistance with the value $R_kA/2$, and the time constant of the RC-link is $RC/2$. The constant part of the grid bias is simply an offset voltage, effected by an adjustment of the potentiometer R_2, which is therefore found to have the double function of determining the gain by its resistance value and the constant voltage by its adjustment.

The resistances of R_k may be so small that their direct influence on the valve bias becomes negligible. They cause a small lowering of the effective valve transconductances.

Because the collector resistances of the mixing stage become fairly large, there is ample signal amplification available in this stage for local feedback to be applied. This is used in the amplifier for determining the response by means of the impedances Z.

Amplifier design

The complete amplifier is shown in the circuit diagram of Fig. 4. Although the number of components has grown, the fundamental simplicity as evidenced by Fig.3 is retained, and there are not any hidden difficulties such as the need for tricky adjustments or special demands on the power supply voltages, which may vary within large limits. The demands on filtering are not very large either, since the current sources for the differential stages reduce hum. Only the negative high tension voltage needs a certain stabilization.

The input common-emitter long-tailed pair of Fig. 3 is a dual n-p-n transistor Tr_1, and it is completed by an n-channel dual f.e.t. Tr_2, the two transistors of which are used as input source followers. This makes the amplifier compatible with valve amplifiers with regard to input impedance as well as to independency of the characteristics of the driving source. So all that is required of the preamplifier is that it shall give sufficient voltage.

The d.c. balancing potentiometer R_{41}, a 15-turn trimming potentiometer, has been moved away from the main signal path into the f.e.t. source circuit, where it gives a smooth adjustment of the differential balance. By this change the two resistors R_7 and R_8 also become more freely selectable for their function to determine the local feedback of the stage and the gain of the amplifier. They should be matched, so as not to cause additional asymmetry to be balanced out. It is the combination of f.e.t. and bipolar transistor pairs that gives the good input property, together with an easily variable amplification and a large bandwidth. Dual transistors must be used to reduce temperature drift, see later.

The mixing stage has been developed to a cascode configuration, which is very important with regard to harmonic distortion because the output voltage swing is large. It is also important that the Miller feedback capacitance is kept very low so that the loading on the preceding stage can be controlled as desired, and the amplifier as a whole be given sufficient bandwidth. The main local feedback is by means of the emitter resistors R_{13} and R_{14}, but they need not be matched as their counterparts R_7 and R_8, as the balancing action of R_{41} is amplified by the input stage.

Local feedback by the two impedances Z starts at a value of about 12dB for low frequencies, but increases within the frequency range 20 to 200kHz to about 26 dB. It forms the amplitude response as shown in Fig.5, curve A. The impedances Z do not cause any common-mode feedback but act together for the differential feedback, so they do not need matching for their action. However, matching is needed for the collector loads of transistors Tr_5 and Tr_6 for symmetry in driving the output valves. The two collector resistors R_{15} and R_{16} should be matched, and also the impedances as they also load the collectors.

As to the valve common-mode biasing, there are only two alterations from the simplified circuit of Fig.3. One is that the potentiometer for adjustment of the constant voltage part has been split up in two fixed resistors, R_{19} and R_{20}, and a 15-turn trimming potentiometer, R_{42} This makes the selection of resistances for a desired value of the amplification fairly easy, and provides for a smooth adjustment of the constant voltage. The other change, mainly for temperature drift is that the current source for the mixing stage, Tr_9 and Tr_{10}, is a complementary pair amplifier.

The gain as defined by Fig.2 is nearly 70, which means that the bias circuit corresponds to a common-cathode resistor of 350 ohms. A common-mode constant grid voltage of about +5V is added by adjustment of R_{42}. The quiescent grid-cathode voltage is about −45V and the valves work in class A.

A negative feedback that senses the differential direct voltages across the cathode resistors has also been added to the circuit. It consists of the matched resistor pairs R_{31}, R_{32} and R_5, R_6 together with the capacitors C_3, C_4. This feedback is coupled to the amplifier inputs and has an upper frequency limit of about 1Hz. It has the same stabilizing effect on the balance between the tube currents as two separate cathode resistors of 200 ohms, connected together in a long-tailed pair configuration but without influence on the common-mode bias.

All the above values are easily changed for desired bias conditions, but a general discussion of valve biasing is outside the scope of this article.

A capacitance of 22 µF was originally used for C_5, but is omitted in the circuit of Fig. 4. However, output triodes in class A with a high load impedance is the only case where the capacitance may be omitted to some advantage.

Response and distortion

The amplitude-frequency response of the complete amplifier is shown in Fig. 5: without feedback by curve B, and with 20dB overall negative feedback by curve C. The low-frequency response for small signals is flat down to 10Hz both with and without feedback. Exact curves showing the fall below 10Hz are not interesting, but it is possible to select a value for C_2 that gives an optimum response to square waves at low frequencies.

There is a dip in transformer response at about 50kHz, which cannot be eliminated by simple feedback circuits. It causes some ringing in square-wave tests, which of course has nothing to do with instability. The capacitance of C_6 in the feedback loop has, however, been chosen so large that it has a damping influence on the ringing. The series resistance of R_{36} has been chosen as a compromise to give about the same frequency response when loaded by a certain broadband loadspeaker as with a resistive load. A capacitance inserted as C_6 in the feedback loop without a series resistance often gives a good frequency response with a resistive load, but oscillations when a loadspeaker is connected. Its influence on the feedback must therefore always be carefully checked.

The branch R_{22} and C_7 between the

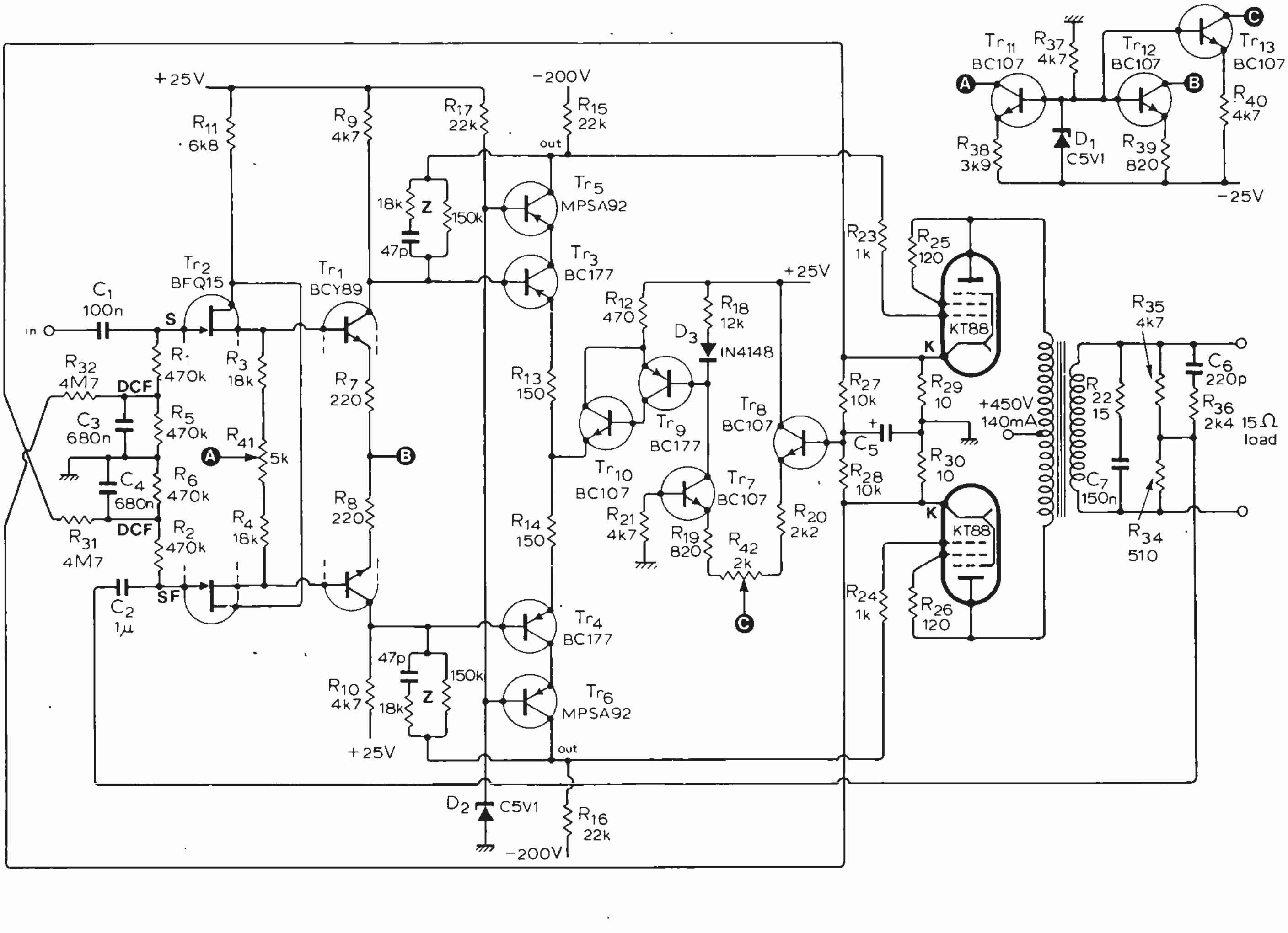


Fig. 4. Complete circuit diagram of the power amplifier. Valves work in class A as C_5 is made zero (see text).

output terminals has been found valuable with several output transformers, and is therefore recommended. It has no effect on the response within the audible band, but represents a resistive load at high frequencies. Values are not critical.

It has been an aim to choose about the same high frequency limit for the response without feedback as in the improved version design by Williamson to make a comparison of the final result fairly easy. It could be an advantage, however, to choose a lower high frequency limit by a change of the impedances Z.

Total harmonic distortion of the driver is quite low. For 30V r.m.s. output on each side it is only about 0.05% at low frequencies and rises to about 0.1% at 20kHz. This leads to a low distortion for the whole amplifier even without overall feedback: at 1kHz this distortion is only 0.08% for 10W and 0.2% for 15W output power.

The overall feedback works fully within the audible band, but the maximum output power falls at the low and high frequency ends. At a distortion of less than a quarter of a percent the available output power with resistive load is 20W at middle frequencies and 15W at 20Hz and 15kHz.

The total harmonic distortion, measured at 20Hz, 1kHz, and 15kHz and with an output power of 10 and 15W is summarized in the table below. The figures are given in percentage distortion, but include what there may be of hum and noise in the prototype amplifier.

Power output (W)	Total harmonic distortion (%) 20Hz	1kHz	15kHz
10	0.05	0.01	0.1
15	0.1	0.02	0.25

Circuit working conditions

In all d.c. amplifiers there is a temperature drift that must be taken account of. In this case there are really two, namely a common-mode drift in the biasing circuit and a differential drift for the signal path. Drift in the output valves is not considered.

An obvious cause of common-mode bias drift is the difference in change of base-emitter voltage with temperature for the transistor pair Tr_7 and Tr_8. The two transistors should be of the same current amplification class, BC107A in the prototypes, in which case the difference may be assumed to be 0.1mV/deg C at the most. The drift voltage is equal in its effect to a false reading of the direct input voltage on the base of Tr_8, and results in a corresponding shift of the anode currents of the valves.

If an ambient temperature change as large as ±20deg C is assumed, the false reading is not more than ±2mV, which is less than 0.3% of the above-mentioned d.c. input voltage, being about 700mV. However, the two transistors must be mounted close together, so that they experience the same ambient temperature change. Preferably they should be plastics transistors and clamped together, but a dual transistor is not necessary.

There is also a temperature drift from differences in the internal heating of the transistors, for instance at power supply variations. This is kept low by means of low collector currents. For the same reason the design assures a small collector current for Tr_9 in the current source, and the transistor drift is partly balanced out by D_3. The balance is not as good as for a couple of equal transistors, but here the drift is inside the feedback loop and has less influence on the valve currents, about one third of that of the preceding transistor pair.

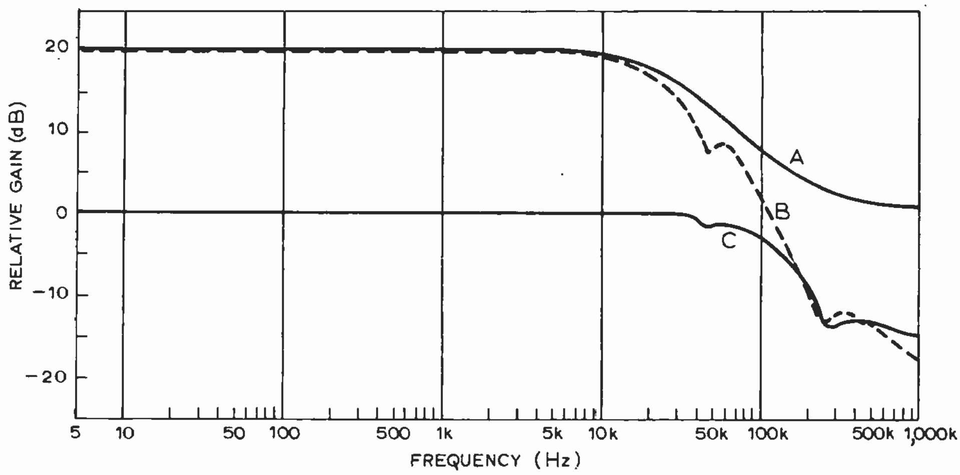
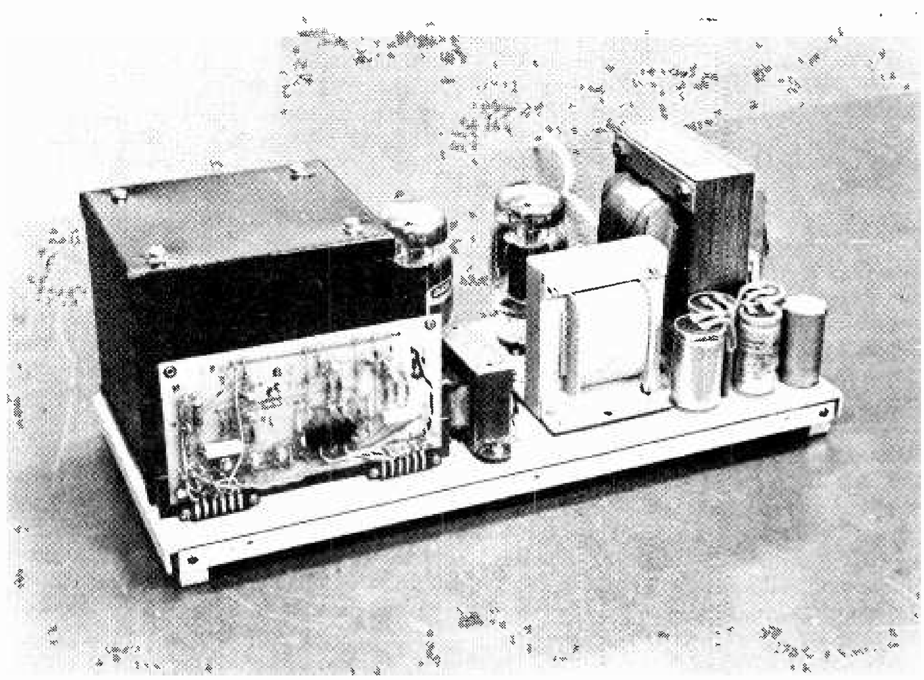


Fig. 5. Amplitude frequency response curves for the driver (A) and for the complete amplifier without (B) and with feedback (C).

The main cause of differential drift is the input dual f.e.t. Although its thermal drift of gate-source voltage difference for specified working conditions is less than 40μV/deg C, its drift in the circuit may be larger, on account of shifts of quiescent points. There is also up to 10μV/deg C drift in the dual bipolar transistor, and some additional drift from the transistor pair Tr_3, Tr_4. As a summation a temperature drift of up to 100 μV/deg C referred to the input of the amplifier will be assumed.

To find what the above drift means as a drift in quiescent current for the valves, the d.c. feedback from the cathodes to the input circuit will first be assumed inoperative. The differential voltage amplification to the grids is 450 and the transconductance is 10mA/V, which gives 0.45mA/deg C differential drift for the anode currents, or ±9mA for a change in temperature of ±20deg C. This is at the limit of what should be allowable, but, on the other hand, fairly wide limits as to the causes are assumed.

The picture of drift changes radically, however, if the d.c. differential feedback



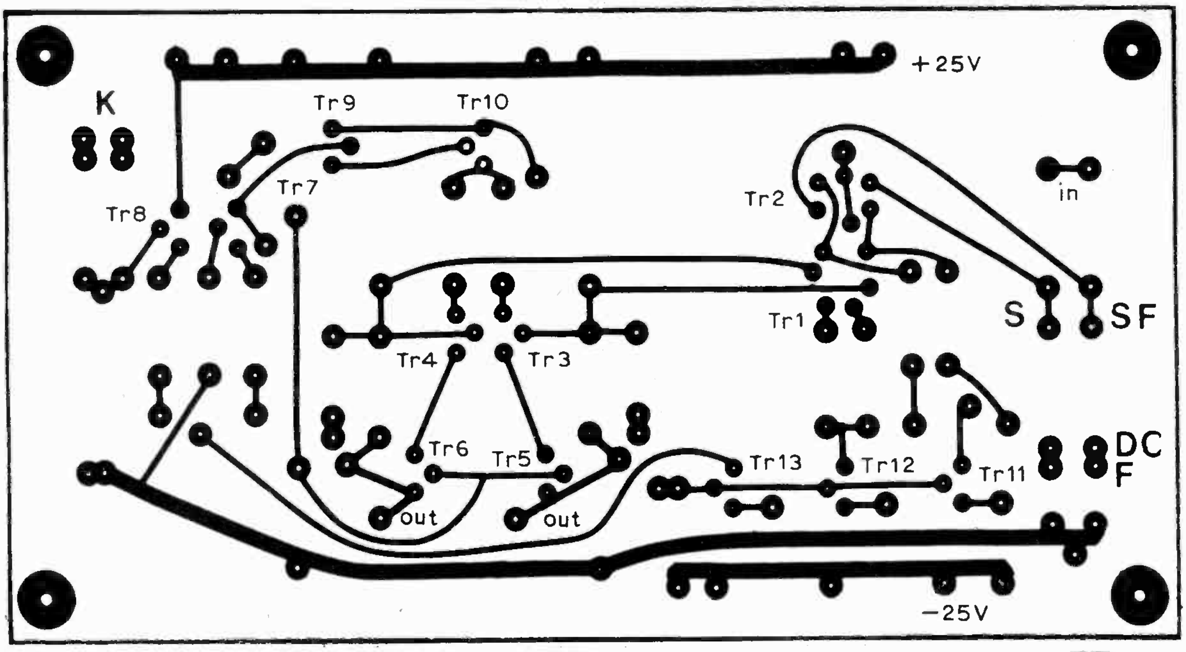


Fig. 6. Components in feedback circuits, R_5, C_3, R_6, C_4 and C_2 are not included on board; neither are R_{15} and R_{16}. Mono printed boards are available for £2 inclusive from M. R. Sagin, 11 Villiers Road, London NW9.

is inserted. The feedback is 14dB from d.c. to about 1Hz, and the above anode drift becomes less than ±2mA for a ±20deg C temperature change. The feedback also reduces d.c. drift from other causes, such as changes of component values with time. Its equivalence to a pair of separate cathode resistances has already been shown.

The above feedback may, on the whole, be regarded as a possibility rather than a necessity, and 14dB is certainly more than necessary. The time constant in the feedback circuit is so large that temporary deviations from symmetry in the signal (musical) voltage should not cause appreciable d.c. shifts.

Stabilization is needed for the negative high tension voltage, because a ±10% variation of this voltage would cause too large variations in the valve bias. A simple stabilization, for instance by means of a series resistance from a −300V supply feeding a chain of six 0.4W, 33V zener diodes is sufficient. The voltage is of course not critical.

Constructional details

The layout of the circuit on a printed circuit board or otherwise is not critical. It has already been mentioned that the two transistors of the pairs Tr_3, Tr_4 and Tr_7, Tr_8 should be mounted for close thermal connexion, and so should Tr_9 be with D_3. To avoid heating effects from the collector resistors R_{15} and R_{16}, mount them with the valves, and not on a p.c. board. The circuit should be mounted away from the mains transformer and filtering choke to avoid induced hum from stray magnetic fields. It should also be kept away from any hot air stream or heat radiation from the valves. These precautions do not cause any problem, as the circuit may be given fairly small dimensions. Simple metal shields have been used in the prototype amplifiers.

Five-percent resistors have been use, and for matched pairs a 2% difference is acceptable, although a closer tolerance may be required for the resistor pairs in the d.c. feedback, or the value of R_1 may prove not to be sufficient.

In a first construction, the d.c. feedback should be omitted, and put into effect only as a finishing touch.

For the positive and negative supply voltages of 25V in Fig. 4 the recommended values are 25 to 30V, but there is no need for symmetry. The value of collector currents for the cascode stage is 6 to 7mA. The currents of the other stages are evident from the values of the resistors R_{38}, R_{39} and R_{40}, since the voltage across these is about 4.3V.

Any transistor in the Philips BFQ10-16 family may be used at the input, and there are of course also other replacement types, for instance the Siliconix E401. There are also a number of replacements for the Motorola MPS-A92, for instance MPS-U60, BFT19 (RCA), and BFW43 and BFW44 (SGS-Ates). There are numerous replacements for BC107 and BC177, and also for the dual transistor BCY89, which is the least expensive of the BCY87-89 family.

Concluding remarks

One reason for the choice of KT88 valves connected as triodes was that they put high demands on the driver, and so are suitable for presentation of driver qualities. The same valves connected as pentodes or with a distributed load are more easily driven because the Miller capactiance is lower. An obvious conclusion is therefore that the driver should suit most power amplifiers except for very large ones that require several output valves in parallel.

The ratio between the negative high tension voltage for the cascode stage and the maximum grid peak-to-peak voltage is about two. When smaller output tubes are used, such as EL34, EL506 or EL84, the negative voltage should be lowered, but the above ratio not made smaller – a value between two and three is preferred. The collector currents for the cascode stage should be maintained, and the collector resistors chosen accordingly.

References

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Williamson, D.T.N. The Williamson Amplifier, A Wireless World publication, Iliffe & Sons, Ltd.

2. Ferguson, W.A. Design for a 20-watt high quality amplifier, *Wireless World*, vol. 61, 1955, p.223.

High Quality Sound Reproduction, Mullard Ltd.

3. How to Build the Osram 912-PLUS, General Electric Co, Ltd.

Heath, W. Ian and Woodville, G. R. "Design for a 50-watt amplifier," *Wireless World*, vol. 63, 1957, p.158.

Logic design course

Digital System Design is the name of a course to be held at Chelsea College, Pulton Place, London SW6, from May 17 to 21. This course is designed to give practising engineers and scientists a formal approach to the logical design of digital systems and should prove useful to those engineers and scientists working in the field of digital electronics who have had no previous training in methods of logic design. Enquiries should be addressed to Professor J. E. Houldin at the above address.

News of the Month

Mobile radio price fears

According to the Mobile Radio Users' Association, essential public services as well as commerce and industry will experience escalating equipment costs during the next ten years in the use of mobile radio. Proposals made by the Home Office in their preparations for the 1979 World Administrative Radio Conference — which will decide the amount of frequency spectrum required for the 1980s — suggest even greater usage of mobile radio frequencies now available.

Such measures "would entail vastly more expensive equipment and re-organization of the present allocated spectrum at a time when users are already experiencing increasing interference in the main conurbations, as well as being forced to share facilities." The Mobile Radio Users' Association is busy gathering support from its members to prepare a case for the allocation of more of the spectrum to mobile radio. They think that unless this is done, unfair and costly restrictions will be imposed on what is an essential cost-saving and efficiency-improving tool for the country, resulting in the "trebling of costs and the curtailing of growth within the industry."

BS9000 mandatory for military equipment

From February 1 the Ministry of Defence introduced a new contracts clause requiring electronic components used in the design of MOD-sponsored equipment to be approved within the BS9000 standards system. Any necessary exceptions will be kept to the minimum. Military forces rely heavily on electronic equipment, which they expect to function reliably under exacting conditions, and they therefore consider it essential to have an effective system of component specification and quality assurance.

The BS9000 series was formulated by the British Standards Institution in 1967, in collaboration with Government departments, industry and other users, to specify a range of electronic components meeting levels of quality assurance and performance acceptable for common use in industry and the military services. The Ministry of Defence has supported the scheme, believing that a national system offers greater benefits than one restricted to military requirements. In particular the larger volume of components covered by BS9000 permits economies in reducing wasteful proliferation of component types. Although the use of BS9000 components is growing, progress has been slower than originally hoped. Since the full advantages of the scheme will not be realised until BS9000 is more widely used, the Ministry of Defence is now taking steps to extend its application in the military equipment industries.

Union for engineers?

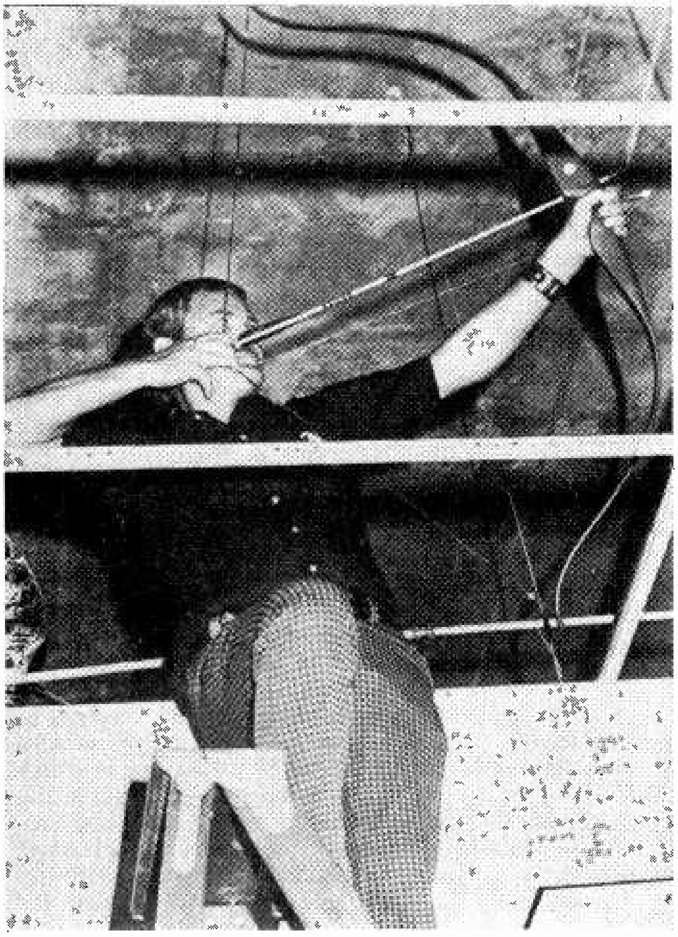
Professional engineers need a union, with strong and experienced leaders and affiliation to the TUC, according to Dr G. F. Gainsborough, secretary of the Institution of Electrical Engineers. Writing in the February issue of *IEE-News* he refers to a recent report* of a Council of Engineering Institutions working party which urges that engineers should join a union, and backs a suggestion that the Electrical Power Engineers' Association (EPEA) should change its name and constitution to make it representative of all engineering disciplines. The March issue of *Wireless World* (p.43) proposed rather a union to be formed on an industry-technology basis for technicians and professional engineers in electronics. (About half of the unions affiliated to the TUC are based on particular crafts, trades or technologies.)

*"CEI Professional Engineers and Trade Unions"

Direction finder for Cape Gris Nez

Following the successful completion of trials at Cape Gris Nez (between Boulogne and Calais) the French office of lighthouses and maritime signals has ordered a v.h.f. direction finder. The monitoring of shipping in the English Channel by radar has not proved itself to be completely satisfactory as the unambiguous identification of ships is not immediate enough and presumes among other things the manoeuvrability of the ships and that the v.h.f. communication channels are not too crowded. This led to the additional use of a v.h.f. direction finder which was tested out for the task. In contrast to other identification aids, direction finders possess the advantage of requiring no extra aids on board ships except the v.h.f. radio systems which most ships have anyway. Also, in the case of emergencies they can immediately provide the exact position of disabled ships. The Rohde & Schwarz NP7 direction finder used works in the frequency range of maritime radio (156 to 162 or 174MHz) and delivers bearing values with a maximum deviation of only one degree. The NP7 operates on the Doppler principle and uses an antenna system made up of 32 dipoles arranged on a circle plus one antenna in the centre. An antenna commutator simulates the rotation of a single antenna on this circle. The bearing indicator automatically provides a three-digit display of the direction to

In the new Radio London Studio, Marylebone High Street. Picture shows d.j. Robbie Vincent at his control desk.



Not the latest electronic guided weapon but Jim Taylor, an installation supervisor for General Telephone and Electronics Company of Florida who resorts to the bowman's ancient art whenever he has to install telephone lines in inaccessible places.

the transmitter target, the measured value being averaged over 180 simulated rotations of the d.f. antenna.

TV goes underground

Platforms on the new Heathrow Central underground station at London Airport will be monitored with a closed-circuit TV system. This will allow London Transport observers at Earls Court station to view the platforms at the last three stations on the new Piccadilly Line extension – Heathrow Central, Hatton Cross, Hounslow West. The installation consists of a single coaxial cable linking all stations along the line and control cables for switching the selected cameras at the different stations to two monitors at Earls Court. The installation contract, awarded to British Relay TV Ltd, covers video-switching and modulating equipment at the "observed" stations, amplifying equipment for picture transmission, at h.f. and the receiving and switching equipment at Earls Court. The system is capable of carrying three vision channels in the 3 to 30MHz frequency band.

Sun-tan for components

A solar radiation simulator is in use at the Product Assessment Laboratories of Plessey in Titchfield. The simulator has been introduced to meet new specifications which have been laid down by the International Electro-Technical Commission and the British Standards Institution. Artificially created sunshine can be applied to test samples to determine their ability to withstand both visible and invisible radiation in natural sunlight. The simulator will show the effect of u.v. radiation on rubbers and plastics such as cable forms and plastic assemblies and will also create a temperature rise in equipment to enable designers to check solar radiation protection and the operation of cooling systems. Electronic trackside railway signalling equipment is under investigation at the Plessey laboratories and the facility is expected to be widely used in testing virtually anything that stands in the open air. The sun simulator is claimed to be able to reproduce the worst solar radiation conditions throughout the world.

Secondary radar for MRCA

A secondary radar data display system to be installed at British Aircraft Corporation's military aircraft division flight test centre at Warton is scheduled to be in service within ten months, serving BAC and the development flying programme of the Multi-Role Combat Aircraft. The design of the system is claimed to provide an economic solution to the surveillance and control problems of any small airfield with radar facilities. It will also increase air safety by providing additional flight data to the air traffic controllers at Warton where full flight envelope testing of supersonic aircraft takes place relatively close to civil air lanes and the busy Manchester control zone.

At present, the air traffic control unit at Warton relies solely on a Marconi S264 primary radar, backed up by a precision approach radar. This has recently been improved by the addition of a digital signal processor and provides primary cover up to a distance of 160 miles. The secondary radar data display system, to be provided under a new contract to Marconi Radar Systems, will take this primary information in its new form and present it to the controller combined with secondary and primary extracted radar data obtained via landline from Civil Aviation Authority's St Anne's facility about four miles away. The ability to revert to a local primary picture is retained. The facilities available at each radar display position include raw local primary radar data, video and digital map data, reference marks, emergency indications plus full control over range, off-centre and presentation parameters.

Colour TV deliveries for '75

Deliveries to UK distributors of UK made and imported colour television receivers reached 150,000 in December, a fall of 7% on December 1974, according to the latest statistics compiled by the British Radio Equipment Manufacturers' Association. This brought the total for the year to 1,590,000, a fall of 28% compared with the same period in 1974. Total monochrome set deliveries for December were 67,000, an increase of 52% compared with December 1974; this brings the year's total to 938,000, a 15% increase on the same period of last year. These figures include deliveries to rental and relay companies.

Leeds electronics exhibition

Visitors to the 1976 Leeds Electronics Exhibition will be able to hear about current technology and applications of microprocessors. Three lectures on this subject are being arranged for day two of the show and one lecture for day three. Also in the programme of lectures which traditionally accompanies the Leeds show is one on switched mode power supplies. The exhibition will take place in the Department of Electrical and Electronic Engineering at Leeds University on June 29, 30 and July 1.

Communication theory

1 — Information is finite

by D. A. Bell

University of Hull

A generation ago one might have said that *language* was one of the main features distinguishing man from the animals. But now it is known that most animals, from chimpanzees to bees, have systematic methods of communication by sounds and gestures; and the unfortunate person who is deaf and dumb (and therefore would a few centuries ago have been regarded as stupid) can communicate by "deaf and dumb language." All of this goes to show that communication can be effected by various means; and the superiority of human speech lies in its speed and flexibility which enable it to convey a very wide range of messages, including abstract ideas.

The introduction of the word *idea* is a cue to point out that the communication or information theory of engineers is not concerned with "ideas": it handles only "messages." This might sound like a severe limitation but in fact it is not, since any set of words, for example, can be regarded as a message; and the "set of words" might be the Bible, the collected works of Shakespeare, or the works of your favourite science-fiction author. By choosing a set of words we have made the number of possible messages finite in the mathematical sense though inconceivably large: there are some 35,000 words in an English dictionary so the number of different sets of, say, 100,000 words is rather more than 10 to the power of 400,000. If I assume that every reader has a copy of the Concise Oxford Dictionary (5th edition, 1964) I can represent any word by a code of the form $n_1\ a\ n_2$ where n_1 is the page number, a is L or R for left-hand or right-hand column and n_2 is the serial number of the word in the column. The opening words of this article would then be represented by: 1L2 509R4 26L13 544R7 767L6.

This is very clumsy and time-consuming as it means looking up every word in the dictionary (though I am sure one would soon get to recognise the codes for common words, like 1L2 and 544R7) but it has several noteworthy features:

(1) It reminds us that communication requires that sender and receiver agree on the code to be used, even if only on a common language.

(2) It is more precise than words. 767L6 in the dictionary reads "might[2]. See MAY [1]", thus distinguishing it from "might[1]" meaning great strength.

(3) It illustrates the point that words may be represented by all sorts of different symbols during the process of communication.

(4) From the sample given above it would appear that the typical length of a code group is 5 characters, which compares with 5 letters for an average English word. But 4 of the 5 characters are now numerals in the scale 0-9 and the fifth has only two values, L or R. So there is some economy.

It also makes it clear that we are talking about the kind of communication which consists in selecting in turn particular signals from a known set of signals or code; and the kind of information which can be communicated in this way is called selective information. Now most of the information we handle is of this kind: the current price of gold; which of the national contestants became Miss World; which premium bond drew a prize; which airline has just had a plane crash; what are the frequencies and times of BBC stereo broadcasts. These are all questions which can be answered by drawing a particular number or name from the range of numbers and names which was known to exist, and less specific or more complex information can be communicated by a more or less lengthy series of words selected from the dictionary. New ideas, on the other hand, cannot always be specified definitively by existing words or groups of words and may have to be assimilated gradually from the context in which new words or phrases are used. If I look in the dictionary for "meaning" I am referred to "significant" and vice versa. But under "bread" I find "Flour moistened, kneaded and baked, usually with leaven". Thus a concrete object can be broken down into its components or alternatively it can be described in terms of shape, colour, texture etc.; but an abstract idea like "meaning" can only be learned through experience of the way in which the word is used. It is also a prime principle of communication theory that one should not communicate information which was already known; this means that the amount of information transmitted is measured by the *increase* in amount of information possessed by the recipient. The method of measuring the amount of information will come later.

Communication is never absolutely certain. The hi-fi enthusiast may ask for "perfect" reproduction, but the engineer knows that at least there will be Johnson noise in the circuits, with power kTB* in bandwidth B. So the engineer must ask "How good is good enough?" Ask him for 60, 70 . . . . dB signal-to-noise ratio and he will tell you whether it is possible and how much it will cost; but ask him for perfection and he will either shake his head or decide for himself what standard the customer will accept as perfect. But if we are communicating only selections from a finite set of signals, it is obvious that the s/n ratio required is just enough to prevent one signal being mistaken for another. This idea is usually illustrated by the analogy of representing the several signals by points in space. (It has to be multi-dimensional space with a large number of dimensions.) These points have to be far enough apart that when the co-ordinates of one of the points are given then in spite of the noise in the system a seeker armed with the co-ordinates will arrive within reach of the desired point and of no other. The sort of practical problems to be solved by communication theory are therefore as follows.

(i) Given a set of messages (of known number) from which selections are to be communicated through a channel of given bandwidth and s/n ratio, what are the best shapes of signal to use to represent the messages?

(ii) With the conditions in (i), what will be the reliability of communication, or

*k = Boltzmann's constant and T = circuit temperature.

how should the conditions be altered to achieve some specified standard of reliability?

(iii) How does speed of communication tie in with everything else?

Ignoring derivations and proofs, we can answer questions (ii) and (iii) by quoting Shannon's key formula

$$C \leqslant W \log (1 + P/N) \qquad (1)$$

which is part of the following theorem: By a sufficiently complicated method of encoding it is possible to communicate information at any rate up to C through a channel of bandwidth W and ratio P/N of signal power to noise power with negligible risk of error. This is the channel capacity theorem. Note that this evades question (i) by postulating "a sufficiently complicated system of encoding." The hypothetical system of coding which allows the equality sign to be used in formula (i) is called "ideal coding." Much effort has been devoted to the search for coding methods which approach this ideal. Another point is that where we have loosely said "with negligible risk of error" one should ask "negligible in comparison with what?" To be precise, Shannon showed that the risk of error may be made as small as we wish by making the signals long enough in time. There are therefore advantages in putting the formula in symmetrical form

$$I \leqslant T W \log (1 + P/N) \qquad (2)$$

where I is the amount of information transmitted in time T.

T can be measured in seconds, W in hertz and P/N is a ratio (e.g. of watts); but we have not yet any measure of I. Now any information can be communicated, between two people using the same code book, by a sufficient number of yes/no questions. This was noted by Francis Bacon in 1623 when he devised a code in which each letter of the alphabet was represented by five binary symbols and said that "And here, by the way, we gain no small advantage, as this contrivance shows a method of expressing and signifying one's mind to any distance by objects that are either visible or audible – provided only the objects are but capable of two differences, as bells, speaking trumpets, fireworks, cannon etc."

A simple example is that about 16 binary decisions should suffice to locate any word in the Concise Oxford Dictionary if I start with first or second half, quarters, eighths . . . and finally down to fractions of a page. (I have to say "about" because the number of pages is not a power of 2 and the number of words per page is not uniform; the Dictionary was not designed for this exercise!) It follows that (selective) information can always be expressed as an equivalent number of binary units; and I in (2) is measured in bits or C in (1) in bits per second. But this is not the whole story. If a "sixteen questions" guessing game with the dictionary leads me to the top half of the right-hand column of p.943 I shall think that the word I am seeking is likely to be *pompous* or *pond*, but unlikely to be *pompano* or *pompier*, for example. So the measure of the amount of information which is communicated must take account of the pre-existing probabilities and not merely absolute certainties; and we now take the view that the amount of information communicated is related to the reduction in uncertainty or to the extent to which it allows a reassessment of probabilities at the receiving end of the channel. It can be shown mathematically that the only satisfactory measure of the uncertainty related to a finite group of probabilities is the *entropy*

$$H = -\sum_{i=1}^{N} p_i \log p_i \qquad (3)$$

where the p_i are the individual probabilities in a set of N distinct probabilities. Since probabilities are by definition less than unity, each log p_i is a negative quantity and H is positive.

Entropy has significance in thermodynamics and statistical mechanics, but the exact relationship between the different applications of entropy need not concern us. It suffices to say that entropy is always associated with ideas of disorder, confusion or indistinguishability of one state of a system from another. It is therefore natural to associate it with uncertainty and use reduction in entropy as a quantitative measure of information.

So far as we are concerned, H in formula (3) is just the weighted mean of all the logarithms of the probabilities, each logarithm being weighted with its own probability of occurrence, and it can be measured in bits. (Readers are probably familiar with the transformation from common logarithms ($\log_{10}$) to natural logarithms ($\log_e$) by multiplying by 2.3. Equally one can work in logarithms to base 2 and if the units in formulae (1), (2) and (3) are bits it must be understood that the logarithms are ($\log_2$). An important property of H is that it has a maximum value of $-\log p$ when all p's are equal and is zero if one probability is unity and all others zero. For if one probability $p_k = 1$, $\log p_k = 0$ and all the other $p_i = 0$; so $\Sigma p \log p = 0$ when one possibility can be selected with certainty.

For a simple application to a communication situation, suppose we are watching a Telex machine which we know is going to print a string of letters. Before a letter is printed there is a probability of 1/26 for each letter of the alphabet and $H = -\log_2 (1/26) = \log_2 26 = 4.7$ bits. If the letter Q is printed, $H = 0$ for this letter; and the information attributed to the communication of one letter is equal to the reduction of entropy of 4.7 bits. But if instead of "a string of letters" the Telex output was known to be English language text, the appearance of Q would be quite improbable but the appearance of E would be probable. This prior knowledge of probabilities constitutes information which we already have at the receiver and thereby reduces the amount of information which has been communicated. This is allowed for by recalculat-

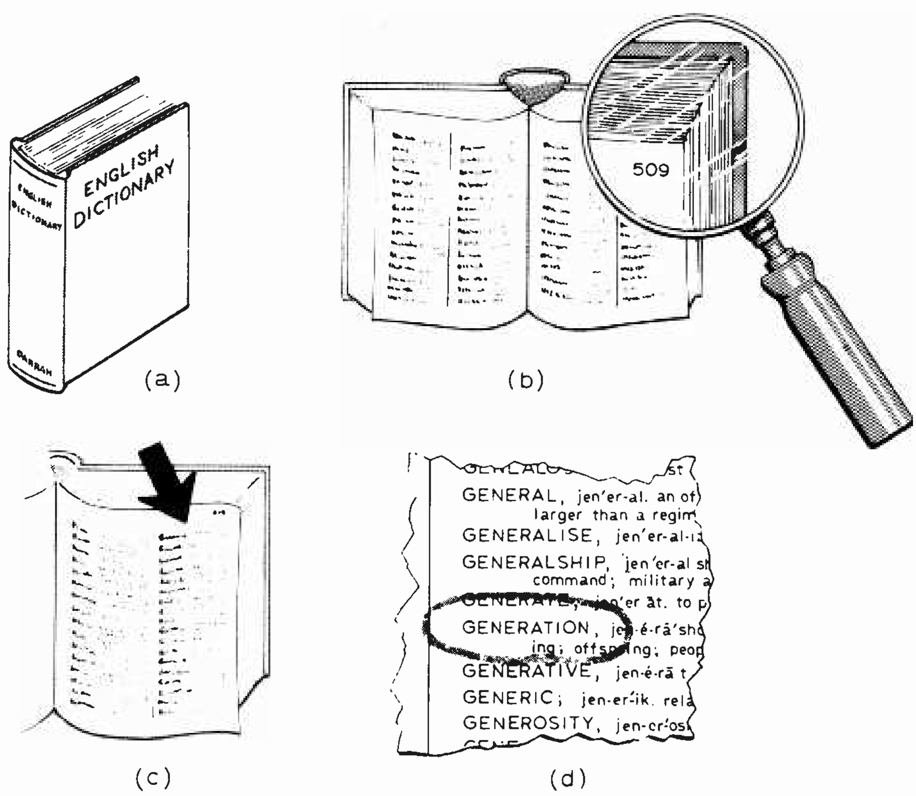


Fig. 1. Identification of a word: (a) the dictionary, (b) the page number, (c) the column, (d) the word.

ing the value of H before the letter was received, putting the English-language weighting for each letter in the formula

$$H = -\sum_{i=1}^{26} p_i \log p_i \qquad (4)$$

This will necessarily be less than the maximum value obtained when all the p's are equal and therefore its reduction to zero will represent less increase in information. (Actually the entropy of the English-language-weighted alphabet of 26 letters is reduced only to 4.3 bits per letter.)

But now let us look at the line engineer's view. Each letter is represented by five units (plus some synchronising pulses), and the receiving equipment must be set up with a threshold which decides between mark and space for each of the five units. Suppose the line is noisy so that there is a 10% chance that any one (but only one) of the units will be incorrectly interpreted. Then 5 letters which differ in one unit from the letter sent will each have a $(1/5) \times 0.1$ chance of being printed and the entropy after receipt of the noisy signal will look like this:

$$H = -\Sigma p \log p = -(5 \times 0.02 \log 0.02 + 0.9 \log 0.9) \qquad (5)$$

In binary units this is 0.701 bits. The information transmitted is the difference between the uncertainty before and the uncertainty after transmission, which in this case with English language is nearly 3.6 bits. So now we are able to measure the amount of information which is communicated even when noise in the channel means that nothing is certain. An important result of applying formula (3) to a binary channel ($N=2$) is that a 50% error rate means zero communication of information. For if when 1 is received the chances are 50 – 50 whether 0 or 1 was transmitted, one might as well toss a coin at the receiver and dispense with the communication channel.

Now we have admitted that there will always be noise in the communication channel. If it is random noise it may have any value of instantaneous amplitude up to infinity, but for just over two-thirds of the time it will not exceed the r.m.s. value. How can we reconcile this presence of occasional noise amplitudes which are many times bigger than the r.m.s. value with the channel capacity theorem?

That there is a real problem is shown by the following very crude and approximate interpretation of formula (2). If the signal-to-noise ratio is good, $1 + P/N \approx P/N$ and the *amplitude* ratio is approximately $\sqrt{(P/N)}$. The logarithm of the square root is half the logarithm of the original quantity, so

$$I \approx 2TW \log [\sqrt{(P/N)}] \qquad (6)$$

Now $2TW$ is the number of independent pulses that can be associated with the time-bandwidth product TW and in the

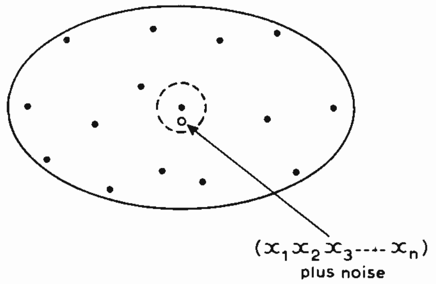


Fig. 2. The distance between signals must be greater than the likely effect of noise.

absence of noise digital information can always be expressed in the form

$$I_D = n \log S \qquad (7)$$

where n is the number of digits and S the number of states or amplitude levels for each digit.

Comparing (6) and (7), the channel capacity theorem seems to be saying that the number of amplitude levels can be spaced at intervals equal to the r.m.s. noise; but the instantaneous noise exceeds the r.m.s. value for about one third of the time, so how can errors then be negligible? The answer is in the first few words of the theorem "By a sufficiently complicated method of coding . . . " A proper derivation of the channel capacity theorem is fairly mathematical, and the further one goes in search of "ideal coding" the more one gets entangled in mathematics; but there are two principles which can be stated non-mathematically:

(1) Since the number of messages is finite, one has only to choose a finite set of signals which are sufficiently different from each other that even in the presence of noise one is unlikely to pick the wrong one. (This difference is often called the "distance" between signals.)

(2) A single instantaneous amplitude of noise may have a large value, but it is unlikely that a number of instantaneous values in succession will all have large values, and the more samples you take the nearer their average† will come to what we regard as the r.m.s. value of the noise.

An example of the second principle is that if you listen to the audio output from a high-gain receiver you will hear noise because the ear can respond to pulses lasting only one tenth of a millisecond; but if you connect an a.c. voltmeter with a response time of about a second, it will probably give a perfectly steady reading. This is because it will have averaged the noise over a TW product of about 10,000.

So "ideal coding" requires first that you construct signals with sufficient mutual differences (or distances) and second that you both construct signals which require a large value of TW and wait until the whole of a signal has been received before you try to identify it. Thus in principle ideal coding involves delay; but if W is of the order of kilohertz then T, and hence the delay, need only be of the order of a second to make TW large.

More recently the question has been put, "Supposing I do exceed the channel capacity defined by formula (1), how bad will the system be?" If we regard all differences between the received and transmitted signals as distortion, it is possible to formulate a relationship between the amount of such distortion and the rate of communication. The latter must take account of the fact that information is not received with certainty. For each received symbol one has only a set of probabilities of the various possible transmitted symbols; and in general different symbols may be made to have different probabilities of error. There results a rather complicated mathematical function called the *rate distortion function* which relates the rate of communication which can be achieved to a specified degree of distortion.

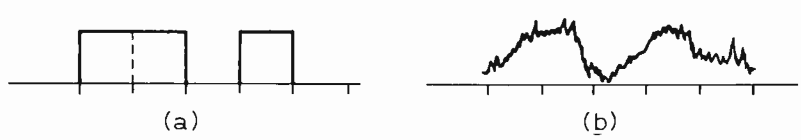
All that we have said so far about finite sets of messages seems to apply readily to telegraphy, where digital signals are natural, but what about telephony, television etc. when the signals are basically in continuous analogue form?

The answer is that continuous analogue signals may be reduced to discrete form by the two processes of quantizing in amplitude and sampling in time. No magnitude is ever known with absolute precision so it can always be equated to the nearest of a number of fixed levels if the latter are at close enough intervals. This process of equating to a pre-selected value is known as quantizing, and is no different from expressing a magnitude by a figure taken to a finite number of decimal places. The fineness of quantizing – the number of decimal places in the analogy – is chosen to give the desired accuracy. The other operation which is needed is sampling in time.

It was mentioned in connection with

†Strictly speaking this "average" must be the root-mean-square value of the samples and what we normally call the r.m.s. value of the noise is that which we should obtain with an infinite number of samples.

Fig. 3. (a) signal transmitted, 11010; (b) signal received, 11010 or 11011?



formulae (6) and (7) that the maximum rate at which independent pulses can be transmitted through a channel is two per unit of time-bandwidth. This is often called the Nyquist rate, since it was stated by Nyquist in relation to telegraphy in 1928* An equivalent statement in very general terms due to Gabor** is that however one may try to construct a minimum signal element it will obey the law

$$\delta f . \delta t \geqslant \tfrac{1}{2} \qquad (8)$$

where the equivalent extent of the signal in bandwidth and time, δf and δt, is measured by a statistical formula which can be applied however fast or slowly the signal is cut off in frequency and in time. This is mathematically true because the frequency spectrum of a signal is the Fourier transform of its time waveform; but the cut-off points equivalent to this δf and δt do not correspend in any way with 3dB points. Gabor's theorem of the minimum signal is in close analogy with Heisenberg's principle of indeterminacy in physics, which is generally written as $\delta p.\ \delta q \approx h$ where h is Planck's quantum and p and q are a pair of conjugate co-ordinates of a particle such as its momentum and position.

The counterpart of the rule about pulse rate is that any waveform of which the Fourier components can be contained in a bandwidth W and of which the duration is T can be reconstructed unambiguously from $2WT$ suitably chosen samples. This is the sampling theorem. If the waveform corresponds to a low-pass band from 0 to W hertz, then evenly spaced samples at two per cycle of the highest frequency are suitable. (This is the form of the sampling theorem which is most commonly used. Other arrangements of $2TW$ samples are possible, and a different sampling pattern is needed for bandpass signals.) The original waveform is reconstructed if the nth sample of amplitude a_n causes the receiver to generate a unit waveform

$$a_n \frac{\sin \pi (2\omega t - n)}{\pi (2\omega t - n)}$$

This method of reconstructing the waveform is open to criticism in theory, though in practice it is good enough provided that TW is large. The difficulty is that the waveform $(\sin x)/x$ extends from $x = -\infty$ to $x = +\infty$ so no one of the waveforms used for reconstruction can be completely contained in the time interval T. But the function is small for x outside $\pm 4\pi$ so the imperfect reconstruction is noticeable only in the neighbourhood of the first and last samples, and this is unimportant if TW is large. Assuming for the moment that formula (1) is of general application, it says that for a given communication

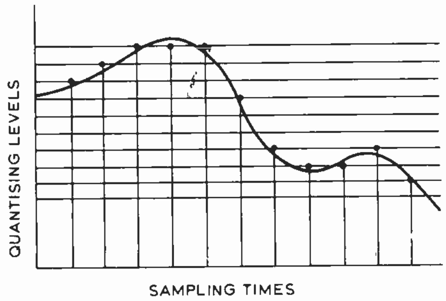


Fig. 4. Digitising a waveform.

rate one can change bandwidth provided one adjusts P/N accordingly, and vice versa. This is a qualitative retrospective justification of systems like f.m. where for a given output the carrier signal-to-noise may be allowed to drop in exchange for the use of a greater bandwidth. The idea of exchanging bandwidth against signal-to-noise was not obvious while we were always thinking of hi-fi transmission of the original sound or other waveform. But it arises naturally from the Shannon approach of communicating signals from a finite and pre-arranged set instead of arbitrary waveforms.

Thus we have shown that information is an objectively measurable quantity; and in consequence communication channels can be designed in terms of the communication of information rather than of the faithful transmission of waveforms.

(Next article: redundancy and the exchange rate)

*H. Nyquist, "Certain Topics in Telegraph Transmission Theory," *Trans. A.I.E.E.* vol. 47, p.617, 1928.

**D. Gabor, "Theory of Communication," *J.I.E.E., Part III*, vol. 93, p.429, 1946.

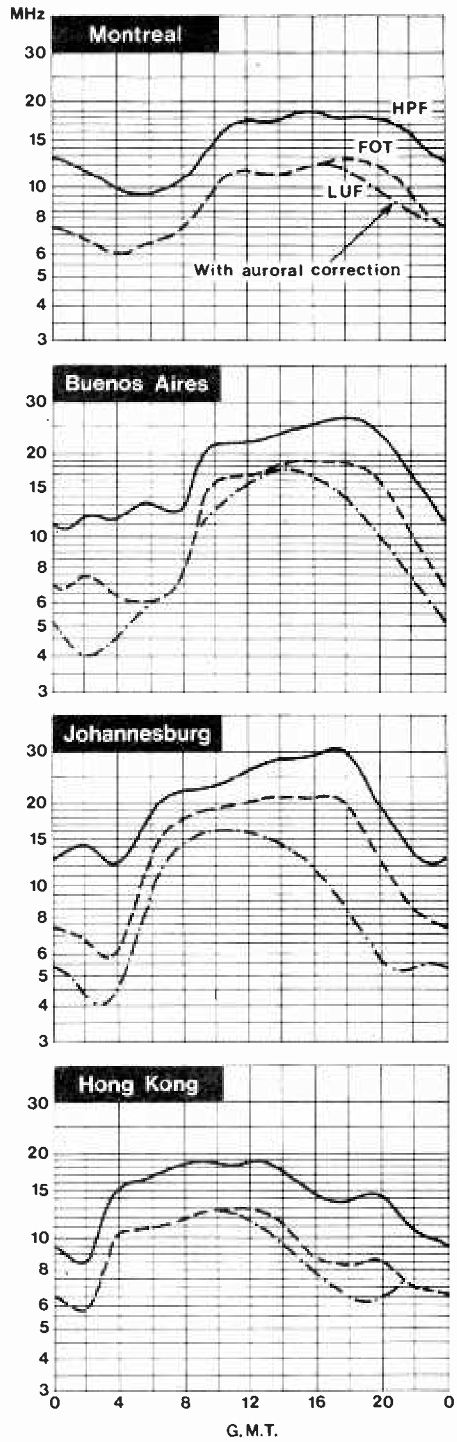
Sixty Years Ago

The following extracts from the April 1916 issue of *Wireless World* were drawn from an informative article by Wm. S. Purser entitled The Banjo – A Pastime for Wireless Operators. "One of the popular fallacies regarding the banjo is that one has to have a black face and sing nigger songs . . . . Some talk has been heard in the past of elevating the banjo, and playing classical music upon it . . . . The banjo may be regarded as symbolical of good fellowship . . . . When purchasing an instrument select a British-made *ordinary* banjo and you will have a reliable article which will stand any climate . . . . Do not be misguided by the expression 'Anything will do to learn on'. The banjo should have five strings . . . . Wireless operators and others going on voyages or to out-of-the-way places should purchase strings by the dozen. Having decided on your brand of strings, always get them from the same place . . . . After gut strings have been exposed to the sea air for a long time on the instrument they gradually turn green". Follow that.

HF predictions

There are no signs of vigour in current solar activity and expectations of an established upward trend by the end of the year seem optimistic at present.

Seasonal changes in highest probable frequency (HPF) and optimum working frequency (FOT) curves become evident this month and magnetic disturbances are likely to occur over March 14 to 19 and April 10 to 15.



FM tuner designs

2 — Improved performance; further facilities

by D. C. Read, B.Sc.

Changes which provide the tuner described in part 1 of this article with some additional control and monitoring facilities and a more flexible input circuit are shown in Fig. 5. The extra gain-controlled r.f. stage comprising the dual-gate m.o.s.f.e.t., Tr_{10}, can be arranged to function in different ways according to local reception conditions. Two alternatives are illustrated in the circuit diagram by the indicated possible connection of a 10kΩ resistor between Tr_1 source and the positive supply rail. Circuit operation is as follows.

With 10kΩ resistor. The stage produces either a gain (maximum 6dB) or a loss (maximum 12dB) under the control of the a.g.c. voltage returned from the i.c. This division into two control regions makes the most efficient use of the available 18dB a.g.c. range whereby large incoming signals are reduced in level to prevent oscillator pulling but weak signals are given low-noise amplification before the LP1186 r.f. and mixer stages, so that the noise these produce is added in smaller proportion.

Without resistor. The stage gives low-noise gain with a value between zero and 12dB again depending on the a.g.c. voltage. This arrangement is suitable for tuners used in fringe areas where received signals are low; i.e. where increased sensitivity is required and high-level incoming signals are not normally encountered.

A further possibility makes even more effective use of the m.o.s.f.e.t. characteristics but at the expense of added complexity, particularly in setting up. If the Tr_{10} source is held at a fixed voltage, say by means of a low-value zener between it and the 0-volt rail with a current feed via a resistor to the positive rail, then the a.g.c. range is extended because the source-follower feedback action which modifies the effect of the control voltage on gate 2 is inhibited.

The spread of characteristics for f.e.t. devices is such that, without this stabilizing feedback, the bias on gate 1 needs preset adjustment to give maximum gain for weak signals. In practice the required bias is easily set by connecting gate 1, actually the earthy end of the input coil, to a variable tapping in a high-resistance potentiometer chain across the zener. Then, with the a.g.c. voltage on gate 2 at its most positive value, the bias is varied until the highest possible stage gain is obtained. The likely performance of such a circuit is a maximum gain of 16dB and a control range of 25 to 30dB.

The circuit which includes the LP1186 module and the impedance-matching stage, Tr_2, is largely as in the simpler version, the only difference being an additional resistor in the a.f.c. feed. The choice of value for this component, which determines a.f.c. sensitivity, is dictated by local reception conditions. High sensitivity is given with the value at 47kΩ as shown in Fig. 5. If equal-strength neighbouring-channel signal[s] are present, the degree of control migh[t] be too great such that the tuner could [b]e captured by an unwanted station as t[he] local oscillator sweeps through t[he] relevant frequency while changing [to] select the wanted station. If this occ[urs] reduce the resistor value, possibly t[o as] low as 5kΩ, which still allows a u[seful] amount of control.

Because of the extra gain now [avai]lable at the tuner front end and [in] the CA3089E module, the i.f. am[plifier] IC_2 is not required and the [input] impedance for F_2 is provided ins[tead by] a grounded-base stage, Tr_3.

● The simpler version described in part 1 comprises tried and trusted circuits, up-dated with refinements intended to make construction, line-up and operation easy; stability and utility are the essential features. The overall design is flexible, and various special facilities can easily be added either during or subsequent to the main construction. These extras include:

—a twin tuned-circuit demodulator which reduces harmonics in the recovered multiplex signal but which needs proper adjustment using a wave analyser or distortion meter
—a stereo-inhibit switch which allows mono reception of weak stereo signals thus giving a 20dB improvement in signal-to-noise
—a buffered and de-emphasized mono feed derived before decoding and intended for tape-recording
—low-pass audio filters to remove unwanted components from the tuner outputs, useful for tape recording either stereo or mono
—a tuning-indicator circuit.

● The more advanced tuner can be provided with any or all of the additions listed above; it also shows further refinements, some optional, which give improved performance in certain respects but which increase the number of necessary adjustments both in setting up the tuner and in its normal operation. These modifications and additions are:
—an extra gain-controlled r.f. stage giving increased sensitivity and stability, and improved signal-to-noise performance. The design of this stage also allows different a.g.c. characteristics to be chosen either as a result of fixed circuit changes or subsequently by adjustment of a panel control to suit various reception conditions
—a more comprehensive a.f.c. system which, like the a.g.c. circuit, can be varied in its effect under external control (R_9 could be a front-panel variable resistor)
—a received signal-strength meter circuit with calibration curve. This meter feed could also be used for stereo-threshold switching.
—adjustable inter-station muting.

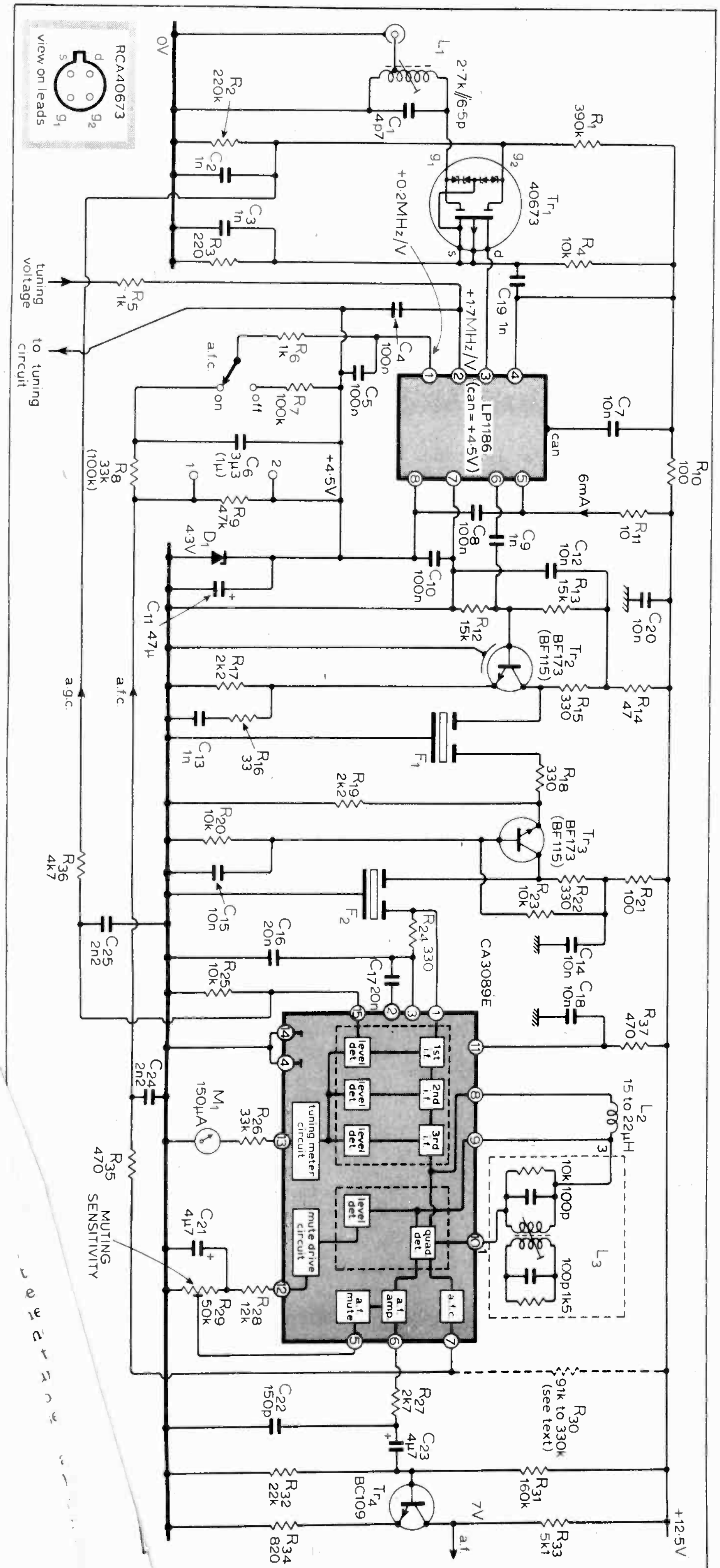


Fig. 5. Improved performance at low signal levels is obtained with this circuit, which uses the tuning and decoder circuits of Fig. 1. Sequence of connections for Tr_2 is b, e, c, screen (on-lead view). On the CA3089E pin 8 corresponds with the tag location.

Although the RCA limiter/demodulator circuit is more complex than its TAA661B counterpart it operates in a similar manner, using an inductive carrier feed to obtain the quadrature reference phase and has the optional dummy tuned circuit to improve linearity of the transfer slope. The external circuit differences mainly concern the use of additional facilities provided by the i.c. Because the a.f.c. signal is derived from a push-pull, open-collector current source in the CA3089E circuit, it is possible that the equal and opposite current condition in a given sample of the i.c. does not occur precisely at the middle of the demodulator S curve. In such a circumstance, a small correcting bias can be provided through a resistor with a value in the 91 to 330kΩ range, connected either to the positive rail, as shown, or to 0 volts, whichever is appropriate. To find the required value and the appropriate supply connection point for this resistor, a method similar to that already described for matching the a.f.c. offset voltage in the simple tuner is suggested; in this instance, however, the S curve is sampled by measuring the voltage across the 150pF capacitor in the pin 6 output circuit.

The completely off-tune condition is used to find the particular voltage value which represents the effective S curve centre and this is then established by tuning to a strong station. Now connect the meter across the a.f.c. sensitivity-controlling resistor, R_9 (points 1 and 2). With the a.f.c. switch off, vary the bias to pin 7 until the measured voltage is zero and remains so with the a.f.c. on. (Note that, as the a.f.c. drive is from a constant-current source, there is automatic compensation for the supply voltage – offset at pin 8 of the LP1186.)

The varying voltage output from pin 13, shown as the meter current curve in

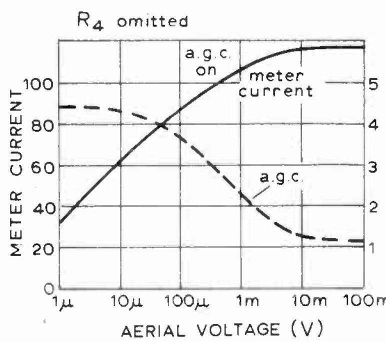


Fig. 6. Curves showing a.g.c. performance and meter current, taken with R_4 omitted. Delayed a.g.c. voltage is at pin 15 on CA3089E.

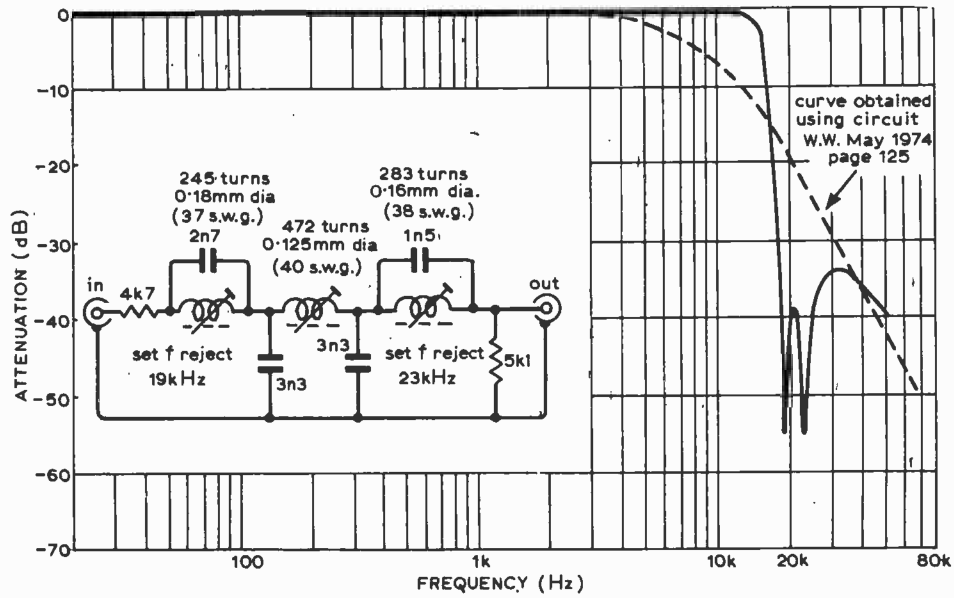


Fig. 7. Double notch output filter option. Inductors wound on 14mm Mullard Vinkor assembly, with Ferrox core violet type LA1228. Filter, which has a 6dB loss, should have 25kΩ load.

Fig. 6, is not used in this tuner for stereo threshold switching. It can, however, be fed to a suitable meter circuit to give a received-signal strength measurement by relating the indicated current to the calibration curve shown in Fig. 6.

Setting of the audio muting sensitivity control is done by tuning manually through a number of stations and increasing sensitivity until the noise between these is reduced to a minimum. The demodulated multiplex signal, at about 140mV r.m.s. for ±75kHz incoming-signal deviation, is fed via Tr_4 to the 50kHz low-pass filter, decoder and audio output circuits, already described. An extra stage around Tr_4 provides a small amount of gain to compensate for the lower output from the CA3089E demodulator and presents the correct source impedance to the filter.

Optional 15kHz low-pass filter

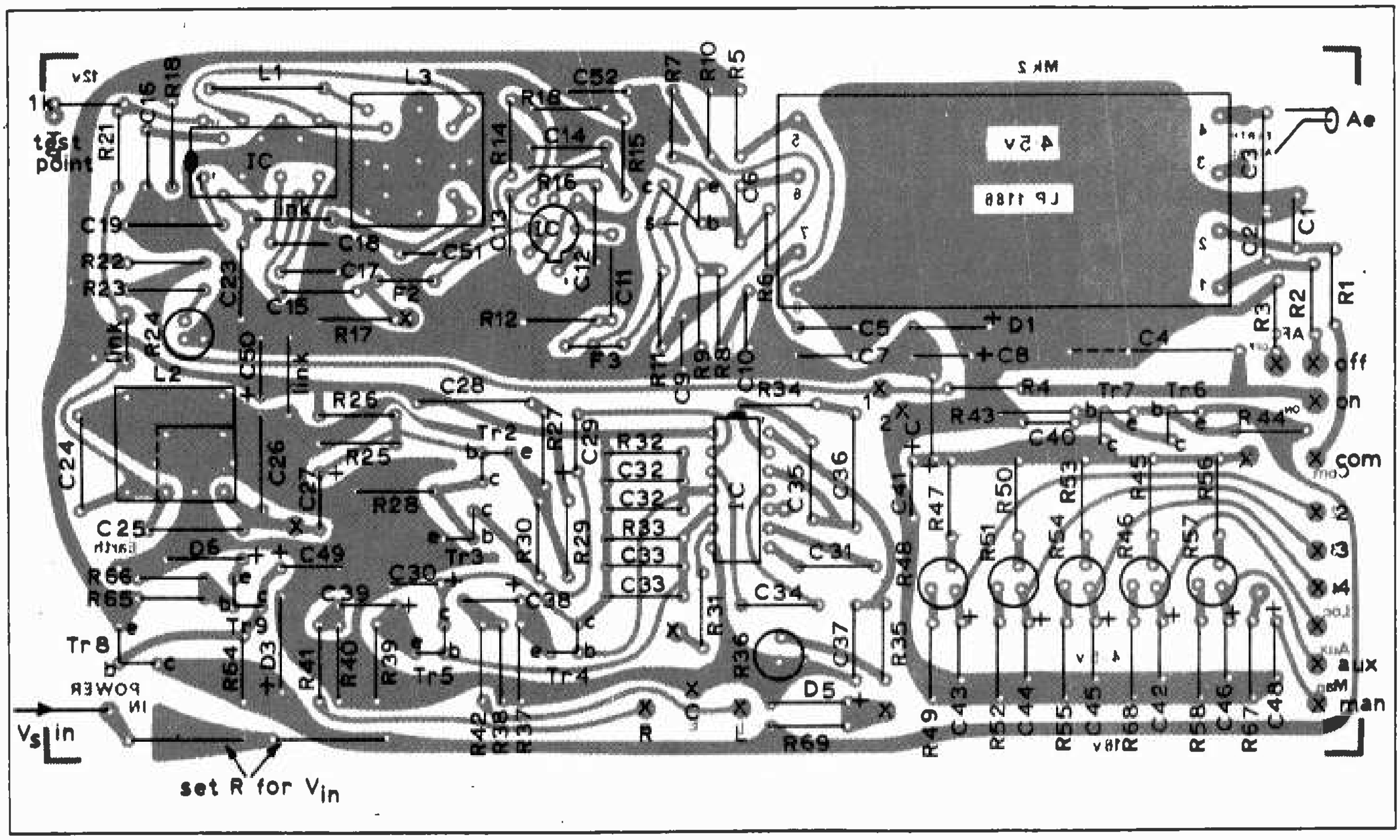
The output signals from the tuner contain components at the pilot-tone frequency and the switching frequency. Apart from producing noise, these unwanted signals can cause difficulty when the tuner stereo output is tape-recorded. If the recording bias beats with one or other of the out-of-band components, or more probably, with their harmonics, then the product frequency could be within the audio band and the resulting signal would produce interference. Such undesirable effects can be prevented by including a low-pass filter in each of the output circuits.

The audio band transmitted is limited to 15kHz, as a necessary factor in normal pulse-code-modulated signal distribution, so it is reasonable to use a sharp filter cut-off at a frequency just above 15kHz. The circuit of a suitable filter is given in Fig. 7 together with its response. The second notch, at 23kHz, is at the frequency allotted to a control signal which the BBC uses for distribution-route and transmitter switching. (An active filter would have required a more extensive circuit requiring many more components to achieve the high rates of response change at cut-off and the notch sides.)

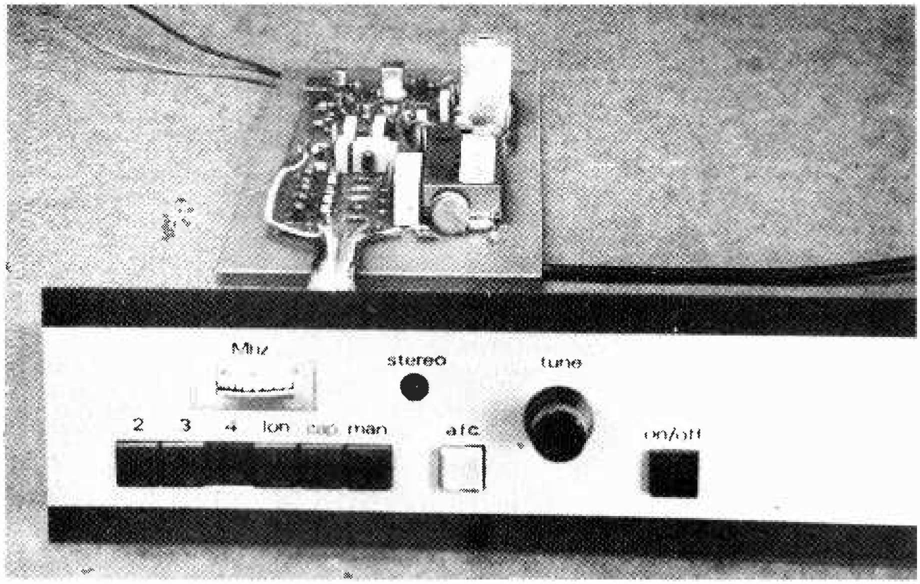
Tuner r.f. and i.f. performance

The four most important figures here are those for i.f. and image rejection, which relate to operation in the r.f. section, and for a.m. and adjacent/alternate channel rejection given by the i.f. circuits.

The first two depend on r.f. circuit



Component location and p.c. board layout for Fig. 1. Boards for Fig. 1 and Fig. 5 circuits are available from M. R. Sagin, 11 Villiers Road, London NW2, price £3 inclusive, and parts are available from Manor Supplies, 172 West End Lane, London NW6.



Front panel and controls can be mounted remote from the printed board.

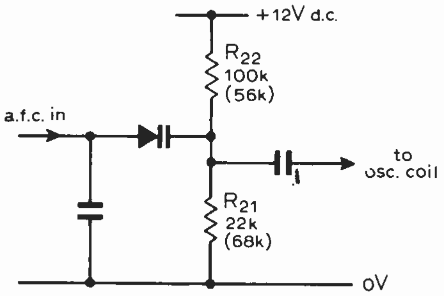
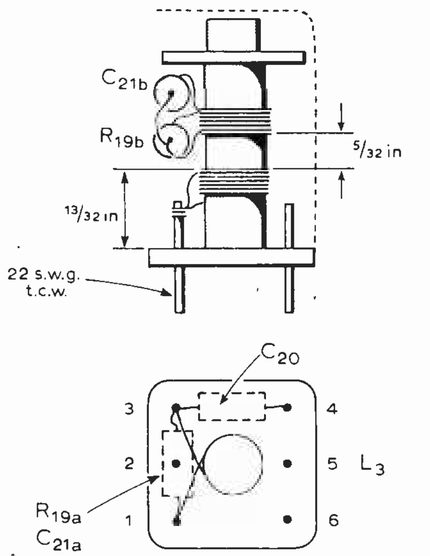


Fig. 8. If Toko EF5600U-1 module is used in place of LP1186 change values of resistors in Toko module to those shown in brackets.



1¼ in former, 6mm (9/32 in dia.) Neosid can 1 3/8 in. high 3/4 in square

2 violet cores 6 x 1 x 12·7

both windings 16 turns 34 s.w.g.

L_3 component numbers above as for Fig. 1. Capacitor marked C_{20} is omitted in Fig. 5. Simpler coil uses 10 turns on Neosid E3 assembly. Phase shift coil is a Sigma SC10 screened r.f. choke, or Painton equivalent. L_2 Fig. 1 is wound on a Mullard Vinkor assembly with 14mm violet core and 172 turns of 38s.w.g. enamelled wire. L_1 in Fig. 5 is 8¼ turns, tapped at 1¼ turns, on Neosid 6mm former with 22s.w.g. wire.

selectivity and in both versions are determined by the performance of the Mullard LP1186 module. The specification for this quotes an i.f. rejection of 65 dB for 95MHz input and an image rejection of 40 dB.

If better r.f. performance is required, this can be easily obtained but at increased cost by replacing the LP1186 with the Toko type EF5600U-1 tuner module which contains four varicap-controlled tuned circuits and has image and i.f. rejection figures both quoted as 90 dB. A module of this type has been successfully fitted to the author's tuner with some small modifications, as below.

Fitting Toko front-end

Change of tuning voltages. For tuners operated in the London area, the necessary changes to pre-set tuning voltages for stations at the ends of the band are:

	LP 1186 (w.r.t. pin 8)	EF5600U-1 (w.r.t. 0V)
89.1 MHz (Radio 2)	2.4V	3.5V
97.3 MHz (LBC)	6.0V	7.5V

Change of d.c. offset and a.f.c. centre-voltage. The EF5600U-1 tuning voltages are referred to 0 volts instead of the +4.5-volt offset present at pin 8 of the LP1186. This difference necessitates two modifications. First, the 4.3-volt zener, marked D_1 in both diagrams, must be replaced with a shorting link. Second, in the Toko module, the maker's circuit diagram shows that the a.f.c. circuit involves a separate diode with a 2-volt bias obtained from resistors numbered R_{21} and R_{22} as illustrated in Fig. 8. Because this circuit is intended for operation with an incoming a.f.c. signal centred on 0 volts, it must be modified to suit the +4.5-volt centre value which obtains in the tuners. The suggested changes are marked in parentheses in Fig. 8, giving an offset of about 6.5 volts.

The figures for a.m. rejection, quoted from the manufacturers' data for 30% a.m., are −45dB for the SGS TAA661B and −55dB for the RCA 3089E. Performance in respect of adjacent/alternate channel rejection is determined by the i.f. pass-band response characteristic which, for both tuner versions, is the resultant of two FM-4 ceramic filters in cascade. These components were also used by Nelson-Jones, and a curve showing the insertion loss for the combination appears in his original article. This gives the 3dB-down bandwidth as ±110 kHz, and off-tune loss figures of 40 dB at ±200 kHz and 60 dB at ±280 kHz. Rejection of unwanted channels is thus more than adequate.

Correction. In Fig. 1, March issue, the value of C_{12} should be 47nF and not 47μF, R_2 should be 1kΩ and not 100kΩ, and D_6 should be a 6.2V zener diode, labelled C6V2. Supply voltage to Fig. 4 circuit is 13V and not 11V.

Literature Received

Radio-frequency shielding materials and their use are treated in a simple manner in a handbook from Metex. R.f. gaskets are fully described in theory and practical applications data is provided, together with detailed information on shielded enclosure windows and ventilators for shielded cubicles. Walmore Electronics Ltd, 11-15 Betterton Street London WC2H 9BS. WW401

An application note on a thermal r.m.s.-to-d.c. converter is published by Burr-Brown. The device exhibits a thermal time-constant of 65ms and a characteristic which is linear and repeatable to within 0.05% over 30dB. It is still accurate to within 2% at 100MHz. Applications include amplifier gain measurement, thermal protection and r.m.s. voltage regulation. Burr-Brown International Ltd, Permanent House, 1y Exchange Road, Watford WD1 7EB. WW402

Aluminium aerial towers are the subject of a leaflet sent to us by Fred Franke Inc., PO Box 2806, 1639 Old Dixie Highway, Vero Beach, Florida, USA. The towers are crank-up, extending types, forty, fifty or sixty feet in height and of triangular section, and a selection of bases and mounting brackets is described. WW403

The British Standards Institution has published group 09:1976 of part 3 of BS4727, which is a glossary of terms used in waveguide engineering. The publication is obtainable from British Standards Institution, Sales Department, 101 Pentonville Road, London N1 0ND at £3.10 by post. WW404

Relays with mercury-wetted contacts from Elliott are described in a booklet which gives mechanical information and electrical characteristics of twelve ranges of relays. Application information on contact protection, screening, etc. is included. Elliott Relays, 70 Dudden Hill Lane, London NW10 1DJ. WW405

Aerial information for equipment in the m.w., v.h.f. and u.h.f. range is presented by Aerialite. The latest to be published includes a leaflet on indoor aerials, two on u.h.f. types and a description of the mounting accessories made by the company. Aerialite Aerials Ltd, Whitgate, Broadway, Chadderton, Oldham, OL9 9QC.............. WW406

An f.m. radiotelephone is illustrated and described by Telefunken in a new leaflet. The 10-channel Teleport VII covers the 80MHz, 160MHz and 460 MHz bands at 2.5W r.f. (1W at 460MHz). Bayly Engineering Ltd, 167 Hunt Street, Ajax, Ontario, Canada............................... WW407

Research Notes

Great balls of fire!

According to a NASA report, glowing spheres have been noticed in almost half the cases where an observer happened to be very close to a stroke of lightning. The nature and indeed the very existence of this ball-lightning has been the subject not only of heated debate among theorists but more recently of some seemingly dangerous research in France.

Scientists at the Commissariat à l'Energie Atomic (CEA) and Electricité de France (EDF) have been photographing lightning discharges caused when rockets trailing thin steel wire were fired into thunder clouds. During the course of these experiments, some twenty artificial lightning strokes were produced and filmed. According to a report in *Nature* (vol. 257, no. 5523), triggered lightning, like upward natural lightning, begins with a slow discharge in the kiloampere range with a rise time longer than 10μs and a total duration of several tenths of a second.

But although nothing resembling some of the more exotic stories of ball-lightning was noticed, there is now firm photographic evidence for balls of lesser degree. During some long-lasting lighting strokes (>½ sec) "luminous spheroids" some 40cm in diameter were observed towards the end of the discharge and, according to the French researchers, their properties are entirely consistent with those of hot blobs of gas. So it seems that lightning folklore and tales of monster blobs of plasma can still thrive on exaggerated stories of the one that got away!

Fibre optics for chemists

Readers of this journal won't need reminding that progress in fibre optics has now reached a point where "light-guides" are very competitive with r.f. waveguides for data transmission. But if the highly critical design criteria for light-guides have provided headaches for some researchers, their less desirable properties have nevertheless resulted in a highly sensitive method of chemical analysis.

It's a form of spectrophotometry developed in the United States in which the transmission properties of a light-guide are intentionally altered by the presence on its surface of microgram quantities of the chemical being evaluated. The refractive indices of the light guide and of a special polymer coating carrying the test chemical are so arranged that light is refracted in and out of the coating as it passes along the guide. In this way a small change in the optical properties of the guide/coating interface are amplified to a very considerable extent. So sensitive is this technique that polymers containing sub-microgram quantities of cyanide ion can alter the light transmission of a guide by over 50% compared with a pure polymer coating. (*Nature*, vol. 257, no. 5528.)

Natural magnetism attracts the birds

Dr William Southern, an American biologist writing in *Science* (vol. 189, no. 143) has evidence to suggest that v.l.f. radio waves affect the migratory pattern of gulls. His experiments were conducted on frequencies around 50Hz using equipment which the US Navy has developed for submarine communication (Project Sanguine). The birds, chicks a few days old, were taken from their colony several miles away and released near the transmitting aerial, some at times when the transmitter was operating and some when it was inactive. The birds released during non-radiating periods were found to migrate in a direction consistent with those in the parent colony, whereas during transmission the migratory pattern became completely random. These results add considerable weight to current theories that birds can orientate themselves to the natural magnetic field. (The writer however, has very little evidence that his amateur transmitting activities in any way deter marauding wood-pigeons!).

Microminiature . . . Picominiature . . . where next?

A comparison of today's microprocessor chips with bipolar transistors of only a decade ago might well convince even the most sceptical that pinhead-sized computers are merely a few years away. But before you go rushing out to buy the latest in 25 microwatt soldering irons (or perhaps commit suicide), be comforted: the end is nigh. A paper by J. T. Wallmark (Inst. of Physics Conf. Ser. No. 25, 133) concludes that by the time present-day circuit elements have been scaled down by about five times, i.e. to around 2μm, basic laws of physics will step into play and limit any further size reduction. The limitations according to this author lie not so much in the technology necessary to produce finer and finer patterns, but intrinsic barriers such as insulation breakdown and excessive current density. One other major problem is that with diminishing size, local variations in the concentration of doping atoms result in excessive spread of device characteristics. So, in the absence of any fundamental discoveries in solid state physics, we might as well forget any dreams about unlimited pocket computer power – that is unless we're prepared for it to think slowly – like people.

Grains of metal in an insulator

Mixtures of conducting and non-conducting materials are interesting to solid-state physicists in their own right but are also now beginning to be used to make devices. Dr Ben Abeles and his co-workers at RCA Laboratories, Princeton, USA, have been exploring the conducting properties of films formed when metals, say gold, and insulating materials such as silica are sputtered together. The metal forms well-dispersed spherical particles in an insulating matrix but the particles are close enough together that, even though they do not touch, electrons can tunnel between them. Tunnelling is a quantum-mechanical phenomenon which does not allow high current to flow but can be controlled more effectively than metallic conduction. One new application for these effects is described in the announcement of a "granular metal semiconductor vidicon". In this, the light-sensitive target consists of the following layers deposited on a glass faceplate: transparent conductive tin oxide, cadmium selenide and granular metal, sputtered from a composite gold-silica target, to a thickness of 400nm.

As is usual in a vidicon camera, the target charges up in proportion to the light falling upon it and an electron beam is scanned over it as a means of reading out the charge pattern. The advantage over targets which have been used up to now, such as those which have the semiconductor left bare or others which have a pure silica layer over the semiconductor, is that the granular metal layer prevents blurring of the image (which occurs on the bare target because of excessive conductivity) and it also eases the flow of image information to the electron beam (which is excessively slow for the pure-silica coated target). C. R. Wronski, Ben Abeles and Al Rose, writing in *Applied Physics Letters*, vol. 27, 91-92, put this more precisely, explaining that photo-generated holes have to be forced through the pure insulator under high fields, while tunnelling allows the same process to be done in the metal-filled insulator under much lower fields.

Letters to the Editor

CONSULTANTS, PROSTITUTES AND CHAUFFEURS

There is chalk and cheese, there are prostitutes and wives, there are also in our domain consultants and consulting engineers. As someone who, starting without the aid of either capital or contracts, has run a successful consulting engineering practice in telecommunications and electronics for rising twenty-five years, I feel I must comment on the article "The consultants" in your November issue.

I have always felt that consulting must be done from the background of complete independence from commercial affiliations and any other loyalties. Independence means just that. If you are paid by someone else and/or use their property for your own purposes you have no higher status than the chauffeur who uses his master's Rolls for weddings and funerals while the latter is out of sight.

I am not the least surprised that your correspondent has found such dissatisfaction with "consultants" — highly likely I would say — but give the real chaps a break. We have had clients in all five continents. We have had large public companies in our domain — sometimes for a period of years — and they wouldn't come back if they were not satisfied, but it is true that more often than not they do not wish it to be known that they used us.

The World Bank will not underwrite any engineering project without the *imprimatur* of consulting engineers. Surely this shows the value, the competence and status of the consulting engineer.

C. A. Henn-Collins,
Henn-Collins Associates,
Castel,
Guernsey.

John Dwyer is deserved of high praise for his clearly written, unbiased, frank, fearless and interesting exploration into the ways and means of independent engineering consultants, and for illuminating certain dark corners.

My own consultancy activities stem from a small family business and much of the money it makes is ploughed back into the purchase of new plant and equipment to enhance the value and quality of the work undertaken for our clients and readers of the hi-fi magazines in which our detailed review and test reports appear. In spite of the expensive plant we are obliged to purchase and maintain from our own resources, our fees are far more modest than those of the consultants referred to in the latter part of the article; and I feel that Derek Bond in his summing-up warning means ". . . if they're inexpensive (not cheap) and good we'll use them . . ."

Like James Moir intimates, we are also experiencing the somewhat unfair competition from college-based consultants, and were very surprised to read that equipment, plant and facilities from the public pocket are, in effect, being used in competition with the consultant who relies essentially on his fees for a living. It is noteworthy that North London Polytechnic at least has blocked one-third of the flow of money from essentially college-financed personal enterprises to private pocket, but this still nevertheless presumes that two-thirds of the money goes as a cheque into the bank account or as pound notes into the pocket of the consulting lecturer, etc. What about other polytechnics and colleges — is it accepted practice for all the income so derived to go to the college official?

One might be inclined to say "so what, good luck to them", except for the startling attitude-reflecting statements, such as ". . . money isn't the thing that counts . . ." (it may not be to the chap getting a fat salary from public funds for his twenty-six-hour week when it is purely pin money, but it certainly is to the professional consultant working his hundred or more hours a week for possibly less money) and ". . . didn't charge nearly as much as outside consultants . . ." (a blatant admission of unfair competition based on public money at the expense of the professional).

Clearly, if all this is true, then the private consultant not in a position to command the use of thousands of pounds worth of equipment, plant and facilities at public cost for nothing is faced with overwhelming and singularly unfair competition. The depreciation and running costs of a small lab could well be up to £10,000 per annum. Apart from having this sort of yearly expenditure immediately available for free the college chap would appear to acquire *at least* two-thirds of the consulting fee for himself (perhaps the whole lot apart from NLP) plus his normal salary. What an incredible situation if it is really a fact!

From the article it appears as though it could be. The implication being that provided the NLP chap puts about one-third in the pool all is well. The article fails to say what happens to the pool of money — whether it is returned to the public funds or shared out at Christmas time!

Perhaps officials from colleges other than NLP who undertake such consultancies with the college's plant, facilities, etc, would care to clarify the scene, saying exactly where the client's money goes and whether any charge is made to the consultant.

I also often wonder what happens to the fees received by the technician, etc, for equipment reviews, he undertakes for the hi-fi magazines using college plant, equipment and facilities, as often indicated by the review. Does he charge less for the review than could a reviewer relying upon the income to live and pocket all the fee? Does he charge the full amount and return it to the public kitty; or does he keep some for himself and return some of the college? Then there are all the other researches written up in the magazines and paid for. Who gets the fees?

Answers to questions like these are very important to the private consultant who has to purchase and maintain his own lab and premises, pay the rates and rent, pay his own telephone bills, pay for his own heating, his own office and secretarial staff, who cannot advertise for business and cannot belong to a trade union, giving him some idea of the unfair competition he is now facing and how long he will be able to stay in business.

Gordon J. King,
Gordon J. King (Enterprises) Ltd,
Brixham.
Devon.

WAS BAIRD FOOLING THE PUBLIC?

The plea in your January issue for a "serious study of the business and technical aspects" of the 30-line Baird activity may well serve to put an end to this confused affair. ("John Logie Baird and the Falkirk transmitter," pp 43-46). Annotated references in the article to reputable proceedings about achievements are intended to convince but give to today's reader a false picture of the happenings of 50 years ago. It should be appreciated that Baird never successfully demonstrated television. Being without a method of synchronisation over a distance, there could be no such event. At every attempted demonstration this primary need had to be faced and contrived. The bringing together of radio transmission, in itself having ideal properties for television purposes, and the trundling mechanical image analyser, was quite incongruous.

Proper electrical circuits for conveying the light values were not to be found in the various Baird set-ups. This was the time of early talking films and picture telegraphy when the stable photocell and bright recording lamp were both readily available. Baird claimed to use visual purple as the light sensitive material.

"Fibre optics," a modern term of wide application, is brought into the article. True, the possibility of using a bundle of fine internally reflecting glass fibres for channelling an image falling on a closely divided grid was well known, a scheme which avoids synchronising and light handling difficulties. The modern plastics as used in optical cables give a high degree of light insulation with but little loss. Fibre optics offer high definition remote viewing with the possibilities of image intensification. These things were not part of the Baird programme, being generally inapplicable to a radio service.

Baird hoped to convey to the public with his inadequate devices that he was in possession of a commercial proposition of considerable potential value. This he aimed to sell by pretence and to that end demonstrations had to be conjured and reports by staff contributors commissioned for publication. The pattern of the *Wireless World* article, almost line by line, shows the marks of this policy. Displayed advertisements in the daily press of the time said "Television is Here." A "Home Televisor" appeared, so here all was revealed for public judgement. The "Televisor" was a typical well made Plessey product. With a monitored signal input (Big Ben clock face) and in an equipped laboratory where auxiliary gear, by way of a heavy duty synchronising and vision amplifier was to hand, the Baird Televisor was shown to be a failure in fulfilling its intended purpose.

This was the end of the 30-line part of the story which is as far as your article goes. No radio enthusiast was fooled. Radio societies, then much attended, were amused. *Wireless World*, always ready to pursue and report, remained silent.

F. H. Haynes,
Bovey Tracey,
Devon.

PHASE EFFECTS IN LOUDSPEAKERS

It is, I think, generally accepted that phase distortion exists, inasmuch as it can be mathematically proven, or perhaps better, displayed on a c.r.t. It is also, I believe, generally accepted that the human brain in some mysterious way "integrates" the incoming signal in the same way as it does a harmonic interval, say a major third, to sound as it does and not as a c.r.t. shows that it should. In the same way (broadly speaking) a received mixture of primary colours is seen as a specific hue. At least, by most of us it is: there are those who do not have this ability visually, and it does not seem beyond belief that there are those who, similarly, lack the audio integrating function which most take for granted, but is not easily quantified in the same way as, say aural frequency response.

I know, for instance, that my hearing cuts off above 17kHz, whereas 20 years ago it was 22kHz (when it was still kc/s) but this is an easily measured function. Perhaps we need a consultant neurologist to enter the discussion?

A. J. Gamble
Ormskirk
Lancs

The long dead and buried question of square waves not being heard differently when considerable phaseshift is applied to the different harmonics, is disinterred again. This despite the fact that no designer of linear phase speakers uses the argument that *because* of the ability of a speaker to reproduce a square wave it will sound better. This is always presented as just one means – and no more — to show that it really possesses phase linearity. It is a "tool" and nothing but a tool and presented as such.

As to audibility of linear phase, Mr. Harwood (conveniently?) completely ignores the articles on "Aural Phase Detection" in the *Journal of the AES* (vol. 22, Nos. 1 and 10) by V. Hansen and E. R. Madsen, which go a long way indeed to proving the importance of investigating this aspect in sound reproduction.

Quite different signals than square waves were extensively used, far more related to musical transient sounds. Altogether it was a very thorough investigation into human perception, with particular regard to the desirability of phase linearity in music reproduction. Far more convincing indeed than the questionable experiments by Mr. Harwood in which only NON linear phase seems to have played a part.

Personally I had the opportunity of investigating loudspeakers that laid claim to phase linearity, to a greater or lesser degree, from France, Germany, Denmark, Japan and England. Most of them first as prototypes and later on as the finished product.

Perhaps the most striking experience was the first in which I and a few other selected people were able to compare two identical loudspeakers, identical as to size and units used, where the first was equipped with a carefully designed, but conventional 3-way crossover filter, and the second with a filter that ensured linear phase from about 300Hz upwards.

Although the first was judged to be a very good speaker of very wide response and an extremely well balanced sound, the difference could be called enormous. Especially transient response was improved to an incredible extent. This concerns pure quality, but the other aspect, the stereo image, also changed in a startling way. By comparison the first pair (for pure quality only single speakers were compared) suddenly gave the impression of presenting a confused though reasonably wide stereo-stage with little depth.

In the meantime I have listened to, and tested extensively, the other ones mentioned. It cannot just be a coincidence that five (!) loudspeakers from five different countries ALL showed the same striking improvement in transient response. The last, one of British origin (this cannot be any other than the DM-6 of course) being an absolute winner and in some ways even beating an electrostatic speaker.

Yes, square waves too! In all cases I was able to make oscillograms in an ordinary, but well damped room, of square waves with the microphone at 1 m distance. Again, no proof of better music, but of linear phase. Single sinewave pulses, and/or half waves have proven to be of more use to confirm in technical tests, qualities heard with music. Symmetry and ringing can be judged over the whole frequency range and in my experience are in 90% of the tests, consistent with subjective experiences. In the case of p.l. it is moreover remarkable to observe the steady position of the reproduced pulse when the microphone is moved vertically, no significant phaseshift can be observed, even in crossover regions.

The transfer function of any link in a reproduction chain should be described by its frequency and phase response; without linear phase accurate reproduction of waveshapes, and envelopes is impossible. To state that this is of no importance takes someone of perhaps great bravery, but more likely, one with prejudices who still thinks of music in terms of simple sinewave structures in which simple evenly related harmonics play a part only. It is of course, in particular, the transient nature of most musical sounds, with its highly complicated structure that is so important to reproduce well. Any system that shows large improvements in transient handling should be taken very seriously indeed, if of course all the other long known important parameters are not neglected. Signs of this were found in some of the prototypes, where some preoccupation with phase made bass or treble suffer. Not however apparent in most of the finalized deisgns. No, if Mr. Harwood were right, a lot of music should be rescored to fit his conclusions!

The linear phase loudspeakers I was privileged to handle proved to me and all my "guinea pigs" beyond all reasonable doubt that it is an important step forward in striving for perfection.

J. Kool,
Technical Editor,
Luister
Amersfoort,
Holland.

While I have to admit that H. D. Harwood's article on the Audibility of Phase Effects in Loudspeakers (*Wireless World*, January 1976) was scrupulously fair with regard to the facts, I would venture to suggest that a good deal of *emotional* weight went behind the thesis that phase-linear speakers are a 'con'. For readers interested in the other side of the coin, could I perhaps publicize an article of mine (1976, Hi-Fi News Annual) in which some of the recent evidence demonstrating the ears' sensitivity to phase effects is presented in detail. I have also outlined there the way in which this evidence has modified current thinking about the mechanisms involved in the ear/brain hearing system.

However, rather than becoming entrenched in our own respective camps and flinging mud at the opposite side, it seems to me that the way forward is to accept the findings of both sets of experimenters, and look for an explanation which admits of both results.

Let me summarise the two, apparently mutually exclusive viewpoints. On the one hand the psycho-acousticians (if they'll forgive the phrase!) have shown that in special circumstances and with special kinds of signals, the ear is capable of detecting 'phase distortion'. The audio-engineers, on the other hand, have demonstrated many times that on typical programme music, phase shifts go unnoticed. Could there be an explanation which is consistent with both these results? Consider the following. Suppose that the transmitting of information is a bit like playing 'Scrabble' (to steal a Magnus Pyke-ism), and suppose that phase shifting is a bit like rearranging the orders of the letters in the words. If I were now to ask my audience to compare the sequence SEPAH with the phase-shifted sequence ASHEP, they might well retort that the information conveyed by both sequences is zero, and that therefore, in information terms, both these sequences are identical. If, however, I presented them with the sequence PHASE, comprehension might dawn!

In other words, if the phase information in a signal is already jumbled, a re-jumbling could well make no difference at all to our perception of the signal – the brain just rejects the phase-information channel, and derives instead, as much information as it can from other channels. If though, the phase channel is pregnant with information (e.g. the phase relationships are undistorted from source to detector) the brain might just be able to put this information to good use.

In terms of audio-programme material, the initial jumbling of phase information occurs long before the signal reaches the speaker – it occurs whenever a multi-mike recording technique (with its attendant mixer desks and pan-potted imaging) is used. What does a bit more phase-jumbling at the speaker end matter here?!

It has been argued that phase distortion occurs even before the microphone stage, because multiple room-wall relections (the ingredients which make for a satisfactory reverberent acoustic) generate a resultant pressure wave at the microphone (or ear) which has a time profile dependent on the position of the source, the properties and positioning of the reflecting surfaces in the room, and the position of the listener. If the phase information really is lost at this stage, then phase-linear-anthings really are a con. (And that includes square-wave tested amplifiers too!) It would appear, however, (even though the experimental evidence is as yet very tentative), that the ear/brain is capable of distinguishing between direct and reflected sound. If this result is confirmed, we can see that the relative phase of the source's harmonics *is* preserved in the direct sound reaching the ear. What is more, comparison of the phase information in the direct sound with that in the reflected sound might be an important direction-locating mechanism in the 'live' acoustic of the concert hall.

In the meantime, I'm not averse to any development which reduces the phase distortion properties of the recording chain, as long as I am not charged exhorbitantly for the privilege.

K. A. Hodgkinson,
Open University,
Milton Keynes.

In Mr Harwood's article, and in the view of many other eminent men in the audio field in the "anti-phase" lobby, one factor stands out as the fundamental argument — that until someone can demonstrate that phase response is important to sound quality on musical signals, they will continue to believe that phase is unimportant. Often this is accompanied by details of experiments "proving" that phase distortion is inaudible, and sometimes the nature and conditions of the experiment give the impression that the proof of a predetermined objective was the purpose of the test. The debate on phase is not going to end unless those who are primarily interested in high quality sound reproduction rather than pro- or anti-phase arguments, come to conclusions based on unbiased listening tests conducted under fair conditions.

There can be no doubt that since linearity of phase response is fundamental to recreating the original wave shape received at the microphone, it can be no disadvantage to eliminate phase distortion throughout the reproducing chain, including the loudspeaker. It can conceivably be argued that a limited amount of phase distortion is not detectable by the ear, but it has been conclusively established by, amongst others, telephone companies that large amounts of frequency dependant time delay (phase distortion) can not only distort speech, but make the human voice totally unintelligible, and phase correctors have to be used in long-distance cable communications. Thus, the debate really centres on how much phase distortion is detectable by the ear, and especially whether the amount and quality of phase distortion in conventional loudspeakers is above or below this limit. It will serve no purpose to add to the debate by quoting experiments, or arguments about phase distortion. But a certain amount of care must be taken in listening tests, without which tests would not be valid.

To start with, testing for wave shape distortion with a microphone in a living room is extremely misleading. Reflections from room walls picked up by the microphone are indistinguishable from the direct sound, whereas the ear finds it quite easy to concentrate on the direct sound, presumably because of the slight delays that occur. Thus while we prefer certain acoustic conditions to others in particular cases, one can always recognise a voice or instrument, irrespective of its environment. In order to test with musical signals, a primary condition must be that the source, together with the reproducing chain, must have a linear phase response. If one were conducting a test to find the limits in variation of frequency response in a loudspeaker, before the difference became audible compared to a flat frequency response, one would naturally arrange for the music source to be recorded with microphones that also had a flat frequency response.

Similarly, if phase distortion is under test, a sound source and reproducing chain which do not have a linear phase response will mask the phase distortion originating in the loudspeakers. If in addition one is used to the type of sound reproduced by a high quality system, one can quite easily be misled into believing that phase is unimportant. This is not to say, as everyone will agree, that reproduction is perfect. No one, to the best of my knowledge, has any doubt that the finest system in existence is still imperfect.

It is, however, unwise to reject phase, as one of the factors giving rise to imperfections without comprehensive tests under relevant conditions. A musical source with undistorted phase response may be difficult to find among commercial sources. One suitable method of recording such a signal for test purposes would be a mono recording using a single high quality microphone and a high quality tape recorder.

Finally, as the purpose is to judge the effect of phase distortion only, and not the quality of the reproducing chain, it is relevant to point out that no two loudspeakers sound exactly alike. To make an A-B comparison, therefore, only one loudspeaker should be used, and this must be one with a minimum of conventional faults. In addition, it must have linear phase response. Phase distortion can be added easily by an electronic phase shift unit, at a high impedance stage of the amplifier.

Phase distortion, artificially introduced, should reflect the characteristics of conventional loudspeakers. Thus, with conventional crossover, or non-staggered units, phase rotation is limited in angle and the frequency region it occurs. Thus a second order filter network has a 180° rotation and a third order 360°, in both cases the rotation occurs mainly in the two octaves on either side of the crossover frequency. Mr Harwood's all-pass networks have a constant rotation of 30°, 60°, and 90° per octave, which do not have the same characteristics as any known loudspeaker. This alone invalidates Mr Harwood's tests as far as loudspeakers are concerned, but experience in this field shows that even this kind of steady rotation can be heard under the right test conditions.

It should be noted that phase distortion is not something that is easily recognised, as we are not conditioned to listen for phase-distorted sound. Differences between live and reproduced sound can too easily be attributed to other causes, without recognising the influence of phase. The relevant criterion, in the first instance, must therefore be that a difference should be heard in an A-B test between distorted and undistorted sound. The relevance of phase distortion in sound reproduction will then have been established.

S. K. Pramanik,
Bang and Olufsen a/s,
Denmark.

CURRENT DUMPING AUDIO AMPLIFIER

Mr Walker's ingenious "current dumping circuit" (*Wireless World*, December 1975, p.560) undoubtedly is one way of solving the difficult problem of cross-over distortion in amplifers. The only claim I would reject is that it is "feedforward".

An essential feature of feedforward is freedom from interaction; i.e. the voltage at the emmitters of Tr_1, Tr_2 (Fig 2, p.561, December 1975, *WW*) should have no effect at the output point of amplifier A. This basic criterion is not met.

The equation given in Fig. 1:

$$I_3 = (V_{in} - I_4Z_4)\frac{Z_2}{Z_1Z_3} + \frac{V_{in}}{Z_3}$$

confirms this.

Feedforward can very easily make distortion worse; indeed I have no doubt that Black found this when his amplifiers went out of adjustment, which may be why when he discovered negative feedback he abandoned feedforward.

To make feedforward work another ingredient is necessary – that of "rigidity of interconnection" (Fig. 2, October 1974, *WW* p.367), i.e. that the error voltage at the output of the main amplifier A_1 should be rigidly interconnected to the output of the subsidiary amplifier A_2V_d so that its waveshape is accurately reproduced. For this reason it is important not to add transformers outside the negative feedback loop.

These two principles together produce "error takeoff" which has the ability to reduce distortion by an arbitrary amount and at the same time maintain stability.

Mr Walker's circuit in my view is an effective application of negative feedback.

A. Sandman,
Royal College of Surgeons,
London, WC2.

Mr Walker replies:

The feedforward ancestry of current dumping can be clearly seen if we disentangle the circuit to show the error amplifier and the main amplifier as separate entities. This is shown below.

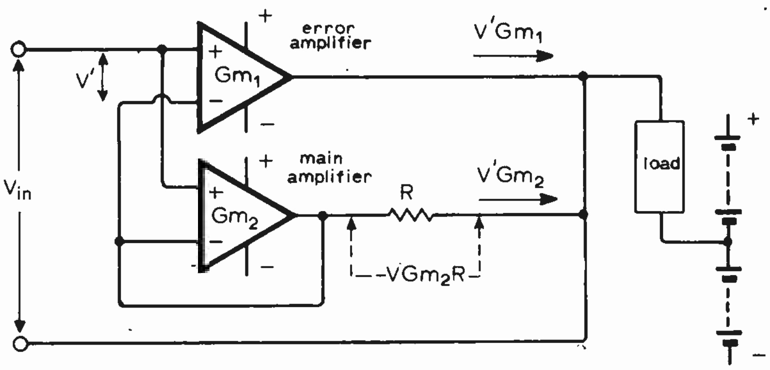
The bottom amplifier has a mutual conductance, G_{m2}, feeding current into the load via resistor R. Current feedback developed across R is fed back to its input. The top amplifier is the "error" amplifier and has a mutual conductance G_{m1}, feeding into the same load. The differential inputs of the two amplifiers are commoned.

The total current in load is $V'G_{m1} + V'G_{m2}$ But $V' = V_{in} - V'G_{m2}R$. Therefore we can write the load current as $(V_{in} - V'G_{m2}R)G_{m1} + V'G_{m2}$ If we now arrange that $R = 1/G_{m1}$ we then have a load current:– $V_{in}G_{m1} - V'G_{m2} + V'G_{m2} = V_{in}G_{m1}$ Note that dependence on G_{m2} has completely disappeared.

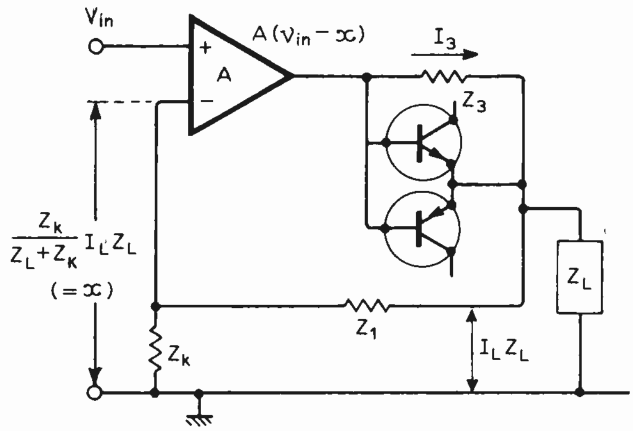
If G_{m2} is very much larger than G_{m1}, the bottom amplifier will provide most of the current and hence the power to the load. Since its mutual conductance does not appear in the transfer characteristics its own distortion will not appear in the load. This is not a result than can be expected from conventional feedback. We call it feedforward because the error correcting current is added in the load outside the feedback loop. (There is no *current* interaction).

Now suppose the top amplifier is replaced by an amplifier of rigidly fixed voltage gain feeding its output into the load via a resistor. It will still have a fully defined overall G_m and operate as before. However, the top amplifier now has an accessible output point of fixed voltage gain relative to its input and this can therefore usefully be used as the drive point for the bottom amplifier.

This combining of error amplifier and drive amplifier brings us to Fig. 1 of the original article. I believe the reasoning to be clear from that point on.



Mr Walker's amplifier shown in basic form.



Mr Bennett's suggested circuit.

I have recently made a more rigorous analysis of the behaviour of the "current dumping" amplifier than that presented by Mr P. J. Walker in his December article, and several interesting properties were brought out.

First there are distortion terms which are not removed by setting $Z_1Z_3=Z_2Z_4$ using the notation of Mr Walker's article. For Fig. 1 of that article,

$$I_L=\frac{AV_{in}(Z_1+Z_2)+A(Z_1Z_3-Z_2Z_4)I_4+}{Z_3[(A+1)Z_1+Z_2]}$$

$$+\frac{Z_3(Z_1+Z_2)I_4}{Z_3[(A+1)Z_1+Z_2]}$$

To obtain some judgement of the importance of the third term, use the circuit values in the original Fig. 2, and worst-case 5% tolerance components, as suggested by Mr Walker. If $A=10^4$, then the third term dominates distortion below 2.5kHz. Incidentally, another distortion term would be introduced in Fig. 2 by the use of voltage gain as indicated.

Now the situation is not so severe in the Quad 405 where inspection reveals A is of the order of 10^6. Also it is important to note that the contribution of I_4 is not the same as cross-over distortion, for in this case the problem may be reduced by feedback, whereas when the output transistors of a class B amplifier are switched off, the feedback loop is powerless to compensate.

The final point, and perhaps the most interesting, is to consider what happens when Z_2 and Z_4 are removed and short-circuited respectively, thus:

$$I_LZ_L=A\left(V_{in}-\frac{Z_KI_LZ_L}{Z_L+Z_K}\right)-I_3Z_3$$

$$=\frac{(Z_L+Z_K)(A_{vin}-I_3Z_3)}{(A+1)Z_K+Z_L}$$

Thus this configuration has no feedback components tolerance problems, does not need a power inductor, and there is no third distortion term due to the presence of Z_K.

The Z_3I_3 term is of equivalent effect to the $Z_3(Z_1+Z_2)I_4$ term in (1), and thus, given an A of order 10^6 may be reduced to similar insignificance.

J. G. Bennett,
Cambridge

There appears to be some mystification surrounding Mr Walker's new amplifier circuit described in the December 1975 issue, pp. 560-562. Consider his Fig. 1. It is a power amplifier in which part of the load current (I_4) comes from the unbiased emitter-followers via Z_4 and the remainder (I_3) from the driver amplifier via Z_3. At the central junction of the potential divider Z_1–Z_2 a feedback voltage is derived, which if the divider ratio is correct ($Z_1Z_2=Z_4Z_3$) depends only on I_3+I_4, i.e. on the total output current. This is not a very special achievement – normally such a voltage would be obtained more straightforwardly across a small resistor in series with the load below the junction of Z_3 and Z_4.

Having established that the voltage fed back is linearly related to the output current, he proceeds by implication to the quite different claim that the *forward* response is linear. There seem to be no grounds for this assertion. In the basic amplifier without feedback it is far from true – in the floating input configuration of Fig. 1 (with the values suggested) the transconductance increases by up to a hundredfold when the transistors turn on – and the application of feedback will reduce the distortion only to the extent expected in any feedback amplifier.

The various voltages marked on Fig. 1 do appear to support the claim; they are, however, correct only if there is no p.d. between the inputs of the driver amplifier A, i.e. if it has infinite gain. The text implies that this is indeed the intended assumption. In that case the benefits attributed to the circuit reduce to the familiar assertion that the distortion can be made negligible by huge amounts of feedback, and it has yet to be shown that Fig. 1 possesses any unique property making is easier than usual to do this.

J. Halliday,
Winchester,
Hants.

Mr Walker replies:

Asking the reader "for the time being" to assume the gain of amplifier A to be completely defined by its external impedances Z_1 and Z_2 was, I thought, a convenient way of defining a finite gain (of around 100 in Fig. 1) and was not intended to imply infinite loop gain in a practical case. For any finite gain for amplifier A it is necessary to change the component equation to give the equivalent of a true "virtual earth". Thus for a gain of A, the real equation for balance becomes

$$\frac{Z_3}{Z_4}=\frac{Z_2A}{Z_1(A+1)+Z_2}$$

and indeed if this is applied to Mr Bennett's formula for the load current, it will be found that terms involving I_4 disappear.

It is this possibility of reducing the output stage distortion to zero (without calling on infinite loop again) that distinguishes this circuit from those in which feedback only is applied.

Mr Bennett's suggested circuit employs feedback in the conventional manner. The circuit principle is found in several excellent commercial amplifiers and, as Mr Bennett rightly points out, if enough feedback is applied the distortion becomes acceptably low.

SUPPRESSOR FOR TV COMMERCIALS?

On reading about Ceefax and Oracle it occurred to me that there are some other useful pieces of information which could be added to TV signals. I refer to the nature of the transmission, especially advertisements. It would be possible to have various codes for different types of advertisement, and for sets to be fitted with a fairly simple decoder which would, at the selection of the viewers, mute the sound and/or blank the vision during transmissions.

Supporters of commercial TV have for long assured us that viewers enjoy advertisements. Now is an opportunity for them to show that they believe what they say, as if they oppose this suggestion it will be clear evidence that their policy is to take our minds by force.

Robin A. Hoare,
Howick,
Auckland,
New Zealand.

Editor's note: Correspondence on "Electrodynamically induced e.m.f." will be resumed in a later issue.

Time-code receiver clock — 3

Construction, alignment and operation

by A. F. Cross, B.Sc.
Thames Television Ltd

The power supply for the time-code receiver clock, shown in Fig. 15, requires little explanation. The nominal d.c. voltage across C_{37} is 10V on load, and this can be used to supply the display. The 10V rail feeds the monolithic voltage regulator IC_{40}, which has an output preset to 5V, and a current output capability in excess of 1A. A heat-sink is required for the regulator.

Construction

The author's aim was a conveniently small clock, and for this reason a compact layout has been adopted. Apart from the power supply, the clock has been constructed on one matrix board 10in × 6in, resulting in overall dimensions of 14in × 7in × 2½in.

Care should be taken with the layout, and the power supply connections should be as short and substantial as practical e.g. at least 20 s.w.g. on the board. It is good practice to decouple the supply rail to the integrated circuits at regular intervals; a 10nF ceramic disc per integrated circuit is ideal. Logic wiring should be no longer than necessary, and compact construction of the receiver will minimise the effect of interference from the logic. Earthing of the zero-volt line is important, preferably to a single point on the chassis. For this reason it is desirable to isolate the aerial coaxial socket, the 5V regulator can then become the common earth point.

The displays are mounted in d.i.l. sockets fitted to a small piece of matrix board, and interconnected using thin single strand insulated wire. The wiring details of the ferrite-rod aerial are shown in Fig. 16. The rod may be housed in a plastic or cardboard tube, along with the tuning capacitors which should have short connections to the coil. A screened cable should be connected as shown, close to the coupling coil. The siting of the aerial should not be critical except in areas of low signal strength; however, placing it within six inches or so of the clock does result in a degradation of the signal due to interference from the power supply. Generally it is more convenient to separate the aerial from the clock so that it may be independently rotated for the best signal. The capacitors across the primary windings are a parallel combination of a nominal 4n7 capacitor plus a smaller value for trimming. The final adjustment of resonant frequency is made with the coil adjuster core.

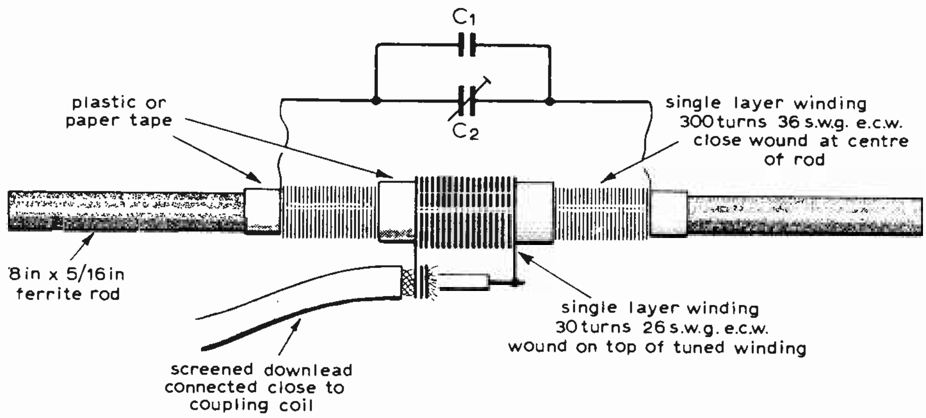


Fig. 16. Ferrite-rod aerial constructional details.

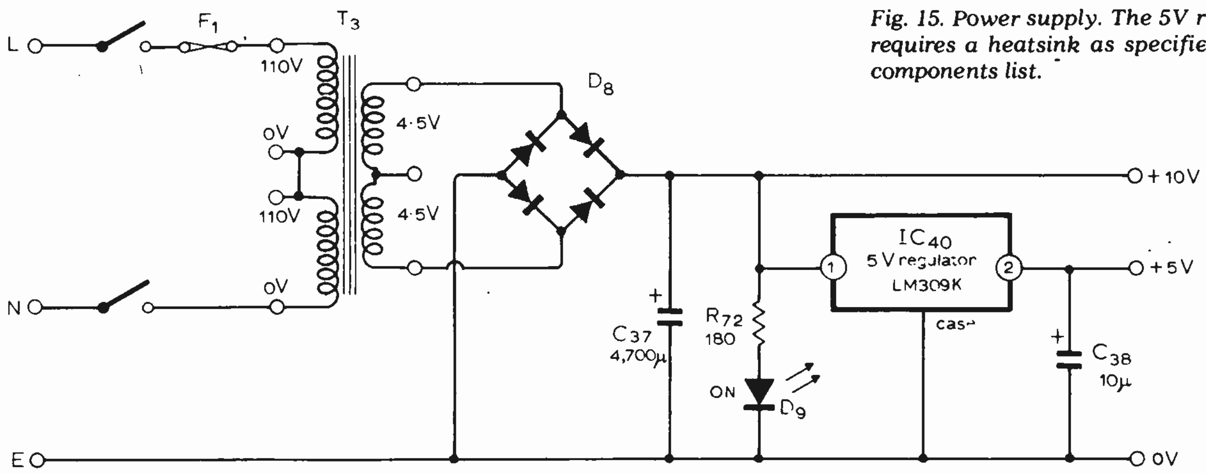


Fig. 15. Power supply. The 5V regulator requires a heatsink as specified in the components list.

Alignment

There are several adjustments to be made before the clock will function correctly. These are; tuning of the ferrite-rod aerial, alignment of the two tuned amplifier stages, adjustment of the muting level, adjustment of the crystal oscillator frequency, and the setting of the two monostable periods.

The a.g.c. used in the receiver must be disabled before accurate alignment is possible. For the initial tuning, however, there will probably be insufficient output to operate the a.g.c. system and the amplifier will be operating at maximum gain. An oscilloscope should be connected to the collector of Tr_3. The adjusters for T_1 and T_2 should be set about half way. With the ferrite rod placed roughly "broadside" to Rugby, the aerial trimmer C_2 should be adjusted over its range until a 60kHz signal is observed on the oscilloscope (this may be only a few millivolts). T_1 and T_2 are now adjusted for maximum output. When the output has reached about 600mV peak-to-peak, the a.g.c. loop will start to operate. To disable this a 47kΩ potentiometer should be connected between the collector of Tr_4 and zero volts. This is now adjusted to give an output between 100 and 200mV peak-to-peak. Fine adjustments to all three tuned circuits can now be made, adjusting the potentiometer as necessary to maintain the output below 200mV. When tuning is complete the potentiometer is removed; the output should increase to between 600mV and 800mV peak-to-peak. (The positive peaks will be somewhat flattened due to non-linear loading of the output.)

Muting level is set by adjusting R_{73}. (With the receiver correctly aligned, the carrier indicator lamp should be flashing with the breaks in the carrier.) When R_{73} is set to maximum resistance the muting level is at a minimum, i.e. relatively weak signals can be received without the muting circuit inhibiting the demodulator. This means, however, that in areas prone to radio interference, such interference may be of a level which prevents the muting circuit from operating when Rugby is not transmitting. If the normal signal strength is good, the muting level can be raised to reject the interference.

The oscillator is easily set to the correct operating frequency, using the received 60kHz carrier as a reference. The output of the first decade divider after the oscillator (pin 11, IC_{21}) provides a 10kHz signal; this is used to trigger an oscilloscope with the timebase set at about 5μs/cm. Displaying the signal on the collector of Tr_3 in the receiver should produce a stable 60kHz trace which drifts slowly across the screen. The trimmer, C_{28}, is now adjusted for minimum drift. Because one cycle of the 60kHz carrier has a period of 16.7μs, a figure for the accuracy can be determined. A relative drift of one cycle per second represents 16.7μs per second or 16.7 parts per million. Ideally the oscillator should be set up to better than one part per million which requires that the relative drift be one cycle of carrier in not less than about 17 seconds (the breaks in the displayed carrier provide convenient one second pulses for timing).

The adjustable monostable periods can be set up using an oscilloscope with a well-calibrated time base (an excellent calibrator is the crystal oscillator and divider chain). The demodulated carrier will normally trigger the monostables once per second. The final adjustment should be made by comparison with the received control pulse once per minute. The end of the 25ms off period (preceding the control pulse) should fall in the middle of the 4ms low pulse on the collector of Tr_{12}; R_{74} is adjusted to achieve this. The end of the 20ms control pulse should fall in the middle of the 4ms high pulse on the collector of Tr_{10}; only R_{75} should be adjusted for this.

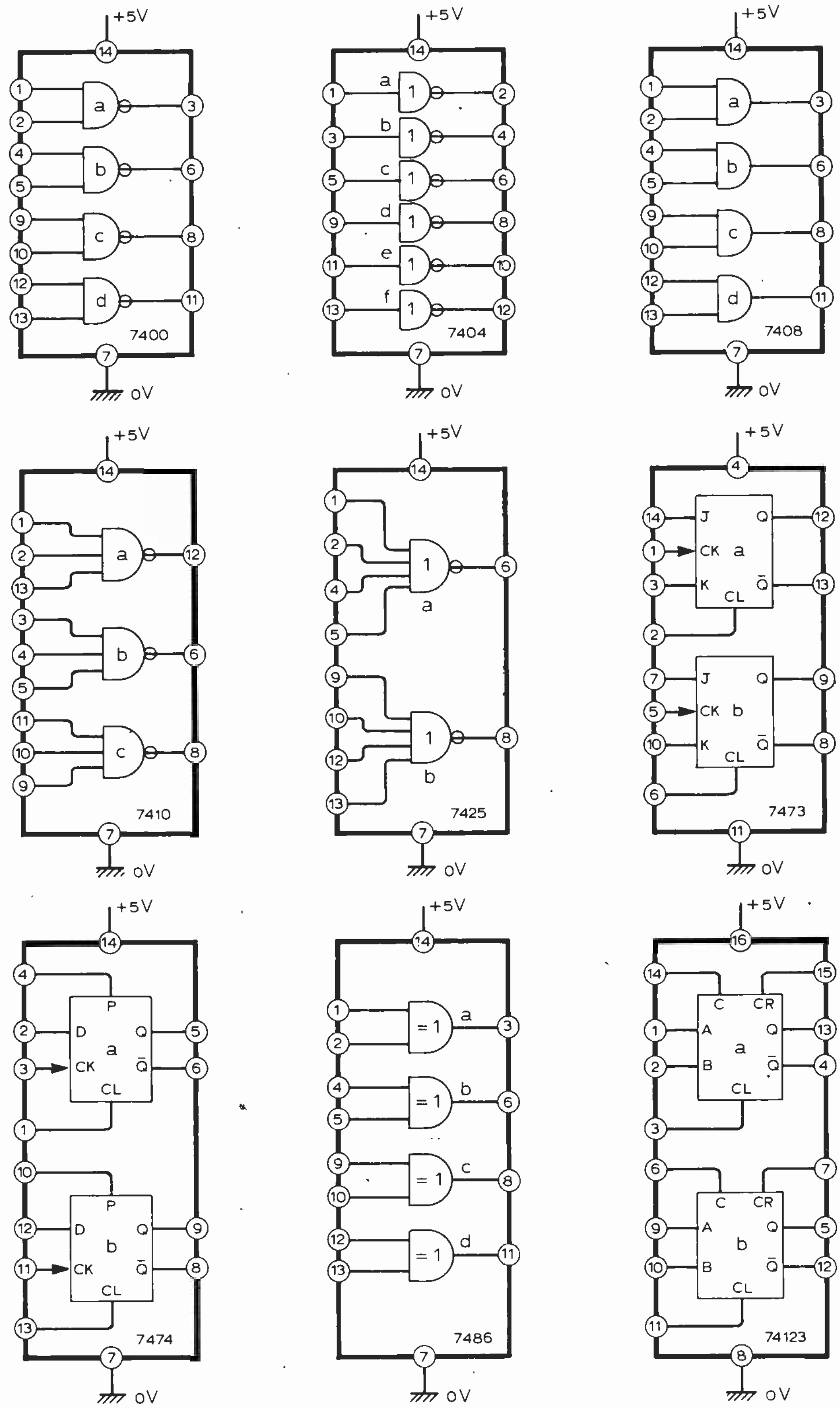


Fig. 17. Connection details for integrated circuits.

Operating the clock

When the clock is switched on the disparity lamp should light, along with the carrier lamp which flashes in sympathy with the signal. Besides the one-second pulses, the time code should be seen as a brief flicker each minute. The other coded information may also be noticed: firstly, the atomic/astronomic time-difference code, which is transmitted as a double break in the carrier in some of the seconds in the first quarter of each minute. This code changes from week to week as the difference varies. Secondly, in the last five seconds of every hour, the modulation is changed to the station call sign (MSF) transmitted twice in Morse code. Until the first code is correctly received, the clock display remains blanked. Upon recognising a control pulse the code lamp should flash, the disparity lamp should go off, and the display should show the received time code (subject to the GMT/BST switch). The disparity light may come on again if either a spurious signal is recognised as a control pulse (followed by correct spurious parity), or if the time code is incorrectly received (but again with the correct detected parity), or if the contents of the display dividers become corrupted by, for instance, momentary loss of power. For the displayed time to become corrupted by received interference, several coincidences must occur; two false control pulses need to be recognised with no intervening correct code, also, both false pulses must be followed by correct parity before they are acknowledged by the control logic. Although the chance of this happening is increased when the transmitter is switched off, the system has been found to give satisfactory results in most environments.

The author wishes to thank Mr J S Sansom, OBE, former director of Studios and Engineering, Thames Television, for permission to publish this article, and Mr B G Scott, chief engineer, for his encouragement and the use of facilities for the project.

Points arising

Because of a change in the transmission specification the following points should be noted. In Fig. 1 the parity bit was shown as a 1, this is now a 0 and, as a result, the parity check from IC_{12a} (Fig. 7) is taken from the $\bar{Q}$ output. If the received parity in the flip-flop is correct the final state is now $Q = 0$.

In the parts list IC_2 was shown as a quad two-input NAND gate package. In Fig. 9, 11 sections a and b of IC_2 are shown as inverters. These are realised by connecting the two inputs of the gates together which then function as inverters.

Meetings

LONDON

1st. IEE — "Electrical engineering and medicine" by Dr D. W. Hill at 18.30 at Savoy Pl., WC2.

6th. IEE — "Position control of floating structures" by P. H. Barton at 17.30 at Savoy Pl., WC2.

7th. IEE — "The history of transmitters — some aspects of early radio" by R. F. Pocock at 17.30 at Savoy Pl., WC2.

7th. BKSTS — "What are audio visuals?" at 19.30 at Thames Television Theatre, 308-316 Euston Road, NW1.

12th. IEE — "Digital systems representation" by S. Y. Foo at 18.30 at Savoy Pl., WC2.

13th. IEE — Colloquium on "Earth leakage protective devices" at 10.30 at Savoy Pl., WC2.

13th. IEE — Colloquium on "Theory and operation of Read type IMPATTs" at 14.30 at Savoy Pl., WC2.

13th. AES — "Developments in noise reduction techniques" by speaker from Dolby Laboratories Inc. at 19.15 at the IEE, Savoy Place, WC2.

14th. IEE — Colloquium on "Evaluation and experience of high level languages for process control computers" at 10.30 at Savoy Pl., WC2.

20th. SERT — One-day seminar on "Applications of computers" at the IEE, Savoy Pl., WC2.

21st. IERE — Colloquium on "Automatic production" at 14.00.

21st. BKSTS — "Video tape recording today and tomorrow" by L. H. Griffiths at 19.30 at Thames Television Theatre, 308-316 Euston Road, NW1.

26th. IEE — "History of magnetic sound recording" by B. Lane at 17.30 at Savoy Pl., WC2.

27th. IEE — Colloquium on "Paging systems" at Savoy Pl., WC2.

29th. IEE — Colloquium on "Parallel digital computing methods: d.d.as and stochastic computing at 10.30 at Savoy Pl., WC2.

29th. IERE — "A novel approach to marine surveying" by J. M. Thompson at 9 Bedford Sq., WC1.

30th. IEE — Discussion on "Part-time undergraduate degree courses in electrical engineering" at 17.30 at Savoy Pl., WC2.

BELFAST

13th. IEE — "Integrated circuits for communications" by S. J. Laverty at 18.30 at Ashby Institute.

BIRMINGHAM

7th. IEE — "Train control, developments on British Rail" by J. W. Birkby at 18.30 at Sumpner Building, University of Aston, Gosta Green.

14th. RTS — "The other side of the camera" by Tom Coyne at 19.00 at BBC Broadcasting Centre, Pebble Mill Road.

BLETCHLEY

8th. IEE — "Tomorrow's world and microwave communications" by P. J. Mountain at 19.30 at Post Office Training Centre, Horwood House.

BRIGHTON

13th. IEE — "Electro-acoustics" by Prof. E. Ash at 19.30 at the University of Sussex.

BRISTOL

5th. IEE — "Automobile Electronics" by C. S. Rayner at 18.00 at Mercury House, Bond Street.

8th. IEE — "Electronic calculators" by B. Clarke at 19.30 at Queens Building, Bristol University.

28th. IEE/IERE — "Marine electronics" by speaker from Marconi International Marine Ltd.

28th. IEETE — "Programmable logic controllers" by C. C. Cargill at 19.30 at Royal Hotel, College Green.

BURY ST EDMUNDS

7th. IEE — "Police Research" by B. J. Blain at the Angel Hotel.

DERBY

6th. IEE — "Automobile electronics" by D. B. Hodgson at 19.00 at the Lecture Theatre, College of Art and Technology, Kedleston Road.

DUBLIN

8th. IEE — "Electronic aids for medical studies" by Dr E. T. Powner and P. J. Best at 18.00 at Physics Laboratory, Trinity College.

DURHAM

5th. IEE — Exhibition and "Telecommunications; past, present and future" by W. J. Bray at Durham Castle.

EASTBOURNE

8th. IEETE — "Royal Greenwich Observatory" by G. H. Gill at 19.30 at The Drive Hotel, Victoria Drive.

EDINBURGH

8th. IEE — Symposium on "Further developments of applications of micro-computer systems" at 9.30 at Heriot Watt University, Grassmarket.

23rd. IEE — Faraday Lecture on "The entertaining electron" by F. H. Steele, afternoon and evening at The Usher Hall.

GLASGOW

21st. IEE — Faraday Lecture on "The entertaining electron" by F. H. Steele in the evening at The Kelvin Hall.

HATFIELD

6th. IEETE — EASCON 76 one-day conference "Links: education — employment" at Hatfield Polytechnic.

KINGSTON-UPON-THAMES

1st. IEETE — "The testing of electrical household appliances" by M. H. Hewett at 19.30 at Kingston Polytechnic, Penrhyn Road.

LIVERPOOL

5th. IEE — "Music hath charms . . ." at 18.30 at the Department of Electrical Engineering, Liverpool University.

LOUGHBOROUGH

27th. IEE — "Introduction of adaptive control techniques into areas of classical control" by J. R. Wolton at 19.30 at Lecture Theatre J002 Ed., Herbert Building, Loughborough University.

MANCHESTER

14th. IEE — "Microprocessors" by Prof. D. Aspinall at 18.15 at the University of Manchester.

MIDDLESBROUGH

7th. IEE — "Rapid fault finding techniques to minimise down time" by R. H. Baulk at 18.30 at Cleveland Scientific Institute, Corporation Road.

NEWCASTLE-UPON-TYNE

12th. IEE — "Colour TV — a popular approach" by G. D. Barnes at 18.30 at Room L101 Merz Court, University of Newcastle-upon-Tyne.

27th. IEE — Faraday Lecture on "The entertaining electron" by F. H. Steele, 19.15 at City Hall.

NOTTINGHAM

6th. IEETE — "Computerised control of Nottingham traffic" by M. B. Tate at 19.00 at New Mechanics Institute, St Trinity Square.

PORTSMOUTH

6th. IEETE — "Oracle — the teletext data broadcasting system" by G. A. McKenzie at 19.30 at Highbury Technical College, Cosham.

RUGBY

7th. IEE — "The future of the IEE" by R. J. Clayton at 18.30 at Lanchester Polytechnic, Rugby.

SHEFFIELD

20th. IEE — "Future role of the IEE by Dr E. Laverick at 19.30 at Sheffield University.

28th. IEE — "Electronic techniques in Archaeology" by Dr E. T. Hall at 18.30 at Sheffield Telephone House.

SWANSEA

8th. IEE — "Transducers for modern automobile systems" by J. Moore at 18.15 at University College.

SWINDON

6th. IEE — "Sonar and underwater acoustic communication" by V. G. Welsby at 18.15 at The College, Regent Circus.

Electronic systems — 3

Modulation and transmitting signals

by W. E. Anderton
Assistant Editor, Wireless World

Modulation is a principle fundamental to all communication systems — speech is a modulation of sound waveforms, pictures are modulations of light intensity and communication within the human body itself relies on modulation of the rate of firing of electro-chemical pulses in the nerves. The fast transmission of information over long distances is only possible using a high speed carrier which will travel for large distances without attenuation; hence electromagnetic radio waves are of prime importance for distant communication. In the case of transmitted radio waves, the process of modulation is to vary some parameter of the basic electromagnetic wave, which is usually called the carrier. Over the years, various modulating methods have been devised and are aimed at transmitting the required information as effectively as possible with the minimum amount of distortion. The primary factors to be considered are signal power, baseband, distortion and noise power — each of these will be described later. Ultimately, it is the ratio of signal power to noise power or output "signal-to-noise ratio" specified for the system which determines its performance.

Baseband

The baseband is defined as the range of frequencies which is to be communicated, e.g., the speech baseband is approximately 300Hz to 4kHz. The ear can perceive sounds outside this defined speech baseband but experiments have shown that adequate intelligibility is achieved using this contracted range. Consequently all telephone systems use this baseband.

Baseband communication (i.e. with no modulation of carrier signal) has a very limited transmission distance. Without electrical assistance, acoustic communication is not possible over distances greater than half a mile. This range may be further restricted by environmental conditions. In fact, the limitations of baseband telephone communication are many and the following list gives some of the more obvious and important of these: (a) the communication link can be made only between fixed locations; (b) a complex switching system must be designed to allow any subscriber to contact any other subscriber; (c) long distance links require amplification in order to overcome cable losses; (d) simultaneous communication with large audiences is impossible; (e) the system's cost is largely in the laying of individual cables to each subscriber.

The development of a "wire-less" system has overcome most of these disadvantages.

Electromagnetic propagation

Early experimenters in electromagnetic propagation discovered that some energy from a high energy spark could be transmitted to a suitable receiver without the use of wires. The spark's energy was coupled to an aerial and propagated through "space" to the receiver. The receiver often being a crude tuned circuit consisting of a coil and another smaller spark gap. This process was termed "impulsive electromagnetic propagation".

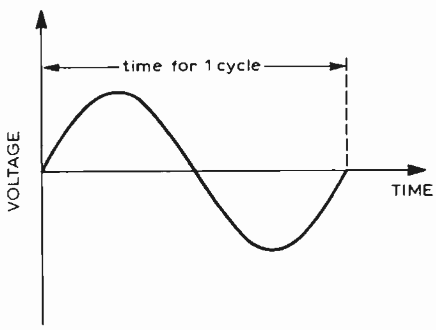
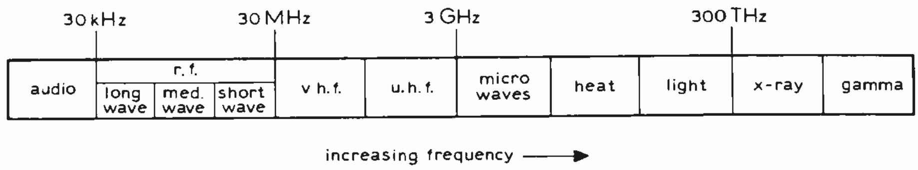


Fig. 1. Oscillatory waveform – the basic carrier wave.

Fig. 2. Frequency bands may be classified as shown here.



Later experiments were performed which, instead of using the impulsive spark energy, used an oscillatory waveform. This waveform (represented as in Fig. 1) could also be propagated from transmitter to receiver.

Wavelength, frequency, wavebands

Sound waves travelling in air do so at a velocity of approximately $343m.s^{-1}$, but radio waves travelling through space do so at the speed of light, i.e. at approximately 300 million $m.s.^{-1}$. The frequency of an electromagnetic wave is defined as the number of complete cycles transmitted per second and because we know the speed of the radio wave we can calculate the length of any one complete cycle in space. This length is known as the wavelength of the radio wave. The formula linking these two quantities is

$$\text{wavelength} = \frac{\text{speed of light}}{\text{frequency}}$$

or

$$\lambda = c/f$$

Electromagnetic propagation is affected by the Earth's atmosphere in various ways which are dependent on the transmission frequency and the distance between transmitter and receiver. Fig. 2 shows a convenient classification of the frequency bands.

Modulation

To send information from transmitter to receiver, the carrier wave must be varied in sympathy with the information to be transmitted. This process is termed "modulation" and the information that is being transmitted is termed the "modulating signal". Modulation occurs whenever a "carrier" is affected by a signal which has to be transmitted. For example, the frequencies and amplitudes of sound waves are modulated by the speech information which is transmitted from person to person whilst the intensity of a light is modulated by a signaller using an Aldis lamp.

The two most important analogue methods are amplitude modulation and angle modulation. Amplitude modulation is most common for applications such as radio broadcasting and radio telephony. The process of amplitude modulation is illustrated in Fig. 3. The a.m. systems are essentially narrow-band and suffer from limitations due to noise which has a direct effect on signal amplitude, and is therefore reproduced as interference.

In competition with a.m. some systems use angle modulation because of its immunity to amplitude varying noise. In angle modulation, the instantaneous angle of the carrier wave is varied and it leads to two forms of modulation known respectively as frequency modulation (f.m.) and phase modulation (p.m.). These two are closely related though practical systems tend to favour f.m. Typical examples are v.h.f. broadcasting, satellite communications and f.m. radar. The frequency modulated carrier wave shown in Fig. 4 requires a much greater available band of frequencies than its a.m. counterpart and an f.m. system is capable of giving a much better signal-to-noise performance than the corresponding a.m. system, or alternatively a considerable economy in power if required.

Carrier keying

If a transmitter is tuned to transmit a carrier wave at frequency f and a receiver at a distant location is tuned to receive this frequency then one would expect that the man at the receiver would be able to detect if the man at the transmitter switched his transmitter on and off. This is the most basic form of modulation and information transmission via a carrier wave. The technique is termed "carrier keying". This simple system can be extended to enable it to convey messages by keying the carrier in a predetermined code sequence. Morse code wireless telegraphy uses a system of long and short pulses. Fig. 5 shows the signal transmitted by a carrier keying system for the morse character "Y". The long bursts of carrier denote a dash and the short bursts a dot.

Amplitude modulation

In a linear amplitude modulation system, the amplitude of the transmitted carrier wave is made to be instantaneously proportional to the amplitude of the modulating signal. The modulation can be sinusoidal, square or any other shape which it is found necessary to transmit. The modulator is similar to a linear multiplier, the inputs being the carrier and the modulation signals. The output is the signal to be transmitted.

transmitted signal = carrier × modulation signal

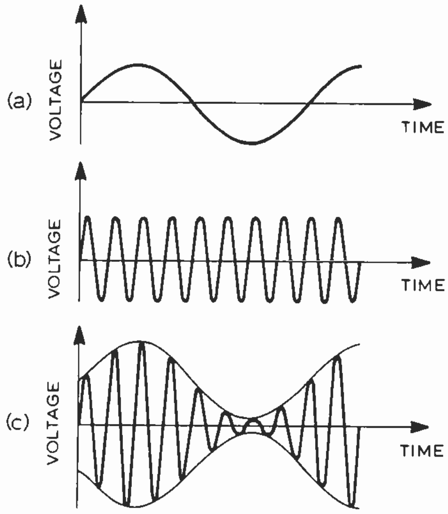


Fig. 3. Illustrating the basic process of amplitude modulation.

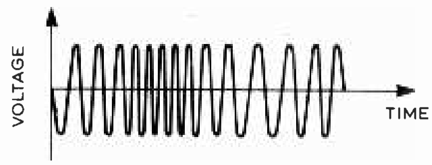


Fig. 4. Frequency-modulated carrier wave.

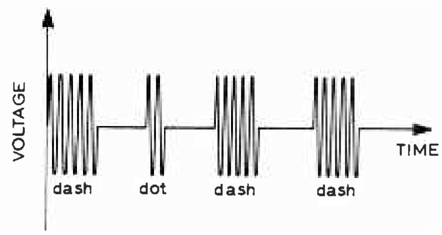


Fig. 5. Signal transmitted by a carrier keying system for the morse character "Y".

If the carrier is modulated with a 400Hz sine wave then the receiver will receive a carrier signal whose amplitude is varying at 400Hz and the variations will be sinusoidal. In the last section we discussed carrier keying as a method of transmitting morse code. There are complications involved when one wants to switch a high power transmitter rapidly on and off. This problem is easily overcome in the amplitude modulation system — one simply switches the modulating signal on and off. The result at the receiver is 400Hz tone bursts which will represent the dashes and dots of the code, while the carrier wave is transmitted continuously. The 400Hz modulation frequency can be replaced by a speech waveform, in which case the carrier will now be amplitude modulated so as to correspond with the speech signal. This system is used widely, an example being the programmes broadcast on the long and medium wavebands.

The next part of this series will examine a.m. and f.m. in more detail. An outline of the basic electronic systems course which this series of articles will cover was published in the first part appearing in the January 1976 issue.

This article was prepared in consultation with Professor G. B. B. Chaplin, University of Essex.

Further reading

Connor, F. R., "Modulation," Edward Arnold, London.

Obtainable from Mr R. A. Smith, Department of Electrical Engineering Science, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, Essex, are the teaching texts for the electronic systems pilot A-level course, price £4.50: communication systems section only, £2.00; computer systems section only, £2.00; feedback systems section only, £2.00; basic electronics section only, £1.50.

Books Received

Handbook of Electronic Circuits by G. J. Scoles. In the authors words "instead of first, dealing with electronic theory in some detail and then proceeding to a mathematical analysis of a small number of selected circuits, it assumes that with the help of a simple explanation the reader already knows sufficient of the theory for him to understand the operation of virtually any electronic circuit. In this way it becomes possible to describe the uses and functioning of more than 200 different circuits, either using non-mathematical explanation or, where relevant, simplified formulae only". A wide cross section of circuits are discussed under 26 general categories purposely omitting r.f. amplifiers and t.v. receiver details because, in the authors opinion, these have been adequately covered in other publications. Price £13.50. Pp. 370. John Wiley & Sons Ltd, Baffins Lane, Chichester, Sussex.

Diode characteristics, equivalents and substitutes by B. B. Babani contains more than 25,000 separate entries including military types. The pocket book also contains a contents page in nine different languages for our overseas friends. Price 95p. Pp. 159. Bernards Publishers Ltd, The Grampians, Shepherds Bush Road, London W6 7NF.

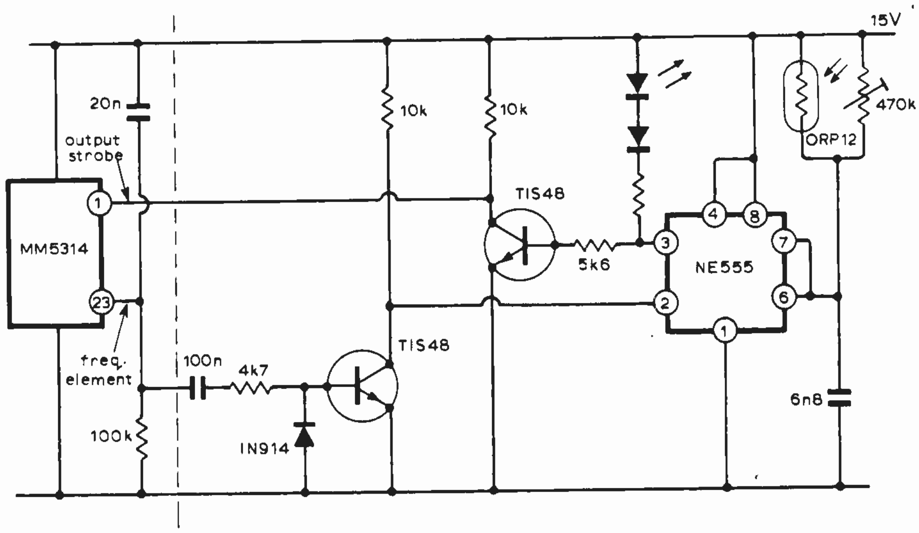
Electronic and switching circuits by S. M. Bozic, R. M. H. Chery and J. D. Parsons. This book is based on lectures given by the authors to undergraduate students. An intermediate level of mathematical knowledge is assumed together with the basic principles of a.c. circuit theory. After explaining physical electronics, the principles of amplification, switching devices, oscillators and power supplies are covered. Final chapters discuss data processing and transmission, industrial applications and electronic instruments. The book also contains problems and solutions which are designed to test whether the reader has understood the text. Price £4.95 paperback, £10.00 hard back. Pp. 380. Edward Arnold Publishers Ltd, 25 Hill Street, London W1X 8LL.

Circuit Ideas

Automatic display-brightness control

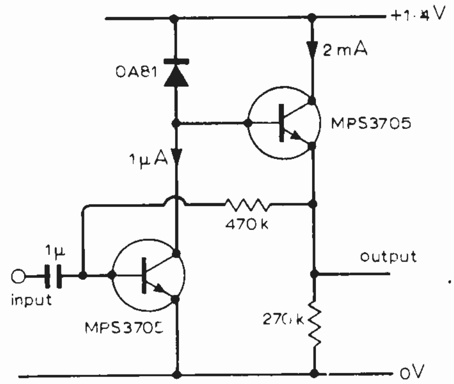
It is quite easy to modulate the intensity of a display by switching it on and off with a varying duty cycle. With single-chip clocks where multiplexing is used, the display on time must be synchronised to the multiplex frequency. This circuit was designed around an MM5314 clock chip but should be usable wherever there are external multiplex-oscillator and strobe-enable outputs. The 555 timer is used in the monostable mode, triggered by the multiplex oscillator to determine the display off time. In bright conditions the ORP12 resistance is low and the display is on most of the time. It is necessary to set an upper limit to the pulse length, otherwise the 555 will not retrigger on each cycle of the multiplex oscillator and only alternate digits will be displayed. The potentiometer should be set to give low light output without mistriggering in dark conditions. The simplest way to control the rate of brightness increase with ambient light is to partially obscure the ORP12 surface. The 555 can also drive a decimal point directly, giving a matched brightness.

M. G. Martin,
Maybush,
Southampton.



Low-current source

It is possible to use a reverse-biased germanium diode as a voltage independent current source for loading silicon transistors. Advantages of this method are less voltage lost across the source when compared with f.e.ts and similar sources, it is cheap, and the diode I_R increases with temperature in much the same manner as the h_{fe}, I_{cbo} in a transistor. The last point allows reliable micropower circuits to operate over a wide temperature range at



optimum current drain. This principle was applied in the amplifier circuit shown. The diode leakage current is arranged to be greater than the collector-emitter leakage of the transistor, permitting linear operation. Performance figures are: a voltage gain of 50, a −3dB bandwidth from 16Hz to 4kHz, a maximum output into 1MΩ of 500mV pk-pk (at 300Hz), an input impedance of 10kΩ (at 500Hz), and a consumption at 20°C of 4πW.

Owing to manufacturing tolerances the operating point can only be guaranteed to within a decade or two, and the diode capacitance is extremely non-linear at low reverse voltages.

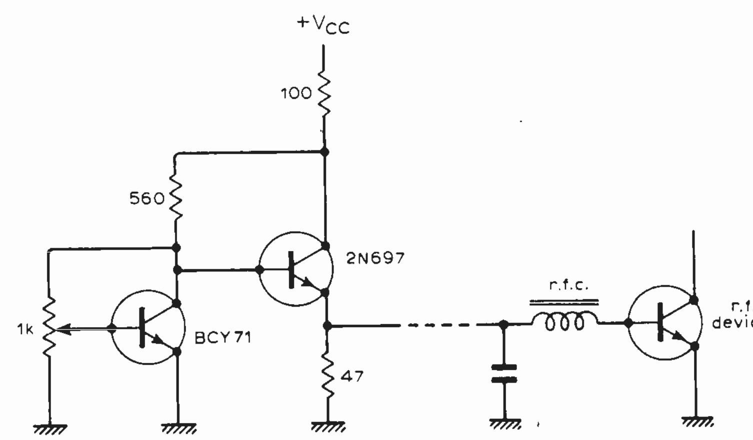
M. G. Baker,
Beaminster,
Dorset.

Bias supply for r.f. power amplifiers

Many designers resort to the use of a single forward-biased diode voltage source when attempting to operate transistor r.f. power amplifiers in the class AB linear mode. This can require the selection of a suitable diode and thus does not lend itself to reproducible design.

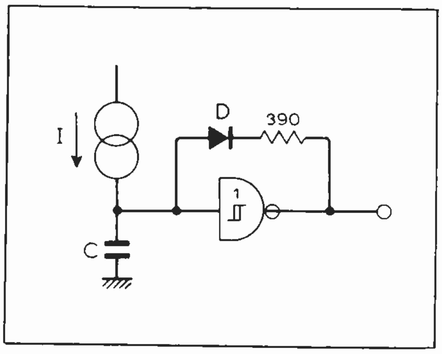
The circuit shown not only offers improved performance, typically 1Ω output impedance and ±3% output voltage change for ±2½V input change, but also allows adjustment of the quiescent collector current. A p-n-p silicon device is used as an amplified diode variable voltage source. If this is in thermal contact with the r.f. device's heatsink, a significant degree of thermal stabilization is obtained. The emitter follower lowers the supply output impedance. The devices shown can be replaced by similar readily available transistors.

C. P. Bartram,
Dept. of Metallurgy
and Science of Materials,
Oxford.



Simple current controlled pulse generator

This simple circuit generates pulses to operate t.t.l. at a variable rate between about 100Hz and several MHz. The diode should be a germanium type of low capacitance and must be able to carry current *I* continuously. The capacitor can be any value from picofarads to millifarads. Suitable inverters are SN7413/14/132 or the Schottky clamped variety for higher speed. Care



must be taken in choosing the current to avoid damaging the inverter and diode. The control current can be obtained by a resistor to +5V. There is an internal resistor of about 4kΩ connected to +5V on the input of the inverter, which gives a minimum pulse rate for any value of C. For further information about such oscillators see *T.I. Applications report* B81.

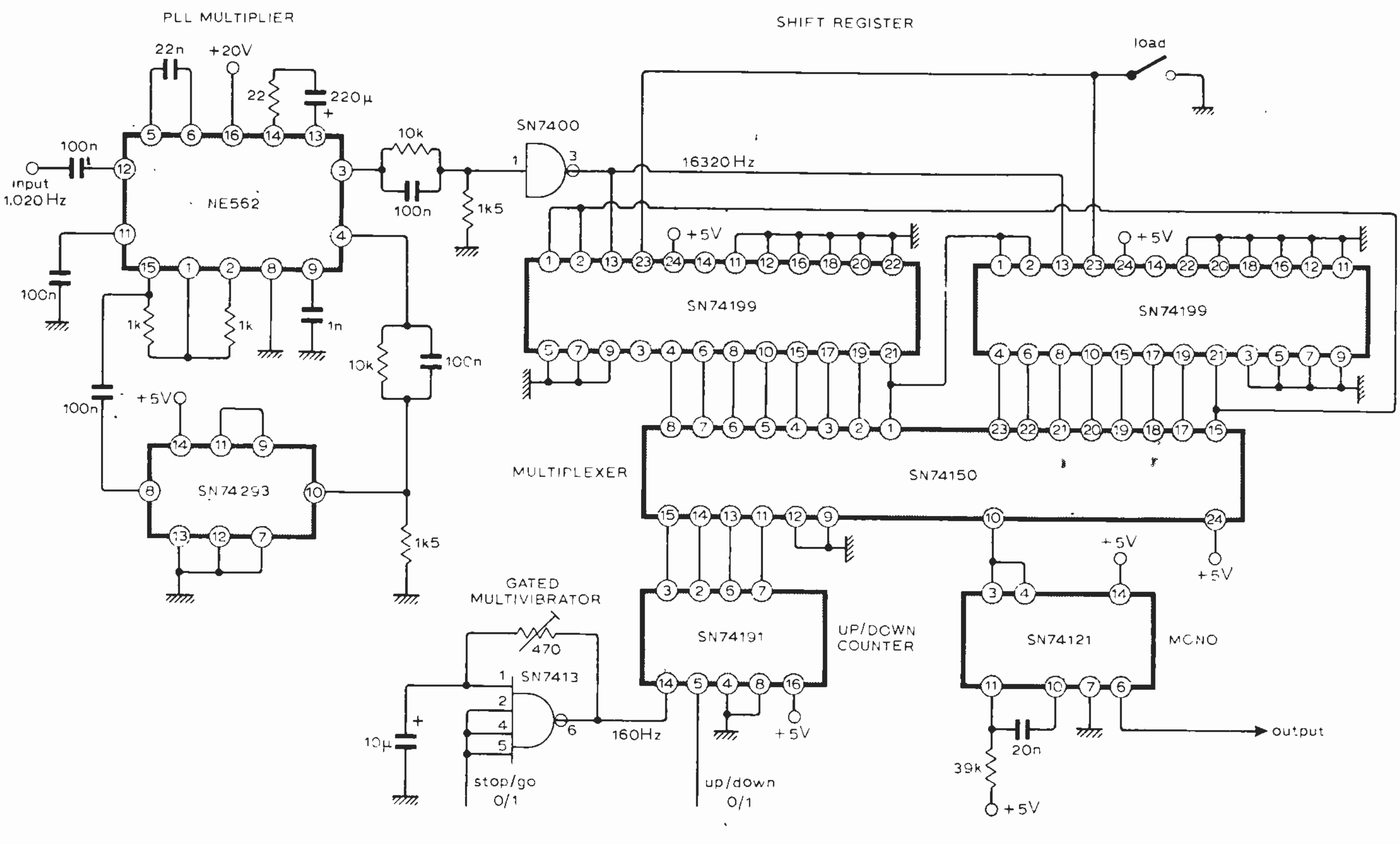
G. W. Haywood,
Bingham,
Notts.

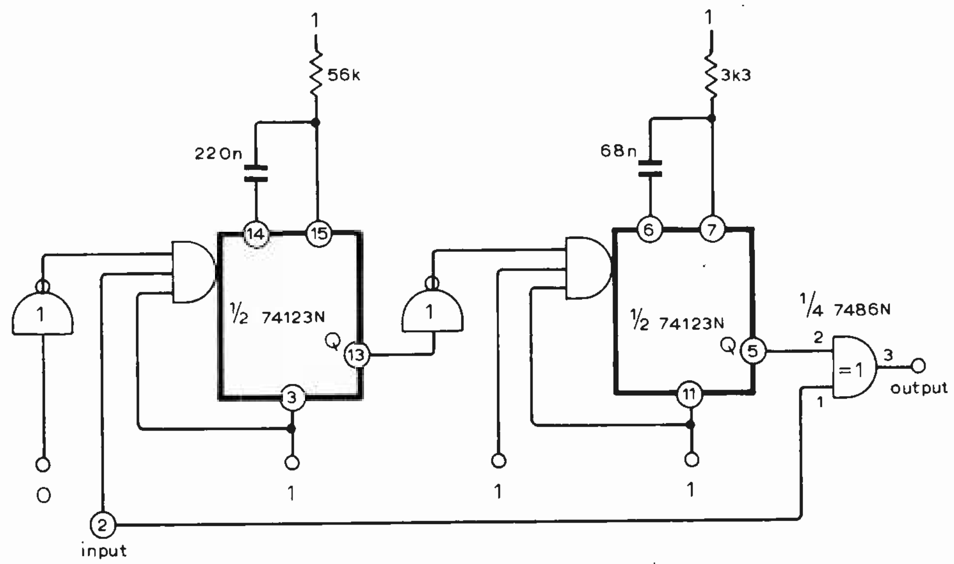
Synchronous-motor phase control

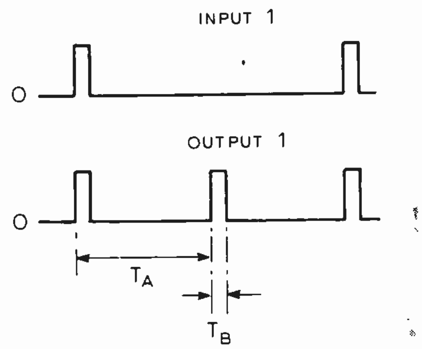
The requirement was for accurate phasing of a 51 pole pair phonic/synchronous motor in a facsimile transmitter. This circuit can be readily adapted for similar applications. A sixteen stage shift register loaded with one bit and connected as a ring counter is clocked at sixteen times the required motor drive frequency. Thus, the output of any one stage is a pulse train with a 1:15 mark/space ratio and a repetition rate equal to the drive frequency. A single pole sixteen way switch can select the output from any stage of the shift register. For every clockwise step of the switch there will be a 360/16 degree phase retard of the output. Similarly for every anticlockwise step there will be a 360/16 degree phase advance. Smaller steps may be achieved by extra stages in the shift register. In terms of shaft rotation each step is 360/16×51 = 0.44°. In the circuit shown a sixteen line-to-one multiplexer acts as the sixteen-way switch. The position of the switch is determined by the data select input. To make the switch rotate uniformly either clockwise or anticlockwise, the data select is connected to a four-bit binary up/down counter. The clock drive for the counter is derived from a gated multivibrator, the rate of which determines the rate at which the phase advances or retards. If necessary another counter can be used to monitor the number of pulses from the multivibrator.

The 1:15 mark/space ratio at the multiplexer output can be improved by a monostable with a period set at half the period of the drive frequency. This puts less demand on the bandpass filter if a sinusoidal output is required. Sixteen clock pulses to the up/down counter produce one complete rotation of the sixteen way switch which means one complete cycle subtracted from or added to the motor drive. In terms of shaft rotation in a 51 pole pair machine, the phase is retarded or advanced 360/51 (7.05°) in sixteen 0.44° steps. In other words, if the gated multivibrator output frequency is *N* pulses/s, the motor speed alters by *N*/7.05 degrees/second.

P. E. Baylis and R. J. H. Brush,
Dept. of Electrical Engineering
and Electronics,
University of Dundee.







Pulse rate doubler

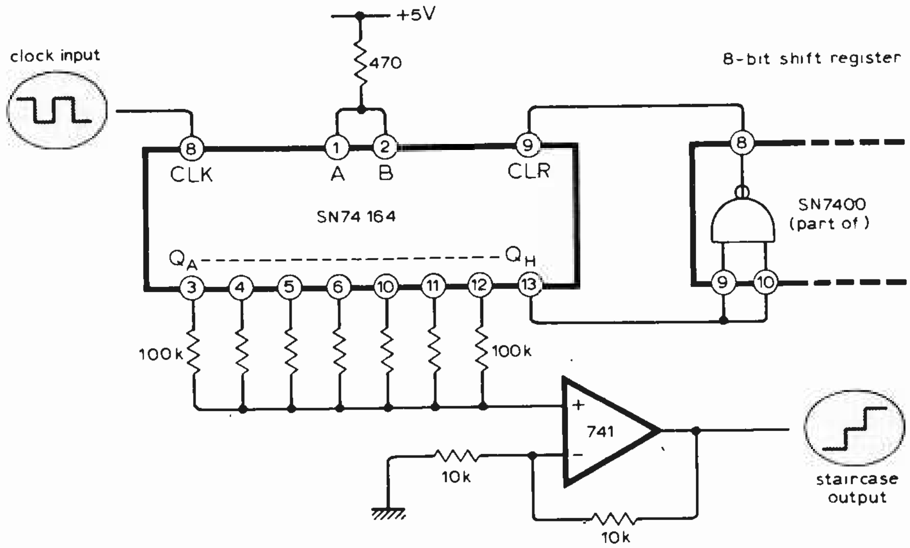
The circuit shown will generate pulses at twice the input frequency. A pulse is applied to the first monostable in the 74123N, which runs for time T_A. The negative edge, terminating T_A, triggers the second monostable which runs for time T_B. Thus, if T_A equals half the input period and T_B equals the width of the input pulse, an additional pulse is generated between each input pulse. An exclusive-OR gate combines both pulses to produce the output. Using R and C values as shown, the circuit will double a pulse of width 800µs and repetition rate about 130 per sec.

K. R. Brooks,
University of Bristol.

Simple staircase generator

The circuit provides a simple means of generating a repetitive staircase waveform. A total of seven steps is generated before the waveform is repeated. This may be increased by cascading several SN74 164 shift registers or decreased by providing the clear pulse from an earlier Q output.

P. Cochrane,
Ipswich,
Suffolk.

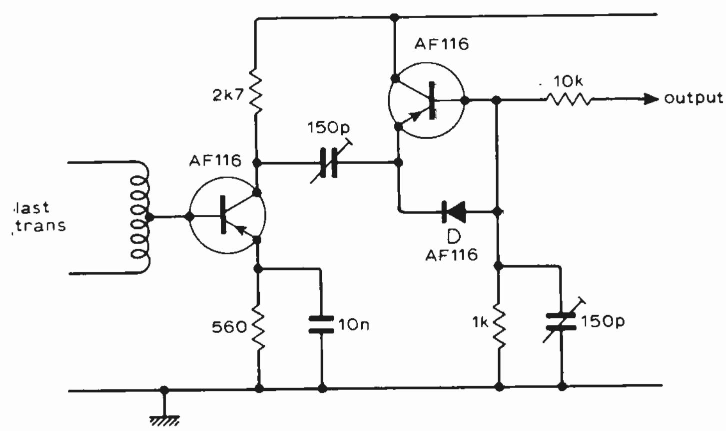


F.m. discriminator

To produce a high quality f.m. tuner I surveyed a number of design techniques using discrete components. After some research I became interested in an article by J. C. Hopkins (*Wireless World*, Sept. 1965). This circuit uses a transistor pump discriminator operating around a 200kHz i.f. This technique, used with a conventional 10.7MHz i.f. strip, produced very good results.

The circuit is similar to J. C. Hopkins's design and requires modifications only to the capacitor values and transistors. The last i.f. stage was modified and the load made resistive. The signal was then coupled to the discriminator which, in turn, was connected to a stereo decoder.

W. Anderson,
Portland,
Dorset.



Wireless World Teletext decoder

6—Lower-case characters and analogue circuits

by J. F. Daniels

The control-codes detection is based on six D-type flip-flops. The first three of these (52,6), (52,8) and (53,6) detect codes which mean "go to red display, green display and blue display" respectively. The fourth one dictates whether the display should be in the alphanumeric or graphics mode, and the fifth one (51,6) indicates when characters should be flashing. The final one is used to derive a wavefrom to switch between the TV and Teletext displays during the insert or boxed mode.

The Teletext specification says that all rows should begin in the steady, alphanumeric white, unboxed condition, and this is achieved by presetting the outputs of the six flip-flops to the required state with the output pulse from (59,8), which is a combined line and field blanking waveform.

Considering first the codes which indicate a change in colour of the display, it can be seen from the code table that bit 1 is always at 1 when a red output is required, bit 2 is at 1 when a green output is required and bit 3 is at 1 when a blue display is required. Combinations of these three bits will also give the complementary colours correctly such as yellow when bits 1 and 2 are both at 1, and also white when all three bits are at 1. The way in which this is achieved in the decoder is to feed bits 1, 2 and 3 respectively to the D inputs of the three flip-flops, (52,6), (52,8) and (53,6) and feed the clock inputs in parallel, with clock pulses occurring only during the fourteen colouring codes in the code table

The clock pulse gating is achieved in (41,10), (49,8), (43,13), (44,6), (58,6) and (49,6). The actual clock pulses are narrow negative-going pulses obtained from decoder (42,2) and are fed into gate (43.13). The other gates merely serve to inhibit the clock pulses at all times other than when a change in colour of the display is required. The input to IC_{49}, pin 9 can be changed by means of the link, from IC_{28}, pin 7 to IC_{59}, pin 2, altering the Clock-pulse-allow waveform to cater for the new code allocations.

The changeover between graphics and alphanumeric operation is obtained in a very similar way to that already described for colours. Flip-flop (53,8) obtains its clock pulses from the same place as the colour changing i.cs and its D input is fed either from (66.12) or (28.10) according to which transmission standard is being received.

Flashing and boxing codes are dealt with, again in a similar way to that already described. Clock pulses are only allowed during the two code positions allocated to flashing and boxing respectively. The D inputs are fed with bit 1 information, and in this way the output of each flip-flop is set either to the on or off condition depending upon which of the control codes is received. Normally, of course, the flip-flops are set to the off condition by the line-blanking waveform, and then somewhere along the character row a flashing code may be received which will set the flip-flop to the on condition. A further code may be received to turn off the flashing or, if no code is received, the line-blanking waveform will again set the flip-flop to the off condition at the end of the row.

Switching between the alphanumeric and graphic displays (both types of character are actually generated for each character box in the display) is achieved with gates (57,8), (57,11), (58,8) and (58,12). Alphanumeric characters are fed into IC_{58}, pin 2 and graphic characters into IC_{57}, pin 10. A feed of bit6 is also connected into IC_{58}, pin 1 and IC_{57}, pin 13. This is to enable the "blast through" mode of operation, in the following manner. Normally when graphics are being displayed, bit 6 is in the 1 condition. If, however, bit 6 is made 0 as for instance in the transmission of upper-case letters, this can be made to switch away from the graphics mode, and into the alphanumeric mode for the duration of the character. In this way switching between graphics and alphanumerics can be obtained very economically, without the need for a separate control character (which would be displayed as a space). The slight disadvantage of this is that only upper-case characters in columns 4 and 5 of the code table may be displayed in this way.

Gate (58,8) is fed with the outputs of gates (57,8) and (58,12), containing the graphics and alphanumeric characters respectively. A third input to this gate is fed with a composite blanking waveform which contains both line and field blanking, and also information to blank the control characters. Gate (44,12) adds together the line and field blanking waveforms, and a third blanking input is provided here which may be used to blank the Teletext display output while watching TV programmes. (It is possible that the Teletext waveform could break through onto the TV picture under some circumstances, if the leads were not properly screened, for instance.) The output of this gate is delayed by capacitor C_{11} to allow for delays in the r.a.ms and r.o.m. This output is added to the control-character blanking waveform in gate (41,13) and the output of this gate is then fed into (58,8) where it serves to blank the video display waveform.

The output of (58,8) is then inverted and gated with the output of the flashing oscillator formed from (67,2) and (67,4). This flashing oscillator is allowed by the D type flip flop (51,6) and gates the display waveform in (57,6). At this point the composite display waveform exists in monochrome form, and then the colours are incorporated by gating this monochrome waveform in the 2-input NOR gates (54,4), (54,13) and (54,1). The three D-type flip-flops enable or disable these gates to form the red, green and blue outputs.

Finally the output of the flip-flop (51,8) is gated with the line and field blanking waveforms to give an output which can be used as a switching waveform when a "boxed" display is wanted.

Lower-case characters

The character-generation circuit already described is capable of generating only upper case, or capital letters. Although this does not detract in any way from the information-carrying capabilities of the system, some people may consider it worthwhile to add the extra circuitry required to display lower case characters.

The method is exactly the same as that described last month for upper case characters, except that some lower case letters, i.e. g,j,p,q,y, drop below the line of normal characters. Provision has already been made for this as the character box is ten lines high and only the top eight lines are used for the upper-case characters and a space line between characters. This leaves two unused lines available to display lower-case descenders.

The same type of r.o.m. is used to contain the lower-case characters, the only difference being that the lower-case memory only contains the thirty two characters in columns six and seven of the code table, the other thirty two spaces being left blank. The complication arises from the fact that characters stored in the memory can only occupy up to eight lines of the display, as the row-address information to the r.o.m. consists of only three bits of information. Fortunately, however, none of the characters having descenders contains information in the top two rows of the character box, and this enables the character to be stored in the r.o.m. two rows higher than its intended display position, as shown in Fig. 1. This means that when the row addresses are applied to the r.o.m. they must be changed for those characters which have descenders, in order to lower the display position by two TV lines.

Figure 2 shows the extra circuitry needed to produce lower-case characters, and in practice these additional i.cs are mounted on a small board which fits above digital board 1 at the opposite end to the analogue board. I.cs 87, 88, 89, and 90 are used to detect the characters which require lowering by two rows, and this information is available at gate (89,4) where a 0 denotes a normal character and a 1 indicates a character that should be lowered by two rows.

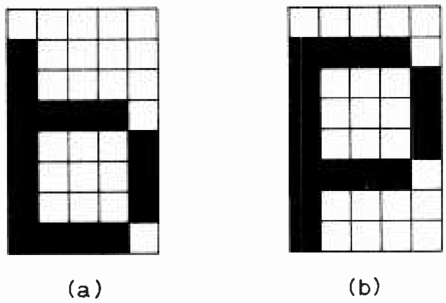


Fig. 1. Lower-case letters with "tails" are stored in the same memory rows as ordinary letters. Row addresses are changed during readout to lower the letters by two rows.

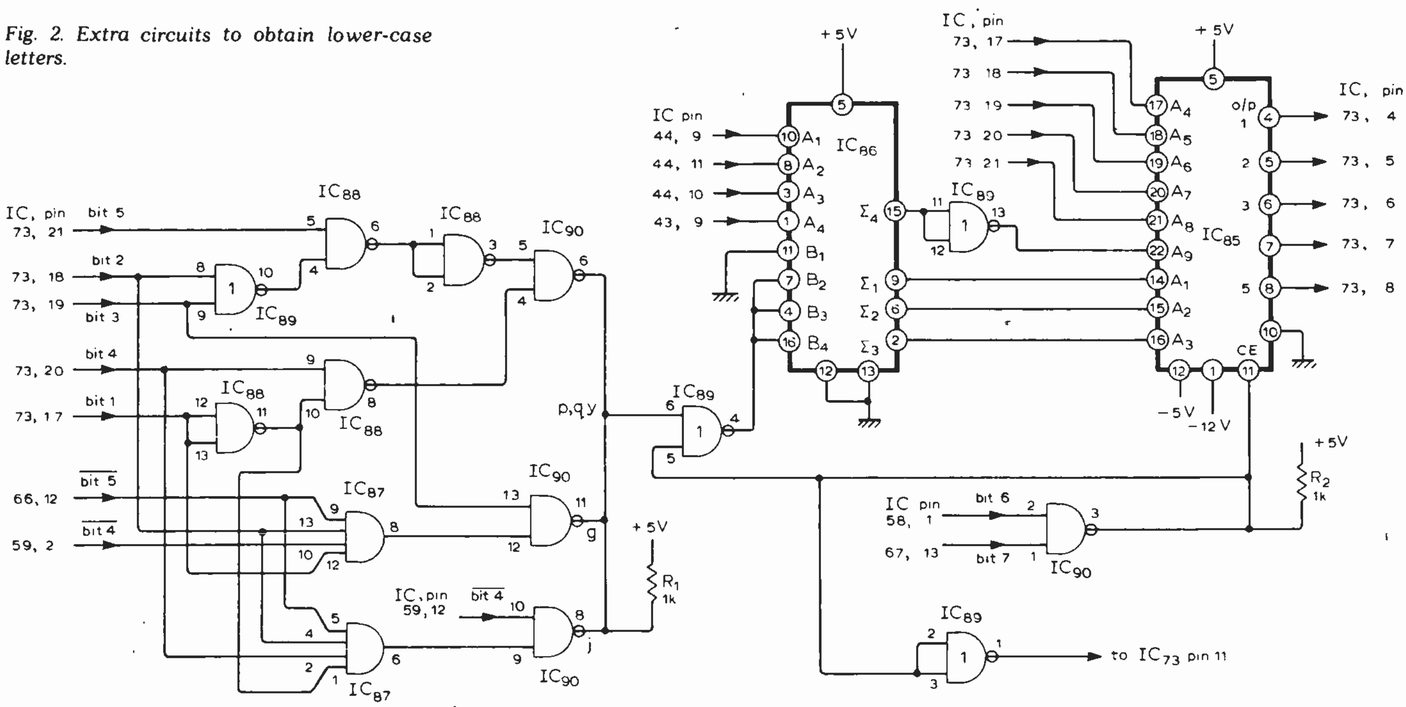
The character generator, IC_{85} is of the same type as the upper case one, a 2513, but its suffix CM3021 indicates that it is programmed with lower case characters. (The upper-case version is suffixed CM2140). Switching between the outputs of the two character generators is facilitated by their "tri-state" outputs. This means that as well as having the normal states of 0 and 1 at the output pins, a third condition can be obtained where the output pin is effectively open-circuited from the rest of the i.c. This third state is controlled by the "chip enable" input, and by suitable control of this input, any number of 2513's may be connected to the same five output rails. In this circuit, switching between the two r.o.m.s is controlled by gate (90,3). The output of this gate goes to 0 only during columns 6 and 7 of the code table, enabling IC_{85}, and the inverse of this waveform is fed to the chip enable pin of the upper-case character generator IC_{73}, enabling it during columns 0-5 of the code table.

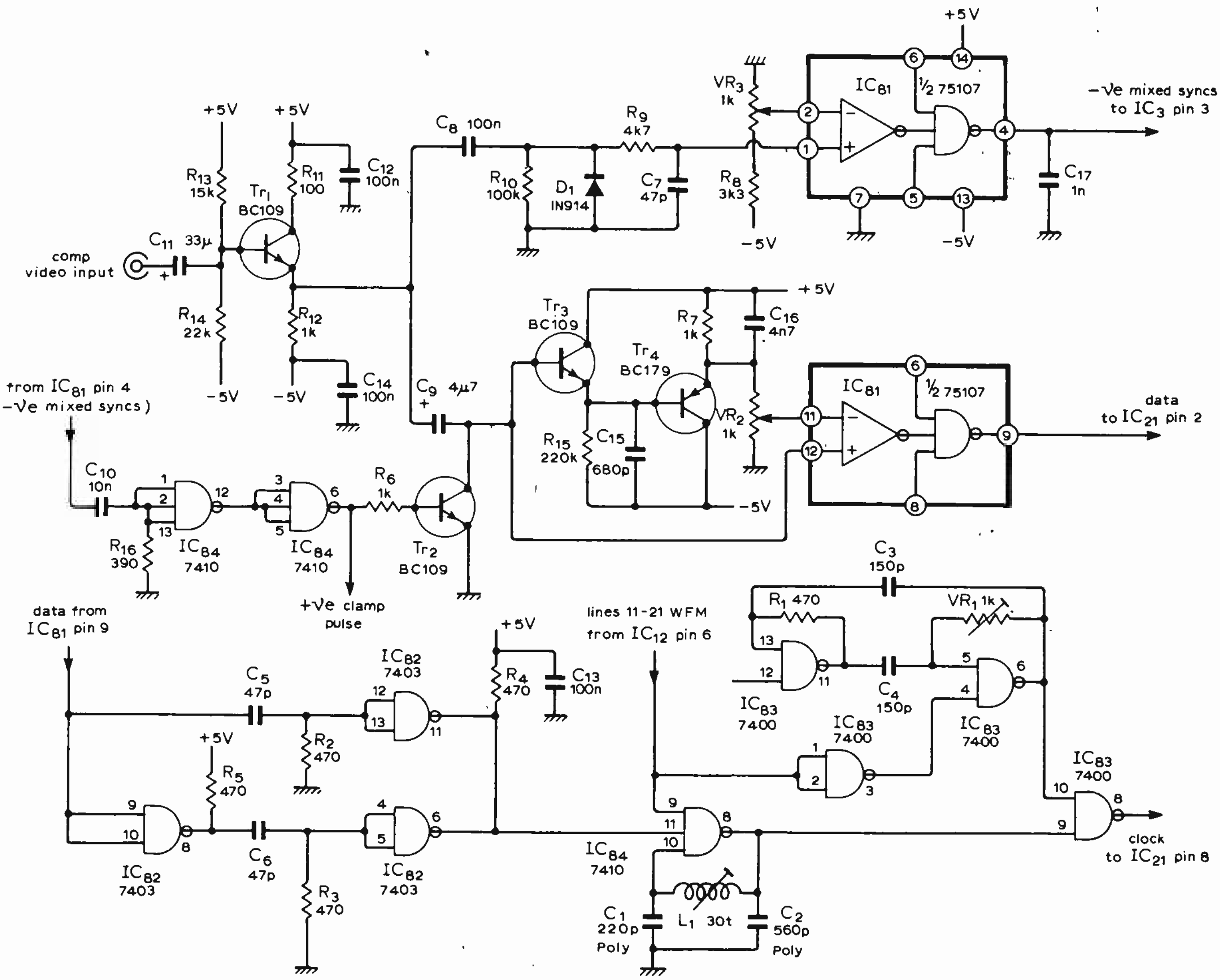
The row addresses to IC_{85} are fed from IC_{86}, which is a four-bit binary full adder, type 7483. The A inputs are fed with the four-bit row-address information from the line counter IC_5, and the B inputs are fed either with a binary zero, during normal characters, or the binary number fourteen during characters which require descending by two rows. Sum outputs one, two and three are fed to the row address inputs of the r.o.m. and these will change for a descended character in such a way that the character will be lowered by two TV lines. Sum output four can be used as a blanking waveform to inhibit the generation of characters during the top two rows of the character box, when a descended character is displayed. The blanking is achieved by means of gate (89,13) which switches the character generator to one of the blank character spaces during the required blanking period. This method of achieving the blanking is extremely useful, as the delay applied to the blanking waveform will be similar to the delay of the character read-out of the r.o.m. (about 400ns). If the blanking had to be added externally to the r.o.m. then some means of delaying the waveform by a suitable amount would have to be found. A useful feature of the lower-case circuitry is that only one track on the upper-case printed board has to be cut when adding the extra board (the chip-enable pin of IC_{73}) and all the connections to the existing boards may be made to the underside of digital board two, which entails a minimum amount of disturbance to the existing upper-case circuitry. For this reason also, I would suggest that the decoder should be built and tested as an "upper-case only" unit initially. The lower-case board can be added later as there is no extra line-up procedure required when this board is fitted.

Analogue board

This board serves three main functions, namely to provide feeds to the digital boards of mixed syncs, separated data,

Fig. 2. Extra circuits to obtain lower-case letters.





and a switched clock waveform which is suitable both for the writing of data into the store and for reading it out during the display period. The input to the analogue board, the circuit of which is shown in Fig. 3, should consist of a composite positive-going video waveform of between about 1 volt and 5 volts peak to peak. Tr_1 is an emitter-follower buffer which provides a suitable low-impedance source to drive the d.c. restorer formed from C_8, R_{10} and D_1. This restores the sync tips of the video waveform to a potential of about −1 volt. Chrominance information is then removed by the low-pass filter R_9, C_7, and the remaining video signal is fed to the positive input of a difference amplifier. The negative input is connected to a potentiometer which controls the point at which the video waveform is sliced. The best setting will depend on the amplitude of the video waveform, but the range of the potentiometer should be great enough to cover the whole of the sync portion of the video waveform and enable separated syncs to be obtained at the output of the difference amplifier. This i.c. is in fact a high-speed dual line receiver with fully t.t.l.-compatible outputs and is ideal for use in this type of circuit.

A mixed sync waveform could, of

Fig. 3. The analogue circuitry to produce syncs, data and clock.

course, be obtained from the TV receiver in which the decoder is to be installed, but it was felt that it would be better to include one in the decoder if only to reduce the number of connections to the TV set. It also has another advantage in that the decoder may be fed from a "video ring main" where a separate feed of syncs may not be available.

As well as feeding the digital boards, the feed of mixed syncs is used to generate a clamp-pulse waveform which is used both on the analogue board and the video switching interface board in the TV receiver. The positive going trailing edge of the line sync waveform is differentiated by C_{10} and R_{16} and coupled into gate (84,12). The resulting negative-going pulse is inverted by gate (84,6) and a positive going clamp pulse is obtained which is about 4µs wide, and occurs during the back porch of the video waveform.

This pulse is used in the analogue board to clamp the video waveform before slicing the Teletext-data in a similar way to that used in the sync separator. Before describing this in great detail, however, it would be as well to discuss some of the problems involved in successfully slicing the data signal.

Data slicing

In the simplest possible system, the video waveform could be fed via a capacitor into the positive input of a differential amplifier and by varying the direct voltage level on the negative input by means of a potentiometer, sliced video and data would be obtained at the output. The fact that picture information is sliced, and present at the output, is immaterial as precautions against this causing trouble have been taken elsewhere in the digital circuitry. However, because of the nature of the video waveform, the varying picture information will cause the average voltage of the signal to vary, and thus alter the position at which the video (and data) is sliced. If the data information were transmitted as perfect square-shaped pulses this would not matter because the output mark/space ratio of the data information would remain unaltered. However, the data cannot be transmitted in this way because the bandwidth requirements would become infinite, and the transmission system must be tailored to suit the normal TV bandwidth of 5.5 MHz. The data is in fact transmitted in the form of raised cosine pulses, and this implies that the data must be sliced fairly close to the halfway point between its positive and negative peaks, if the mark/space ratio of the received data is to be close enough to the original for correct decoding. This is the case even if the received signal is completely undistorted by the receiver tuner and i.f. strip. In cases where the receiver i.f. amplifier has insufficient bandwidth or large group-delay errors, or the aerial is mismatched into the receiver, the setting of the slice level will be even more critical and in very severe cases of "ghosting" or i.f. misalignment it may be impossible to find a suitable point at which to slice the video waveform and obtain error-free readouts. The simple system described above could only be adjusted to give satisfactory results during periods of static transmission such as test card, where the picture information is constant and the slice level would remain unaltered.

One way to overcome the problem of changing level of the video waveform would be to use the d.c.-restored video present at the cathode end of D_1. However, a better system is to clamp the video during the back porch, and this method is used in this design. Tr_2 is

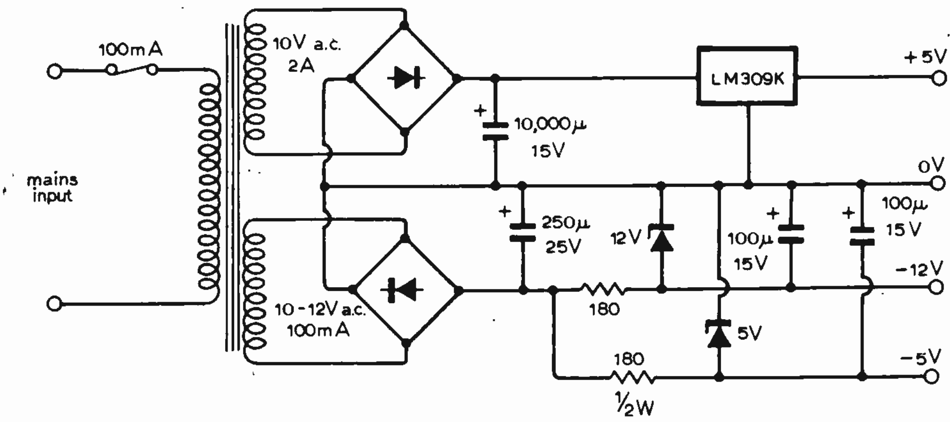


Fig. 4. A suggested power supply circuit.

turned on during the back porch by the clamp pulse, thus holding black level to approximately 0 volts regardless of the average level of the signal. Purists may point out that the clamp action will be upset by the colour burst. In practice, however, this only becomes a problem if large variations in level of the chrominance information occur, which will in turn cause the clamping point to vary slightly. If this is really a problem that cannot be solved by improving the aerial installation, then a 4.43MHz tuned circuit should be included in series with the collector of Tr_2. It has not been included as a standard feature in the circuit, partly because it has not proved niecessary, but mainly because it would be rather difficult to set up correctly without expensive test gear.

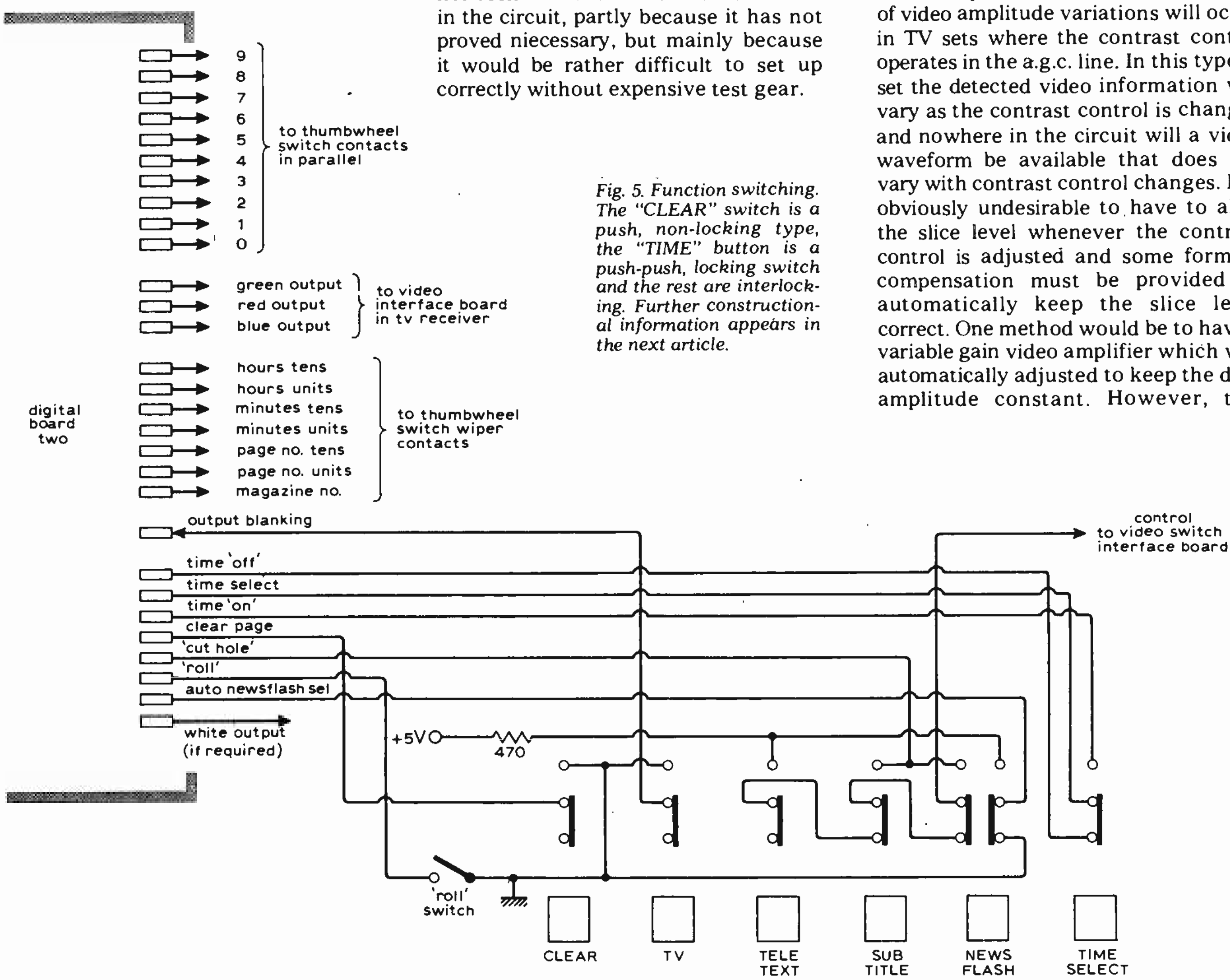


Fig. 5. Function switching. The "CLEAR" switch is a push, non-locking type, the "TIME" button is a push-push, locking switch and the rest are interlocking. Further constructional information appears in the next article.

The system described so far, consisting of a clamped video signal, sliced by means of a differential amplifier having a variable voltage level at its second input, is capable of giving very good results under most reception conditions. The slice level setting can be fairly critical under adverse conditions, however, and although the black level end of the waveform is maintained at a fixed level by the clamp, variations in amplitude of the video signal will also cause unwanted movement of the data level.

Small variations between the signal amplitude of different TV channels which may occur with some types of i.f. strip can be enough to prevent correct decoder operation. A more likely cause of video amplitude variations will occur in TV sets where the contrast control operates in the a.g.c. line. In this type of set the detected video information will vary as the contrast control is changed and nowhere in the circuit will a video waveform be available that does not vary with contrast control changes. It is obviously undesirable to have to alter the slice level whenever the contrast control is adjusted and some form of compensation must be provided to automatically keep the slice level correct. One method would be to have a variable gain video amplifier which was automatically adjusted to keep the data amplitude constant. However, this would undoubtedly be expensive, and a much simpler way of achieving the same end is to alter the slice level automatically, to enable it to follow the varying data amplitude. This is done by detecting the data amplitude with a peak-detector circuit and then using this information to set the slice level midway between the data peaks and black level.

Tr_3 forms the positive-data peak detection circuit with the decay time set by the time constant R_{15}, C_{15}. This time constant is made fairly long compared to the data bytes to prevent too much decay during the worst case condition of fourteen consecutive zeros. TR_4 then serves to offset the base-emitter voltage drop of Tr_3 and the shorter time constant R_7, C_{16}, increases the rise time of the peak detector circuit to reduce the effect of large noise spikes. The actual slice level is adjustable by means of VR_2 over the full range from 0 volts to the positive data peak level. Although theoretically this potentiometer should be in its mid position for correct data slicing, non-linearity distortion introduced by certain types of vision detector circuit will mean that the best results may be obtained if the slice level is not mid-way between the positive and negative peaks of the data. The difference amplifier used to perform the actual data slicing is the other half of the dual line receiver, IC_{81}.

Clock generation

It has already been explained that the clock waveform generated on the analogue board consists of the outputs of two oscillators, one locked to the incoming data, and the other adjustable in frequency to enable the display width to be adjusted. Switching between the two clock generators is performed by the 'lines 11-21' waveform. Gates (83,11) and (83,6) are cross coupled to form a free running oscillator. Oscillation is inhibited during lines 11-21 by the waveform present at gate (83,3), and by also inhibiting oscillation at the start of each TV line – Q of monostable 3 is fed into gate (83,11) – the oscillator is phase-locked to the TV lines. This ensures that the characters will have "clean" verticals. If the oscillator was merely free running the phase would alter at random from one TV line to the next, and ragged verticals would result. VR_1 adjusts the frequency of oscillation and forms the display width control.

Gate (84,8) forms the active part of the data clock oscillator. The frequency of oscillation is determined by L_1, C_1 and C_2. The waveform on pin 9 of the i.c. only allows oscillation to take place during lines 11-21, and at all other times the gate output is held at 1 allowing the display clock through gate (83,8) to the output line. The oscillator is locked to the incoming data by means of narrow negative going spikes fed into the third input of (84,8). These spikes occur at every data transition, gate (82,11) providing the spikes derived from positive-going data transitions, and gate (82,6) spikes derived from negative-going data transitions. Although the oscillator circuit may appear rather crude, it has been found to give excellent results in practice. The main point in its favour is that it is extremely easy to set up, as there is only one adjustment, that being L_1. The specified coil former is the Neosid A6 assembly, but in practice equally good results will be obtained with any former of approximately 3/16in diameter, containing an adjustable ferrite core, so long as it can be tuned in to the correct frequency of about 7MHz. The frequency stability of the circuit has been found to be perfectly adequate so long as polystyrene capacitors are used for C_1 and C_2. The preferred method of adjusting the oscillator frequency will be dealt with later in the article, as will the rest of the decoder line up.

Power supply

The power requirements of the decoder are fairly modest. Five volts for the t.t.l. circuitry is required at approximately 1.3A, and this can most conveniently be obtained from a three-terminal regulator of the LM309K variety. The input voltage to the regulator must not be too great, however, as the device will be working fairly close to its limits and may exceed its maximum power dissipation figure. For this reason, the regulator must be mounted on a suitable heatsink.

A negative five-volt supply is required at a current of about 25mA, and a negative 12-volt supply for the character-generator i.c. at only a few milliamps. Both negative supplies may be derived from simple zener-diode type stabilizers, and a suitable power supply circuit is shown in Fig. 4.

Constructors should see that the connecting wires between the power supply and the decoder are of a suitable gauge to prevent excessive voltage drop of the plus five-volt rail. At a current of something greater than one amp, it only takes a few feet of thin connecting wire to cause a voltage drop of greater than 0.25 volts which will be sufficient to bring the five-volt rail outside the recommended specification for t.t.l. devices.

(To be continued)

The next article in this series will give constructional details of the teletext decoder. Subsequently there will be an article on interfacing the decoder with various colour television sets in common use.

Who thought up the synchronous satellite?

Dr Harold A. Rosen, a vice-president of Hughes Aircraft Company and a pioneer developer of synchronous communications satellites, has won the first L.M. Ericsson International Prize for "proposing the introduction of geostationary communications satellites and for his scientific and technological contributions to their development, design and operation." The prize, of 100,000 Swedish crowns (about £11,000) will be presented by King Carl XVI Gustaf at ceremonies in Stockholm in May. To be awarded every three years, the prize honours the memory of Lars Magnus Ericsson, founder of the L.M. Ericsson Telephone Company.

Dr Hakan Sterky, chairman of the prize committee, says "Dr Rosen proposed that a single satellite could be orbited at an altitude where it matches the earth's rotation and appear to be stationary, thereby simplifying connection with earth stations and providing 24-hour-a-day service". British readers, in particular, will be surprised that no acknowledgement is made to Arthur C. Clarke, who is widely considered to be the originator of the idea of satellites in synchronous orbit. Clarke pointed out in the October 1945 issue of *Wireless World* (eleven years before Dr Rosen joined Hughes) that a space-station orbit with a radius of 42,000km "has a period of exactly 24 hours. A body in such an orbit, if its plane coincided with that of the earth's equator, would revolve with the earth and would thus be stationary above the same spot on the planet. It would remain fixed in the sky of a whole hemisphere and unlike all other heavenly bodies would neither rise nor set." Further, a satellite in this orbit "could be provided with receiving and transmitting equipment . . . and could act as a repeater to relay transmissions between any two points on the hemisphere beneath . . ." (See "Extra-terrestial relays", October 1945, pp. 305-308).

Hughes Aircraft state that all of the Intelsat communications satellites "are a result of Dr Rosen's synchronous-orbit concept." This is strange in view of the fact that it was a vice-president of Hughes Aircraft Company, Dr F. P. Adler, who gave public acknowledgement to Clarke's proposal more than a decade ago (June 1965 issue, p.269). Moreover, L. M. Ericsson have indicated that they know of Clarke (although they do not seem to be aware of the thoroughness of his 1945 proposal). Readers may be forgiven for questioning whether it really was Dr Rosen's concept.

Radio Telephones?

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KEEP IN TOUCH!

Phase shift in loudspeakers

Considering the cause and measurement of phase shifts

by James Moir

James Moir & Associates

When the sound pressure maxima immediately in front of a loudspeaker do not occur at exactly the same instants in time as the corresponding maxima in the voltage across the loudspeaker voice coil, they are said to differ in phase. The phase shifts that actually occur in some typical current speaker systems were measured to obtain objective data.

The time delays or phase shifts produced by loudspeakers arise for several reasons which we will consider, starting with the simplest example, a single-unit wide-range loudspeaker. The mechanical force exerted on the adjacent section of the coil former by the current in the voice coil is in phase with that current, but the phase of the current with respect to the voltage across the voice coil varies throughout the frequency band because of the reactances present in the moving coil system. Typical measured values of the phase difference between the applied voltage and the resulting current for a simple single cone loudspeaker are shown in Fig. 1. The phase shift in the region of the bass resonance is critically dependent upon the type of enclosure. Below the bass resonance frequency the current in the voice coil is seen to be inductive with the current lagging the voltage, the phase angle approaching 40°; but the phase changes rapidly as the resonant frequency is passed, the current and voltage being in phase at resonance (100Hz), but the current leads the voltage above the resonant frequency where the voice coil behaves as a capacitor. In this particular example the current is in phase with the voltage again just below 300Hz but above this frequency the coil is generally inductive, the phase angle increasing continuously. Thus it will be seen that the mechanical force on the voice coil former is only rarely in phase with the applied voltage.

This effect is of greater significance in multi-unit speaker systems. These must incorporate electrical filters that protect the relatively fragile high frequency units from the powerful low frequency signals and channel the electrical signals into the speaker units best able to handle them. In a three or four unit system the filters are often of considerable complexity.

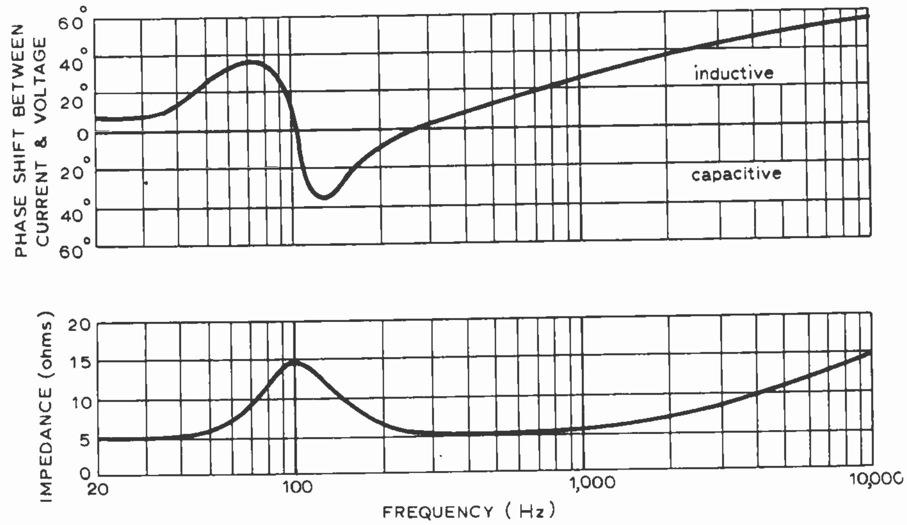
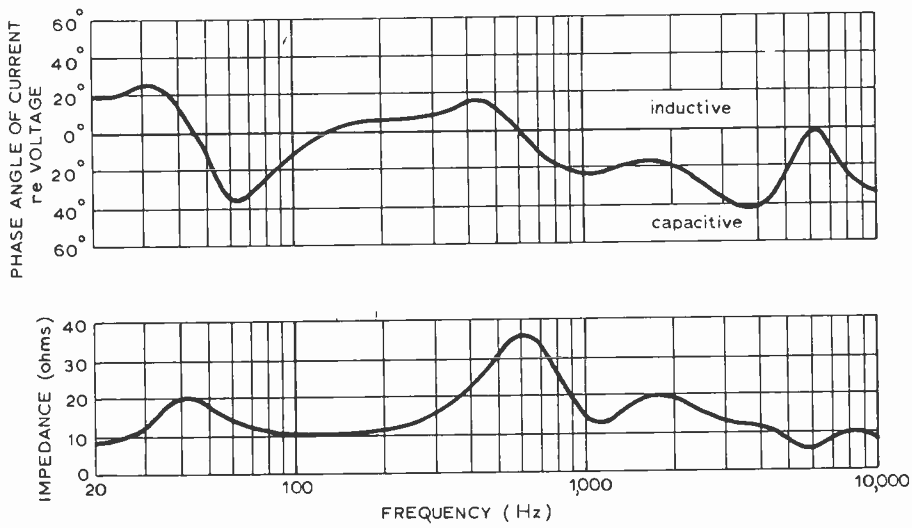


Fig. 1. Typical phase difference between applied voltage and resulting current for a single cone loudspeaker. The corresponding impedance curve is shown below.

Fig. 2. Phase angle and impedance curves for a three-unit loudspeaker system.



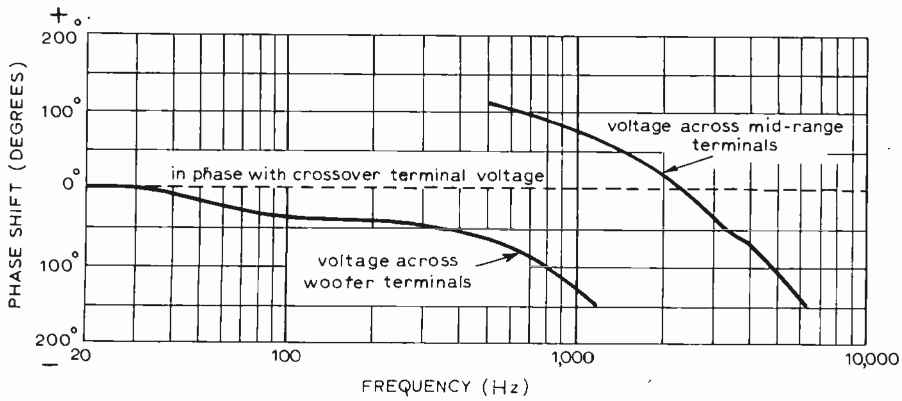


Fig. 3. Phase shift through a typical crossover network.

The curves of Fig. 2 illustrate the phase difference between the applied voltage and the current into the speaker system, but the voltage across the individual speaker units is not in phase with the voltage across the system terminals as a result of the reactance present in the crossover filters. Fig. 3 illustrates the phase shift between the voltage applied to the system terminals and the voltage across the terminals of the woofer and mid-range units in a well known multiple unit system having an excellent reputation. It will be seen that the filter networks introduce a considerable additional phase shift. In the cross-over region the voltage across the higher frequency unit is generally shifting in phase in the opposite direction to that across the lower frequency unit.

These phase shifts are all introduced by the electrical system but there are additional phase shifts in the mechanical coupling between the voice coil and the apex of the cone and between the apex of the cone and the remainder of the cone and surround. These are difficult to quantify but an approximate analysis shows that they are very frequency dependent and significant.

Acoustic phase shifts

The major phase shifts appear when sound waves are launched into the air. In a single cone wide range loudspeaker unit, the high frequency components of the acoustic signal are generally radiated from a small area near the cone apex, there being little high frequency radiation from the areas of cone near the surround. At frequencies below about 1kHz the whole cone tends increasingly to act as a more or less rigid piston and the signals are radiated by the whole of the cone and part of the surround. Thus the area radiating the high frequencies is usually about an inch behind the effective centre of the low frequency radiation and in consequence signals in the high frequency band will appear a fraction of a millisecond behind the low frequency signal radiated by the whole area of the cone.

These phase shifts due to the variation in the effective position of the source are much more serious in a multiple unit system employing separate speaker units for the low, mid and high frequency ranges. In the usual type of enclosure the 'tweeter' handling the frequencies above 4-5 kHz will be mounted near the top of the enclosure, adjacent to the mid-range unit and perhaps 12-14 inches away from the centre of the l.f. unit. Generally the radiating surface of the tweeter will be a few inches in front of the effective radiation centre of the l.f. cone, so the higher frequencies will travel through the air a fraction of a millisecond before the frequencies handled by the woofer.

In practice the listener will sit two to four metres away from the loudspeaker enclosure and unless he is on the median line between the h.f. and l.f. units the path length between his ears and the h.f. unit will differ from the path length between his ears and the l.f. unit. In consequence, the signals from one unit will arrive before those from the other unit, or in conventional terms, there will be a phase difference between the signals from the two loudspeakers. This is of special significance in the changeover region when phase interference results in the appearance of peaks and dips in the frequency response, though the effect of phase shift on frequency response is not the real aspect of the present discussion.

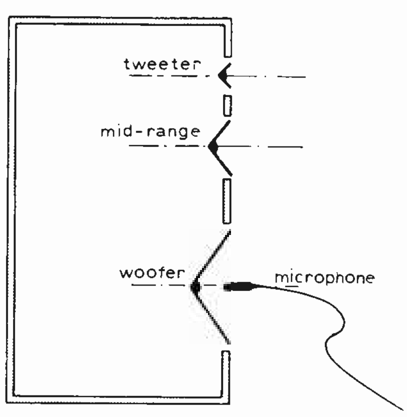


Fig. 4. Measurement of a woofer's phase shift with the microphone mounted in the plane of the front baffle.

Several recent speaker system designs attempt to minimize the phase shifts due to the cross-over networks and the lack of coincidence in the vertical plane of the emitting surfaces, by displacing the units, the high frequency radiators generally being set back behind the plane of the woofer. The exact positions of the various units are difficult to determine by measurements of the relative phase of the acoustic outputs of the units, but the "correct" positions can be found experimentally by adjustment of the unit location with a square voltage waveform applied. The adjustment must be done either in the open air or in an anechoic chamber to avoid the gross phase shifts that characterize any ordinary room.

Phase shift measurements

Measurements of the overall phase shift between the system input voltage that has been adopted as the reference and the sound pressure in front of the loudspeaker is not as simple as it might appear at first thought. While the position of the microphone diaphragm is obvious, the effective centre of the acoustic radiation from the speaker diaphragm is not known and cannot be determined with the required accuracy. Moreover the effective centre of radiation varies with frequency.

The microphone must be mounted in front of the loudspeaker and the spacing between speaker and microphone introduces a fixed time delay, or in phase shift terms, a phase shift linearly proportional to frequency. As this time delay is constant at all frequencies it does not introduce phase distortion, so any measurement of the phase shift should ignore that fraction of the total phase difference that is due to the physical spacing between microphone and loudspeaker.

This ambiguity in deciding on the actual part of the loudspeaker cone that emits the signal at any specific frequency limits the upper frequency to which phase shifts can be measured with an adequate degree of accuracy. At a frequency of 5kHz for example, the wavelength in air is 6.86cm and in consequence the phase nominally changes by 360 degrees for each 6.86cm increase in spacing between microphone and loudspeaker unit. If the phase shift measurements are to be really accurate the distance between the diaphragm of the measuring microphone and the point on the diaphragm for which the signal is emitted must be known with an accuracy that can rarely be achieved.

A first choice for the position of the measuring microphone would be the speaker/microphone spacing standardized for frequency response measurements, one metre. At a frequency of 5kHz this is $100/6.86 = 14.6$ wavelengths and an equivalent phase shift of $14.6 \times 360 = 5260$ degrees approximately, due

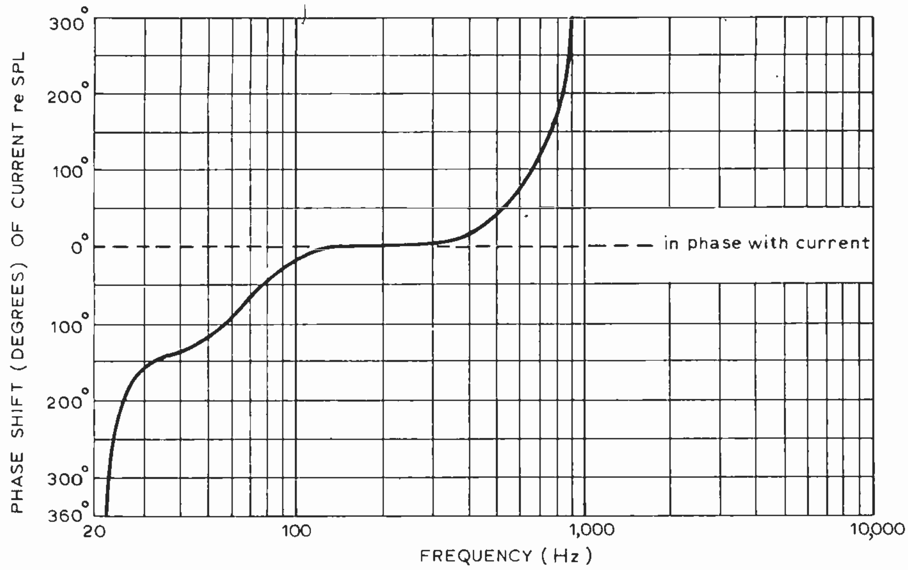


Fig. 5. Phase versus frequency response of a moving coil loudspeaker measured as shown in Fig. 4.

only to the distance between microphone and loudspeaker, and in consequence, a phase shift that does not introduce any waveshape distortion. It will be seen from Fig. 1 that a typical single unit speaker system will introduce a phase shift of about 30°-60° at this frequency. Thus if the phase shift due to the speaker unit itself is to be measured to an accuracy as poor as 20%, it is necessary to measure the overall phase shift between input voltage and the sound pressure at the microphone one metre away, to an accuracy of about 5°-10° in 5000° i.e. about 0.1%. This is just not possible for the effective centre of radiation in the speaker diaphragms, the point from which the one metre spacing is to be measured, is not known.

Nominally the constant time delay due to the speaker/microphone spacing of one metre can be compensated by the insertion of a delay line having a delay time of about 0.3ms. In practice this is not satisfactory for the speaker/microphone distance of one metre cannot be determined when the centre of the acoustic radiation from the speaker cone is not known with any accuracy.

An alternative solution to the problem is to minimize the spacing between microphone and loudspeaker, for this minimizes the time delay that must be compensated. Consideration suggests that the best compromise may be to mount the microphone with its diaphragm in the plane of the speaker opening (Fig. 4). At this position the phase shifts due to spacing time delay are of no significance at low frequency and only become of consequence at frequencies above about 10kHz where the wavelength is about 3.5cm. The microphone can probably be located with a positional accuracy that is perhaps one tenth of this, limiting the accuracy to which the overall phase shift can be measured to about ±15 degrees at a frequency of 10kHz. Fig. 5 indicates the phase shift/frequency response of a typical wide range single unit loudspeaker when the measuring microphone is mounted in the plane of the diaphragm opening.

Choosing a microphone location close to the loudspeaker unit may be the best compromise but it is not without its limitations, apart from that of accuracy mentioned earlier. As far as a listener is concerned the effective phase shift is that at his ears about two to three metres away from the loudspeaker. This cannot be directly measured if a multi-unit speaker system is employed. At any listening position there is in addition to the phase shifts discussed, another and generally more significant cause of phase shift, that due to the difference in the length of the air path between the listener's ears and the two sources of the acoustic signal. If there are only two units in the system the listener can eliminate these differences by sitting exactly on the medium line between the two units, but this is not possible if a three unit system is employed. If the phase shift at the listener's ears must be known, it must be separately measured for each unit, and if the total resultant phase shift at the distant listening point is to be obtained, it must be calculated from geometric considerations. This is clearly a tedious piece of simple arithmetic, but the writer has gone on record many times as saying that these phase shifts are of no consequence.

Value of phase shift measurement

Measurements of the phase shifts to a point in the diaphragm plane is of real use to the speaker development engineer when he is assessing the effect of design changes. Phase changes more rapidly in the vicinity of a resonance that does the amplitude and is a more sensitive indication of the resonant frequency and its Q. Thus the effect of such changes as cone or surround doping can be rapidly assessed even though the effect of such a change is small and in the midst of a lot of other irregularities.

When a stereo system is employed, the absolute values of phase shift in the loudspeakers are of little significance, but it is important to ensure that the phase shifts do not change too rapidly with frequency and that there is uniformity of phase shift between the speakers coming off the production line. Rapid changes in the phase/frequency response of nominally identical samples leads to unstable positioning of the stereo image.

My thanks are due to Mr W. R. Stevens of our laboratory for the measurements of phase response which have been quoted.

Announcements

Papers presented at the second international conference on software engineering for telecommunication switching systems held in February in Salzburg, Austria are to be published as **"Software engineering for telecommunication switching systems"**, IEE Conference Publication 135. Further information can be obtained from The Marketing Department, The Institution of Electrical Engineers, PO Box 8, Southgate House, Stevenage, Herts. SG1 1HQ.

A **service** for the design of **l.s.i. circuits** is available from Smiths Industries Ltd, Aviation Division, Cheltenham. A computer aided design and testing facility has been established to provide a design service for the low-volume market.

The Duddell medal and prize has been awarded by the Institute of Physics to Mr G. N. Hounsfield of EMI Ltd for his development in the use of X-rays for the examination of three dimensional structures.

The **National Closed Circuit Television Association's Annual Conference** at University College, Cardiff is to be held from April 5th to 8th. Further information can be obtained from V. Ginn, College of Education, Cyncoed Road, Cardiff.

Sonab Ltd has moved to 214 Harlequin Avenue, Brentford, Middlesex TW8 9DW.

Cathodeon Crystals Ltd, Linton, Cambridge CB1 9JU, has received BS9000 approval for the manufacture of crystal based components for the telecommunications and electronics industries.

British Relay TV, Overline House, Crawley, Sussex is now relaying Southern-TV as a fourth channel to viewers connected to its cable-TV networks in the London regions of Bow, Fulham, Hammersmith, North Kensington, Paddington and Poplar.

Wound Electronic Components Ltd, Excelsis Works, Gogmore Lane, Chertsey, Surrey KT16 9AP are offering **toroidal transformers** designed and manufactured to customers specification.

Belmont A/V Ltd, Fircroft Way, Edenbridge, Kent TN8 6HA, UK distributors of the B.I.C. range of loudspeakers, have announced the granting of a US patent to B.I.C. for their application of the **venturi principle** in the field of **acoustics.**

Automatic battery switch-off circuit

Extending the life of small instrument batteries

by D. T. Smith

Clarendon Laboratory, University of Oxford

Nowadays, many small electronic instruments are powered by batteries. Battery prices have risen in recent years, and with the increasing prices of raw materials such as zinc, costs are likely to rise further. Moreover, it is frustrating to find equipment out of action due to flat batteries just when it is needed.

Much laboratory equipment is used intermittently and batteries then have a long life if the equipment is always switched off after use. However, people often forget to switch off, particularly when there is no obvious reminder (such as a light or noise) that the equipment is on. In practice, instruments are frequently left on for days or weeks when not in use. The circuit described here was designed so that it can be built into equipment without affecting performance or the normal controls, but will switch off the battery after a reasonable time it if it not switched off manually. We chose a time of about 10 hours so that the equipment would operate for a full working day without interruption. Normal operation can be restored by moving the manual switch to off and back to on.

Circuit operation

Both capacitors discharge when the battery is off. When the battery is switched on, C_1 charges and gives a pulse of current to the base of Tr_1, which conducts and feeds current to the base of Tr_3 to allow current to flow to the load. Initially, C_2 remains uncharged, and with the bias on the gate of Tr_4, the tail current of the pair $Tr_{4,5}$ is all taken by Tr_4. Base current is fed to Tr_2 which in turn drives Tr_3 into saturation. Voltage drop across Tr_3 is, therefore, quite small. Capacitor C_2 is slowly charged via R_7 until Tr_5 is conducting and drawing tail current. Current through Tr_4 is decreased together with the base current of Tr_2, and Tr_3 is no longer saturated. The output voltage then falls and the bias on Tr_4 falls, while the bias of Tr_5 remains constant, so that a regenerative feedback loop is formed and the circuit snaps off.

When the circuit has switched off, the only drain on the battery is the current though R_1 (10MΩ) and transistor leakage, and this is a negligible drain to normal batteries. With the output off, C_2 discharges rapidly through the gate of Tr_5. When the operator switches off, C_1 discharges through D_1 and R_1 with a time constant of one second, so that the circuit is ready to be switched on again without delay.

The circuit switches off when the voltages on the gates of the f.e.ts are about equal, that is, when C_2 has charged to about half of the output voltage. This gives an operating time $T = \log_e 2 . C_2 R_7 \approx 0.7\, C_2 R_7$.

The values shown give a calculated time of just under 10 hours. Other periods can be obtained by altering C_2 or R_7.

The value of R_2 is chosen to suit the working current and battery voltage. A low value of R_2 increases the battery drain, while a high value limits the working current; a suitable value is

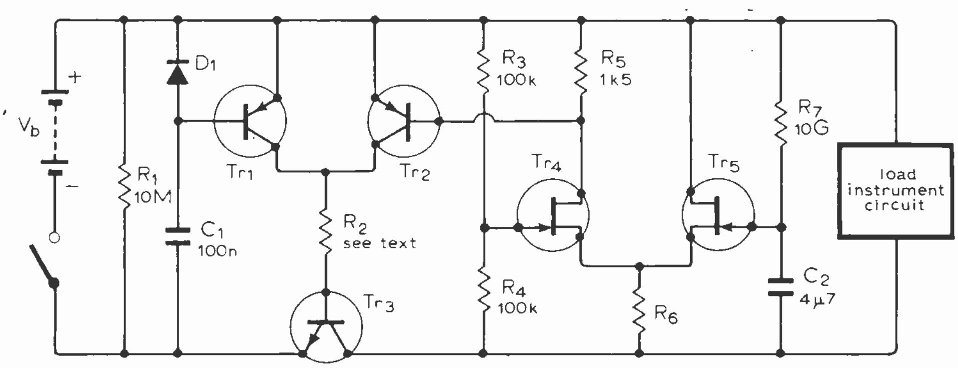
$$R_2 = \frac{15 V_b}{I_{out}}$$

Construction

The circuit was built as a printed circuit board with a p.t.f.e. insulated tag for the junction of R_7, C_2 and the gate of Tr_5. This extra insulation is necessary to give a leakage resistance large compared with the high resistance of R_7 (10 GΩ), and care should be taken to keep this part of the circuit clean and dry to prevent the insulation from deteriorating. The circuit is not critical, as accurate timing is not required. A polycarbonate capacitor was used for C_2 to ensure low internal leakage. A maximum gate current of 2nA as quoted in manufacturers data for the 2N3819 would be disastrous, but in practice the gate current for this device is usually below 10 pA.

This circuit has been fitted to a number of a.f. oscillators without any inconvenience to normal operation. Users need not be aware of the presence of the circuit.

Fig. 1. Circuit diagram of the switch-off unit.



Components

$Tr_{1,2}$	2N4061, BC478 or similar small silicon p-n-p type
Tr_3	2N3053, BC142 or a similar medium power silicon n-p-n type
$Tr_{4,5}$	2N3819 (n-channel silicon f.e.t.)
D_1	any small silicon diode
R_6	4k7 (9 or 12V battery) 10k (15 to 27V battery)
R_7	10GΩ ± 20% H13. Welwyn Electric Ltd, Bedlington, Northumbria NE22 7AA. (£1.08 in small quantities)

Diode model of the m.o.s.f.e.t.

An insight into device operation to clear up some of the difficulties encountered in its initial study

by B. L. Hart

North East London Polytechnic

From the point of view of the circuit engineer the d.c. model, for a given application, of an active device can be classified as "good" if it is as simple as possible, and easy to use on both pencil-and-paper and computer aided designs. Also it should be characterized by parameters that are readily obtainable by measurements at the device terminals and that relate circuit performance potentialities and limitations to device design choices and fabrication process technology.

The classic Ebers-Moll[1] (E-M) d.c. model of a bipolar junction transistor (b.j.t.) certainly fulfills these criteria. There can be little doubt that the E-M model has clarified the operation of a number of circuit designs and been responsible for the generation of some new ones. The advent of the equally classic Beaufoy-Sparkes[2] charge-control model of a b.j.t. facilitated the paper design, and predictable practical performance, of saturated b.j.t. switching circuits such as inverters, bistables, etc, and led to the formulation of various figures-of-merit for fast switching b.j.ts.

Recently, work by Gibson[3], Wedlock[4], and others has led to the development of a simple d.c. m.o.s.f.e.t. model which is analogous to the E-M model of a b.j.t. The aim of this article is twofold: to clarify — at a level comprehensible by the circuit engineer, rather than the device physicist — the basic operation of a m.o.s.f.e.t.; to introduce the Gibson-Wedlock model and show how it meets the criteria of "goodness" outlined above.

Basic operation

Because of its importance in digital electronics we consider, throughout, an enhancement-mode[5] device. The symbolic representation, together with schematic cross-sectional views of the n-channel device selected for discussion are shown in Fig.1(a), (b) and (c) respectively. The source(S) – drain (D) spacing is L and, by definition, the gate(G) "width" is W. The S and D diffusions – richly doped by comparison with the p-type substrate – are designated n^+ and have a plentiful supply of electrons. Let us see what happens for the bias conditions $V_{GS} = V_{BS} \neq 0$. The action of the device may, for the time being, be represented by two p.n junction diodes – the source-substrate junction, and the drain-substrate junction – connected back-to-back. Irrespective of the polarity of V_{DS} there can be no significant drain current, I_{DS}. This is also the case if the substrate connection, B, is left floating (though this is an operating condition not recommended) because one or the other of the two diodes is always reverse-biassed.

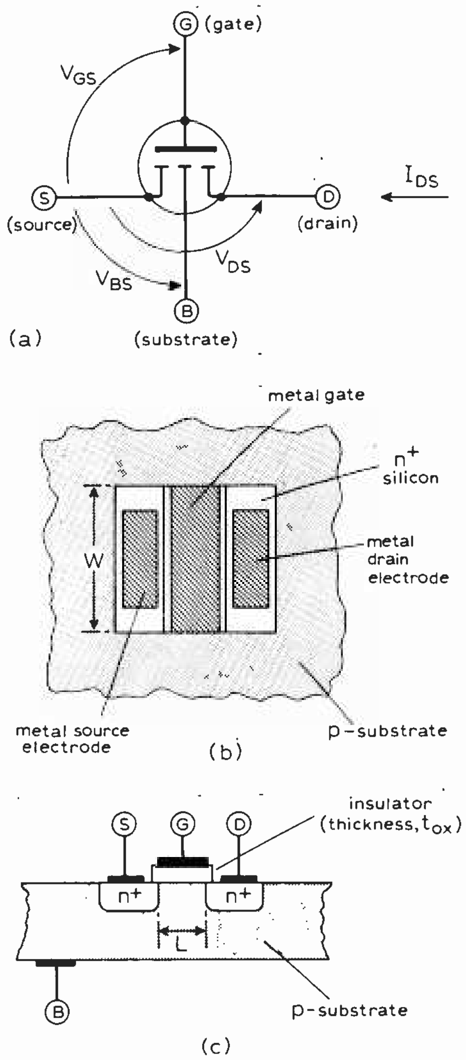


Fig. 1. N-channel enhancement-mode m.o.s.f.e.t. (a) symbolic representation and terminal voltage designation (b) plan view of physical construction (c) cross-section corresponding to (b)

Suppose, instead, that $V_{BS} = V_{DS} = 0$ but $V_{GS} > 0$. Under d.c. conditions there is no current in the gate lead, i.e. $I_G = 0$, because of the insulating properties of the oxide layer. Gate G acquires a positive charge and a corresponding negative charge is induced in the substrate surface layer beneath the gate. This arises as a result of electrons, drawn in from S and D, that are attracted to this region by the field in the oxide and holes that are repelled away from it. When V_{GS} is sufficiently positive – by an amount known as the threshold voltage, V_T – enough electrons are concentrated in the substrate surface layer to compensate the positive charge due to substrate doping and device processing. Thus, when $V_{GS} = V_T$ the phenomenon of "inversion" is said to occur: the substrate just under the gate changes its polarity from p to n or "inverts." It must be borne in mind that the designation "n" means, basically, that the majority carriers are electrons, whether this be due to the fixed initial doping of the substrate wafer, or the induced doping from device biassing.

After inversion has occurred a continuous conducting layer or "channel" links the S and D diffusions. This channel, which is of uniform shape throughout its length, is normally only a few angstroms thick i.e. much less than the thickness, t_{ox}, of the oxide insulating layer (typically, 100nm). The n-channel forms with the p-substrate an induced p.n junction and, as with any conventionally fabricated junction there is an associated depletion region (see Fig.2(a), in which the thickness of the channel is exaggerated for clarity) and this serves to make the device self-isolating. Thus, built-in junction-isolation is not required, and a consequent saving in chip area is achieved, when a number of similar devices share a common substrate as in single-polarity m.o.s.-f.e.t. memory systems such as those used in pocket calculators.

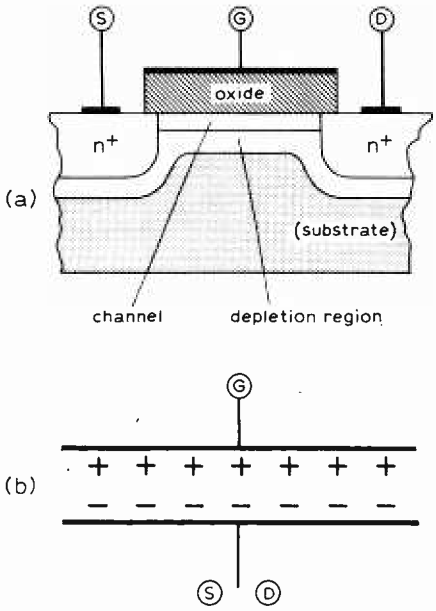


Fig. 2 (a) Showing the presence of channel and depletion regions (b) equivalent circuit of 2(a)

Under conditions of strong inversion ($V_{GS}-V_T>V_T$, say) and with $V_{DS}=0$ the m.o.s.f.e.t. behaves physically as a parallel plate capacitor system (Fig.2(b)), in which one plate is G and the other, accessible via the source-drain connection, is the channel. The magnitude of the charge density on each plate is $C_0(V_{GS}-V_T)$, where C_0 is the gate-oxide capacitance per unit area. Let us now keep $V_{GS}>V_T$ and arrange that $0<V_{DS}\ll V_{GS}$. The charge of majority carriers on the lower plate of the capacitor is able to drift, under the influence of the x-directed field: there is no reverse-biassed p.n junction to impede the flow of electrons from S to D because the channel carriers have the same polarity as the S and D diffusions, hence $I_{DS}>0$. Variations in V_{GS} cause variations in the density of charge carriers available for conduction, and it is the modulation of I_{DS} by the perpendicular field which gives the name field effect to the control function of this type of structure. (We have chosen $V_{DS}>0$ for convenience. The choice $V_{DS}<0$ leads to a negative value for I_{DS}: once a channel is established the induced majority carrier charge can drift from S to D or with equal ease – provided $|V_{DS}|\ll V_{GS}$ – from D to S, the particular direction being dependent on the polarity of V_{DS}.

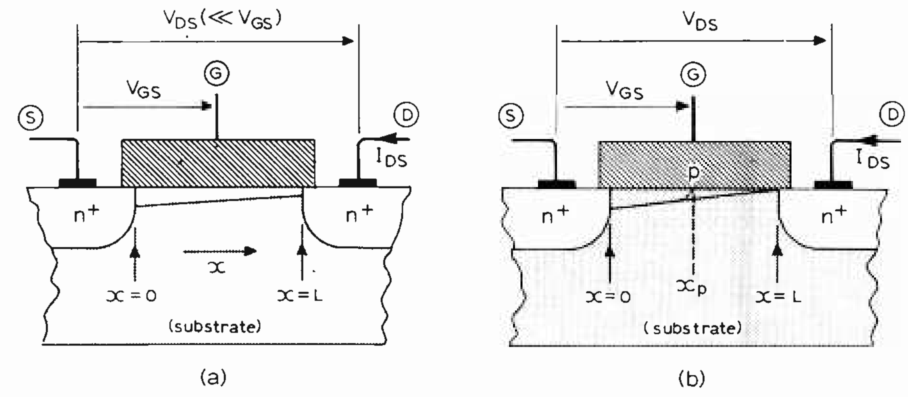
The assumed condition $V_{DS}\ll V_{GS}$ ensures that the field in the oxide – and the channel charge density – varies only slowly throughout the channel length, and is perpendicular to the substrate surface. This is the 'gradual-channel approximation' used in first-order mathematical treatments. The existence of a finite V_{DS}, and hence I_{DS}, means that the channel charge density $\sigma(x)$ is non-uniform. The x – directed field in the channel produces a potential difference $V(x)$ between S and some point in the channel distance x away from it.

Thus, $$\sigma(x)=-C_o\left\{V_{GS}-V_T-V(x)\right\} \quad (1)$$

If $V_{DS}\ll V_{GS}$, $\sigma(0<x<L)\approx -C_0\left\{V_{GS}-V_T\right\}$, and the channel depth varies only slowly along its length – see Fig.3(a). When V_{DS} is comparable with V_{GS}, $\sigma(x)$ varies significantly along the channel and this leads to a more pronounced wedge-shaped profile; however, a conducting channel always links S and D providing $|\sigma(0\leqslant x<L)|>0$. A limiting condition exists when $V_{GS}-V_T-V_{DS}=0$ because, then, $|\sigma(x)|$ falls to zero at the drain end, i.e. $V(x)=V_{DS}$, where the field in the oxide is least (Fig.3(b) – full line for channel outline). When $V_{DS}>(V_{GS}-V_T)$ the channel does not extend along the full length of the source-drain separation but terminates (is pinched-off) at some point P distant x_P from S, at which $|\sigma(x_P)|\approx 0$. (Fig.3(b), dotted curve).

The choice of the term pinch-off for this mode of operation is not a completely happy one since it suggests that $I_{DS}=0$ which is clearly not possible here because it is the presence of I_{DS} which is responsible for $V(x_P)$. A self-limiting process is established in which the current remains sensibly constant at that value corresponding to $x_P=L$, despite further increases in V_{DS}. Obviously $|\sigma(x_P\leqslant x<L)|$ cannot be precisely zero because that would mean the absence of charge carriers in the surface substrate layer for $x_P\leqslant x<L$. That part of V_{DS} in excess of $(V_{GS}-V_T)$ appears across the virtually depleted region between P and D and the field there helps speed the small, but finite, number of electrons at P on the remainder of their journey to D. Current continuity in the path from S to D is maintained because I_{DS} is dependent on the product $\sigma(x)v(x)$, where $v(x)$ is the mean carrier velocity. As $|\sigma(x)|$ decreases with x, $|v(x)|$ increases. A self-limiting process, such as the one mentioned, is not unfamiliar in electronic devices and suggests the existence of some internal negative feedback mechanism. A simple hydraulic analogy will help to clarify this for the case of the m.o.s.f.e.t.

Fig. 3. (a) Channel conditions for $V_{DS}<<V_{GS}$ (depletion layer omitted) (b) Channel conditions for $V_{DS}=(V_{GS}-V_T)$, full-curve; $V_{DS}>(V_{GS}-V_T)$, dotted curve.



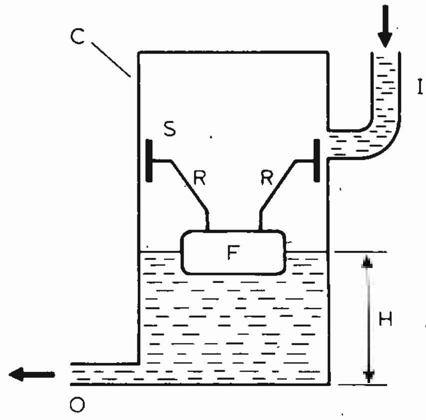


Fig. 4. An hydraulic analogy to m.o.s.f.e.t. pinch-off mode operation

Fig. 4 shows the cross-section of a possible self-limiting water flow system. C is a cylindrical chamber with an inlet pipe I, the diameter of which is much greater than that of the outlet tube, O, located at the bottom. Cylindrical sleeve, S, attached by rigid support rods, R, to a float unit, F, slides up and down the internal wall of C and – in one position – is capable of completely covering the inlet port. Under steady-state conditions (hydrodynamic equilibrium) F floats to a level, H, above O causing S to partially cover the inlet port. In likening this condition to pinch off in a m.o.s.f.e.t. we note that a flow rate (channel current), which is a function of the bore of O, is associated with a head, H (channel voltage) that, in itself, restricts the flow rate to a sensibly constant value dependent on the mechanical dimensions (electrical parameters) of the component parts. Other, and more precise, hydraulic analysis could be envisaged, but the one mentioned serves well enough for our discussion. The ideal constant-current characteristic of pinch-off operation is not observed practically because of the dependence of I_{DS} on conducting channel length, which is a weak function, usually, of V_{DS}. Though this effect is understood, and can be allowed for, it is neglected in the d.c. model now presented.

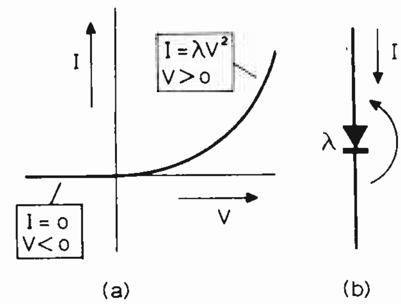


Fig. 5. (a) Characteristics of a square-law-diode (b) symbolic representation of (a)

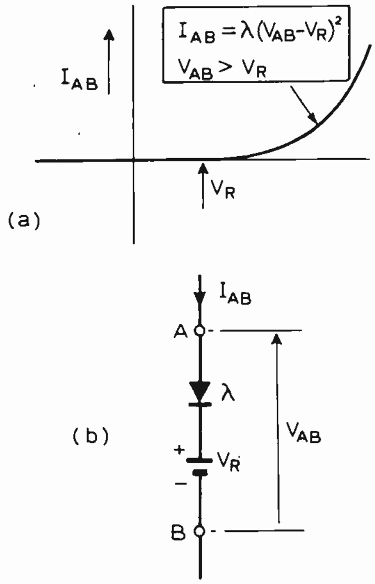


Fig. 6 An equivalent circuit of (a) is shown in (b)

Fig. 7. M.o.s.f.e.t. square-law-diode d.c. model (a) form based on equation (4) of text (b) arrangement of (a) (c), development of (b)

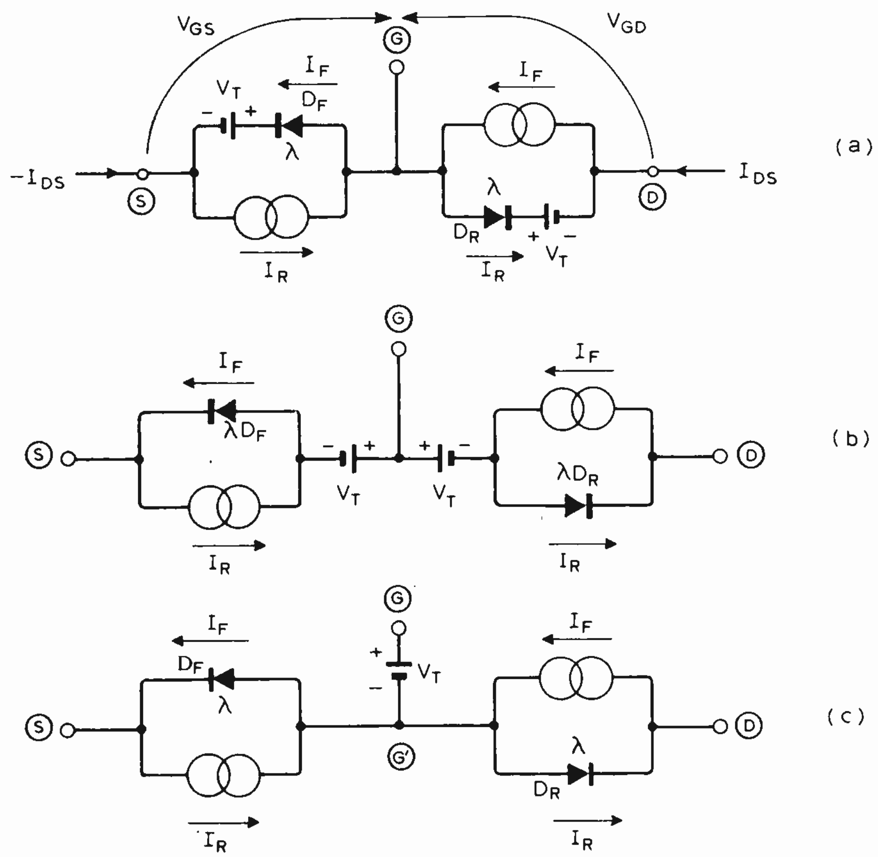
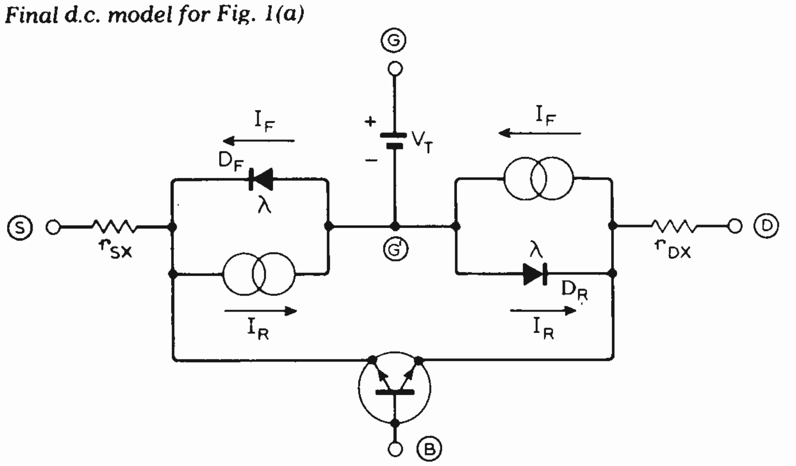


Fig. 8. Final d.c. model for Fig. 1(a)



M.o.s.f.e.t. d.c. model

For $V_{GS}<V_T$, $V_{DS}<(V_{GS}-V_T)$, the d.c. characteristic of the n-channel m.o.s.-f.e.t. shown in Fig. 8 can be expressed mathematically in the form,

$$I_{DS} = \lambda[2V_{DS}(V_{GS}-V_T)-V^2_{DS}] \quad (2)$$

where λ is a conductance coefficient (with dimensions A/V^2) given by,

$$\lambda = \mu_e \epsilon\epsilon_{ox}(W/2)L\, t_{ox} \quad (3)$$

in which: ϵ = permittivity of free space; ϵ_{ox} = relative permittivity of oxide; μ_e = effective mobility of electrons in the substrate surface layer.

A simple derivation of (2), based on a quantitive discussion of the physical electronics of device operation outlined above will be given in Part 2.

For the present purposes we can put (2) into a more convenient form by making the temporary substitutions:

$$a = (V_{GS}-V_T) : b = V_{DS}$$

Then, $I_{DS} = \lambda[2ab-b^2] = \lambda[a^2-(a-b)^2]$ (3)

Now, $(a-b) = (V_{GS}-V_T-V_{DS})$
$= (V_{GD}-V_T)$ (4)

Hence, substituting back into (3), (2) becomes,

$$I_{DS} = \lambda[(V_{GS}-V_T)^2-(V_{GD}-V_T)^2] \quad (5)$$

Equation (5) can now be used, directly, in the construction of a d.c. model by imagining a fictitious square-law-diode with the d.c. characteristic in Fig. 5(a).

There is no standard symbol for such a device: the one proposed here, and favoured by this author, for its simplicity is shown in Fig. 5(b). Clearly, the d.c. circuit model for a square law characteristic offset from the origin by an amount V_R, Fig. 6(a), is an ideal square-law diode with an inbuilt opposing battery V_R (see Fig. 6(b)).

By an extension of this argument the model representing equation (5) and hence (2), is shown in Fig. 7(a). The intermediate form Fig. 7(b) and the final form, Fig. 7(c), both have terminal voltages and currents respectively identical to those of Fig. 7(a) and are thus – from a circuit theory and application standpoint – equivalent to Fig. 7(a). Two effects have been ignored, substrate bias and bulk resistance, but these will be considered in Part 2.

(To be continued)

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World of Amateur Radio

Integrated-circuit transceivers

Back in 1970, Tich Ryan, G3VJN, found that the linear integrated circuit amplifiers types CA3020 and CA3020A, usually regarded as intended for audio frequency applications, were generally capable of providing significant r.f. output at frequencies as high as 21MHz. On 7MHz the CA3020 will usually provide 500mW output and the CA3020A over 1-watt.

A number of British amateurs have since used such devices in conjunction with the SL600 series of integrated circuits to provide compact, all-solid-state s.s.b./c.w. transceivers. One of those who have recently been interested in this approach is Leslie Moxon, G6XN, who has built an equipment which includes two of the recent SL613 devices to provide r.f. clipping of the speech. Powered by a 6-volt lantern battery, his transceiver provides an output of about 250mW on 14MHz from a CA3020A and is capable of working quite easily into Eastern Europe. He has also been developing a 2-watt "linear" amplifier for use when higher power is needed for long-distance contacts.

More repeaters

Two more v.h.f. repeaters have been authorized by the Home Office: Moel-y-Parc, GB3MP, and Burnley, GB3RF, both intended primarily for use by n.b.f.m. mobile and portable stations. GB3MP is expected to open during March or April on channel R6 (145.15MHz in, 145.75MHz out) and is sited at the IBA's television station near Clywd, North Wales. Under normal propagation conditions, it is expected to provide coverage of much of North Wales and North-west England, including Manchester, Liverpool, Preston and the coastal strip up to the Morecambe Bay area as well as parts of the Isle of Man. The repeater, under the aegis of the UK FM Group (Western), has been financed largely by contributions from over 125 licensed members.. The vertically polarized aerials, between 200 to 300 ft up the IBA mast, are over 1300 ft above sea level. Applications have also been submitted by this group for 70cm u.h.f. repeaters at Manchester (GB3MR), Colwyn Bay (GB3LL), Liverpool (GB3LI) and Stoke-on-Trent (GB3ST). A linear repeater project is also being considered.

The very high usage of the London repeater, GB3LO, has been measured by W. Blanchard, G3JKV, and amounts to an average of between 51 to 58 minutes per hour throughout the period 0800 in the morning to midnight and remains substantial at all times except between 0400 and 0600.

The latest IARU list of repeaters in the German Federal Republic includes over 120 operational stations including some cross-band (432/144 MHz), r.t.t.y., 1260MHz and amateur TV repeaters. A 70cm amateur TV repeater in Alexandria, Virginia, has a vision output of 800 watts e.r.p. and handles both vision and sound signals conforming to the US 525-line specification.

Random communication?

There seems among some British amateurs a growing degree of disillusion with the way that amateur phone communication is developing, arising from the widespread adoption of the popular and effective Japanese s.s.b. transceivers for h.f. and increasingly for v.h.f. Operation of these units, unless carried out with specific aims or as part of an interest in aerials or propagation, often fails to retain the interest of amateurs who previously spent part of their time testing home-built equipment or "assembling" highly individual stations based on commercial and surplus units. Often — as in the classic Tony Hancock record — amateurs who acquire the current all-swinging little boxes show a burst of eager activity followed by fewer and fewer appearances on the bands. Is there any morale to be drawn from the fact that similar fading interest does not seem to affect those who pursue specific operating interests such as low-power (QRP) operation, the various specialist modes or even c.w.? One has the impression (or is it merely prejudice?) that amateur operating activity that involves some degree of personal effort or skill or training or with a definite technical or other aim results in far more dedication than random radiotelephone operation based on one specific piece of equipment. Few people would wish for long to sit beside an ordinary telephone dialling random numbers — or would they?

On the bands

The Home Office has approved the start of the GB2ATG r.t.t.y. news bulletin broadcasts from March 7, following four weeks of trial transmissions. The bulletins are transmitted on Sundays at 1200 (3590kHz, F1, 170Hz shift); 1215 (144.6MHz beaming north from London, F1, 850Hz shift); and 1230 (London area only, 144.6MHz, F2, 170Hz shift).

The Royal Signals Institution has made a grant of £200 to the Royal Signals Amateur Radio Society towards the cost of new aerials, including a ten-element crossed-Yagi, to allow the headquarters station, G4RS, at Blandford Camp, Dorset, to operate through the Oscar beacons.

The Home Office has refused an RSGB request to lift or modify the restrictions applying to the use of 430 to 432 MHz by amateurs living within the area 53-55° north, 2-3° west and has stated that these are likely to continue for many years.

During December/January a number of contacts were made on 1.8MHz by European stations (including some in the UK) with Australian stations in Victoria and Western Australia. The "twilight boundary" or "Grey line" technique (working along the great circle route representing the dawn/dusk or dusk/dawn boundary) has also brought good long-distance contacts to many stations on 3.5MHz during recent months.

The RSGB has recommended that QSL cards should not exceed about 5½ by 3½ inches as larger cards cause handling problems for the QSL Bureaux.

In brief

Class A licences in the series G4FAA are likely to be issued soon. Over 21,750 people held UK Class A, B or amateur TV licences on November 30, 1975 and there were almost 6000 mobile licences . . . The British Amateur Radio-Teleprinter Group are holding a "Spring r.t.t.y. contest" between 0200 GMT on March 27 to 0200 GMT on March 29 . . . The Norwegian national society, NRRL, has a membership of just over 2500 with about 3700 licensed amateurs in the country and with some 18 repeaters in operation . . . "World Radio Club", the BBC World Service weekly programme for short-wave listeners, has recently enrolled its 25,000th member . . . The RSGB are providing an examination centre in Central London for the next Radio Amateurs' Examination on May 20 . . . Among recent new ITU prefix allocations are: D2A to D3Z Angola; D4A to D4Z Cape Verde; and D5A to D5Z Liberia . . . The Emley Moor beacon station (February issue) is under the aegis of the Northern Heights Amateur Radio Society and is not yet in regular operation . . . A mobile rally is being held for the North Midlands at Drayton Manor Park, Tamworth on April 25; the White Rose Rally is at Lawnswood School, Leeds on March 28.

PAT HAWKER, G3VA

Introducing analogue multipliers

This article is complemented with the practical circuits of set 29 of Circards

by J. Carruthers, J. H. Evans, J. Kinsler & P. Williams

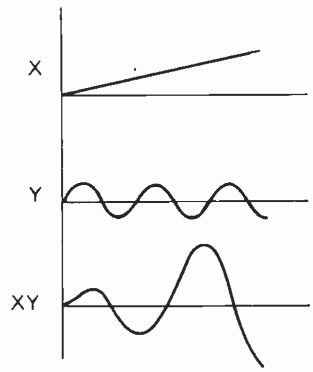
Paisley College of Technology

In the processing of electrical signals there is a need for circuits that can perform all the standard arithmetical processes – addition, subtraction, multiplication and division. The first two fall into the domain of linear amplifiers and present no great difficulty; the last-mentioned pair provide a real challenge to the ingenuity of circuit designers. Fig. 1 shows the waveforms of a particular example where an input signal *Y* is to be under the control of a second input *X*, the output being of the form *XY*. This is a gain-controlled amplifier and is one of the simpler forms of multiplier since usually the gain is required to be either positive or negative and not both. Hence *X* takes up only one polarity, and Fig. 2 shows the multiplier as needing to operate in only two of the four quadrants viz *X* positive, *Y* positive and *X* positive, *Y* negative. Such a system can be realized as in Fig. 3 where v_1 corresponds to *Y* and v_2 to *X*. In many such circuits it is not even essential that the gain be a linear function of v_2, in which case the circuit ceases to be a multiplier. A problem with circuits based on this idea is that of finding a resistor having negligible non-linearity over a suitable range of currents and voltages, while being controllable by an external signal.

While true and direct multiplication would be ideal, and can be obtained by using suitable transducers such as Hall-effect devices (see card 9), the designer often has to resort to devices and circuits obeying other laws. These are then manipulated until some combination of them yields a term which is proportional to the product of two signals.

It can be very difficult to eliminate all unwanted terms consistently and over a wide range of temperatures and supply voltages. One well-established technique is to use a circuit with a square-law voltage transfer function. This can be synthesized by a "piece-wise linear" technique, where a network of diodes, resistors and reference voltages, provides a slope that changes progressively as the input increases (see card 1). With a large enough number of segments, a power law can be approached to any desired degree of accuracy. For economy the number of segments has to be restricted particularly if both polarities of input have to be accommodated – twenty or so might be needed in such a case.

1



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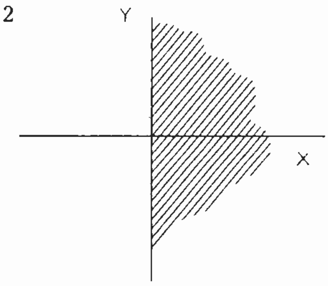

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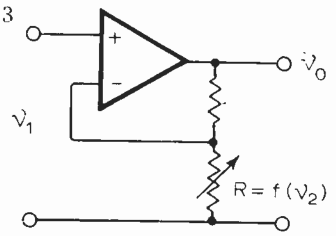

The quarter-squares multiplier applied in analogue computing uses two such squaring circuits as shown in Fig. 4. The sum of the two input signals is fed to one squarer, and the difference to a second. Each output contains a product term but also the square of each input signal. By subtracting the two outputs, these square terms cancel leaving only the product term, in this case 4*XY* i.e. a quarter of the output giving the desired multiplication of *X* by *Y* (card 1).

Of considerable interest in this respect are the characteristics of field-effect transistors. Both junction and m.o.s. devices have an on-resistance below pinch-off that is controlled by the gate-source voltage. The resistance is non-linear but can be linearized with feedback, while the control-law contains a square-law term (card 10).

Although bipolar transistors have output current/input voltage transfer characteristics which include square-law terms, their true nature is exponential with all their higher-order terms. It would be pointless to try to manipulate these transfer functions in the same way as above. Instead the exponential function is exploited directly in various ways. The exponential equation is reasonably accurate for p-n junctions over a few decades of currents. To ensure that the current in the diode/transistor is well-controlled the device can be placed in the feedback path of an operational amplifier, Fig. 5.

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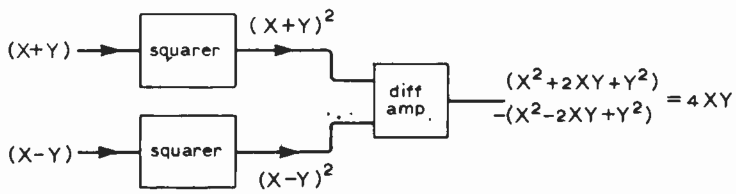
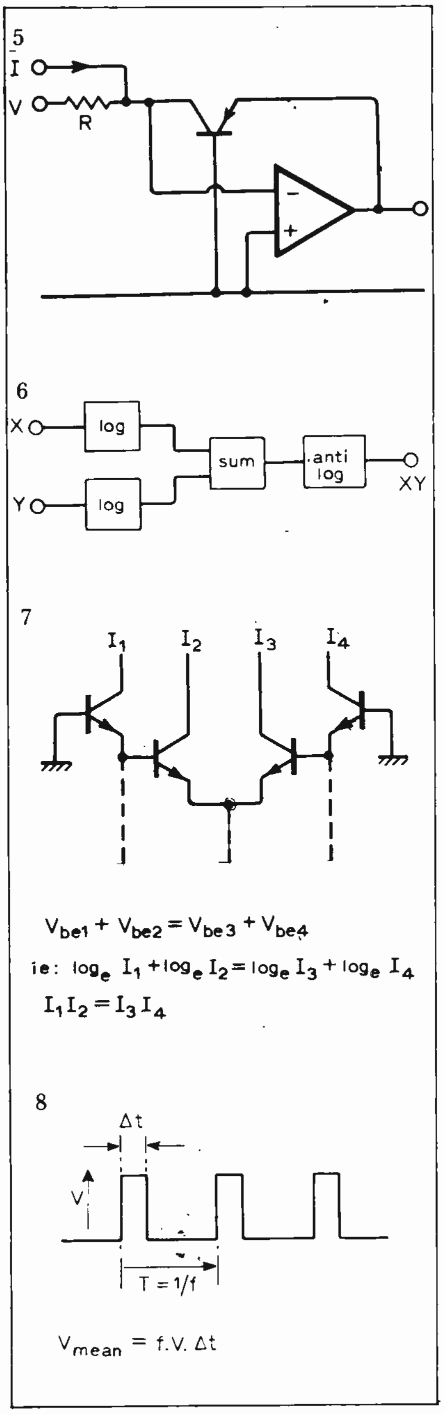


One problem introduced by the use of a transistor is that of the increased loop gain, the transistor operating effectively in common-base with a voltage gain dependent on the input voltage. This leads to h.f. oscillation unless the amplitude-frequency response is carefully controlled by means of external compensation – one possibility being capacitive feedback from output to inverting input, by-passing the transistor at high frequencies. To use this logarithmic function for multiplication (as in card 4) the system shown in block diagram form in Fig. 6 may be used. The antilog circuit is simply a log circuit with input (resistor) and feedback (diode/transistor) elements interchanged. Similar systems can be devised to provide other power law and ratio circuits by expressing the desired function in log/antilog forms first.



A related technique uses multiple transistors (card 8), shown in a general configuration in Fig. 7. It is assumed that the currents are controlled by external generators and/or feedback with one of them, or the difference between two of them, as the output. In the example shown, for I_2 maintained constant, $I_1 \propto I_3 I_4$ i.e. a multiplier. As shown, operation would be restricted to a single quadrant, but a large number of circuits have been published both to extend the operation into all four quadrants and to produce a range of interrelationships such as those based on the log approach.

A totally different approach yielded many ingenious and effective multipliers, prior to the ready availability of matched transistors. It stems from the concept that the terms to be multiplied need not remain in the same physical domain while being processed e.g. the variables of interest may both be voltages and the output may also be required as a voltage but each input may be used separately to control a different parameter of an output waveform, while a third property might be proportional to the product of the other two.

Consider the pulse waveform shown in Fig. 8. The pulse height is V, the repetition frequency $f=1/T$ and the pulse width of Δt. The mean output voltage as would be indicated on a moving coil meter is given by the product of these three variables, increases in each individually producing a proportional change in that mean value. Thus if any pair of these variables (f, V), (f, Δt) or (V, Δt) is brought under the separate and linear control of two input voltages, then the mean output voltage is a measure of the input product (card 2). There is a close relationship between these circuits and various forms of pulse modulators in the same way that the analogue multipliers described earlier are related to amplitude modulators.

There are purely digital methods of multiplication, but an intermediate solution is offered by the multiplying d.-to-a. converter. For a given binary input the converter has a number of output switches activated. If these operate on an external reference voltage the final output depends on the product of that reference voltage and the binary number. A class of digital circuits called binary-rate-multipliers is used to operate on a pulse train, producing a second train of pulses at a slower rate, card 3. At first sight this must cast doubts on the terminology since we associate multiplication with outputs greater than the inputs. The property of the circuit is however to multiply the input pulse rate by a factor such as $n/100$ where $n < 100$ and n can take up any value between 1 and 100, i.e. it is equivalent to multiplying by n but shifting the decimal point by two places.

The variety of methods available for achieving the multiplication of two variables electronically is growing, and modules are readily available to a high degree of accuracy. As the methods vary widely in both properties and in the physical processes involved it is important to consider the options carefully – it is a field where the opportunities to place one's foot firmly in it (unspecified) are remarkably high.

Topics of set 29 Circards

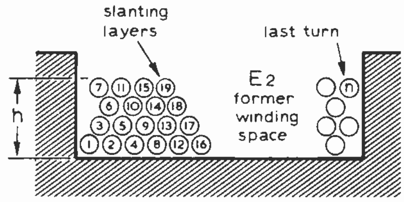
Quarter-squares multiplier
V-f converter multiplier
Delta-sigma modulator/multiplier
Log-antilog multiplier
Triangle-wave averaging multiplier
Four-quadrant multiplier – characteristics
Four-quadrant multiplier – applications
Translinear multiplier
Hall-effect multiplier
F.e.t. analogue multiplier

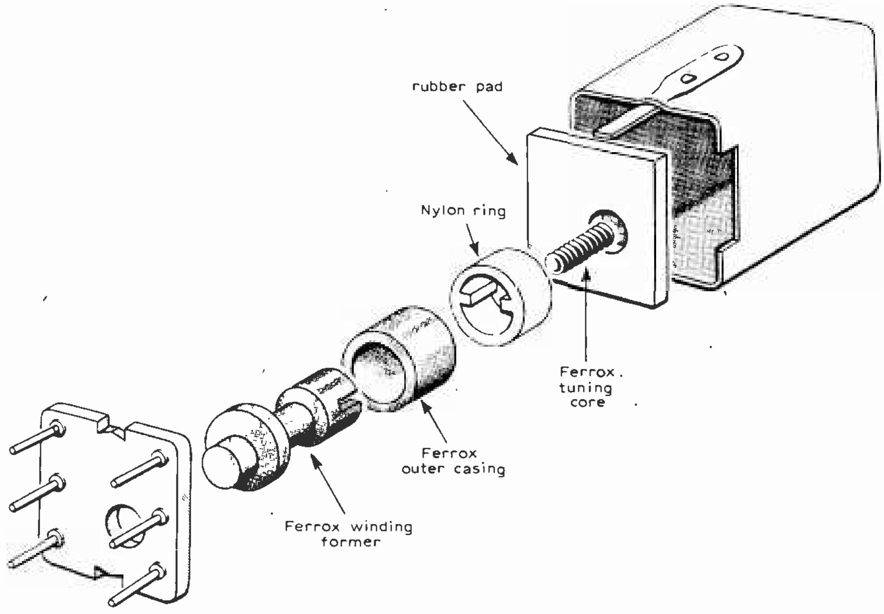
Television tuner design notes

Constructional hints in the light of experience

by D. C. Read, B.Sc.

Following publication of the TV tuner design details (*WW*, October, November, December 1975 and January 1976), a number of aspects of construction and operation have been queried. Happily, none of the questions suggest faulty design; most are concerned with minor effects, and the problems that have occurred have been easy to solve. For readers who are at present building the tuner or perhaps thinking of doing so, the various points are discussed below.

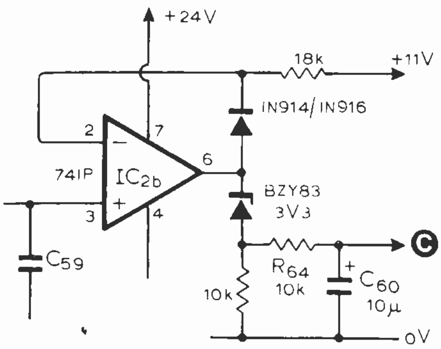




Modification to accommodate 05 version of ELC1043 module

As shown in Fig. 17 (part 3), the tuning-voltage spread for the ELC1043/05 is about 1 volt at the lower frequencies. If a module on the low side of this spread is installed, the tuning voltage required to select channel 21 (471.25MHz) would probably be about 0.5 volt. But with the circuit as in Fig. 14 (part 3) the least voltage which can be fed from IC_{2b} to the u.h.f. tuner (point C in Fig. 2 Part 1) is appreciably more than 1 volt.

To obtain the necessary lower voltage, the IC_{2b} circuit modification suggested below would be suitable. It provides a voltage offset for IC_{2b} output which is maintained at a constant value over a considerable range of ambient temperature.



In this modified circuit, the 3.3 volt zener diode draws a low bias current through the 18kΩ and 10kΩ resistors from the 11-volt supply rail, and holds point C at a constant 2 volts negative with respect to the IC_{2b} output. Given this standing bias, the tuning voltage fed to the u.h.f. module can be reduced to zero or even below, and therefore enables selection of channel 21. The silicon junction diode connected between IC_{2b} output (pin 6) and the inverting input (pin 2) provides an overall positive voltage-versus-temperature variation which matches and counteracts the negative-going drift in the zener.

A tuner modified in this way has been tested over an ambient temperature range much greater than would be experienced in practice. The trial showed that voltage tracking between the diodes was quite effective so that the a.f.c. system does not have to adjust for variation in the added bias.

Pile-winding of Neosid type-E2 coils

The components list in part 3 shows that inductors L_8 - L_{13} are pile-wound on type-E2 formers. Pile winding is an effective way of reducing self-capacitance in coils, particularly those with a relatively large number of turns e.g. L_{10}. It prevents spurious resonances occurring and is generally used to ensure that the larger part of the designed circuit capacitance is obtained from known, discrete components rather than from indeterminate strays in the winding.

The accompanying diagram illustrates how the windings are started and then gradually stacked, as it were, in vertically-slanted layers across the former winding space. The winding height (h) must be judged to suit the number of turns. The basic aim, of course, is to keep turns with the largest r.f. voltage difference as far apart as possible. With care it is not a difficult construction technique to master; the friction of silk-covered litz wire eases the slant stacking. Failing its use, it may be found that tuning capacitance values as shown in the Fig. 2 circuit will have to be reduced to accommodate the extra winding capacitance which will result; in this event, the specified tuner performance might be difficult to achieve.

As shown in the exploded diagram on p.83, a rubber "cushion" with an offset hole is included in the necessary fitments and is laid between the top of the former and the shielding can. It is a most important item. If the tuning core is screwed fully "home" with the cushion omitted, it could reach, and press against, the former base. When this happens, further rotation of the core lifts the nylon collar clear of the ferrite ring, allowing it to move up and down with the resulting random changes of inductance. It might then be necessary to remove the inductor screening can from the board, dismantle it and re-seat the collar.

The rubber cushion fills the gap between the collar and the can top and so restricts any such movement. To help it do this, remember to push each can firmly down on to the board before soldering the lugs to the earth plane; this action compresses the rubber.

Adjustment of L_{14}/L_{15} coupling capacitor

In Fig. 2, it is shown that the "top-C" coupling for L_{14}/L_{15} is provided on the printed-wiring board by track capacitance. Because of variation in the etching process, some of the boards supplied have a value of capacitance which is too large (too little space between tracks). In this event, the sound i.f. response as exampled in Fig. 20 of part 4 might be difficult to achieve, and the value would have to be reduced.

Adjustment is easily made by carefully scraping a small amount of copper from the board so as to widen the gap between tracks until the response is correct. As explained in step 9 of the line-up instructions (part 4), satisfactory response obtains when the transfer of energy by the L_{14}/L_{15} circuit is equal about the carrier frequency. For a value of coupling C which is too large, the tendency will be for more energy to be transferred on the high-frequency side of the carrier i.e. the part of the spectrum towards the vision-frequencies.

Pre-set tuning arrangements

The photograph in part 4 shows a push-button assembly connected to a tuner board equipped for sound-only reception; the full vision and sound version can also be fitted with push-button control. But, in adding this facility, the high-value variable resistors provided in these assemblies for pre-set adjustment are not suitable as direct replacements for the components (R_{91} R_{94}, R_{97}, R_{100}) specified for the tuning-voltage supply circuit given in Fig. 2.

The difference in resistance value creates two problems, both involving the 22μF tantalum capacitors (C_{70} to C_{73}) connected across each pre-set. Referring to Fig. 2, the R_{61}/C_{59} combination at the input to IC_{2b} is needed to reduce a.f. modulation present in the discriminator output feed used for a.f.c. But when channel reselection takes place, the voltage on C_{59} must be appropriately increased or reduced as quickly as possible to complete the re-tuning process. Mainly, voltage change results from the charge transfer between C_{59} and whichever of the 22μF tuning-supply reservoir capacitors is connected into circuit at the instant of reselection. The feed of current from the d.c. supply through the relevant pre-set resistor then completes the change. The effective time constant is determined by the pre-set chain resistance, which is 10 kΩ in the original (published) circuit as compared with 100 kΩ for the push-button assemblies. Thus with the push-button unit, the time taken to bring the voltage within the range covered by a.f.c. and so re-establish settled tuning conditions is increased by up to 10 times.

The other problem concerns the leakage current taken by tantalum capacitors and the variation of this with temperature. For these capacitors, leakage can double for every 10 deg C change in temperature; for a d.c. source impedance of 2.5 kΩ, as in the original circuit, this represents a voltage change of about 5mV. Such a voltage applied to the ELC1043 u.h.f. module causes a frequency change of about 0.1MHz, which is easily corrected by a.f.c. With a d.c. source of 25 kΩ as presented by the push-button pre-sets, however, the frequency bias resulting from capacitor leakage could be as much as 1MHz. Although this is still within the a.f.c. range, the offset is unacceptably large because in one direction the degree of control then remaining to counteract all other tuning change effects is severely limited.

In practice, an elegant arrangement is possible: the two pre-set chains – high and low resistance – can be connected in parallel. If this is done, the high-resistance push-button pre-sets are initially put to mid-range and coarse adjustment for the required channels is carried out using the original low-value resistors. Subsequently, fine tuning is completed by means of the high-value controls so that the a.f.c. system is then arranged to operate exactly in the middle of its range for each selected station.

Component-location diagram

The following are errors in the location diagram supplied with the printed wiring board.

- The tantalum capacitor C_{74} across zener diode D_{14} at the base of T_{14} is shown reversed. As indicated in the circuit diagram of Fig. 2, the C_{74} positive terminal should be connected to the transistor base and to the positive end of the parallel zener.
- The positions marked IC_{2a} and IC_{2b} are inverted in the diagram although the component type numbers are correct. The SN72741P, IC_{2b}, is at the top and the SN72748P, IC_{2a}, at the bottom.

Finally, the ELC1043/05 module can be obtained from Manor Supplies, who also offer an alignment service.

T. C. Owen

Many of the long standing advertisers in *Wireless World* will be saddened to hear of the death of T. Charles Owen, who was advertisement manager of the journal from 1925 to 1959. Born in 1894 (the year Heinrich Hertz died), Tommy Owen made his career among the pioneers of radio. He joined Marconi's Wireless Telegraph Company in 1912 as an assistant in the cashier's department, and knew Marconi personally. He handled the cash side of *The Marconigraph*, and when this became *The Wireless World* in 1913, began his long, 47 years' association with the journal.

At the outbreak of the First World War in 1914 he joined the Royal Welch Fusiliers and saw service in France, but was invalided out in 1916. He returned to *Wireless World* in 1917 and subsequently was put in charge of the office, sales and despatch department of Wireless Press Ltd, then at Marconi House in the Strand, London. Iliffe bought this company in 1924 and shortly afterwards Mr Owen was made advertisement manager of *Wireless World*. It was in the early 1920's that he got to know E. K. Cole, J. L. Baird and many other pioneers of radio and television in the U.K. The old 2LO broadcasting station in London was familiar ground to him.

A genial, greatly respected figure, he conducted the advertisement business of *Wireless World* with continuing success until his retirement in 1959, when he was succeeded by G. Benton Rowell. Mr. Owen died in February, aged 81.

G.B.R.

New Products

Function generator

The model 119 voltage-controlled frequency function generator has been added to the range produced by Exact Electronics Ltd. This unit has a frequency range from 0.02Hz to 2.2MHz with sine, square, triangle and variable time symmetry of all waveforms for ramp and pulse operation. A v.c.f. input is provided to allow the generator frequency to be varied either up or down over a total range of 1,000:1. Minus 10V d.c. will increase the frequency by three decades from a minimum multiplier setting, and plus 10V d.c. will decrease it by a similar amount from a maximum multiplier setting. The "high" output delivers 20V pk-pk on open circuit, or 10V pk-pk into 50 ohms whilst the "low" output gives 632mV pk-pk open circuit or 316mV pk-pk into 50 ohms. An amplitude control provides a 30dB attenuator for both high and low outputs which are available simultaneously. An invert switch allows the pulse and ramp waveforms to be reversed in polarity and a d.c. offset control gives up to ±10V adjustment. A t.t.l.-compatible pulse output is provided in the front panel. Dana Electronics Ltd, Collingdon Street, Luton, Beds.

WW 301 for further details

Infrared oven

For reflow soldering, drying thick-film paste, curing photo-resists and sprays and many other small-scale heating, drying, soldering and curing applications, a new infrared oven has been introduced to this country by Dage Intersem Ltd. Called the TR-91, it is manufactured by Glo-Quartz Ovens Inc, California and is suitable for bench-top use. It incorporates a variable speed (0-4ft per minute) stainless steel conveyor belt and may be integrated into existing production lines. Dage Intersen Ltd, Haywood House, Pinner, Middlesex.

WW 302 for further details

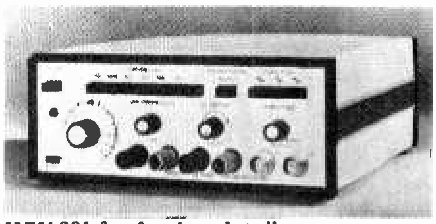
Inverter for TV sets

Inverter LF100T has been designed to operate mains-driven TV sets from a 12-volt car battery or similar d.c. source. The inverter delivers a rectangular output waveform with a form factor suited to models relying on r.m.s. or peak voltage values. The maximum power output is 100W at a nominal 240V a.c. Input must be within 11 to 16V d.c. Full protection against output short circuits or overloads is incorporated and the unit is fuse protected against incorrect input polarity connection. Further protection is provided by an electronic trip circuit which shuts down the power unit should the battery voltage fall below 11V, thereby preventing undue battery drain. The unit also trips should over heating occur. Dimensions are 180 × 130 × 90mm, it is mechanically robust and will withstand electrical surges of up to 20V for 80ms or spikes up to ±300V for 15μs. Weir Instrumentation Ltd, Durban Road, Bognor Regis, Sussex.

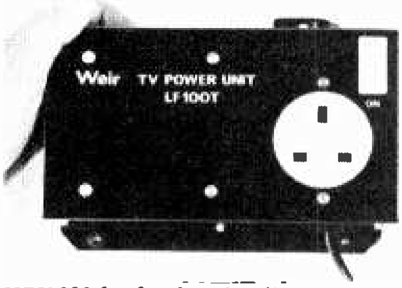
WW 303 for further details

Spark tester for defects

Designed for the detection of flaws, defects or porosity in non-conductive materials, the Goodburn model GBP20 portable h.f. spark tester incorporates a replaceable plug-in coil. The tester has a variable output control which adjusts the spark length to suit different applications, combining optimum frequency with safety in use. The unit will test such materials as rubber, plastics, ebonite and bituminous coatings up to 25mm thick. Voltage input can be set to 100/125V or 220/250V at 30W power consumption. Output frequency is 200kHz and maximum output voltage 55kV. The generator is housed in a compact pistol-shaped moulded polythene case. In testing, the surface of an object is systematically checked by passing over it with the correct probe. Voids and defects will be recognized by the passage of a bright spark accom-

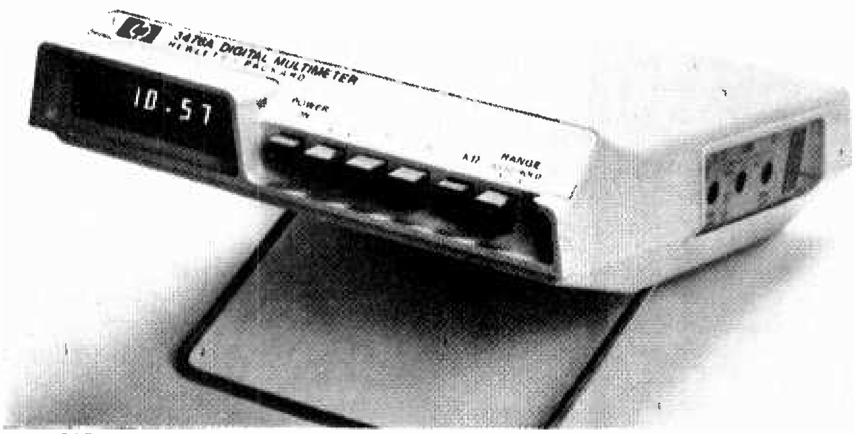


WW 301 for further details

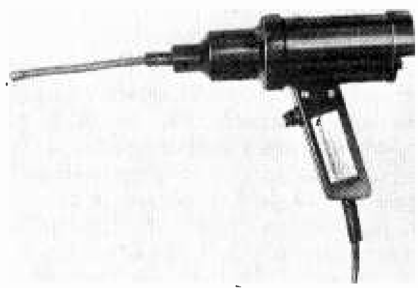


WW 303 for further details

WW 302 for further details



WW 305 for further details



WW 304 for further details

panied by an audible hissing noise. Goodburn, The Welding Centre, Arundel Road, Trading Estate, Uxbridge, Middlesex UB8 2SE.

WW 304 for further details

Digital multimeter

A new 3½-digit, five function, autoranging digital multimeter from Hewlett-Packard measures voltages from ±0.1mV to 1kV d.c. and from 0.3mV to 700V r.m.s. a.c. Resistance is measured from 1mΩ to 1MΩ whilst current can be measured from 0.1mA to 1.1A d.c. and 0.3mA to 1.1A a.c. Autozero, autopolarity and autoranging are built in. Typical accuracy for direct voltage measurements is 0.5% and direct current accuracy is 1%. On alternating voltage ranges, frequency is specified to 10kHz, while a.c. measurement is to 5kHz. Accuracy of resistance measurements is within 0.6% on the three highest ranges and 0.4% on the two lower ranges. Open circuit voltage is less than 4V. Input resistance on all voltage ranges is 10MΩ with input capacitance of less than 30pF. The model 3476 is protected to 1100 volts peak on all ranges. A range hold feature is included that allows the instrument to be locked to any desired range. Hewlett Packard Ltd, King Street Lane, Winnersh, Wokingham, Berkshire RG11 5AR.

WW 305 for further details

Integrator

The D-block integrator from Lee-Dickens Ltd operates by providing a pulse rate which is linearly proportional to an input amplitude. The pulses are then amplified to drive a separate electromagnetic counter. The unit accepts signals with a minimum span of 100mV and input currents of 0-10 and 4-20mA. The output pulse is 24V d.c., 40ms wide and the output, at minimum input, may be up to any count rate between 120 and 12,000 counts per hour. The module will operate from either 100-120V or 210-250V and the power requirement is approximately 2VA. Each instrument is supplied factory calibrated from Lee-Dickens Ltd, Desborough, Kettering, Northants.

WW 306 for further details

Instrument case

Boss Industrial Mouldings has recently introduced the BIM300 instrument case. The unit measures 250 × 167.5 × 68.5mm and has a volume of 2000cu.cm. The case has two similar covers screwed onto an 18s.w.g. chassis which is pre-punched to accept an IEC mains socket. Internal upper and lower brackets are also provided for mounting printed circuits boards. The top and bottom covers are constructed from s.w.g.· aluminium which is stove enamelled in either red, grey or orange. The cases are priced at around £12.50 in one off quantities from Boss Industrial Mouldings Ltd, Higgs Industrial Estate, 2 Herne Hill Road, London SE25 OAU.

WW 307 for further details

Automatic millivoltmeter

An analogue, alternating millivoltmeter from the NF Circuit Design Block Co., the Model M-176, will change ranges automatically from 1mV to 300V full-scale. A hold mode is provided and with this in use the ranges can be changed manually. Range-change switching points are at 25% f.s.d. in the downward direction and slightly over 100% upwards, although provision is made for variations. A row of l.e.ds indicates the range in use. A sensitivity control is fitted for convenience in making ratio measurements. The stated error is ±3% or less; frequency/indication response is within 0.3dB from 20Hz to 500kHz and 1dB from 10Hz to 1MHz and a 1V output is taken to front panel sockets. Lyons Instruments, Hoddesdon, Herts.

WW 308 for further details

Flexible jumperlinks

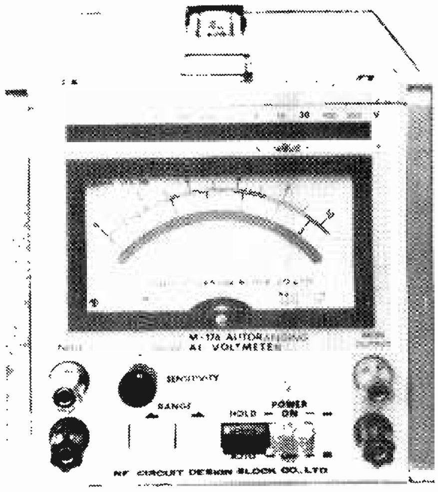
The latest ribbon cabling product to be offered by Tekdata Ltd is CK Jumperlinks. These are sections of flat interconnections for short-distance connection of p.c.bs and connectors. They are custom made in rolls ready to be cut by the user, and consist of tinned copper wires or self-fluxing enamel wires held at the required pitch by woven supporting strips. Any wire pitch or length up to 8cm can be ordered in quantity and coloured bands at stipulated separations can indicate the cutting points. The maximum wire gauge is 30 s.w.g. After a section has been cut from the strip of sections and the ends trimmed, it is ready for termination at lay-on joints or poke-through holes and it may be reflow soldered. Tekdata Ltd, Westport Lake, Canal Lane, Tunstall, Stoke on Trent, Staffs.

WW 309 for further details

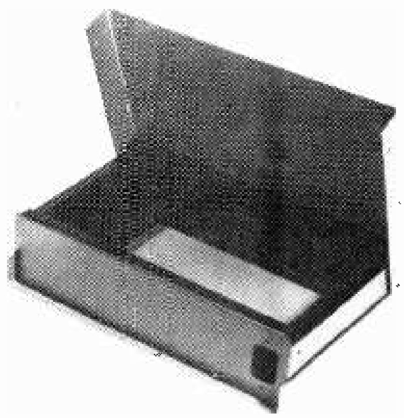
Logic-state indicator

The Ryley Logic Clip is a dual-in-line instrument which provides a simultaneous display of the logic state at each pin of an i.c. Indication is by means of l.e.ds which have a numerical-slide for pin number identification. The clip has high impedance inputs each with a 1.5V threshold for use on t.t.l., d.t.l. and c.m.o.s. devices operating at 5V. Power for the logic clip is derived automatically from the i.c. under test. The device costs £25 + v.a.t. and is available from Electroplan Ltd, P.O. Box 19, Orchard Rd, Royston, Herts. SG8 5HH.

WW 310 for further details



WW 308 for further details



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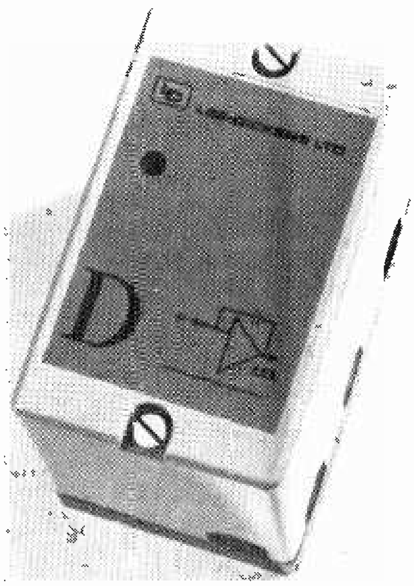

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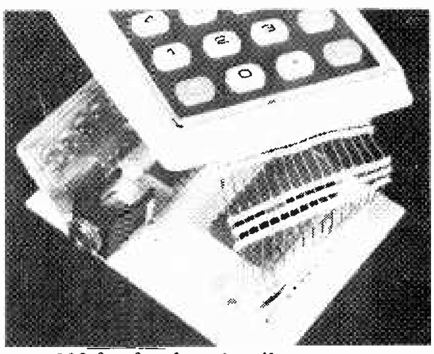

WW 309 for further details

Solid State Devices

Names of suppliers of devices in this section are given in abbreviation after each entry and in full at the end of the section.

Microcomputer kit

A microcomputer kit called the SDK-80 incorporates all of the l.s.i. integrated circuits, crystal, sockets, printed circuit board and auxiliary components necessary to build an 8-bit n.m.o.s. microcomputer system. The kit uses the 8080A c.p.u., the 8228 system controller and the 8224 clock generator with 256 bytes of read/write memory, 2k bytes of programmable read only memory, a programmable serial communications input/output port and 24 other programmable input/output lines. The kit is also supplied with a detailed set of instructions together with system and software manuals. **Intel**

WW 311 for further details

Microprocessor

An eight-bit microprocessor set developed by GIM of Glenrothes, the series 8000 is available as a set of five integrated circuits, as a microcomputer or as a set of plug-in circuit boards. Software support is available. The cost (£17.50 for the c.p.u. – one-off) makes it practicable to use the set for relatively mundane work, as in weighing machines, typewriters and cash registers. The use of the GIM p-channel nitride process used in equipment which is approved to Post Office D4000 means that it can be used in a telecommunications role. **GIM**

WW 312 for further details

Divide-by-four

A 1GHz divide-by-four circuit from Motorola, the MC1699 requires only 160mV pk-pk input from 50MHz to 1GHz. Below 50MHz, the device is best triggered by 1 or 2ns rise time pulses, such as those from emitter-coupled logic. Clock enable and reset inputs are provided and the circuit needs +2V and −5V supplies. The package is currently a flat ceramic type, but the d.i.l. ceramic variety is soon to be used in addition. **Motorola**

WW 313 for further details

Watch calendar circuit

A 12-hour watch circuit in the c.m.o.s. family of devices is announced by RCA. The 32-terminal, leadless package is a watch/calendar unit, designed for use with external display drives and intended for a 32.768kHz drive. The TA6342 will display hours and minutes, with seconds or month, a.m. or p.m. or date. The date display is compensated for 30 and 31 day months, but not 28-day Februaries so that annual re-setting is needed. By the provision of separate photocell, R and C the display can be made to vary in brightness to accommodate ambient lighting changes. Supply voltage is between 2.2V and 3.2V. **RCA**

WW 314 for further details

Microwave i.c. amplifiers

The Avantek range of thin film microwave amplifiers is now available in the UK. The devices are designated the UTO-500 series and are housed in the TO-8 packages suitable for operation in microstrip circuits. There are ten devices ranging in gain from 6 to 27dB and output powers from −2 to +17dBm. Maximum noise figures range from 2.5 to 11dB. All of the amplifiers have a bandwidth of 5 to 500MHz flat within ±1dB. Inputs and outputs have a 50Ω impedance with a v.s.w.r. of less than 2. **Walmore**

WW 315 for further details

Precision voltage source

The ZN423T provides a 1.26V source and is suitable for use in stabilised power supplies d-a-d converters and instruments. The device, which is encapsulated in a two-pin TO18 package, offers a slope impedance of 5.5Ω, a temperature coefficient of 100 p.p.m. per deg C, and an operating temperature range from 0 to +70°C. The 100+ price is £0.70 each. **Ferranti**

WW 316 for further details

Precision op-amp

The AD510 is a laser-trimmed op-amp offering a maximum offset voltage of 25μV, a 10nA bias current, 1μV pk-pk input noise for a 0.01 to 10Hz bandwidth and an open-loop gain of over 1×10^6. The device is available for operation between 0 and +70° C or in the military temperature range of −55 to +125° C. Both types are packaged in a TO-99 can. **Analog Devices**

WW 317 for further details

Transistor for s.m.p.s.

Mullard have recently extended their range of high-voltage, high-speed switching transistors with the addition of the BUX86. The device is an n-p-n type with a power rating of 20W, a V_{ces} of 800V and a V_{ceo} of 400V. Applications include switched-mode power supplies, inverters and converters. **Mullard**

WW 318 for further details

Micro circuit oscillator

The latest addition to the range of standard microcircuit products produced by Redac Software Ltd is the TF105 audio oscillator, a hybrid thick-film oscillator which can be used for either analogue or digital clock application. The unit is a ±10 p.p.m./deg C sine wave oscillator, the frequency of which can be set by the user in the range 100Hz to 100kHz. It will operate between 5 and 30V with split or single supplies and over the temperature range −20 to +85°C with a high amplitude stability. The output is d.c. coupled with a low offset voltage. With the addition of a dual ganged potentiometer a wide range RC oscillator can be constructed. Dimensions of the unit are 2.5 × 3.5 × 0.8cm. **Racal.**

WW 319 for further details

Low-pass filters

A range of low-pass filters in standard 16-pin d.i.l. packages is available. The filters, manufactured by the American E.S.C. Electronics Corporation provide a cut-off frequency range from 200kHz to 1MHz and an impedance range from 75Ω to 1kΩ. Insertion loss is less than 0.5dB. The operating temperature range is −55°C to +125°C and the device conforms to applicable portions of MIL-F-18327C. **G.E. Electronics**

WW 320 for further details

Telephone relay drivers

Two new i.cs from National Semiconductor, DS3686 and DS3687 will drive 48V telephone relays without the need for external circuit protection. Both devices convert standard bipolar and c.m.o.s. logic signals to the high voltage, high current levels required by telephone relays. The DS3686 is a positive-voltage driver; DS3687 a negative-voltage driver. Outputs are rated at 65V and the devices will sink 300mA per channel. **National**

WW 321 for further details

Suppliers

RCA Ltd, Sunbury-on-Thames, Middx.
Mullard Ltd, Mullard House, Torrington Place, London, WC1.
Walmore Electronics Ltd, 11 Betterton Street, London WC2H 9BS.
Ferranti Ltd, Gem Mill, Chadderton, Oldham, Lancashire.
Analog Devices Ltd, Central Ave, East Molesey, Surrey.
Intel Corporation (UK) Ltd, Broadfield House, 4 Between Towns Road, Cowley, Oxford OX4 3NB.
National Semiconductor UK Ltd, 19 Goldington Road, Bedford MK403LF.
Motorola Ltd, Semiconductor Products Division, York House, Empire Way, Wembley, Middx HA9 OPR.
General Instrument Microelectronics Ltd, 57 Mortimer Street, London W1N.
G. E. Electronics (London) Ltd, Eardley House, 182/4 Campden Hill Road, Kensington, London W8 7AS.
Racal-Redac Ltd, Newtown, Tewkesbury, Gloucestershire, GL20 8HE.

Advanced Microdevices have informed us that they are now at Room 322, Ebury Gate, 23 Lower Belgrave St, London SW1W 0NS.

Real and Imaginary

by "Vector"

FIFTY YEARS OF THE BEAM

Holiday-makers in Cornwall may have discovered the charming little Poldhu Cove, a few miles west of Mullion. Relatively few visitors, however, make the short pilgrimage up a cliff path and round the headland to a spot which, if it had been in the United States, would surely have become a shrine long before this. For here was the cradle of long-distance radio communications.

But this is England (if the Cornish Nationalists will pardon the expression) so, apart from the magnificent views, there isn't much else to see. Some traces of building foundations, a granite obelisk and that's all, except for a plaque recording the bridging of the Atlantic by wireless signals in 1901 and the evolution of the beam system half a century ago. Of the mighty Poldhu station itself, scarcely a vestige remains.

Wireless telegraphy generated centimetric waves which were directed — well, more or less — by forms of parabolic reflector; then Marconi discovered that an elevated antenna wire gave better ranges than the Hertzian dipole mounted on the transmitting or receiving instrument and this ushered in a phase of omnidirectional working in which the reflector sank into oblivion.

Gradually the operating ranges increased to line-of-sight and somewhat beyond and it was found that the longer the wavelength that was used, the further the signals reached, until at length ranges were being recorded that were utterly inconsistent with theory.

Voltaire's comment that "If God did not exist it would be necessary to invent him" fitted the situation perfectly, except that in this case it was the ionosphere that had to be invented. It was a concept which was still being hotly debated twenty years later, until its existence was proved by the work of Appleton, Breit and Tuve, T. L. Eckersley *et al* in the 1920s.

Ionosphere or no ionosphere, the practical workers in the field evolved the golden rule that long distances could be achieved only by using long wavelengths and high power. It worked. By the 1920s wavelengths of the order of thousands of metres were the norm for long-distance working and the use of reflectors was in any case physically impracticable because of the huge sizes which would be involved. But by this time the reflector approach had long since been forgotten and plans were under way for a chain of longwave high-power stations to link the Empire.

In 1916, Marconi, who had largely been responsible for the trend toward long wavelengths, reverted to experiments on 2 metres but only for short range working. His personal assistant on this occasion, Charles Samuel Franklin, having an antenna of manageable size to work with, added a reflector and thereby concentrated the signal into a beam with consequent economies in power and an increase of privacy (the work was for the Italian Navy). Subsequently Franklin continued his short-wave experiments and in the immediate post-war period built a 15-metre link between Birmingham and Hendon which also used reflectors. This was also highly successful.

Every now and then reports would come in of the signals being received over long distances. There was also the matter of the amateurs who, confined to the then despised and "useless" bands below 200 metres, were occasionally reporting that their signals had been picked up in the USA and even further afield. Franklin pondered over these circumstances; true, reception was erratic in the extreme but that it occurred at all was remarkable. He persuaded Marconi to let him investigate and in due course installed himself at the existing long-wave station at Poldhu. Here, working at astonishing speed, he built an 8-valve transmitter to operate at 97 metres, and a half-wave antenna with a reflector that could be switched in and out at will.

Aboard Marconi's yacht *Elettra* special receiving gear had been fitted and on April 11, 1923, the ship set out from Falmouth heading for Madeira and, eventually, St. Vincent in the Cape Verde Islands, with Marconi aboard. At first, it seemed, the experiment was a failure, for the Poldhu signals attenuated rapidly then disappeared altogether. This was the now familiar (but then unknown) "skip distance effect". Fortunately the voyage continued and, after some hundreds of miles, Marconi was able to record good reception.

The results were spectacular but left room for improvement. As it turned out later, 97 metres was a bad choice for daylight reception, while the reflector wasn't providing the anticipated increase in gain. But more than enough had been done to show the enormous potential in short-wave long-haul radio communication.

With all speed Franklin redesigned the transmitter for 92 metres working at a power of 17kW and at the same time improved the reflector, although this wasn't ready in time for the next series of tests. Even so, on May 30, 1924, Marconi was able to telephone direct to Sydney from Poldhu. Subsequent tests on various wavelengths between 32 and 92 metres showed that the daylight range increased as the wavelength decreased; on 32 metres, reception at Sydney was possible for 23½ out of the 24 hours. All the data from these tests were rigorously examined and formed the foundation of our present knowledge of the ionosphere.

The story of how the long-projected plan for a long-wave, high power chain of stations throughout the British Empire was abandoned in favour of the beam system is well-known. Perhaps less well-known is the magnitude of the gamble which Marconi took in offering the stations to the British Post Office and the Empire Governments. At the time of the contract, no fully engineered version of the beam transmitter existed; serious teething troubles were being experienced with the transmitting valves; neither the antennas nor the reflectors were fully engineered, while the problem of how to transfer the energy from the transmitter to the antenna without undue losses had still to be solved. To cap it all, Marconi had no means of knowing whether the long ranges obtained in the tests would continue or not. For all he knew, transient freak conditions might have been responsible — circumstances which might never be repeated. Although the contract was wholly conditional upon successful performance, he took the risk.

His decision was a measure of his faith in Franklin. And Franklin performed wonders. To overcome the valve problem he personally designed the first "CAT" (Cooled Anode Transmitter) valves in which the copper anode was also the envelope. Next, he re-engineered the transmitters, antennas and reflectors (and, with no precedents to guide him, the antennas themselves were no mean problem, consisting as they did of a large number of elements, all of which had to be fed in a common phase relationship).

Then came the matter of an efficient power transfer. Franklin solved this by the invention of the concentric feeder, or coaxial cable. And he did the whole lot in a matter of months — he had to, because construction of some of the stations had already begun! Let's be honest with ourselves for a moment. How many electronics engineers of today have the capability of tackling an entirely new system and designing and engineering its transmitters, valves and antennas from scratch? And Franklin's end-products were no lashups, either. Forty years later one or two of his original transmitters were still in regular traffic service and in some part of the world may still be so — and that's engineering by any standards.

On October 18, 1926 the first beam circuit came officially into service, linking Britain and Canada.

Fifty years ago. Poldhu station has since disappeared almost without trace and I suspect that C. S. Franklin is all but forgotten.

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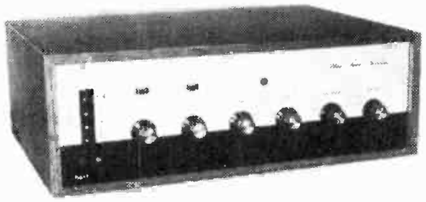

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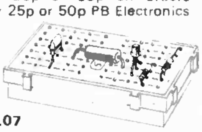

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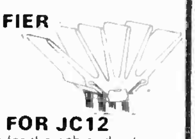

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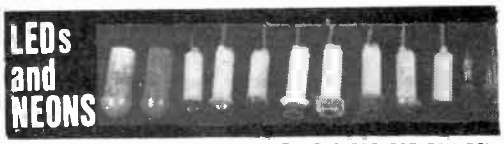

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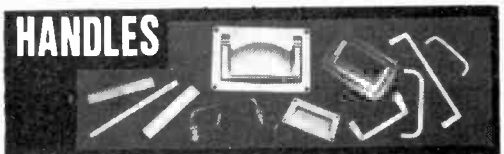

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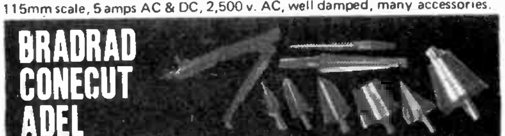

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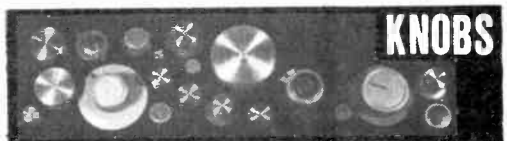

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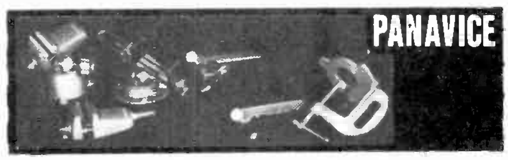

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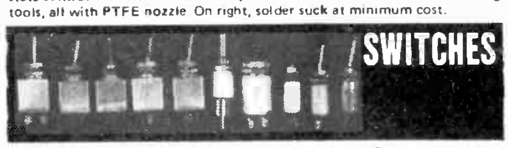

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196.2, CO x 2, 220v. 2A
198.1, 5-position toggle
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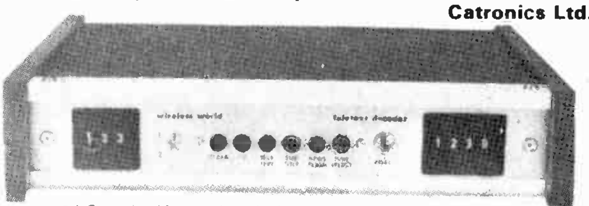

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Catronics

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Carshalton, Surrey
Tel: 01-669 6700

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ADVANCED CLOCK KIT

Complete kit including attractive slim case for 6 digit alarm clock with bleep alarm, snooze and automatic intensity control, high brightness display driving-with optional touch switch controls and crystal control/battery-back-up (both extra) using MK50253 and LED displays. Kit also includes PCBs, active and passive components, IC socket, miniature cool transformer, switches, flat cable, loudspeaker, mains plug and lead, perspex panel, and full instructions. With 0.5" JUMBO FND500 Displays **£27.31**

P.E. CAR CLOCK with Journey Timer

6 digit clock for use in any car with 12V battery with an independent journey timer incorporated. Bright Jumbo LED display comes on with ignition – automatic intensity control. Complete kit of all parts needed including case, PCBs and all components. Full instructions **£39.50**

Easy to build **E.E. DIGITAL CLOCK** (Jan. issue). Kit of all components including case etc for this attractive clock with 12mm green display. Full instructions **£15.70**

50 Hz Xtal Timebase Kit for clocks (incl. advanced kit above) **£6.28**

CMOS ICS		CD4031	1.82	CD4062	7.33	CD4518	1.03	**DISPLAY INT.**	
RCA MOT. ONLY		CD4032	0.88	CD4063	0.90	CD4520	1.03	SN75491	0.81
CD4000	0.17	CD4033	1.14	CD4066	0.58	CD4527	1.30	SN75492	1.02
CD4001	0.17	CD4034	1.56	CD4067	2.95	CD4532	1.16	7447	1.05
CD4002	0.17	CD4035	0.97	CD4068	0.18	CD4555	0.74	7448	0.85
CD4006	0.97	CD4036	1.82	CD4069	0.18	CD4556	0.74		
CD4007	0.17	CD4037	0.78	CD4070	0.18	MC14528	0.86	**FLAT CABLE**	
CD4008	0.79	CD4038	0.88	CD4071	0.18	MC14534	6.04	20WAY1M	1.00
CD4009	0.46	CD4039	2.86	CD4072	0.18	MC14553	4.07	1C.M for	8.50
CD4010	0.46	CD4040	0.88	CD4073	0.18	MC14566	1.21	10WAY1M	0.60
CD4011	0.17	CD4041	0.69	CD4075	0.18	MCM14552	8.05	10M FOR	4.80
CD4012	0.17	CD4042	0.69	CD4076	1.27				
CD4013	0.46	CD4043	0.83	CD4077	0.18			**IC SOCKET PINS**	
CD4014	0.83	CD4044	0.77	CD4078	0.18	**CLOCK CHIPS**		100	0.50
CD4015	0.83	CD4045	1.15	CD4D81	0.18	MK50253	5.60	1000	4.00
CD4016	0.46	CD4046	1.10	CD4082	0.18	MM5314	4.44	3000	10.50
CD4017	0.83	CD4047	0.74	CD4085	0.59	AY51224	3.66		
CD4018	0.83	CD4048	0.46	CD4086	0.59	AY51202	4.76	**LSI SOCKETS**	
CD4019	0.46	CD4049	0.46	CD4089	1.27			**PINS**	**+SUP-**
CD4020	0.92	CD4050	0.46	CD4093	0.66			**PORTS**	
CD4021	0.83	CD4051	0.77	CD4094	1.53	**CMOS BOOKS**		24 PIN	0.30
CD4022	0.79	CD4052	0.77	CD4095	0.86	No VAT or P&P		28 PIN	0.30
CD4023	0.17	CD4053	0.77	CD4096	0.86	RCA1975	2.67	40 PIN	0.30
CD4024	0.64	CD4054	0.95	CD4099	1.50	MCMOS	2.77		
CD4025	0.17	CD4055	1.08	CD4502	0.98			**VEROCASES**	
CD4026	1.42	CD4056	1.08	CD4510	1.12			751410J	2.64
CD4027	0.46	CD4057	20.35	CD4511	1.28	**DISPLAYS**		751411D	3.04
CD4028	0.74	CD4059	3.64	CD4514	2.56	5LT-01	5.80	751412K	4.00
CD4029	0.94	CD4060	0.92	CD4515	2.56	DL704E	0.75	CA3130	0.88
CD4030	0.46	CD4061	16.43	C04516	1.12	FND500	1.02		

FND500 Jumbo 0.5in. CC Red LED now only £1.02.

This full specification prime unit from Fairchild offers outstanding value – compare its price with other digits of comparable size and high quality. **DL704E** 0.3" CC Red LED now only **75p**.

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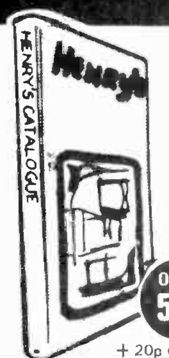

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telephone: 01-883 3705

C-MOS

mix prices

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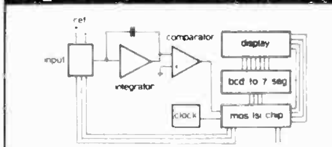
CD4000AE	19p *	17p *	14p *
CD4001AE	19p *	17p *	14p *
CD4002AE	19p *	17p*	14p *
CD4006AE	£1.59 *	£1.33 *	£1.06 *
CD4007AE	23p *	19p*	15p *
CD4008AE	£1.75 *	£1.46 *	£1.17 *
CD4009AE	Use	CD4049*	
CD4010AE	Use	CD4050*	
CD4011AE	19p *	17p*	14p *
CD4012AE	19p *	17p*	14p *
CD4013AE	59p *	50p*	46p *
CD4014AE	£1.75 *	£1.46 *	£1.17 *
CD4015AE	£1.75 *	£1.46 *	£1.17 *
CD4016AE	55p *	48p*	44p *
CD4017AE	£1.29 *	£1.07 *	93p *
CD4018AE	£1.89 *	£1.56 *	£1.25 *
CD4019AE	80p *	66p*	53p *
CD4020AE	£1.97 *	£1.64 *	£1.31 *
CD4021AE	£1.75 *	£1.46 *	£1.17p *
CD4023AE	19p *	17p*	14p *
CD4022AE	£1.83 *	£1.53 *	£1.22 *
CD4024AE	£1.26 *	£1.05 *	84p *
CD4025AE	19p *	17p*	14p *
CD4026AE	£2.79 *	£2.32 *	£1.86 *
CD4027AE	98p *	82p*	65p *
CD4028AE	£1.53 *	£1.28 *	£1.02 *
CD4029AE	£1.89 *	£1.56 *	£1.15 *
CD4030AE	71p *	59p*	47p *
CD4035AE	£1.75 *	£1.46 *	£1.17 *
CD4040AE	£2.01 *	£1.69 *	£1.34 *
CD4042AE	£1.49 *	£1.24 *	99p *
CD4046AE	£2.15 *	£1.79 *	£1.44 *
CD4049AE	69p *	58p*	46p *
CD4050AE	69p *	58p*	46p *
CD4051AE	£2.78 *	£2.32 *	£1.85 *
CD4052AE	£2.78 *	£2.32 *	£1.85 *
CD4056AE	£2.12 *	£1.76 *	£1.41 *
CD4060AE	£2.39 *	£1.99 *	£1.55 *
CD4066AE	£1.13 *	94p*	75p *
CD4068AE	28p *	24p*	19p *
CD4069AE	28p *	24p*	19p *
CD4070AE	28p *	24p*	19p *
CD4071AE	28p *	24p*	19p *
CD4077AE	71p *	59p*	47p *
CD4081AE	28p *	24p*	19p *
CD4082AE	28p *	24p*	19p *
CD4085AE	£1.28 *	£1.06 *	85p *
CD4086AE	£1.28 *	£1.06 *	85p *
CD4093AE	£1.56 *	£1.20 *	£1.04 *
CD4099AE	£2.95 *	£2.46 *	£1.96 *
CD4511AE	£2.36 *	£1.79 *	£1.44 *
CD4528AE	£1.30 *	£1.08 *	87p *

3½ DECADE DVM I.C.



This state-of-the-art MOS LSI chip contains all the logic necessary for a 3½ decade, dual slope integrating, automatic polarity detecting DVM. Supplied with free data and circuit booklet. AY-5-3507

OUR PRICE ONLY £6.59.*
(Data and Circuit Booklets alone 20p.)

The AY-5-1224 tick-tock

Another marvel from G.I. A 16 pin 12-24 hr. Clock I.C. with 25 pin capability and low external parts count. Supplied with manufacturers detailed leaflet £3.95p*(inc. VAT) (Leaflet alone 20p.) Full Kit (excluding case) available towards end of 1975. Phone Clive for details.

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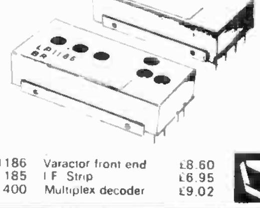

LP1186	Varactor front end	£8.60
LP1185	I.F. Strip	£6.95
LP1400	Multiplex decoder	£9.02

I.C. SOCKETS

Pin Sockets, pins in strips of 100. Just snip off what you need. 65p per strip *

Dual in line

8 pin 13p.	24 pin 26p.	TO5
14 pin 15p	28 pin 30p.	8 pin 31p
16 pin 15p	36 pin 39 p.	10pin 35p

FREE CIRCUITS

Our 8 Page A4 Audio I.C. Booklet is supplied FREE with purchases of Linear I.C.'s worth £1. or more (35p. if sold alone) Contains circuits and pin connections

- 15 Amplifiers 250 mW to 20 watts
- 5 Audio Pre-Amplifiers
- 1 Tape Pre-Amplifier
- 1 Power Driver
- 1 Instrument Amplifier (Bifet)
- 1 General Purpose Mini Amplifier
- 1 D.C. Controlled Gain Control
- 1 Micro-mini radio (2 I.C's)

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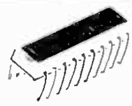
Vceo 25v 2N5777
Vcbo 25v
Vebo 8v
I1 250 mA
Pd 200 mW
Hfe 2500
e b c
35p.

LINE-O-LIGHT



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74 TTL

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7401	14p*	12p *	10p *
7402	14p*	12p *	10p *
7403	15p*	12½p*	10p *
7404	16p*	13p*	11p *
7408	16p*	13p*	11p *
7409	16p*	13p*	11p *
7410	16p*	13p*	11p *
7413	29p*	24p*	20p *
7417	27p*	22½p*	20p *
7420	16p*	13p*	11p *
7427	27p*	22½p*	18p *
7430	16p*	13p *	11p *
7432	27p*	22½p*	18p *
7437	27p*	22½p*	18p *
7441	75p*	62p*	50p *
7442	65p*	55p*	43p *
7445	85p*	71p*	57p *
7447	81p*	75p*	65p *
7448	75p*	62p*	50p *
7447A	95p*	83p*	67p *
7470	30p*	25p*	20p *
7472	25p*	21p*	17p *
7473	30p*	25p*	20p *
7474	32p*	26p*	21p *
7475	47p*	39p*	31p *
7476	32p*	26p*	21p *
7482	75p*	62p*	50p *
7485	£1.30 *	£1.09 *	87p *
7486	32p*	26p*	21p *
7489	£2.92 *	£2.80 *	£2.10 *
7490	49p*	40p*	32p *
7491	65p*	55p*	45p *
7492	57p*	46p*	36p *
7493	45p*	40p*	32p *
7495	67p*	55p*	45p *
74100	£1.08 *	89p*	72p *
74107	35p*	28p*	22p *
74121	34p*	28p*	23p *
74122	47p*	39p*	31p *
74141	78p*	63p*	53p *
74145	68p*	58p*	48p *
74154	£1.62 *	£1.48 *	86p *
74174	£1.00 *	83p*	67p *
74180	£1.06 *	88p*	71p *
74181	£3.20 *	£2.50 *	£1.90 *
74192	£1.35 *	£1.14 *	90p *
74193	£1.35 *	£1.14 *	90p *
74196	£1.64 *	£1.34 *	99p *

LINEAR I.C.'s

555 (8 pin dip)V	55p *
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556 (14 pin dip)	£1.29 *
703 (RF/IF Amp)	68p
709 (8 pin dip)	38p
709 (TO-99)	45p
709 (14 pin dip)	39p
710 (8 pin dip)	39p
710 (TO-99)	45p
710 (14 pin dip)	44p
711 (TO-99)	51p
711 (14 pin dip)	44p
720 (A.M. Radio)	£1.76
723 (TO-99)	£1.09
723 (14 pin dip)	55p
741 (8 pin dip)	30p
741 (TO-99)	43p
741 (14 pin dip)	36p
747 (14 pin dip)	£1.04
748 (8 pin dip)	42p
748 (TO-99)	46p
748 (14 pin dip)	49p
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Regulators 100 mA	
78L05WC (TO-92)	60p *
78L12WC (TO-92)	60p *
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78L05AWC (TBA625A)	90p *
78L12AWC (TBA625B)	90p *
78L15AWC (TBA625C)	90p *
Regulators 500mA	
78M05HC	£1.35 *
78M12HC	£1.35 *
78M15HC	£1.35 *
78M18HC	£1.35 *
78M24HC	£1.35 *
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7805KC (TO-3)	£2.09 *
7812KC (TO-3)	£2.09 *
7815KC (TO-3)	£2.09 *
7818KC (TO-3)	£2.09 *
7824KC (TO-3)	£2.09 *
Regulators 1A	
7805UC (TO-220)	£1.72 *
7812UC (TO-220)	£1.72 *
7815UC (TO-220)	£1.72 *
7818UC (TO-220)	£1.72 *
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ICL8030	£3.52 *

AY-1-0212	£6.93
AY-1-5051	£1.44
AY-5-1224	£3.95 *
AY-5-3500	£6.59 *
AY-5-3507	£6.59 *
AY-5-4007	£7.94 *
BHA0002	£3.01
CA2111	£1.19
CA3045	£1.69
CA3046	88p
CA3053	59p
CA3065	£1.60
CA3075	£1.64
CA3078	£1.26
CA3080	59p
CA3081	£1.86
CA3082	£1.86
CA3089E (TDA1200)	£2.43
CA3097E	£1.67 *
CA3123E	£1.76
CA3130	84p
CA3401E (LM3900)	68p
CA3600E	£1.44
L005T1 (TO.3)	£1.46 *
L036T1 (TO.3)	£1.46 *
L037T1 (TO-3)	£1.46 *
L129 (SOT-32)	85p *
L130 (SOT-32)	85p *
L131 (SOT-32)	85p *
LM301T (TO-99)	65p
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LM301A S(8 pin dip)	59p
LM307 T (TO-99)	59p
LM307 S (8 pin dip)	57p
LM308 T (TO-99)	£1.96
LM308 S (8 pin dip)	98p
LM308A T (TO-99)	£7.92
LM308A S (8 pin dip)	£6.90
LM309K	£2.34 *
LM339	£2.25
LM370N	£2.85
LM371	£2.08
LM372N	£1.99
LM373N	£2.99
LM377N	£2.71
LM380	£1.25
LM381	£1.85
LM382	£1.66
LM703	68p
LM1820	£1.03

LM2111	£1.12
LM3900	69p
LM3909	66p *
MC1303L	£1.94
MC1306P	85p
MC1310P	£2.10
MC1312P	£2.52
MC1314P	£4.34
MC1315P	£4.85
MC1327P	£1.48
MC1330P	89p
MC3401P	81p
MC1339P	£1.60
MC1350	68p
MC1351	92p
MC1352	92p
MC1357	£1.60
MC1358(CA3065)	£1.23
MC1375	£1.56
MC1455 (555T)	65p *
MC1456CG	£1.77
MC1458CP1	89p
MC1468G	£2.30 *
MC1495L	£4.48
MC1496G	£1.01
MC3302P	£1.65
MC3401P	81p
MFC4000B	87p
MFC4060A	85p *
MFC6030A	85p *
MFC6040	£1.01
MM5314	£4.80 *
MM5316	£9.99 *
MVR5V (TO-3)	£1.45 *
MVR12V (TO-3)	£1.45 *
MVR15V (TO-3)	£1.45 *
NE540L	£1.25
NE546A	£1.16
NE555V	69p *
NE556	£1.29 *
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SN76013N	£1.98
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SN76227N(MC1327)	£1.89
SN76532N	£1.86
SN76544N	£1.81
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TAA370	£3.45
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TAA700	£5.03
TBA120S	£1.25
TBA231	£1.02
TBA281 (723)	£2.59
TBA500Q	£3.16
TBA520Q	£3.85
TBA530Q	£3.27
TBA540Q	£3.72
TBA550Q	£5.29
TBA560CQ	£5.29
TBA625A	£1.03 *
TBA625B	£1.03 *
TBA625C	£1.03 *
TBA651	£1.87
TBA720Q	£2.79
TBA750Q	£2.79
TBA800	£1.11
TBA810S	£1.24
TBA810AS	£1.24
TBA820	86p
TBA920Q	£4.71
TBA990Q	£4.71
TCA270Q	£5.24
TCA760	£2.16
TCA800Q	£7.24
TCA830S	£1.04
TCA940	£2.25
TDA1054	£1.50
TDA1200	£2.43
TDA1405	80p *
TDA1412	80p *
TDA1415	80p *
TDA2010	£3.00
TDA2020	£3.75
ULN2111A	£1.52
ZN414	£1.26

ZN414 Leaflet free with devices (10p alone)

MC1310; 2, 4 & 5 Leaflet free with devices (10p alone)

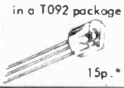
LED DISPLAYS

Litronix Double Digit Displays 0.5" Common Anode; 2 R/H Decimal Points
DL721 ± 1.9
DL727 0.0 to 9.9
Suitable for Clocks, Meters, Instruments, Channel Indicators
Our price £4.75 * each

NEW

C.Anode R/H Dec. pt. · C.Anode L/H Dec. pt. · C.Anode ± 1 · C.Cathode R/H Dec. Pt.

Low cost Red GaAsP Motorola MLED 500 in a T092 package 15p.*



0.33"	Litronix DL 707 Series	all £1.82* each	(Red only)
0.33"	Monsanto MAN 50/70/80/3600	all £1.82* Each	(Red, green, yellow, Orange)
0.33"	Xciton XAN 70 Series	all £1.49* Each	(Red Green, yellow)
0.43"	Monsanto MAN 4000 Series	all £2.32* Each	(Red, Green, Yellow, Orange)
0.63"	Litronix DL747 'Jumbo' Series	all £2.42* Each	(Red only)

Common Cathode as Common Anode (Red only)

NOTE: MAN 4000 Series pin outs are 14 pin dil the same as MAN 50; 70 and 80 series.

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BCD encoded digital switch Reading 0 to 9. Suitable for digital clock alarm setting DVM input Scaling etc.

1 to 9. £1.49 each *

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Free snap-on plastic retainer

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Red	16p	15p	13p *	27p	24p	22p*	18p	16p	14p *
Green	27p	24p	22p*	33p	30p	27p*	30p	27p	25p *
Orange	27p	24p	22p*	33p	30p	27p*	30p	27p	25p *
Yellow	34p	31p	29p*	35p	32p	29p*	35p	33p	30p *

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Our Bulk Buying Power enables a repeat of our Special Offer:
0.33" (LIT 707) 90p.*(inc. VAT)
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OPTO-ISOLATORS

IL1 4N25 or TIL116
6 pin industry standard package
2.5KV isolation £1.00.*

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6-0-6V	100 mA	97p. *
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24-0-24V	500 mA	£2.48 *
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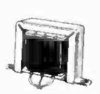
0-24-30-40-48-60 V	-	£5.18 *	£7.02	- *
0-19-25-33-40-50 V	£2.70 *	£3.40 *	£4.53	- *



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Advert No. 1A of Series B

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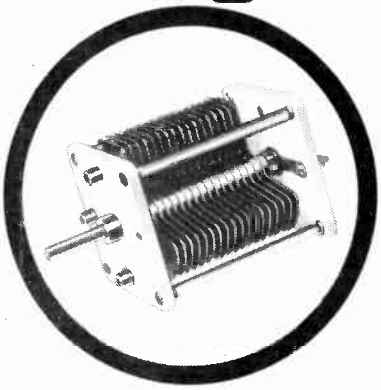

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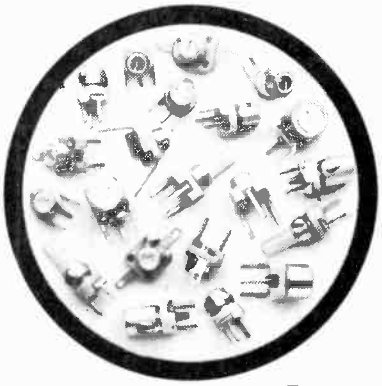

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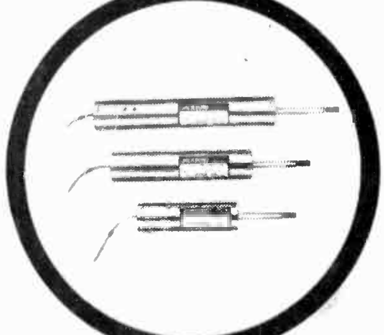

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High sensitivity and linearity coupled with infinite resolution make these linear and angular displacement transducers ideal for a wide variety of control and measurement applications.

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The JAMES SCOTT Alignment Units for D.R. and F.M. Multi-Channel Tape Recorders.

The F.M. Alignment Unit Type FMU/1 illustrated was designed at the Royal Radar Establishment, Malvern, to suit Ampex Recorders working on the IRIG intermediate band specification (using ES 100 Electronics) e.g. Model Numbers FR 1200, FR 1260, FR 1300, FR 1800L, FB 400, PR 500

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Wireless World, April 1976

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Wireless World, April 1976

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Buy a really good set of speakers and you've got yourself a better hi-fi system . . . buy a set of Celestion Dittons and you've got one of the best!

Whether you already own or are thinking of buying either a 'package' hi-fi system or are selecting your own individual units, a pair of good speakers will pay dividends in terms of sound quality.

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(tick appropriate box/boxes)

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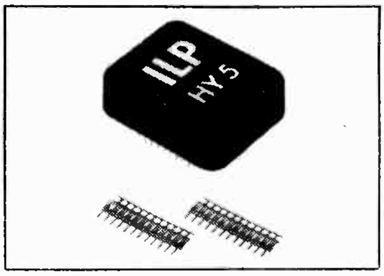
15—240 Watts!

HY5
Preamplifier

The HY5 is a mono hybrid amplifier ideally suited for all applications. All common input functions (mag Cartridge, tuner, etc) are catered for internally, the desired function is achieved either by a multi-way switch or direct connection to the appropriate pins. The internal volume and tone circuits merely require connecting to external potentiometers (not included). The HY5 is compatible with all I.L.P. power amplifiers and power supplies. To ease construction and mounting a P.C. connector is supplied with each pre-amplifier.
FEATURES: Complete pre-amplifier in single pack — Multi function equalization — Low noise — Low distortion — High overload — Two simply combined for stereo
APPLICATIONS: Hi-Fi — Mixers — Disco — Guitar and Organ — Public address
SPECIFICATIONS:
INPUTS. Magnetic Pick-up 3mV; Ceramic Pick-up 30mV; Tuner 100mV; Microphone 10mV; Auxiliary 3-100mV; input impedance 47kΩ at 1kHz
OUTPUTS. Tape 100mV; Main output 500mV R.M.S.
ACTIVE TONE CONTROLS. Treble ± 12dB at 10kHz, Bass ± at 100Hz
DISTORTION. 0.1% at 1kHz. Signal/Noise Ratio 68dB.
OVERLOAD. 38dB on Magnetic Pick-up. SUPPLY VOLTAGE ± 16-50V.
Price £4.75 + £1.19 VAT P&P free.



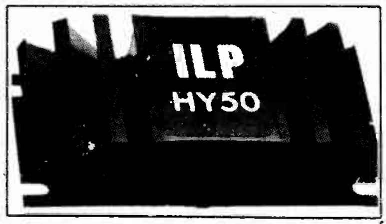
HY30
15 Watts into 8Ω

The HY30 is an exciting New kit from I.L.P. it features a virtually indestructible I.C. with short circuit and thermal protection. The kit consists of I.C., heatsink, P.C. board, 4 resistors, 6 capacitors, mounting kit, together with easy to follow construction and operating instructions. This amplifier is ideally suited to the beginner in audio who wishes to use the most up-to-date technology available.
FEATURES: Complete Kit — Low Distortion — Short, Open and Thermal Protection — Easy to Build
APPLICATIONS: Updating audio equipment — Guitar practice amplifier — Test amplifier — audio oscillator
SPECIFICATIONS
OUTPUT POWER 15W R.M.S. into 8Ω. DISTORTION 0.1% at 15W.
INPUT SENSITIVITY 500mV FREQUENCY RESPONSE 10Hz-16kHz −3dB.
SUPPLY VOLTAGE ± 18V
Price £4.75 + £1.19 VAT P&P free.

Available June '76

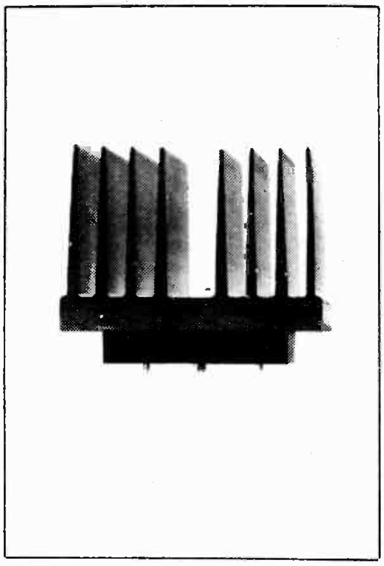
HY50
25 Watts into 8Ω

The HY50 leads I.L.P.'s total integration approach to power amplifier design. The amplifier features an integral heatsink together with the simplicity of no external components. During the past three years the amplifier has been refined to the extent that it must be one of the most reliable and robust High Fidelity modules in the World.
FEATURES: Low Distortion — Integral Heatsink — Only five connections — 7 Amp output transistors — No external components
APPLICATIONS: Medium Power Hi-Fi systems — Low power disco — Guitar amplifier
SPECIFICATIONS: INPUT SENSITIVITY 500mV
OUTPUT POWER 25W RMS into 8Ω LOAD IMPEDANCE 4-16Ω DISTORTION 0.04% at 25W at 1kHz
SIGNAL/NOISE RATIO 75dB FREQUENCY RESPONSE 10Hz-45kHz −3dB.
SUPPLY VOLTAGE ± 25V. SIZE 105.50.25mm.
Price £6.20 + £1.55 VAT P&P free.



HY120
60 Watts into 8Ω

The HY120 is the baby of I.L.P.'s new high power range, designed to meet the most exacting requirements including load line and thermal protection this amplifier sets a new standard in modular design.
FEATURES: Very low distortion — Integral heatsink — Load line protection — Thermal protection — Five connections — No external components
APPLICATIONS: Hi-Fi — High quality disco — Public address — Monitor amplifier — Guitar and organ
SPECIFICATIONS
INPUT SENSITIVITY 500mV
OUTPUT POWER 60W RMS into 8Ω LOAD IMPEDANCE 4-16Ω DISTORTION 0.04% at 60W at 1kHz
SIGNAL/NOISE RATIO 90dB FREQUENCY RESPONSE 10Hz-45kHz −3dB SUPPLY VOLTAGE ± 35V
SIZE 114.50.85mm.
Price £14.40 + £1.16 VAT P&P free.

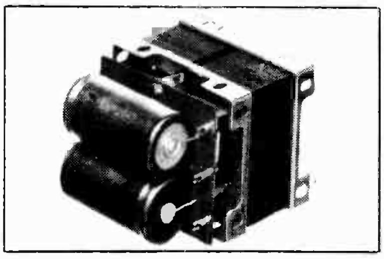


HY200
120 Watts into 8Ω

The HY200 now improved to give an output of 120 Watts has been designed to stand the most rugged conditions such as disco or group while still retaining true Hi-Fi performance.
FEATURES: Thermal shutdown — Very low distortion — Load line protection — Integral heatsink — No external components
APPLICATIONS: Hi-Fi — Disco — Monitor — Power slave — Industrial — Public Address
SPECIFICATIONS
INPUT SENSITIVITY 500mV
OUTPUT POWER 120W RMS into 8Ω LOAD IMPEDANCE 4-16Ω DISTORTION 0.05% at 100W at 1kHz
SIGNAL/NOISE RATIO 96 dB FREQUENCY RESPONSE 10Hz-45kHz — 3dB SUPPLY VOLTAGE ± 45V
SIZE 114.100.85mm
Price £21.20 + £1.70 VAT P&P free.

HY400
240 Watts into 4Ω

The HY400 is I.L.P.'s "Big Daddy" of the range producing 240W into 4Ω! It has been designed for high power disco or public address applications. If the amplifier is to be used at continuous high power levels a cooling fan is recommended. The amplifier includes all the qualities of the rest of the family to lead the market as a true high power hi-fidelity power module.
FEATURES: Thermal shutdown — Very low distortion — Load line protection — No external components
APPLICATIONS: Public address — Disco — Power slave — Industrial
SPECIFICATIONS
OUTPUT POWER 240W RMS into 4Ω LOAD IMPEDANCE 4-16Ω DISTORTION 0.1% at 240W at 1kHz
SIGNAL/NOISE RATIO 94dB FREQUENCY RESPONSE 10Hz-45kHz — 3dB SUPPLY VOLTAGE ± 45V
INPUT SENSITIVITY 500mV SIZE 114x100x85mm
Price £29.25 + £2.34 VAT P&P free.



POWER SUPPLIES

PSU36 suitable for two HY30's **£4.75** plus £1.19 VAT. P/P free
PSU50 suitable for two HY50's **£6.20** plus £1.55 VAT. P/P free
PSU70 suitable for two HY120's **£12.50** plus £1.00 VAT. P/P free
PSU90 suitable for one HY200 **£11.50** plus £0.92 VAT. P/P free
PSU180 suitable for two HY200's or one HY400 **£21.00** plus £1.68 VAT. P/P free

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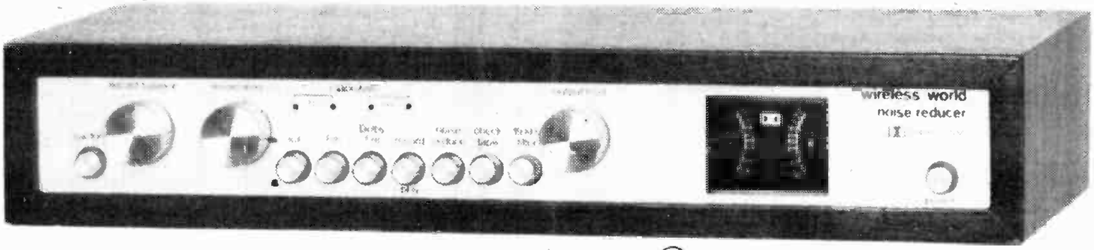

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Trademark of Dolby Laboratories Inc.

We are proud to announce the latest addition to our range of matching high fidelity units.

Featuring:

- switching for both encoding (low-level h.f. compression) and decoding
- a switchable f.m. stereo multiplex and bias filter
- provision for decoding Dolby f.m. radio transmissions (as in USA)
- no equipment needed for alignment
- suitability for both open-reel and cassette tape machines
- check tape switch for encoded monitoring in three-head machines

Typical performance

Noise reduction: better than 9dB weighted

Clipping level: 16.5dB above Dolby level (measured at 1% third harmonic content)

Harmonic distortion 0.1% at Dolby level typically 0.05% over most of band, rising to a maximum of 0.12%.

Signal-to-noise ratio: 75dB (20Hz to 20kHz, signal at Dolby level) at Monitor output.

Dynamic Range > 90dB

30mV sensitivity.

The kit includes:

—complete set of components for stereo processor

—regulated power supply components

—board-mounted DIN sockets and push-button switches

—fibreglass board designed for minimum wiring

—solid mahogany cabinet, chassis, twin meters, front panel, knobs, mounting screws and nuts

PRICE: £34.40+VAT

Calibration tapes are available for open-reel use and for cassette (specify which) .... **Price £1.80**+VAT*

Single channel plug-in Dolby(TM) PROCESSOR BOARDS (92 x 87mm) with gold plated contacts are available with all components .... **Price £6.50**+VAT

Single channel board with selected fet .... **Price £2.00**+VAT

Gold plated edge connector .... **Price £1.27**+VAT*

Selected FET's **54p** each+VAT, **96p**+VAT for two, **£1.76**+VAT for four

Please add VAT at 25% unless marked thus*, when 8% applies
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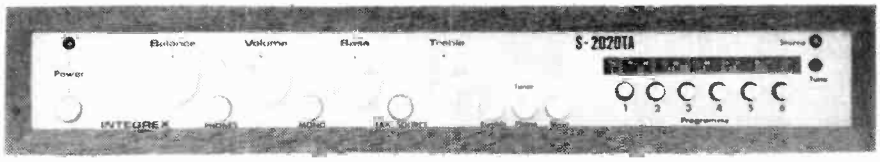
SOLID MAHOGANY CABINET



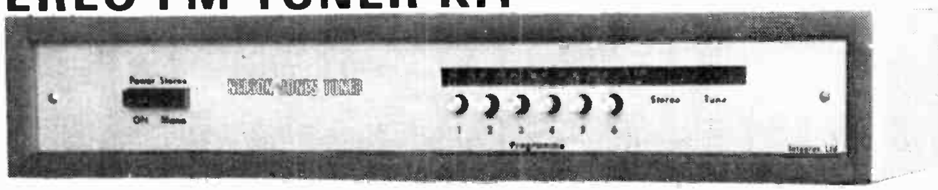
A high-quality push-button FM Varicap Stereo Tuner combined with a 20W r.m.s. per channel Stereo Amplifier.

Brief Spec. Amplifier: Low field Toroidal transformer, Mag. input, Tape In/Out facility (for noise reduction unit, etc), THD less than 0.1% at 20W into 8 ohms. All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section: uses Mullard LP1186 module requiring no RF alignment, ceramic IF, INTERSTATION MUTE, and phase-locked IC stereo decoder. LED tuning and stereo indicators. Tuning range 88—104MHz. 30dB mono S/N @ 1.8μV.THD typ. 0.4%

PRICE: £48.95+VAT

NELSON-JONES STEREO FM TUNER KIT

A very high performance tuner with dual gate MOSFET RF and Mixer front end, triple gang varicap tuning, and dual ceramic filter/dual IC IF amp.



Brief Spec. Tuning range 88—104MHz. 20dB mono quieting @ 0.75μV. Image rejection — 70dB. IF rejection—85dB. THD typically 0.4%
IC stabilized PSU and LED tuning indicators. Push-button tuning and AFC unit. Choice of either mono or stereo with a choice of stereo decoders.

Compare this spec. with tuners costing twice the price

Mono £26.31+VAT
With ICPL Decoder £30.58+VAT
With Portus-Haywood Decoder £32.81+VAT

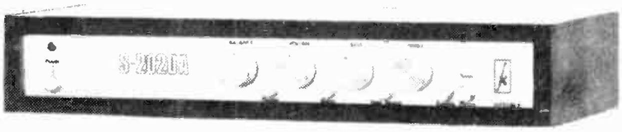
STEREO MODULE TUNER KIT

A low-cost Stereo Tuner based on the Mullard LP1186 RF module requiring no alignment. The IF comprises a ceramic filter and high-performance IC Variable INTERSTATION MUTE. PLL stereo decoder IC

Sens. 30dB S/N mono @ 1.8μV
THD typically 0.4%
Tuning range 88—104MHz
LED sig. strength and stereo indicator

PRICE: Mono £25.55+VAT
Stereo £28.65+VAT

S-2020A AMPLIFIER KIT



Developed in our laboratories from the highly successful "TEXAN" design. PC mounting potentiometers, switches, sockets and fuses are used for ease of assembly and to minimize wiring

Typ. Spec. 20+20W r.m.s. into 8-ohm load at less than 0.1% THD. Mag. PU input S/N 60dB. Radio input S/N 72dB. Headphone output. Tape In/Out facility (for noise reduction unit, etc.). Toroidal mains transformer.

PRICE: £30.94+VAT

ALL THE ABOVE KITS ARE SUPPLIED COMPLETE WITH ALL METALWORK, SOCKETS, FUSES, NUTS AND BOLTS, KNOBS, FRONT PANELS, SOLID MAHOGANY CABINETS AND COMPREHENSIVE INSTRUCTIONS

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BASIC MODULE TUNER KIT (stereo) . £15.25+VAT
PHASE-LOCKED IC DECODER KIT . . . £4.47+VAT
PUSH-BUTTON UNIT . . . . £3.50+VAT

PORTUS-HAYWOOD PHASE-LOCKED STEREO DECODER KIT . . . . £7.93+VAT

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IT'S ALL IN OUR FREE CATALOGUE

Component Packs

CP1	150	Capacitors, mixed bag of paper silver mica electrolytics etc Approx quantity, counted by weight (post and packing)	60p
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CP4	12	Potentiometers pre-sets w/wound, carbon etc Mixed types and values	60p
CP5	5	Earphones, single low impedance for transistor radios, cassettes, etc Less plugs for suitable plugs see PAKs CP9 and CP10	60p
CP6	50	10-5 mounting pads, fits between transistor and board for that pro finish	60p
CP8	500	Cable clips for G P O ⅛" dia cable Nylon with hardened steel pin (probably tungsten) per sealed box of 500	60p*
CP9	5	3 5mm plugs, miniature jack, to fit earphones in PAK CP5	60p*
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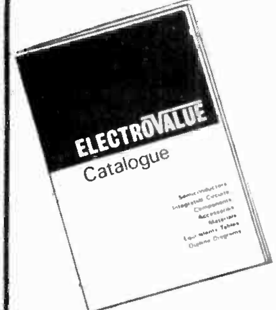

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2,200mfd/100 volt, **90p.** P.P. 25p.
4,700mfd/25 volt, **65p.** P.P. 20p.
6,800mfd/16 volt, **50p.** P.P. 15p.
10,000mfd/25 volt, **75p.** P.P. 25p.
25,000mfd/40 volt, **£1.25.** P.P. 30p.
47,000mfd/40 volt, **£2.00.** P.P. 50p.
100,000mfd/10 volt, **£1.50.** P.P. 50p.
160,000mfd/10 volt, **£2.00.** P.P. 50p.

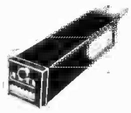
OVERLOAD CUT OUTS

Panel mounting 800 M/A 1.8 amp. 10 amp. **55p ea.**

SMITHS GEARED MOTORS 240V AC

3 rev. per min. **£1.50.** P.P. 25p.
4 rev. per min. **£1.50.** P.P. 25p.
6 rev. per min. **£1.50.** P.P. 25p.
2 rev. per hour. **£1.50.** P.P. 25p.
6 rev. per hour. **£1.50.** P.P. 25p.

HIGH-SPEED MAGNETIC COUNTERS



4 digit (non reset) 24v or 48v (state which)
4 x 1 x 1 in. **£1.** P.P. 20p.
5 digit (non reset) 24v **1.50.** P.P. 20p.
3 digit 12v (Rotary Reset) 2¼ x 1¾ x 1¼ **£1.40.** P.P. 15p.
6 digit (Reset) 220v. a.c. **£3.50.** P.P. 25p.

S-DECS AND T-DECS

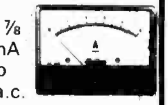
S-DEC **£1.90** T-DEC **£3.60**
U-DEC A **£4.20** U-DEC B **£6.90**
Post & Packing 25p.

MINIATURE METERS

500 micro-amp (level stereo beacon, etc) scaled half back/half red. Size 1 x 1 in. **65p.** P.P. 15p.

PANEL METERS

2⅜ in. x 1⅞



T1	50µA	T8	500mA
T2	100µA	T9	1Amp
T3	500µA	T10	50v.a.c.
T4	1mA	T11	300v.a.c.
T5	10mA	T12	50/0/50µA
T6	50mA	T13	100/0/100µA
T7	100mA	T14	500/0/500µA

All at **£3.75.** P.P. 15p.

PANEL METERS

4½ ins. x 3¼
D1 50µA
D2 100µA
D3 200µA
D4 500µA
All at **£4.60.** P.P. 15p.

S.T.C. CRYSTAL FILTERS

(10.7Mhz) 445-LQU-901A (50 Khz spacing), **£3.** P.P. 20p.
445-LQU-901B (25Khz spacing). **£4.** P.P. 20p. 10.7Mhz Canned I.Fs. Size 1 x ½ x ½ in. (with data) **65p.** P.P. 10p.

3 GANG TUNING CAPACITOR

8.5 PF, to 320 P.F. **80p.** P.P. 20p.

V.H.F./U.H.F. POWER TRANSISTORS

(type BLY 38). 3 watt output at 100-500 Mhz. **£2.25.** P.P. 10p.

SIEMENS MINIATURE RELAYS

6v.4 c/o **65p.** 24v.2 c/o **50p.**

MINIATURE RELAYS

(1⅜ x 1¼ x ½) 24 v.4 c/o **35p.** P.P. 5p.

MAINS RELAY 240v.a.c.

3 c/o 10 amp. contacts **80p.** with base P.P. 20p

24v a.c. RELAY (PLUG IN)

3 pole c/o **75p.** P.P. 15p.
2-pole c/o **55p.** P.P. 15p.

S.C.R.

1 amp. 400 P.I.V. **35p.**
5 amp. 400 P.I.V. **40p**

MINIATURE "ELAPSED TIME" INDICATORS

(0.5000 hours) 45 x 8mm **75p.** P.P. 15p.

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Resistors/capacitors 600 new components **£2.75.** P.P. 36p.
Trial order 100 pcs **75p.** P.P. 20p.

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Input 240v. a.c. giving 17½v d.c. at 1½ amp (unsmoothed) 2¾ x 2½ x 2¼ in. **£2.25.** P.P. 45p.

ADVANCE TRANSFORMERS "VOLSTAT"

Input 240v. a.c. C.V.50. 38v. at 1 amp; 25v. at 100/m/a; 75v. at 200 m/a **£3.** P.P. 65p.
C.V. 75.25v. at 2½ amp. **£3.25.** P.P. 75p.
C.V. 100.50v. at 2 amp; 50v. at 100 m/a **£4.** P.P. 75p.
C.V. 250.25v. at 8 amp; 75v. at ½ amp. **£6.50.** P.P. £1.50.
C.V. 500.45v. at 3 amp; 35v at 2 amp. **£12.** P.P. £1.75.

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6AN8	0.82
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6AW8A	0.90
6AX4	0.88

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6BA6	0.41
6BC8	0.90
6BE6	0.41
6BG6G	1.23
6BH6	0.75
6BJ6	0.64
6BK7A	0.85
6BQ5	0.36
6BQ7A	0.64
6BR7	1.20
6BR8	1.25
6BS7	1.64
6BW6	1.00
6BW7	0.65
6BX6	0.30
6BY7	0.40
6BZ6	0.57
6C4	0.47
6C5G	0.59
6C6	0.47
6C9	2.00
6C10	0.80
6CB6A	0.47
6C12	0.40
6C17	2.34
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6F12	0.50
6F13	0.90
6F14	0.88
6F15	0.76
6F18	0.64
6F23	0.80
6F24	1.00
6F25	1.17
6F26	0.40
6F28	0.78
6F32	0.70
6G6G	0.60
6GH8A	0.88
6GK5	0.76
6GU7	0.88
6H6GT	0.29
6J5GT	0.53
6J6	0.35
6J7G	0.35
6J7(M)	0.65
6JU8A	0.88
6K7G	0.35
6K8G	0.53
6L1	2.34

6L6GC	0.68
6L7(M)	0.59
6L12	0.47
6L18	0.64
6L19	2.00
6LD12	0.45
6LD20	0.88
6N7GT	0.70
6PL12	0.45
6P15	0.36
6Q7G	0.50
6Q7GT	0.60
6Q7(M)	0.64
6R7G	0.70
6R7(M)	0.88
6SA7	0.55
6SC7GT	0.50
6SG7	0.52
6SH7	0.55
6SJ7	0.64
6SK7GT	0.52
6SQ7	0.50
6U4GT	0.82
6U7G	0.55
6V6G	0.30
6V6GT	0.53
6X4	0.47
6X5GT	0.50
6Y6G	0.94
6Y7G	1.17
7A7	1.00
7B6	0.88
7B7	0.82
7D6	2.00
7F8	1.76
7H7	0.88
7R7	2.00
7V7	1.76
7Y4	0.80
7Z4	0.80
8D8	0.50
9BW6	0.88
9D7	0.70
10C2	0.76
10D1	0.82
10DE7	0.88
10F1	0.88
10F3	1.17
10F9	0.76
10F18	0.60
10L14	0.53
10LD11	0.82
10PL12	0.45
10P13	0.88
10P14	2.34
10P18	0.49
12A6	0.75
12AC6	0.90
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12AE6	0.90
12AT6	0.47
12AT7	0.40
12AU6	0.53
12AU7	0.39

12AV6	0.59
12AX7	0.39
12AY7	0.94
12BA6	0.53
12BE6	0.50
12BH7	0.59
12BY7	0.85
12E1	3.51
12J5GT	0.39
12J7GT	0.70
12K5	1.17
12K7GT	0.50
12K8	0.85
12Q7GT	0.50
12SA7GT	0.70
12SC7	0.50
12SG7	0.55
12SH7	0.50
12SJ7	0.60
12SK7	0.64
12SN7GT	0.75
12SQ7	0.76
12SQ7GT	0.76
12SR7	0.75
14H7	0.64
14S7	1.10
18	1.17
19AQ5	0.65
19BG6G	1.17
19G6	7.00
19H1	4.00
20D1	0.80
20D4	2.34
20F2	0.88
20L1	1.29
20P1	1.00
20P3	0.94
20P4	1.17
20P5	1.50
25A6G	0.70
25L6G	0.70
25Y5	0.80
25Y5G	0.60
25Z4G	0.50
25Z5	0.75
25Z6G	0.80
28D7	2.00
30A5	0.76
30C1	0.47
30C15	0.80
30C17	0.85
30C18	0.85
30F5	0.75
30FL1	1.10
30FL2	1.10
30FL12	1.06
30FL13	0.64
30FL14	0.82
30L1	0.40
30L15	0.82
30L17	0.76

30P4MR	1.05
30P12	0.80
30P4	0.88
30P19	0.88
30P16	0.43
30P18	0.50
30PL1	1.00
30PL12	0.45
30PL13	1.20
30PL14	1.29
30PL15	0.90
35A3	0.76
35C5	0.85
35D5	0.90
35L6GT	0.88
35W4	0.60
35Z3	0.88
35Z4GT	0.82
35Z5GT	0.90
42	1.00
50B5	1.00
50C5	0.70
50CD6G	1.46
50EH5	0.88
50L6GT	1.00
72	0.70
77	0.70
85A2	0.75
85A3	0.75
90AG	2.93
90CG	2.81
90CV	2.81
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303	1.17
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AZ1	0.50
AZ31	0.60
AZ41	0.50
BL63	2.34
CL33	1.85
CV6	0.62
CV63	1.00
CV988	0.29
CY1C	1.00
CY31	0.70
D1	0.50
D63	0.30
DAC32	0.80
DAF91	0.40
DAF96	0.60
DC90	0.70
DD4	0.80
DF33	0.76
DF91	0.30
DF96	0.65
DH63	0.50
DH76	0.50
DH77	0.53
DH81	0.88
DK32	0.60
DK40	0.82
DK91	0.50
DK92	1.15
DK96	0.70
DL92	0.47
DL94	0.82
DL96	0.64
DM70	0.80
DM71	1.76
DW4/350	1.17
DY87/6	0.41
DY802	0.47
E80CC	2.57
E80F	2.20
E83F	1.60
E88CC	1.20
E92CC	0.70
E180CC	0.82
E180F	1.17
E182CC	3.00
E280F	5.00
E1148	0.62
EA50	0.40
EA76	1.40
EABC80	0.45
EAC91	0.65
EAF42	0.88
EAF801	0.80
EB34	0.35
EB91	0.23
EBC41	0.88
EBC81	0.45
EBC90	0.53
EBC91	0.53
EBF80	0.40
EBF83	0.50

EBF89	0.40
EBL21	2.34
EC52	1.00
EC53	1.00
EC54	1.00
EC86	0.90
EC88	0.90
EC92	0.55
ECC32	1.00
ECC33	2.00
ECC35	2.00
ECC40	1.20
ECC81	0.40
ECC82	0.39
ECC83	0.39
ECC84	0.40
ECC85	0.47
ECC86	1.00
ECC88	0.55
ECC189	0.80
ECC804	0.80
ECC807	1.41
ECF80	0.50
ECF82	0.50
ECF86	0.88
ECF804	2.63
ECH21	2.34
ECH35	1.60
ECH42	0.80
ECH81	0.40
ECH83	0.52
ECH84	0.50
ECL80	0.50
ECL82	0.45
ECL83	0.82
ECL84	0.70
ECL85	0.70
ECL86	0.47
EF22	1.00
EF40	0.88
EF41	0.82
EF42	0.90
EF73	1.76
EF80	0.30
EF83	1.45
EF85	0.40
EF86	0.50
EF89	0.35
EF91	0.50
EF92	0.60
EF93	0.41
EF94	0.40
EF97	0.94
EF98	0.95
EF183	0.40
EF184	0.40
EF804	1.75
EH90	0.44
EK90	0.41
EL32	0.60
EL34	1.00
EL35	3.00
EL37	3.00
EL41	0.60

EL81	0.70
EL83	0.70
EL84	0.36
EL86	0.60
EL90	0.53
EL95	0.70
EL360	1.80
EL506	1.20
EM80	0.53
EM81	0.76
EM83	0.64
EM84	0.47
EM85	1.20
EM87	1.10
EMM803	2.50
EY51	0.50
EY81	0.50
EY83	0.70
EY84	0.92
EY87/6	0.40
EY88	0.60
EY91	0.50
EZ35	0.50
EZ40	0.55
EZ41	0.55
EZ80	0.35
EZ81	0.35
EZ90	0.47
FC4	1.00
FW4/500	1.17
FW4/800	1.17
GY501	0.82
GZ30	0.55
GZ32	0.59
GZ33	1.46
GZ34	0.80
GZ37	1.20
HABC80	0.80
HL13C	0.60
HL23	0.70
HL23DD	0.80
HL41	1.00
HL41DD	1.00
HL42DD	1.00
HN309	1.76
HVR2	1.00
HVR2A	1.17
KT2	0.88
KT8	2.93
KT41	1.17
KT44	1.17
KT63	0.60
KT66	2.93
KT88	5.75
KT81	2.10
KTW61	1.76
KTW62	1.76
KTW63	1.17
M8162	1.00
ME1400	2.50
MHL4	1.00
MHLD6	1.00
MKT4	1.17
MU12/14	1.17
N308	1.05
N339	1.29
N379	0.50
P61	0.60
PABC80	0.45
PC86	0.70

PC88	0.70
PC95	0.70
PC97	0.42
PC900	0.30
PCC84	0.40
PCC85	0.50
PCC88	0.65
PCC89	0.50
PCC189	0.60
PCC805	0.82
PCC806	0.76
PCF80	0.47
PCF82	0.50
PCF84	0.70
PCF86	0.50
PCF87	0.90
PCF200	1.00
PCF201	1.05
PCF800	0.82
PCF801	0.65
PCF802	0.50
PCF805	0.85
PCF806	0.60
PCF808	0.82
PCH200	1.00
PCL82	0.45
PCL83	0.50
PCL84	0.50
PCL86	0.55
PCL88	1.29
PCL800	1.11
PCL805/ PCL85	0.70
PEN4DD	2.00
PEN25	1.00
PEN45	1.00
PEN45DD	1.00
PEN46	0.60
PEN453DD	2.00
PENA4	1.17
PENDD/ 4020	1.00
PFL200	0.82
PL33	0.50
PL36	0.70
PL38	1.76
PL81	0.53
PL81A	0.60
PL82	0.43
PL83	0.50
PL84	0.50
PL302	0.88
PL504/500	0.82
PL505	1.65
PL508	1.10
PL509	1.65
PL801	0.80
PM84	0.76
PY31	0.52
PY33/2	0.50
PY80	0.47
PY81	0.40
PY82	0.40

PY83	0.45
PY88	0.47
PY301	0.59
PY500	1.11
PY500A	1.11
PY800	0.45
PY801	0.45
PZ30	0.50
QP21	1.10
QQV03/10	2.10
QS75/20	1.00
QS95/10	1.00
QS150/15	1.80
QV03/12	1.76
QV04/7	1.17
QV06/20	3.50
R11	0.80
R16	2.05
R17	1.00
R18	0.92
R19	0.75
R20	0.65
R52	0.55
RK34	1.00
SP13C	0.74
TH4B	1.00
TH233	1.00
TP2620	1.00
TP22	1.00
TP25	1.00
UABC80	0.47
UAF42	0.75
UBC41	0.60
UBC81	0.60
UBF80	0.47
UBF89	0.47
UBL21	2.34
UC92	0.60
UCC84	0.90
UCC85	0.53
UCF80	0.90
UCH21	2.34
UCH42	0.88
UCH81	0.47
UCL82	0.45
UCL83	0.64
UF41	0.82
UF42	0.82
UF80	0.41
UF85	0.52
UF89	0.47
UL41	0.75
UL84	0.49
UM80	0.60
UR1C	1.00
UU5	1.17
UU9	0.55
UU12	0.35
UY41	0.50
UY42	0.60
UY85	0.50
U10	1.17
U12/14	1.17
U16	1.17

U17	0.80
U18/20	1.17
U19	4.00
U22	0.85
U25	0.70
U26	0.65
U31	0.50
U33	1.75
U35	1.75
U37	2.05
U45	1.17
U47	0.70
U49	0.65
U50	0.55
U76	0.82
U78	0.47
U81	0.80
U153	0.40
U191	0.50
U192	0.40
U193	0.45
U251	0.94
U281	0.75
U282	0.70
U291	0.50
U301	0.65
U329	0.94
U339	0.50
U381	0.50
U403	0.90
U404	0.75
U801	0.80
U4020	0.75
VP13C	0.60
VP23	0.65
VP41	0.88
VR105	0.59
VT61A	0.76
VU111	0.80
VU120	1.17
VU120A	1.17
VU133	0.80
W76	0.50
W81M	1.17
W107	0.75
W729	1.17
XE3	5.85
XFY12	0.56
XH15	0.56
X41	1.00
X61	1.46
X65	1.46
X66	1.46
X76M	0.85
XSG15	1.17
Z145	0.88
Z152	0.30
Z329	0.75
Z719	0.30
Z729	0.50
Z749	0.80
Z759	5.85
Transistors and Diodes	
1N1124A	0.68
1N4744A	0.18

1N4952	0.64
2N404	0.23
2N966	0.68
2N1756	0.64
2N2147	1.10
2N2297	0.29
2N2369A	0.18
2N2613	0.50
2N3053	0.42
2N3121	3.22
2N3703	0.25
2N3709	0.26
2N3866	1.29
2N3988	0.64
2S323	0.64
AA119	0.20
AA120	0.20
AA129	0.20
AAZ13	0.23
AC107	0.20
AC113	0.33
AC114	0.52
AC126	0.16
AC127	0.22
AC128	0.26
AC132	0.26
AC154	0.33
AC156	0.26
AC157	0.33
AC165	0.33
AC166	0.33
AC167	0.77
AC168	0.49
AC169	0.42
AC176	0.71
AC177	0.36
ACY17	0.33
ACY18	0.26
ACY19	0.25
ACY20	0.23
ACY21	0.25
ACY22	0.20
ACY28	0.23
AD140	0.47
AD149	0.64
AD161	0.59
AD162	0.59
AF102	1.16
AF106	0.64
AF114	0.33
AF115	0.20
AF117	0.25
AF121	0.39
AF124	0.33
AF125	0.22
AF126	0.23
AF139	0.84
AF178	0.88

AF180	0.62
AF186	0.71
AF239	0.49
ASY27	0.55
ASY28	0.42
ASY29	0.64
BA102	0.59
BA115	0.18
BA116	0.23
BA129	0.16
BA130	0.13
BA153	0.20
BCY10	0.59
BCY12	0.64
BCY33	0.26
BCY34	0.29
BCY38	0.29
BC107	0.16
BC108	0.16
BC109	0.16
BC113	0.33
BC115	0.20
BC116	0.33
BC118	0.29
BF154	0.33
BF158	0.23
BF159	0.33
BF163	0.26
BF173	0.49
BF180	0.39
BF181	0.52
BF185	0.52
BFY50	0.29
BFY51	0.25
BFY52	0.26
BTX34/400	2.57
BY100	0.23
BY101	0.20
BY105	0.23
BY114	0.23
BY126	0.20
BY127	0.23
BYY23	1.29
BYZ10	0.33
BYZ11	0.33
BYZ12	0.33
BYZ13	0.33
BYZ15	2.26
CG12E	0.26
CG64H	0.26
FSY11A	0.29
FSY41A	0.29
GD4	0.42
GD5	0.36
GD6	0.36
GD8	0.26
GD9	0.26

GD11	0.26
GD12	0.26
GD14	0.64
GD15	0.52
GD16	0.26
GET113	0.26
GET118	0.26
GET119	0.33
GET573	0.49
GET587	0.55
GET872	1.23
GET873	0.20
GET882	0.64
GET887	0.29
GET889	0.29
GET890	0.29
GET896	0.29
GET897	0.29
GET898	0.29
GEX13	0.23
GEX35	0.29
GEX36	0.64
GEX45	0.42
GEX55	0.97
GT3	0.33
M1	0.20
MAT100	0.50
MAT101	0.55
MAT120	0.50
OA9	0.16
OA10	0.55
OA47	0.13
OA70	0.20
OA73	0.20
OA79	0.12
OA81	0.12
OA85	0.12
OA86	0.26
OA90	0.16
OA91	0.12
OA95	0.12
OA200	0.12
OA202	0.13
OA210	0.62
OA211	0.88
OC19	1.62
OC22	0.49
OC23	0.49
OC24	0.49
OC25	0.49
OC28	0.77
OC29	0.81
OC36	0.55
OC38	0.55
OC41	0.64
OC42	0.81
OC43	1.52
OC44	0.13

OC45	0.14
OC46	0.20
OC65	1.45
OC70	0.16
OC71	0.14
OC72	0.14
OC74	0.29
OC75	0.14
OC76	0.20
OC77	0.35
OC78	0.20
OC78D	0.20
OC79	0.52
OC81	0.14
OC81D	0.14
OC82	0.14
OC82D	0.14
OC83	0.26
OC84	0.31
OC123	0.29
OC140	1.23
OC169	0.29
OC172	0.46
OC200	0.50
OC201	0.50
OC202	0.55
OC203	0.39
OC204	0.39
OC205	0.55
OC206	1.17
OC812	0.52
ORP12	0.68
SFT237	0.50
SM1036	0.64
ST1276	0.64
SX1/6	0.23
U14706	0.33
XZ30	0.33
Y543	0.23
Y728	0.23

ALL PRICES INCLUDE V.A.T. NOTHING EXTRA TO PAY

MATCHED TRANSISTOR SETS
LP15 (AC113, AC154, AC157, AA120), 68p per pack.
1/OC81D and 2/OC81, 55p.
1/OC44 and 2/OC45, 55p.
1/OC82D and 2/OC82, 62p. Set of 3/OC83, 84p.
1 watt Zenners. 2.4v., 2.7v., 3v., 3.6v., 4.3v., 4.7v., 5.1v., 13v., 15v., 16v., 18v., 20v., 24v., 30v., 23p each.

All goods are unused and subject to the manufacturers' guarantee. Business hours Mon.-Fri. 9-5.30 p.m. Closed 1-2 p.m.
Terms of business. Cash or cheque with order. Despatch charges: — Orders below £10 in value, add 25p for post and packing. Orders over £10 post and packing free of charge. All orders cleared same day. Any parcel insured against damage in transit for 5p extra per parcel. Conditions of sale available on request. Many others in stock too numerous to list. Please enclose S.A.E. for reply to any enquiries.

orchard electronics

TRANSISTORS

	p		p		p		p		p		p		p
				BC132	11	BC178B	18	BC261A	16	BC559	9	BF166	38
AC125	20	ASY26	30	BC135	12	BC179B	19	BC262A	15	BCY70	16	BF167	21
AC126	20	ASY27	34	BC136	16	BC182B	10	BC266A	18	BCY71	18	BF173	20
AC127	20	ASY28	30	BC137	16	BC182L	11	BC267A	14	BCY72	14	BF178	24
AC128	20	ASY29	30	BC138	15	BC183B	10	BC268B	13	BD115	60	BF179	25
AC132	35	ASY67	70	BC139	35	BC183L	10	BC269	13	BD121	90	BF180	30
AC141	20	BA145	15	BC142	22	BC184B	12	BC287	20	BD123	90	BF181	30
AC142	17	BA154	10	BC143	24	BC184L	11	BC300	27	BD124	68	BF183	34
AC151	24	BA155	12	BC147A	9	BC186	25	BC301	26	BD131	36	BF184	25
AC153	27	BAX12	10	BC147B	10	BC187	26	BC302	24	BD132	38	BF185	28
AC176	20	BAX13	4	BC148	9	BC204A	16	BC303	30	BD133	65	BF194	10
AC188	20	BAX16	6	BC148B	10	BC205A	15	BC304	27	BD135	37	BF195	10
AD161	42	BC107	11	BC149B	11	BC206A	15	BC307A	16	BD136	39	BF196	12
AD162	42	BC107A	12	BC149C	11	BC207A	11	BC308A	14	BD137	44	BF197	12
AF114	24	BC108	10	BC153	18	BC208A	11	BC309B	16	BD138	47	BF200	38
AF115	24	BC108B	11	BC154	18	BC209B	13	BC317A	12	BD139	54	[illegible]	30
AF116	24	BC109	11	BC157B	12	BC212A	13	BC319B	12	BD155	75	BF258	50
AF117	24	BC109B	12	BC158A	12	BC212L	15	BC322B	15	BD165	34	BF259	32
AF118	47	BC109C	13	BC159A	12	BC213B	12	BC327	20	BD232	70	[illegible]	28
AF124	30	BC115	15	BC167A	11	BC213L	14	BC328	18	BDY20	80	[illegible]	30
AF125	30	BC116	15	BC168B	11	BC214	15	BC337	18	BF115	22	[illegible]	30
AF126	28	BC117	28	BC171A	14	BC214L	17	BC338	16	BF154	20	BF336	34
AF139	34	BC118	30	BC172A	15	BC237A	16	BC461	36	BF158	20	BFW10	68
AF186	50	BC119	28	BC173B	16	BC238A	15	BC557	9	BF159	26	BFW11	68
AF239	37	BC125	14	BC177	17	BC2395	15	BC558	9	BF160	20	BFX13	55

SILICON RECTIFIERS
50V 3A 13p
100V 3A 15p
200V 3A 18p

THYRISTORS
100V 1A 30p
200V 1A 40p
600V 1A 60p
BT106 120p

RESISTORS
1p each
⅓ watt E12 range
1Ω–10mΩ

DIODES
IN4002 6p
IN4006 10p
IN4148 5p

INTEGRATED CIRCUITS
TTL DIGITAL
7400 18p
7401 20p
7402 18p
7403 18p
7404 23p

BRIDGE RECTIFIERS
100V 1A 24p
WO 01
200V 1A 25p
WO 02
400V 1A 26p
WO D4

DIL SOCKETS
8 pin 13p
14 pin 15p
16 pin 17p

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709 (8 pin Dil) 40p
741 (8 pin Dil) 43p
NE555 60p

ZENERS (400mw)
BZX83/BZY88
3V3 3V6 3V9
4V3 4V7 5V1
5V6 6V2 6V5
7V5 8V2 9V1
10V 12V 13V
15V 18V 30v
All at 12p' each

VOLTAGE REGULATORS
(TO3)
5V 1A 175p
12V 1A 175p
15V 1A 175p

LED
125R Red 20p
125A Amber 27p
125Y Yellow 27p
TIL209 Red 25p

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TEL. 54525

ADD 8% VAT TO PRICES MARKED ADD 25% VAT TO ALL OTHER PRICES OR AS CURRENT VAT LEGISLATION. SEND C W O (EXCEPT GOV T DEPT) POST & PACKING 20P. BARCLAYCARD & ACCESS BY POST OR 15 MIN ON TELEPHONE ORDERS. CATALOGUE LIST FREE. MONEY BACK IF NOT SATISFIED

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BC109 8p
BFY51 14p
FET3819 14P
741 8pin 20P
NE555 42p
7400N 9P

RED LEDS 11p

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74 series TTL IC's

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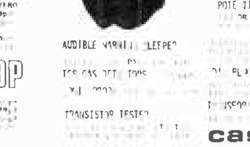

DALO pen 69P

POTENTIOMETERS

AUDIBLE WARNING BLEEPER

cassettes

Dil sockets

BARGAIN PAKS £1ea. Full spec

TELEPHONE 54525

WW — 060 FOR FURTHER DETAILS

BI-PAK SEMICONDUCTORS

COMPONENTS

CARBON RESISTOR PAKS
These Paks contain a range of Carbon Resistors, assorted into the following groups:—

R.1	50 Mixed 100 ohms — 820 ohms ⅛th W	0.60
R2.	50 Mixed 1K ohms — 8.2K ohms ⅛th W	0.60
R3.	50 Mixed 10K ohms — 82K ohms ⅛th W	0.60
R4.	50 Mixed 100K ohms — 820K ohms ⅛th W	0.60
R5.	30 Mixed 100 ohms — 820 ohms ½ W	0.60
R6.	30 Mixed 1K ohms — 8.2K ohms ½ W	0.60
R7.	30 Mixed 10K ohms — 82K ohms ½ W	0.60
R8.	30 Mixed 100K ohms — 820K ohms ½ W	0.60

These are unbeatable prices.

LOW COST CAPACITORS
500 μF 50V Elect 0.09 each
01 μF 400V 0.03 each

REPANCO CHOKES & COILS

RF Chokes	CH1	2.5mH	0.27
	CH3	7.5mH	0.29
	CH5	1.5mH	0.26
	CH2	5.0mH	0.28
	CH4	10mH	0.31
COILS	DRX1 Crystal set		0.29
	DRR2 Dual range		0.42

CARBON POTENTIOMETERS
Log and Lin 4.7K, 10K, 22K, 47K, 100K, 220K, 470K, 1M, 2M.

VC 1	Single Less Switch	0.20
VC 2	Single D.P. Switch	0.40
VC 3	Tandem Less Switch	0.60
VC 4	1K Lin Less Switch	0.20
VC 5	100K Log anti-Log	0.60

HORIZONTAL CARBON PRESETS
0.1 Watt 0.09 each
100, 220, 470, 1K, 2.2K, 4.7K, 10K, 22K, 47K, 100K, 220K, 470K, 1M, 2M, 4.7M.

REPANCO TRANSFORMERS *
240V. Primary. Secondary voltages available from selected tappings 4V, 7V, 8V, 10V, 40V, 50V and 25V-0-25V.

Type	Amps	Price	P&P
MT50/½	½	£1.79	0.45
MT50/1	1	£2.24	0.48
MT50/2	2	£3.06	0.60

COIL FORMERS & CORES
NORMAN ¼" Cores & Formers 0.07p
⅜" Cores & Formers 0.09p

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DP/DT Toggle 0.28p
SP/ST Toggle 0.22p

FUSES
20mm, 100mA, 200mA, 250mA, 500mA, 1A, 1.5A, 2A QUICK BLOW *0.05p each
Anti-surge 20mm only *0.8p each

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VB 1
containing approx. 50sq. ins. various sizes all 0.1 matrix *0.60p
VB 2
containing approx. 50 sq. ins. various sizes all 0.15 matrix *0.60p

DECON-DALO 33PC Marker*
Etch resistant printed circuit marker pen. Full instructions supplied with each pen *0.92p

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Takes 6 H.P. 7's complete with terminal clip and lead *0.31p each

V.A.T.

ALL PRICES EXCLUDE V.A.T.

Please add 8% to all prices marked *. Remainder add 25%. Do NOT add V.A.T. to prices marked †.

INSTRUMENT CASES *

(In 2 sections, Black Vinyl covered top and sides and bezel)

No.	Length	Width	Height	Price
BV1	8"	x 5¼"	x 2"	*£1.25
BV2	11"	x 6"	x 3"	*£1.62
BV3	6"	x 4¾"	x 1½"	*£0.92
BV4	9"	x 5¼"	x 2½"	*£1.39

ALUMINIUM BOXES

No.	Length	Width	Height	Price
BA1	5¼"	x 2¼"	x 1½"	*0.45
BA2	4"	x 4"	x 1½"	*0.45
BA3	4"	x 2¼"	x 1½"	*0.45
BA4	5¼"	x 4"	x 1½"	*0.54
BA5	4"	x 2½"	x 2"	*0.45
BA6	3"	x 2"	x 1"	*0.39
BA7	7"	x 5"	x 2½"	*0.79
BA8	8"	x 6"	x 3"	*£1.02
BA9	6"	x 4"	x 2"	*0.65

(Each complete with ½" deep lids & screws)
PLEASE ADD 20p POSTAGE AND PACKING FOR EACH BOX

COMPONENT PAKS

Pak No.	Qty	Description	Price
C1	200	Resistors mixed values approx. count by weight	.60
C2	150	Capacitors mixed values approx. count by weight	.60
C3	50	Precision Resistors mixed values	.60
C4	75	⅛th W Resistors mixed preferred values	.60
C5	5	Pieces assorted Ferrite Rods	.60
C6	2	Tuning Gangs. MW/LW VHF	.60
C7	1	Pak Wire 50 metres assorted colours	*.60
C8	10	Reed Switches	*.60
C9	3	Micro Switches	*.60
C10	15	Assorted Pots & Pre-Sets	.60
C11	5	Jack Sockets 3 x 3.5m. 2 x standard Switch Type	.60
C12	30	Paper Condensers preferred types mixed values	.60
C13	20	Electrolytics Trans. types	.60
C14	1	Pack assorted Hardware-Nuts/Bolts,Grommets, etc.	*.60
C15	5	Mains Slide Switches, 2 Amp	.60
C16	20	Assorted Tag Strips Panels	.60
C17	10	Assorted Control Knobs	.60
C18	4	Rotary Wave Change Switches	.60
C19	2	Relays 6-24V Operating	*.60
C20		Sheets Copper Laminate. approx. 200 sq. ins.	*.60

Please add 20p post and packing on all component packs, plus a further 10p on pack nos. C1, C2, C19 & C20.

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SOLVE THOSE STICKY PROBLEMS! *with*

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The wonder bond which works in seconds. Bonds plastic, rubber, transistors, components, permanently, immediately!

OUR PRICE ONLY 70p *
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CP 1	Single lapped screen	*0.08
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CP 3	Stereo Screened	*0.12
CP 4	Four Core Common Screen	*0.21
CP 5	Four Core individually screened	*0.28
CP 6	Microphone Fully Braided Cable	*0.11
CP 7	Three Core Mains Cable	*0.11
CP 8	Twin Oval Mains Cable	*0.08
CP 9	Speaker Cable	*0.06
CP 10	Low Loss Co-Axial	*0.14

P&P
Postage and Packing add 25p unless otherwise shown. Add extra for airmail. Minimum order £1.00

ANTEX EQUIPMENT *

SOLDERING IRONS

x25. 25 watt	*£2.45
Model G. 18 watt	*£2.70
CCN 240. 15 watt	*£2.90
SK2.Soldering Kit	*£3.90

BITS AND ELEMENTS *

Bit No.			
102	for model CN240	3/32"	*42p
104	for model CN240	3/16"	*42p
1100	for model CCN240	3/32"	*42p
1101	for model CCN240	3/8"	*42p
1102	for model CCN240	¼"	*42p
1020	for model G240	3/32"	*42p
1021	for model G240	1/8"	*42p
1022	for model G240	3/16"	*42p
50	for model X25	3/32"	*44p
51	for model X25	1/8"	*44p
52	for model X25	3/16"	*44p

ELEMENTS *

Model ECN	£1.10*
Model EG 240	£1.35*
Model ECCN 240	£1.55*
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SOLDERING IRON STAND
ST3 Suitable for all models *£1.10
Antex heat shunt *10p

PLUGS		PRICE
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PS 2	D.I.N. 3 Pin	0.11
PS 3	D.I.N. 4 Pin	0.14
PS 4	D.I.N. 5 Pin 180°	0.15
PS 5	D.I.N. 5 Pin 240°	0.15
PS 6	D.I.N. 6 Pin	0.16
PS 7	D.I.N. 7 Pin	0.17
PS 8	Jack 2.5mm Screened	0.17
PS 9	Jack 3.5mm Plastic	0.11
PS 10	Jack 3.5mm Screened	0.17
PS 11	Jack ¼" Plastic	0.14
PS 12	Jack ¼" Screened	0.20
PS 13	Jack Stereo Screened	0.33
PS 14	Phono	0.09
PS 15	Car Aerial	0.14
PS 16	Co-Axial	0.14

INLINE SOCKETS

PS 21	D.I.N. 2 Pin (Speaker)	0.13
PS 22	D.I.N. 3 Pin	0.19
PS 23	D.I.N. 5 Pin 180°	0.19
PS 24	D.I.N. 5 Pin 240°	0.19
PS 25	Jack 2.5mm Plastic	0.15
PS 26	Jack 3.5mm Plastic	0.15
PS 27	Jack ¼" Plastic	0.28
PS 28	Jack ¼" Screened	0.32
PS 29	Jack Stereo Plastic	0.28
PS 30	Jack Stereo Screened	0.35
PS 31	Phono Screened	0.17
PS 32	Car Aerial	0.20
PS 33	Co-Axial	0.20

SOCKETS

PS 35	D.I.N. 2 Pin (Speaker)	0.07
PS 36	D.I.N. 3 Pin	0.09
PS 37	D.I.N. 5 Pin 180°	0.09
PS 38	D.I.N. 5 Pin 240°	0.10
PS 39	Jack 2.5mm Switched	0.11
PS 40	Jack 3.5mm Switched	0.11
PS 41	Jack ¼" Switched	0.19
PS 42	Jack Stereo Switched	0.28
PS 43	Phono Single	0.07
PS 44	Phono Double	0.09
PS 46	Co-Axial Surface	0.09
PS 47	Co-Axial Flush	0.19

P.C.B. KITS & PENS

PROFESSIONAL D.I.Y. PRINTED CIRCUIT KIT
Containing 6 sheets of 6" x 4" single sided laminate, a generous supply of etchant powder, etching dish, etchant measure, tweezers, etch resistant marking pen, high quality pump drill with spares, cutting knife with spare blades, 6" metal ruler, plus full easy to follow instructions. *£7.80 per kit
Spare container of etchant for above, complete with instructions *70p

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C90	*44p
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S270	2 pin DIN plug to 2 pin DIN socket length 10m	.80p
S271	5 pin DIN plug to 2 phone plugs connected to pins 3 & 5 length 1.5m	.70p
S275	5 pin DIN plug to 2 phono sockets connected to pins 3 & 5 length 23cm	.68p
S318	5 pin DIN socket to 2 phono plugs connected to pin 3 & 5 length 23cm	.68p
S404	Coiled stereo headphones extension cord extends to 7m	£1.40
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K4007 1/P Impedance 8 ohms.
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Crossover Frequency 3 KHz.
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24	⅛" Cassette Editing Kit	*£1.84
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33	Splicing Tape	*38p
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41	8 Track Cartridge Head Carrier	88p
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£19.95 Fitted with Phase Lock-loop Decoder

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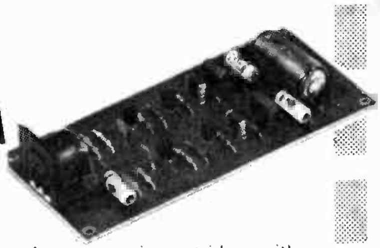
Used with your existing audio equipment or with the BI-KITS **STEREO 30** or the **MK60** Kit etc. Alternatively the **PS12** can be used if no suitable supply is available, together with the Transformer **T461**.
The S450 is supplied fully built, tested and aligned. The unit is easily installed using the simple instructions supplied.

- ★ FET Input Stage
- ★ VARI-CAP diode tuning
- ★ Switched AFC
- ★ Multi turn pre-sets
- ★ LED Stereo Indicator

Typical Specification:
Sensitivity 3μ volts
Stereo separation 30db
Supply required 20-30v at 90 Ma max.

MPA 30



Enjoy the quality of a magnetic cartridge with your existing ceramic equipment using the new M.P.A. 30, a high quality pre-amplifier enabling magnetic cartridges to be used where facilities exist for the use of ceramic cartridges only.
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A top quality stereo pre-amplifier and tone control unit. The six push-button selector switch provides a choice of inputs together with two really effective filters for high and low frequencies, plus tape output.

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P.U. Input equalises to R1AA curve with 1dB from 20Hz to 20KHz.
Supply — 20-35V at 20mA

Dimensions 299mm x 89mm x 35mm

MK. 60 AUDIO KIT: Comprising 2 x AL60's. 1 x SPM80. 1 x BTM80. 1 x PA100. 1 front panel and knobs. 1 Kit of parts to include on/off switch, neon indicator, stereo headphone sockets plus instruction booklet. **COMPLETE PRICE £27.55.** plus 62p postage

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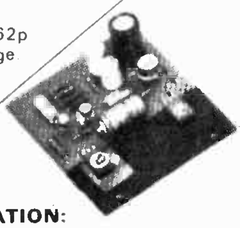
AL10-20-30 AUDIO AMPLIFIER MODULES



The AL10, AL20 and AL30 units are similar in their appearance and in their general specification. However, careful selection of the plastic power devices has resulted in a range of output powers from 3 to 10 watts R.M.S.
The versatility of their design makes them ideal for use in record players, tape recorders, stereo amplifiers and cassette and cartridge tape players in the home.

SPECIFICATION:
- **Harmonic Distortion Po=3 watts f=1KHz 02.5%**
- **Load Impedance 8-16ohm**
- **Size: 75mm x 63mm x 25mm**
- **Frequency response ±3dB Po=2 watts 50Hz-25Hz**
- **Sensitivity for Rated O/P — Vs=25v. RL=8ohm f=1KHz 75mV.RMS**

AL10 3w R.M.S. **£2.30** AL20 5w R.M.S. **£2.65** AL30 10w R.M.S. **£2.95**

STEREO 30

COMPLETE AUDIO CHASSIS
7+7 WATTS R.M.S.

P & P 45p
£15.75

The Stereo 30 comprises a complete stereo pre-amplifier, power amplifiers and power supply. This, with only the addition of a transformer or overwind will produce a high quality audio unit suitable for use with a wide range of inputs i.e. high quality ceramic pick-up, stereo tuner, stereo tape deck etc. Simple to install, capable of producing really first class results, this unit is supplied with full instructions, black front panel knobs, main switch, fuse and fuse holder and universal mounting brackets enabling it to be installed in a record plinth, cabinets of your own construction or the cabinet available. Ideal for the beginner or the advanced constructor who requires Hi-Fi performance with a minimum of installation difficulty (can be installed in 30 mins).

TRANSFORMER £2.45 plus 62p p &p
TEAK CASE £3.65 plus 62p p & p.

AL 60 25 Watts (RMS)

★ Max Heat Sink temp 90C. ★ Frequency response 20Hz to 100KHz ★ Distortion better than 0.1 at 1KHz ★ Supply voltage 15-50v ★ Thermal Feedback ★ Latest Design Improvements ★ Load — 3,4,8, or 16 ohms ★ Signal to noise ratio 80db ★ Overall size 63mm. 105mm. 13mm.

Especially designed to a strict specification. Only the finest components have been used and the latest solid-state circuitry incorporated in this powerful little amplifier which should satisfy the most critical A.F enthusiast.

£3.95

NEW PA12

NEW PA12 Stereo Pre-Amplifier completely redesigned for use with AL10/20/30 Amplifier Modules. Features include on/off volume, Balance, Bass and Treble controls. Complete with tape output.

Frequency Response 20Hz-20KHz (—3dB). Bass and Treble range 12dB. Input Impedence 1 meg ohm. Input Sensitivity 300mV. Supply requirements 24V .5mA. Size 152mm x 84mm x 33mm.

£6.50

PS12

Input voltage 15-20v A.C. Output voltage 22-30v D.C.
Output current 800 mA Max. Size 60mm x 43mm x 26mm.
Transformer T538 £2.30

OUR PRICE **£1.20**

Stabilised Power Supply Type SPM80

SPM80 is especially designed to power 2 of the AL60 Amplifiers, up to 15 watts (R.M.S.) per channel simultaneously. With the addition of the Mains Transformer **BMT80,** the unit will provide outputs of up to 1.5A at 35V. Size: 63mm. 105mm. 30mm.
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Transformer BMT80
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£3.00

BI-PAK

P.O. BOX 6, WARE, HERTS.

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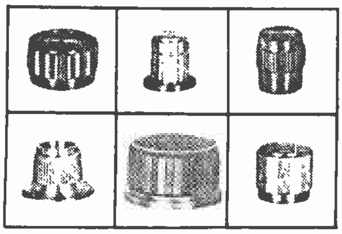

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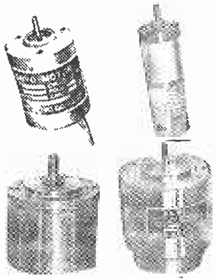

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TABAI

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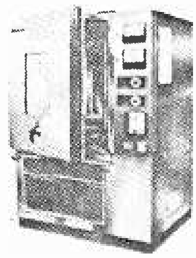

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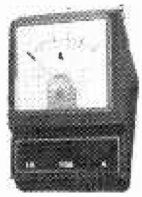
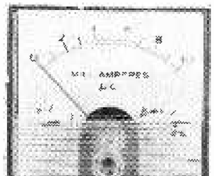
ALPS



LABORATORY TYPE SE65E



TYPE TAD

Dims in mm	48 x 42	66 x 50	85 x 70	118 x 106	150 x 110
50 µA	£3.73	£3.91	£4.10	£5.00	£5.55
500 µA	£3.44	£3.61	£3.82	£4.72	£5.42
1mA	£3.37	£3.54	£3.74	£4.63	£5.33
15vDC	£3.40	£3.59	£3.77	£4.67	£5.36
300vAC	£3.57	£3.76	£3.94	£4.83	£5.40

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TYPE SA

Dims in mm	43 x 43	51 x 51	61 x 61	82 x 78
50 µA	£3.62	£3.69	£3.97	£4.22
500 µA	£3 31	£3.38	£3.63	£3.86
1mA	£3.21	£3.28	£3.53	£3.82
15vDC	£3.25	£3.32	£3.60	£3.86
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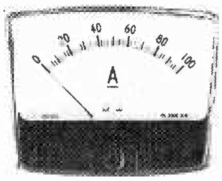

TYPE SR

Dims in mm	73 x 56	78 x 63	92 x 72
50 µA	£4.03	£4.28	£4.52
500 µA	£3.68	£3.93	£4.18
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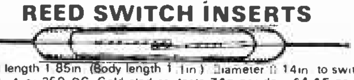

Overall length 1 85in (Body length 1 1in) Diameter 0 14in to switch up to 500mA or 250vDC Gold clad contacts **74p** per doz **£4.15** per 100 **£29.65** per 1,000 All carriage paid U.K

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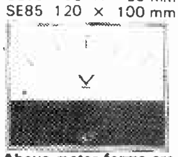

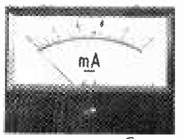

SU45 69 × 53 mm
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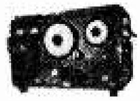

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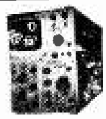
RACAL/AIRMEC 201A. 30kHz-30mHz. As new. P.O.A.
ADVANCE SG21 VHF Square-wave generator 9kHz-100mHz. **£25.**

OSCILLOSCOPES



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TEKTRONIX 545A with CA unit. DC-30mHZ. Price only **£295.00**
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2100 Series:
8 models covering impedances of 50Ω 75Ω, 600Ω unbalanced and 600Ω balanced. 0-100dB in 1 dB steps. Frequency range D.C. to 250MHz.
NEW 2100 style Attenuators, 50Ω with 0.1dB steps to 10dB which may be combined with standard 1dB units on a common panel.

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Small, compact Attenuators with designed-in reliability. Fitted with SMA connectors 'L' band units, 50Ω, D.C. to 2GHz, 'S' band units 50Ω, D.C. to 4GHz. 1 watt power rating. 'L' Band Attenuators with 1 dB and 10dB steps can be supplied together in a case for laboratory use.

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Ladder network Attenuators suitable for controlling output signal levels where high accuracy is not essential. Separate units provide 1.0 and 10dB steps and the two units can be supplied mechanically linked as a tandem pair. Frequency range to 150 MHz.

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High discrimination 600Ω balanced Attenuator with 0.1 dB increments to a total of 121dB. Frequency range DC to 1MHz. NEW 140Ω balanced Attenuator to similar design, 0.1dB dB increments to 91dB.

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Rack mounting programmable Attenuators providing 0.1dB, 1.0dB and 10dB steps for use primarily in automatic/computer-controlled test systems. Programming modes:
(1) 4-line compatible BCD,
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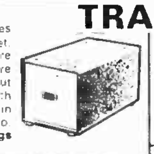
TRANSFORMERS

CASED TRANSFORMERS



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SAFETY ISOLATING

See catalogue for full range

Prim 120/240V Sec 120/240V Centre Tap with screen

VA (WATTS)	REF No	PRICE Cased £	PRICE Plugs 2 Pin + 1 Earth £	PRICE Open £	Post £
60	149	9 03	0 98	4 70	0 72
200	151	12 29	0 98	8 61	0.97
250	152	13.81	0 98	10 31	1 18

AUTO TRANSFORMERS

See catalogue for full range

VA (Watts)	Ref No	PRICE Cased	PRICE Plugs 2 & 3 pin £	PRICE Open £	Post £
1500	93	23.26	0.95	19.22	OA

MINIATURE & EQUIPMENT

Primary 240V with Screen

See catalogue for full range

VOLTS Sec. 1	VOLTS Sec. 2	MILLIAMPS Sec. 1	MILLIAMPS Sec. 2	REF No.	PRICE £	Post £
3-0-3	—	200	—	238	1.56	0.34
0-6	0-6	500	500	234	1.56	0.34
0-6	0-6	1000	1000	212	2.12	0.46
9-0-9	—	100	—	13	1.60	0.34
0-9	0-9	330	330	235	1.62	0.34

12 and 24 VOLTS PRIMARY 200-240 Volts

See catalogue for full range

AMPS 12V	AMPS 24V	REF No.	PRICE £	Post £
0.3	0.15	242	1.66	0.34
0.5	0.25	111	1.60	0.46
1	0.5	213	1.90	0.61
2	1	71	2.47	0.61
4	2	18	3.07	0.62
6	3	70	4.50	0.72
8	4	108	5.11	0.85

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2" SIZE: 60mm Wide × 45mm High × 40mm Deep.
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VU Meters are complete with detectors. Modern wide view. Price 2" £3.20 Post 10p. Price 4" £4.00. Post 10p. Lamps 40p per set. Plus 8% VAT

30 VOLTS

PRIMARY 200/240V
SECONDARY 12, 15, 20, 24, 30V

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AMPS	Ref. No.	Price £	Post £
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50 VOLTS

PRIMARY 200/240V
SECONDARY 19, 25, 33, 40, 50V

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AMPS	Ref. No.	PRICE	Post £
1	103	3.58	0.76
2	104	5.30	0.85

60 VOLTS

PRIMARY 200/240V
SECONDARY 24, 30, 40, 48, 60V

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AMPS	Ref. No.	Price £	Post £
0.5	124	2.51	0.72
1	126	3.75	0.72
2	127	5.36	0.85

BRIDGE RECTIFIERS

ONE AMP	Price	FOUR AMP	Price
50 P.I.V.	0.25	100 P.I.V.	0.55
100 P.I.V.	0.25	200 P.I.V.	0.59
200 P.I.V.	0.28	400 P.I.V.	0.65
600 P.I.V.	0.30	600 P.I.V.	0.75
TWO AMP	**Price**	**SIX AMP**	**Price**
50 P.I.V.	0.35	50 P.I.V.	0.65
100 P.I.V.	0.40	100 P.I.V.	0.70
200 P.I.V.	0.45	200 P.I.V.	0.80
400 P.I.V.	0.50	400 P.I.V.	0.90

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2 KVA ISOLATORS
Fully impregnated & screened
2 primary windings 110V each
2 secondary windings 115V each
(2 matching transformers)
£29.50 plus carr. & VAT.

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NEW CATALOGUE 25p

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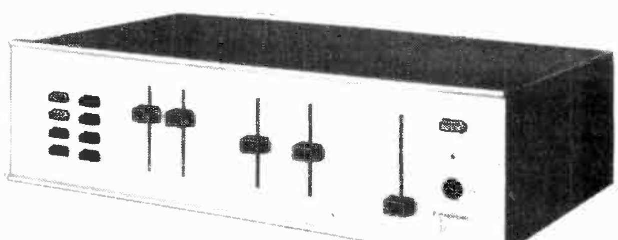
High Definition Stereo Amplifier



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Maximum power output: 90 watts av. per channel into 5 ohms.

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Distortion, power amplifier: Typically 0.006% at 25 watts, less than 0.02% at rated output (Typically 0.01% at 1 Khz)

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Line —85 dBV measured flat (ref 100v)
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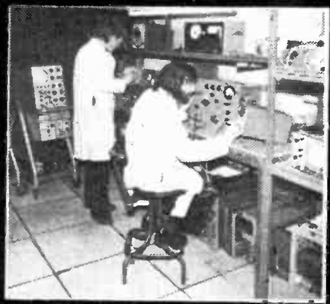

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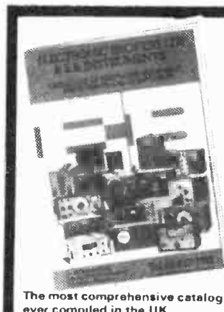

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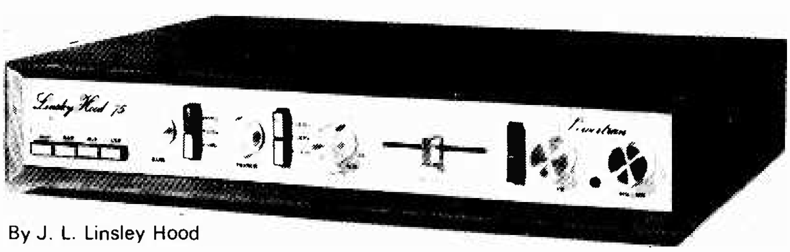
HI-FI NEWS 75W/CHANNEL AMPLIFIER



By J. L. Linsley Hood

In Hi-Fi News there was published by Mr. Linsley-Hood a series of four articles (November, 1972-February, 1973) and a subsequent follow-up article (April, 1974) on a design for an amplifier of exceptional performance which has as its principal feature an ability to supply from a direct coupled fully protected output stage, power in excess of 75 watts whilst maintaining distortion at less than 0.01% even at very low power levels. The power amplifier is complemented by a pre-amplifier based on a discrete component operational amplifier referred to as the Liniac which is employed in the two most critical points of the system, namely the equalization stage and tone control stage, positions where most conventional designs run out of gain at the extremes of the frequency spectrum. Unusual features of the design are the variable transition frequencies of the tone controls and the variable slope of the scratch filter. There is a choice of four inputs, two equalized and two linear, each having independently adjustable signal level. The attractive slimline unit pictured has been made practical by highly compact PCBs and a specially designed Toroidal transformer.

Pack		Price
1.	Fibreglass printed-circuit board for power amp	£0.85
2.	Set of resistors, capacitors, pre-sets for power amp	£1.70
3.	Set of semiconductors for power amp	£6.50
4.	Pair of 2 drilled, finned heat sinks	£0.80
5.	Fibreglass printed-circuit board for pre-amp	£1.30
6.	Set of low noise resistors, capacitors, pre-sets for pre-amp	£2.70
7.	Set of low noise, high gain semiconductors for pre-amp	£2.40
8.	Set of potentiometers (including mains switch)	£2.05
9.	Set of 4 push-button switches, rotary mode switch	£3.70
10.	Toroidal transformer complete with magnetic screen/housing primary: 0 117-234 V; secondaries: 33-0-33 V, 25-0-25 V	£9.15
11.	Fibreglass printed-circuit board for power supply	£0.65
12.	Set of resistors, capacitors, secondary fuses, semi-conductors for power supply	£3.50
13.	Set of miscellaneous parts including DIN skts, mains input skt, fuse holder, inter-connecting cable, control knobs	£4.25
14.	Set of metalwork parts including silk screen printed fascia panel and all brackets, fixing parts, etc.	£6.30
15.	Handbook	£0.30
16.	Teak cabinet 18.3" x 12.7" x 3.1"	£9.85

2 each of packs 1-7 inclusive are required for complete stereo system. Total cost of individually purchased packs £72.25

FREE TEAK CASE WITH FULL KITS

KIT PRICE ONLY **£62.40**

WIRELESS WORLD FM TUNER

Designed in response to demand for a tuner to complement the world-wide acclaimed Linsley Hood 75W Amplifier, this kit provides the perfect match. The Wireless World published original circuit has been developed further for inclusion into this outstanding slimline unit and features a pre-aligned front end module, excellent a.m. rejection and temperature compensated varicap tuning, which may be controlled either continuously or by push button pre-selection. Frequencies are indicated by a frequency meter and sliding LED indicators, attached to each channel selector pre-set. The PLL stereo decoder incorporates active filters for "birdy" suppression and power is supplied via a toroidal transformer and integrated regulator. For long term stability metal oxide resistors are used throughout.

Pack		Price
1.	Fibreglass printed board for front end IF strip, demodulator, AFC and mute circuits	£2.15
2.	Set of metal oxide resistors, thermistor, capacitors, cermet preset for mounting on pack 1	£4.80
3.	Set of transistors, diodes, LED, integrated circuits for mounting on pack 1	£6.25
4.	Pre-aligned front end module, coil assembly, three section ceramic filter	£8.80
5.	Fibreglass printed circuit board for stereo decoder	£1.10
6.	Set of metal oxide resistors, capacitors, cermet preset for decoder	£2.60
7.	Set of transistors LED, integrated circuit for decoder	£3.45
8.	Set of components for channel selector switch, module including fibreglass printed circuit board, push-button switches, knobs, LEDs, preset adjusters, etc.	£8.30
9.	Function switch, 10 turn tuning potentiometer, knobs	£5.30
10.	Frequency meter, meter drive components, fibreglass printed circuit board	£8.60
11.	Toroidal transformer with electrostatic screen. Primary: 0—117V—234V	£4.45
12.	Set of capacitors, rectifiers, voltage regulator for power supply	£2.95
13.	Set of miscellaneous parts, including sockets, fuse holder, fuses, inter-connecting wire, etc.	£1.50
14.	Set of metal work parts including silk screen printed facia panel, acrylic silk screen printed tuning indicator panel insert, internal screen, fixing parts, etc.	£6.50
15.	Construction notes (free with complete kit)	£0.25
16.	Teak cabinet 18.3" x 12.7" x 3.1"	£9.85

One each of packs 1-16 inclusive are required for complete stereo FM tuner. Total cost of individually purchased packs £76.85

FREE TEAK CASE WITH FULL KITS

KIT PRICE only **£66.75**

Wireless World Amplifier Design

Full kits are not available for these projects but component packs and PCBs are stocked for the highly regarded Bailey and 20W class AB Linsley Hood designs, together with an efficient regulated power supply of our own design. Suitable for driving these amplifiers is the Bailey Burrows pre-amplifier and our circuit board, for the stereo version of it features 6 inputs, scratch and rumble filters and wide range tone controls which may be either rotary of slider operating.
For those intending to get the best out of their speakers, we also offer an active filter system, described by D. C. Read, which splits the output of each channel from the pre-amplifier into three channels each of which is fed to the appropriate speaker by its own power amplifier. The Read/Texas 20W, or any of our other kits are suitable for these. For tape systems a set of three PCBs have been prepared for the integrated circuit based, high performance stereo Stuart design. Details of component packs are in our free list.

30W Bailey Amplifier	
BAIL Pk 1 F/Glass PCB	£1.00
BAIL Pk. 2 Resistors, Capacitors, Potentiometer set	£2.35
BAIL Pk 3 Semiconductor set	£4.70
20W Linsley Hood Class AB	
LHAB Pk 1 F/Glass PCB	£1.05
LHAB Pk 2 Resistor, Capacitor, Potentiometer set	£3.20
LHAB Pk 3 Semiconductor set	£3.35
Regulated Power Supply	
60VS Pk 1 F/Glass PCB	£0.85
60VS Pk 2 Resistor, Capacitor set	£1.95
60VS Pk 3 Semiconductor set	£3.10
60VS Pk 6A Toroidal transformer (for use with Bailey)	£7.95
60VS Pk 6B Toroidal transformer (for use with 20W LH)	£7.25
Bailey Burrows Stereo Pre-Amp	
BBPA Pk 1 F/Glass PCB	£2.35
BBPA Pk 2 Resistor, capacitor semiconductor set	£6.10
BBPA Pk 3R Rotary Potentiometer set	£2.40
BBPA Pk 3S Slider Potentiometer set with knobs	£2.70
Active Filter	
FILT Pk 1 F/Glass PCB	£1.05
FILT Pk 2 Resistor, Capacitor set (metal oxide 2%, polystyrene 2½%)	£4.20
FILT Pk 3 Semiconductor set	£2.65
2 off Pks 1, 2, 3 rqd for stereo active filter system	
Read/Texas 20W Amp	
READ Pk 1 F/Glass PCB	£0.70
READ Pk 2 Resistor, Capacitor set	£1.10
READ Pk 3 Semiconductor set	£2.40
6 off pks 1, 2, 3 required for stereo active filter system.	
Stuart Tape Recorder	
TRRP Pk 1 Replay Amp F/Glass PCB	£1.10
TRRC Pk 1 Record Amp F/Glass PCB	£1.70
TROS Pk 1 Bias/Erase/Stabilizer F/Glass PCB	£1.20

PRICE STABILITY!

Order with confidence! Irrespective of any price changes we will honour all prices in this advertisement for two months from issue date provided that this advertisement is quoted with your order. E&OE VAT rate changes excluded.
All components are brand new first grade full specification devices. All resistors (except where stated) are low noise carbon film types. All printed circuit boards are fibre-glass, drilled, roller tinned and supplied with circuit diagrams and construction layouts.
U.K. Orders: Subject to 25% *Surcharge for VAT. Carriage free MAIL ORDER ONLY (*or at current rate if changed)
Securicor Delivery. For this optional service (Mainland only) add £2.50 VAT inc. per kit.
Overseas Orders: No VAT. Postage charged at actual cost plus 50p packing and handling.

Further details of above and additional packs given in our FREE LIST

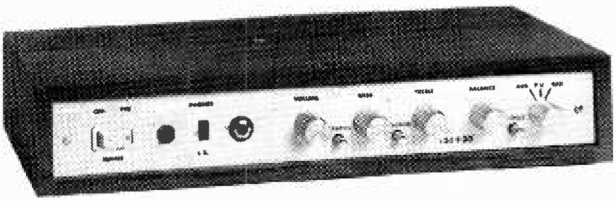
DEPT. WW 04

POWERTRAN ELECTRONICS
PORTWAY INDUSTRIAL ESTATE
ANDOVER, HANTS SP10 3NN

Portugal Mozambique Belgium Sumatra

Hong Kong Jersey Australia St. Lucia India Barbados Antigua Jordan Spain Israel Mauritius St. Vincent Uganda Ascension Island Malta Sierra Leone Somalia New Guinea Italy Kuwait Netherlands Canada Trinidad Malaya Austria

AUDIO KIT SUPPLIERS TO THE WORLD



T20+20 and our new T30+30 20W, 30W AMPLIFIERS

Designed by Texas engineers and described in Practical Wireless the Texan was an immediate success Now developed further in our laboratories to include a Toroidal transformer and additional improvements, the slimline T20 + 20 delivers 20W per channel of true Hi-Fi at exceptionally low cost The design is based on a single F/Glass PCB and features all the normal facilities found on quality amplifiers, including scratch and rumble filters, adaptable input selector and head phones socket. In a follow up article in Practical Wireless further modifications were suggested and these have been incorporated into the T30 + 30 These include RF interference filters and a tape monitor facility Power output of this new model is 30W per channel

Pack	T20	T30
1 Set of low noise resistors	0.95	1.05
2. Set of small capacitors	1.50	2.10
3. Set of power supply capacitors	1.40	2.05
4. Set of miscellaneous parts	1.90	1.90
5. Set of slide, mains, P.B. switches	1.20	1.20
6. Set of pots, selector switch	2.00	2.00
7. Set of semiconductors, ICs, skts.	7.25	7.75
8. Toroidal transformer — 240V prim. e.s. screen	4.95	6.80
9. Fibreglass PCB	2.50	2.90
10. Set of metalwork, fixing parts	4.20	4.80
11. Set of cables, mains lead	0.40	0.40
12. Handbook (free with complete kit)	0.25	0.25
13 Teak cabinet 15.4" x 6.7" x 2.8"	4.50	4.50

FREE TEAK CASE WITH FULL KITS

T20+20 KIT PRICE only **£28.25**

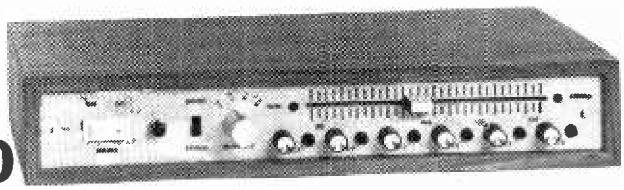
T30+30 KIT PRICE only **£32.95**

2 NEW TUNERS!

WW SFMT II

Following the success of our Wireless World FM Tuner kit we are now pleased to introduce our new cost reduced model, designed to complement the T20 and T30 amplifiers. The frequency meter of the more advanced model has been omitted and the mechanics simplified, however the circuitry is identical and this new kit offers most exceptional value for money. Facilities included are switchable afc, adjustable, switchable muting, channel selection by slider or readily adjustable pre-set push-button controls and LED tuning indication Individual pack prices in our free list.

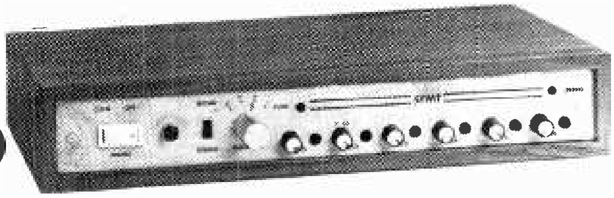
KIT PRICE **£47.40**



POWERTRAN SFMT

This easy to construct tuner using our own circuit design includes a pre-aligned front end module, PLL stereo decoder, adjustable, switchable muting, switchable afc and push-button channel selection As with all our full kits, all components down to the last nut and bolt are supplied together with full constructional details

KIT PRICE **£32.60**



CONVERT NOW TO QUADRAPHONICS

KIT PRICE **£37.15**

With 100s of titles now available no longer is there any problem over suitable software No problems with hardware either Our new unit the SQM1-30 simply plugs into the tape monitor socket of your existing amplifier and drives two additional speakers at 30W per channel. A full complement of controls including volume, bass, treble and balance are provided as are comprehensive switching facilities enabling the unit to be used for either front or rear channels, by-passing the decoder for stereo-only use and exchanging left and right channels The SQ matrix decoder is based upon a single integrated circuit and was designed by CBS whilst the power and tone control sections are identical to those used in our T30 + 30 amplifier which the SQM1-30 matches perfectly Kit price includes CBS licence fee

Special offer to T20 + 20 and Texan owners!

Owners of T20 + 20 and Texan amplifiers, which have no tape monitor outlet, purchasing an SQM1-30 will be supplied, on request, a free conversion kit to fit a tape monitoring facility to the existing amplifier This makes simple the connection to the highly adaptable SQM1-30 quadraphonic decoder/rear channel amplifier

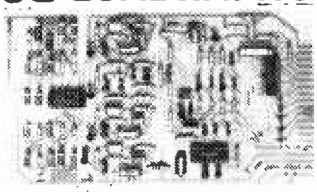
SQ is a trade mark of CBS Inc

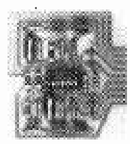
SEMICONDUCTORS

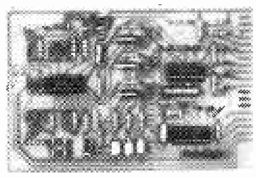
as used in our range of quality audio equipment.

2N699	£0.20	BC212K	£0.12	MPSA65	£0.35
2N1613	£0.20	BC182L	£0.10	MPSA66	£0.40
2N1711	£0.25	BC184L	£0.11	MPSU05	£0.60
2N2926G	£0.10	BC212L	£0.12	MPSU55	£0.70
2N3055	£0.45	BC214L	£0.14	SBA750A	£2.50
2N3442	£1.20	BCY72	£0.13	SL301	£1.30
2N3711	£0.09	BD529	£0.85	SL3045	£1.60
2N3904	£0.17	BD530	£0.85	SN72741P	£0.40
2N3906	£0.20	BDY56	£1.60	SN72748P	£0.40
2N4062	£0.11	BF257	£0.40	TIL209	£0.30
2N4302	£0.60	BF259	£0.47	TIP29A	£0.50
2N5087	£0.42	BFR39	£0.25	TIP30A	£0.60
2N5210	£0.54	BFR79	£0.25	TIP29C	£0.71
2N5457	£0.45	BFY51	£0.20	TIP30C	£0.78
2N5459	£0.45	BFY52	£0.20	TIP41A	£0.74
2N5461	£0.50	CA3046	£0.70	TIP42A	£0.90
2N5830	£0.35	LP1186	£5.50	TIP41B	£0.82
40361	£0.40	MC1310	£2.90	TIP42B	£0.98
40362	£0.45	MC1351	£1.05	1N914	£0.07
BC107	£0.10	MFC4010	£0.95	1N916	£0.07
BC108	£0.10	MJ481	£1.20	1S920	£0.10
BC109	£0.10	MJ491	£1.30	5B05	£1.20
BC109C	£0.12	MJE521	£0.60		
BC125	£0.15	MPSA05	£0.25	FILTERS	
BC126	£0.15	MPSA12	£0.55	FM4	£0.80
BC182	£0.10	MPSA14	£0.35	SFG10 7MA	£2.80
BC212	£0.12	MPSA55	£0.25		
BC182K	£0.10				

SQ QUADRAPHONIC DECODERS







Feed 2 channels (200-1000mV as obtainable from most pre-amplifiers or amplifier tape monitor outlets) into any one of our 3 decoders and take 4 channels out with no overall signal level reduction. On the logic enhanced decoders Volume, Front-Back, LF-RF balance LB-RB balance and Dimension controls can all be implemented by simple single gang potentiometers

These state-of-the-art circuits used under licence from CBS are offered in kits of superior quality with close tolerance capacitors, metal oxide resistors and fibre-glass PCBs designed for edge connector insertion All kit prices include CBS licence fee.

M1 Basic matrix decoder with fixed 10-40 blend All components, PCB **£5.90**

L1 Full logic controlled decoder with "wave matching" and "front back logic" for enhanced channel separation All components PCB **£17.20**

L2A More advanced full logic decoder with "variable blend" "extended frequency response" increased front back separation All components, PCB **£24.60**

EXPORT NO PROBLEM

Our Export Department will be pleased to advise on postal costs to any country in the world. Some of the countries to which we sent kits in 1975 are shown surrounding this advertisement

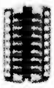
Finland Anguilla Nigeria Denmark South Africa Borneo New Zealand Java St. Martin, France Kenya

NEW PRODUCTS

PROTO BOARDS

Build & test circuits as fast as you think!

PB100	10 IC cap breadboard kit 4 5 x 6 0 x 1 3"	£17.45
PB101	10 14-DIP cap 5-way post 940 solderless tie points 5 8 x 4 5"	£26.15
PB102	12 14 DIP cap like PB101 with 1 240 tie points 7 0 x 4 5"	£34.90
PB103	24 14 DIP cap 4 5 way posts 2 250 tie points 6 0 x 9 0"	£52.35
PB104	32 14 DIP cap 3 060 solderless tie points 8 0 x 9 76"	£69.80



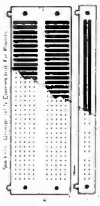
LOGIC MONITOR
Simultaneously displays static and dynamic logic states of DTL TTL HTL or CMOS DIP ICs Pocket size LM-1 £59.95.

PROTO-CLIP
For power on hands off signal tracing Bring IC leads up from PC board surface for fast trouble shooting

PC14	14-pin	£3.25
PC16	16-pin	£3.40

SOCKETS & BUS STRIPS

Plug in wire test modify or expand without patch cords or solder Snap together to form breadboard needed



PN/Description		Hole-to-Hole	Term'ls	Price
QT59S Socket	6 5"	6 2"	118	£10.90
QT59B Bus	6 5"	6 2"	20	£2.20
QT47S Socket	5 3"	5 0"	94	£8.75
QT47B Bus	5 3"	5 0"	16	£2.00
QT35S Socket	4 1"	3 8"	70	£7.45
QT35B Bus	4 1"	3 8"	12	£1.75
QT18S Socket	2 4"	2 1"	36	£4.15
QT12S Socket	1 8"	1 5"	24	£3.30
Q18S Socket	1 4"	1 1"	16	£2.85
QT7S Socket	1 3"	1 0"	14	£2.65

HIGH-SPEED TTL

	1	25	100+
SN74H00	0.34	0.33	0.30
SN74H01	0.34	0.33	0.30
SN74H04	0.38	0.37	0.34
SN74H05	0.37	0.36	0.33
SN74H08	0.40	0.39	0.37
SN74H10	0.36	0.35	0.33
SN74H11	0.36	0.35	0.33
SN74H20	0.36	0.35	0.33
SN74H21	0.36	0.35	0.33
SN74H22	0.36	0.35	0.33
SN74H30	0.36	0.35	0.33
SN74H40	0.36	0.35	0.33
SN74H50	0.36	0.35	0.33
SN74H51	0.36	0.35	0.33
SN74H52	0.36	0.35	0.33
SN74H53	0.36	0.35	0.33
SN74H54	0.36	0.35	0.33
SN74H55	0.36	0.35	0.33
SN74H60	0.36	0.35	0.33
SN74H61	0.36	0.35	0.33
SN74H62	0.36	0.35	0.33
SN74H71	0.80	0.78	0.75
SN74H72	0.74	0.73	0.70
SN74H73	0.90	0.88	0.85
SN74H74	0.87	0.85	0.81
SN74H76	0.90	0.88	0.85
SN74H101	0.80	0.78	0.75
SN74H102	0.80	0.78	0.75
SN74H103	1.10	1.09	1.05
SN74H106	0.95	0.93	0.90

HIGH-BRIGHTNESS L.E.D.s

.200" dia.

	100+
ED5053 = RED	20p
ED5053Y = YELLOW	20p
ED5053G = GREEN	20p
ED5053O = ORANGE	20p

.125" dia.

	100+
ED209 = RED	13p
ED209Y = YELLOW	19p
ED209G = GREEN	19p
OC-1 = CLIP FOR ED5053	3½p

LOW-POWER TTL

	1	25	100+
SN74L00	0.34	0.33	0.30
SN74L02	0.34	0.33	0.30
SN74L03	0.39	0.37	0.34
SN74L04	0.39	0.37	0.34
SN74L10	0.34	0.33	0.30
SN74L20	0.39	0.37	0.34
SN74L42	1.62	1.58	1.50
SN74L51	0.34	0.33	0.30
SN74L73	0.74	0.71	0.68
SN74L74	0.89	0.87	0.80
SN74L90	1.62	1.58	1.50
SN74L93	1.74	1.71	1.65
SN74L95	1.62	1.58	1.50

WIRELESS WORLD TELETEXT DECODER

1024-bit Static
N-Channel Ram
Type 2602 B
(1000 ns)
16-pin Moulded Dip
£2.75 each

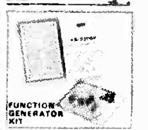
STANDARD MICROSYSTEMS

	1-up	25-up	100-up
COM2502	£6 60	£5 30	£4 62
COM2502P	£4 65	£3 95	£3 50
COM2017	£7 05	£6.00	£5 00
COM2017P	£4 75	£4.15	£3 75
COM2502H	£12 80	£11 25	£10 30
COM2017H	£12 80	£11 25	£10 30
COM2601	£16 40	£14 25	£13 15
COM5016	£6 70	£6 15	£5 60
KR2376-ST	£11 50	£9 20	£8 19
KR3600-ST	£12 00	£10 20	£9 25
LMX5010	£6 70	£6 15	£5 55

WAVEFORM GENERATOR KITS

XR-205K £12.30

Here's a highly versatile instrument at a fraction of the cost of conventional unit — it includes two XR205 IC's, data & applications, PC board (etched & drilled ready for assembly) and detailed instructions



The Function Generator Kit features sine, triangle and square wave. THD 0.5% typ., AM/FM capability.

XR-2206KA FUNCTION GENERATOR KIT £11.50
Includes monolithic function generator IC PC board, and assembly instruction manual

XR-2206KB FUNCTION GENERATOR KIT £16.00
Same as XR-2206KA above and includes components for PC board

INTERFACE MODULES

CY1010	Instr Amp Bipolar input	£18.98
CY1011A	Instr Amp Bipolar input	£31.90
CY1020	Instr Amp FET Input	£22.00
CY1021	Instr Amp FET Input	£31.90
CY1021A	Instr Amp FET Input	£38.50
CY2137	DAC 10 Bit Low Drift	£30.80
CY2218	DAC 12 Bit 2 Quad Multiplying	£96.80
CY2237	DAC 12 Bit Low Drift	£46.20
CY2735	OAC 4 Digit BCD Low Cost	£57.75
CY3035	ACD 8 Bit Sect Counting Low Cost	£57.75
CY3635	ADC 3 Digit BCD Sect Count Low Cost	£77.55

7400 Series TTL

	1	25	100+
SN7400	0.14	0.13	0.12
SN7401	0.14	0.13	0.12
SN7402	0.14	0.13	0.12
SN7403	0.14	0.13	0.12
SN7404	0.15	0.14	0.13
SN7405	0.15	0.14	0.13
SN7406	0.30	0.29	0.28
SN7407	0.30	0.29	0.28
SN7408	0.15	0.13	0.12
SN7409	0.15	0.13	0.12
SN7410	0.14	0.13	0.12
SN7411	0.23	0.22	0.21
SN7412	0.19	0.18	0.17
SN7413	0.30	0.29	0.28
SN7414	0.71	0.70	0.69
SN7415	0.30	0.29	0.27
SN7416	0.28	0.27	0.26
SN7417	0.28	0.27	0.26
SN7420	0.14	0.13	0.12
SN7421	0.95	0.94	0.93
SN7422	0.25	0.24	0.23
SN7423	0.26	0.25	0.22
SN7425	0.26	0.25	0.22
SN7426	0.26	0.25	0.22
SN7427	0.26	0.25	0.22
SN7428	0.39	0.38	0.37
SN7430	0.14	0.13	0.12
SN7432	0.25	0.24	0.22
SN7433	0.36	0.35	0.34
SN7437	0.27	0.26	0.22
SN7438	0.27	0.26	0.22
SN7439	1.10	1.08	1.06
SN7440	0.14	0.13	0.12
SN7441	0.70	0.69	0.66
SN7442	0.63	0.60	0.53
SN7443	1.00	0.99	0.90
SN7444	1.08	1.07	1.05
SN7445	0.85	0.83	0.70
SN7446	1.03	1.00	0.85
SN7447	1.03	1.00	0.85
SN7448	0.85	0.83	0.70
SN7450	0.14	0.13	0.12
SN7451	0.14	0.13	0.12
SN7453	0.14	0.13	0.12
SN7454	0.14	0.13	0.12
SN7455	0.40	0.39	0.38
SN7460	0.14	0.13	0.12
SN7462	0.45	0.44	0.42
SN7464	0.45	0.44	0.42
SN7465	0.45	0.44	0.42
SN7470	0.30	0.27	0.25
SN7471	0.60	0.59	0.58
SN7472	0.25	0.24	0.21
SN7473	0.30	0.27	0.26
SN7474	0.31	0.29	0.26
SN7475	0.40	0.39	0.38
SN7476	0.31	0.29	0.26
SN7478	0.65	0.63	0.61
SN7480	0.43	0.41	0.36
SN7481	1.00	0.95	0.90
SN7482	0.75	0.70	0.62
SN7483	0.81	0.80	0.68
SN7484	0.90	0.86	0.85
SN7485	1.25	1.15	1.00
SN7486	0.31	0.28	0.25
SN7489	3.50	3.20	3.00
SN7490	0.45	0.42	0.35
SN7491	1.00	0.95	0.90
SN7492	0.45	0.42	0.35
SN7493	0.45	0.42	0.35
SN7494	0.48	0.45	0.40
SN7495	0.60	0.56	0.50
SN7496	0.70	0.67	0.60
SN7497	2.90	2.50	2.35
SN74100	1.35	1.30	1.25
SN74104	0.31	0.29	0.26
SN74105	0.31	0.29	0.26
SN74107	0.31	0.29	0.26
SN74109	1.00	0.97	0.95
SN74110	0.55	0.50	0.45
SN74111	0.81	0.80	0.76
SN74114	1.00	0.97	0.95
SN74115	1.00	0.97	0.95
SN74118	1.00	0.95	0.90
SN74121	0.31	0.29	0.25
SN74122	0.44	0.41	0.37
SN74123	0.62	0.58	0.50
SN74125	0.70	0.65	0.60
SN74126	0.75	0.70	0.65
SN74128	1.40	1.35	1.30
SN74132	2.10	2.05	2.00
SN74136	0.95	0.90	0.85
SN74140	2.50	2.45	2.40
SN74141	0.75	0.70	0.62
SN74145	1.15	1.10	1.05
SN74147	2.95	2.90	2.85
SN74148	2.30	2.25	2.20
SN74150	1.35	1.30	1.25
SN74151	0.68	0.62	0.55
SN74152	1.55	1.50	1.45
SN74153	0.68	0.62	0.55
SN74154	1.55	1.50	1.45
SN74155	0.68	0.62	0.55
SN74156	0.68	0.62	0.55
SN74157	0.90	0.85	0.80
SN74158	1.50	1.45	1.40
SN74160	0.95	0.90	0.80
SN74161	0.95	0.90	0.80
SN74162	0.95	0.90	0.80
SN74163	0.95	0.90	0.80
SN74164	1.60	1.55	1.50
SN74165	1.60	1.55	1.50
SN74166	1.40	1.30	1.15
SN74170	2.40	2.30	2.20
SN74173	1.65	1.60	1.55
SN74174	1.15	1.10	1.00
SN74175	0.97	0.90	0.80
SN74176	1.10	1.05	1.00
SN74177	1.10	1.05	1.00
SN74180	1.10	1.05	1.00
SN74181	3.50	3.45	3.35
SN74182	1.10	1.05	1.00
SN74184	1.60	1.55	1.50
[illegible]	2.30	2.25	2.20
SN74188	4.90	4.85	4.80
SN74190	1.75	1.70	1.65
SN74191	1.70	1.65	1.60
SN74192	1.25	1.05	1.00
SN74193	1.25	1.05	1.00
SN74194	1.10	1.05	1.00
SN74195	0.90	0.85	0.80
SN74196	1.05	1.00	0.95
SN74197	1.05	1.00	0.95
SN74198	2.05	2.00	1.70
SN74199	2.05	2.00	1.70
SN74200	6.00	5.95	5.80
SN74221	1.80	1.75	1.70
SN74251	1.80	1.75	1.70
SN74278	3.00	2.90	2.80
SN74279	1.20	1.15	1.10
SN74293	1.00	0.95	0.90
SN74298	2.60	2.55	2.50

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8	115
10	100
12	90
15	70
18	50
20	35
22	25
24	15

£15.00 each

C-MOS Types

	1	25	100+
4000AE	0.17	0.14	0.12
4001AE	0.17	0.14	0.12
4002AE	0.17	0.14	0.12
4004AE	1.93	1.55	1.29
4006AE	0.97	0.78	0.64
4007AE	0.17	0.14	0.12
4008AE	0.79	0.64	0.53
4009AE	0.46	0.37	0.31
4010AE	0.46	0.37	0.31
4011AE	0.17	0.14	0.12
4012AE	0.17	0.14	0.12
4013AE	0.46	0.37	0.31
4014AE	0.83	0.67	0.55
4015AE	0.83	0.67	0.55
4016AE	0.46	0.37	0.31
4017AE	0.83	0.67	0.55
4018AE	0.83	0.67	0.55
4019AE	0.46	0.37	0.31
4020AE	0.92	0.74	0.61
4021AE	0.83	0.67	0.55
4022AE	0.79	0.64	0.53
4023AE	0.17	0.14	0.12
4024AE	0.64	0.52	0.43
4025AE	0.17	0.14	0.12
4026AE	1.42	1.14	0.94
4027AE	0.46	0.37	0.31
4028AE	0.74	0.59	0.49
4029AE	0.94	0.76	0.63
4030AE	0.46	0.37	0.31
4033AE	1.14	0.92	0.76
4035AE	0.97	0.78	0.64
4040AE	0.88	0.71	0.58
4041AE	0.69	0.56	0.46
4042AE	0.69	0.56	0.46
4043AE	0.83	0.67	0.55
4044AE	0.77	0.62	0.51
4047AE	0.74	0.60	0.50
4048AE	0.46	0.37	0.31
4049AE	0.46	0.37	0.31
4050AE	0.46	0.37	0.31
4051AE	0.77	0.62	0.51
4052AE	0.77	0.62	0.51
4053AE	0.77	0.62	0.51
4055AE	1.08	0.87	0.72
4056AE	1.08	0.87	0.72
4060AE	0.92	0.74	0.61
4066AE	0.58	0.47	0.39
4069AE	0.18	0.15	0.12
4071AE	0.18	0.15	0.12
4076AE	1.27	1.02	0.85
4081AE	0.18	0.15	0.12
4510AE	1.27	1.02	0.85
4516AE	1.27	1.02	0.85
4518AE	1.82	1.46	1.21
4520AE	1.82	1.46	1.21
4901AE	0.35	0.32	0.30
4911AE	0.35	0.32	0.30

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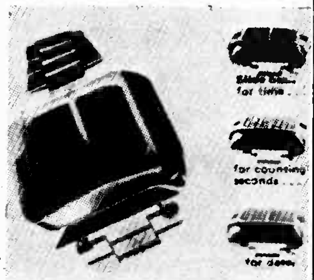
	Output Vdc	Amps	Prices
RED BARON SERIES: 5 to 28V/0.8 to 3.0 Amps.			
APS5-3	5	3 0	£22
APS12-1 6	12	1 6	
APS 15-1 5	15	1 5	
APS 24-1	24	1 0	
APS 28-0 8	28	0 8	
GREEN HORNET SERIES: 5 to 28V/2 to 6 Amps.			
PS5-6	5	6	£35
APS12-4	12	4	
APS15-3	15	3	
APS24-2 2	24	2 2	
APS28-2	28	2	
BLACK BEAUTY SERIES: 5 to 28V/4 to 10 Amps.			
APS5 10	5	10	£54
APS12-7	12	7	
APS15-6	15	6	
APS24-5	24	5	
APS28-4	28	4	
BLUE MAX SERIES: 5 to 28V/9 to 25 Amps.			
APS5 25	5	25	£107
APS6 22	6	22	
APS12 17	12	17	
APS15 15	15	15	
APS20 11	20	11	
APS24-10	24	10	
APS28-9	28	9	

NEW Solar Powered Watch with 100-YEAR CALENDAR



Solar cells draw power from the sun (10 to 15 minutes per day) or from ambient light (slightly longer) to keep batteries fully charged. Batteries operate up to 10 years. LSI circuitry is programmed to provide a calendar to the year 2100, automatically adjusting for 30 and 31 day months, even leap years. Automatic brightness control adjusts LED for perfect viewing even in outdoors. Shows minutes and hours, counts out seconds or shows the date. Easily adjusts to reset hour or date without affecting calendar. Shock and water resistant. Accurate to 5 seconds per month. **Price: £298.50 each.**

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WW—092 FOR FURTHER DETAILS

VALVES

A1065	1.25	EF36	0.65	GZ37	1.00
AR8	0.60	EF37A	1.10	KT66	2.90
ARP3	0.60	EF40	0.70	KT88	3.85
ATP4	0.50	EF41	0.75	MH4	1.00
B12H	3.00	EF80	0.35	ML6	0.75
DAF96	0.60	EF83	1.25	OA2	0.45
DF96	0.60	EF85	0.40	OB2	0.45
DK96	0.75	EF86	0.45	PABC80	0.40
DL92	0.50	EF89	0.35	PC86	0.65
DL96	0.70	EF91	0.60	PC88	0.65
DY86/87	0.45	EF92	0.50	PC97	0.55
DY802	0.45	EF95	0.45	PC900	0.55
E88CC/01	1.30	EF183	0.40	PCC84	0.45
E180CC	1.00	EF184	0.40	PCC89	0.60
E182CC	3.00	EFL200	0.75	PCC189	0.65
EA50	0.40	EL34	0.70	PCF80	0.40
EABC80	0.40	EL35	0.70	PCF82	0.40
EAF42	0.70	EL37	2.20	PCF84	0.65
EB91	0.30	EL41	0.80	PCF86	0.65
EBC33	1.00	EL81	0.60	PCF200	0.90
EBC41	0.75	EL84	0.35	PCF201	0.90
EBF80	0.40	EL85	0.60	PCF801	0.55
EBF83	0.45	EL86	0.50	PCF802	0.55
EBF89	0.40	EL90	0.50	PCF805	1.10
EC52	0.40	EL91	1.00	PCF806	0.90
ECC81	0.45	EL95	0.70	PCH200	0.80
ECC82	0.35	EL504	0.80	PCL81	0.60
ECC83	0.35	EL821	1.80	PCL82	0.40
ECC84	0.35	EM31	0.70	PCL83	0.70
ECC85	0.45	EM80	0.55	PCL84	0.50
ECC86	1.25	EM84	0.40	PCL86	0.60
ECC88	0.55	EM87	1.00	PCL805/85	0.60
ECC189	0.80	EY51	0.45	PFL200	0.70
ECF80	0.45	EY81	0.45	PL36	0.60
ECF82	0.45	EY86/87	0.45	PL81	0.55
ECF801	0.75	EY88	0.50	PL82	0.50
ECF804	2.50	EZ40	0.70	PL83	0.50
ECH42	0.85	EZ41	0.75	PLR4	0.50
ECH81	0.40	EZ80	0.30	PL504	0.85
ECH84	0.60	EZ81	0.35	PL508	0.95
ECL80	0.60	GT1C	5.00	PL509	1.35
ECL82	0.40	GY501	0.80	PL802	1.85
ECL83	0.75	GZ32	0.65		
ECL86	0.60	GZ34	0.80		

A lot of these valves are imported and prices vary for each delivery, so we reserve the right to change prices for new stock when unavoidable

PLUMBICON TUBES TYPE XO 1071 Mullard....... £150.00

PY33	0.35	U25	1.00	UCL83	0.70	Z900T	1.50	5R4GY	1.00	6AQ5	0.55
PY80	0.60	U26	0.80	UF41	0.70	1A3	0.55	5U4G	0.55	6AQ5W	0.70
PY/81/800	0.50	U27	1.00	UF80	0.40	IL4	0.30	5V4G	0.65	6AS6	0.80
PY82	0.45	U191	0.75	UF85	0.50	IR5	0.50	5Y3GT	0.60	6AS7G	1.00
PY83	0.50	U801	0.80	UF89	0.50	IS4	0.35	5Z3	1.20	6AT6	0.60
PY88	0.50	UABC80	0.45	UL41	0.70	IS5	0.35	5Z4G	0.60	6AU6	0.40
PY500	1.10	UAF42	0.70	UL84	0.50	IT4	0.35	5Z4GT	0.65	6AV6	0.50
PY801	0.55	UBC41	0.60	UY41	0.50	IX2B	0.75	6AB7	0.60	6AX4GT	0.75
QQV03-10	1.50	UBF80	0.50	UY85	0.50	2D21	0.50	6AC7	0.60	6AX5GT	1.00
QQV06-40A	8.00	UBF89	0.50	VR105/30	0.45	2K25	9.00	6AH6	0.70	6B7	0.70
QV03-12	1.60	UBL1	1.00	VR150/30	0.45	3A4	0.60	6AK5	0.45	6BA6	0.40
SC1/400	3.60	UBL21	0.75	X61M	1.50	3D6	0.40	6AK8	0.40	6BE6	0.40
SC1/600	5.50	UCC85	0.50	X66	0.75	3S4	0.50	6AL5	0.30	6BG6G	1.00
SP61	0.80	UCF80	0.80	Z800U	3.00	3V4	0.85	6AL5W	0.60	6BJ6	0.75
TT21	6.00	UCH42	0.80	Z801U	3.00	5B/254M	5.00	6AM5	1.00	6BQ7A	0.60
		UCH81	0.50			5B/255M	5.00	6AM6	0.60	6BR7	1.30
		UCL82	0.45			5B/258M	5.50	6AN8	0.70	6BW6	1.10

VIDECON TUBE TYPE P 864 B English Electric £20.00

TRANSISTORS

Please write or phone for current price of any of the transistors diodes shown below

AAZ12-BAV10	AF186	BCY33	CRS25/025	OC26	OC170	2N3054
AC113	AF239	BCY72	GET115	OC28	OC172	2N3055
AC126	AFZ12	BF115	GET116	OC29	OC200	2N3391
AC127	ASY26	BF167	GEX66	OC35	OC204	2N3730
AC128	ASY27	BF173	NKT222	OC36	OC206	2N3819
AC176	ASY28	BF185	NKT304	OC42	ZR11	2N4038
ACY17	BC107	BFY51	NKT404	OC44	ZR21	2N4058
ACY18	BC108	BFY52	OA5	OC45	ZR22	2N4061
ACY19	BC109	BSY27	OA47	OC70	2N456A	2N4172
ACY20	BC113	BSY38	OP70	OC73	2N525	2N5295
ACY39	BC116	BSY95A	OA71	OC75	2N696	3N126
ACY40	BC118	BY100	OA73	OC78	2N708	3N128
AD149	BC136	BYZ16	OA79	OC78D	2N918	3N154
AD161	BC137	CRS1/20	OA91	OC81	2N1305	3N159
AD162	BC148A	CRS1/30	OA200	OC82	2N1307	SX754
ADZ11	BC172	CRS3/10	OA202	OC82DM	2N1309	2S303
ADZ12	BC172A	CRS3/20	OAZ200	OC83	2N2062	T12082
AF114	BC212A	CRS3/30	OC22	OC83B	2N2411	40235
AF115	BCY31	CRS3/40	OC25	OC139	2N2989	40250
AF116				OC140	2N3053	40251
AF117						IN23A
AF118						IN25
AF124						IN38A
AF125						IN43
AF126						IN70
AF127						IN677
AF139						IN4148
AF178						IN4785

VALVES AND TRANSISTORS

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6BW7	1.00	12E1	3.75
6C4	0.40	12K5	1.50
6C6	0.50	12K7GT	0.55
6CB6	0.50	12K8GT	0.75
6CH6	1.60	12Q7GT	0.50
6CL6	0.75	12SA7GT	0.80
6D6	0.45	12SG7	0.55
6EA8	0.75	12SJ7	0.55
6F7	1.10	12Y4	0.40
6F8G	0.75	14S7	1.00
6F12	0.60	19AQ5	0.70
6F17	1.00	19G3	8.00
6F33	3.50	19G6	6.50
6H6	0.45	19H5	15.00
6J4WA	1.25	20P3	0.60
6J5	0.65	20P4	1.10
6J5GT	0.55	25L6GT	0.70
6J6	0.35	30C15	1.00
6J7	0.65	30C17	1.10
6J7G	0.40	30C18	1.10
6K6GT	0.80	30F5	1.00
6K7	0.55	30FL1	1.10
6K7G	0.35	30FL12	1.10
6K8GT	0.55	30L15	1.00
6L6M	1.90	30L17	1.00
6L7G	0.40	30P12	1.00
6SA7	0.55	30P19	1.00
6SC7	0.75	30PL1	1.00
6SG7	0.55	30PL13	1.10
6SJ7	0.60	30PL14	1.10
6SJ7GT	0.35	35L6GT	0.80
6SK7	0.60	35W4	0.55
6SL7GT	0.55	35Z4GT	0.70
6SN7GT	0.55	50C5	0.65
6SQ7	0.60	50CD6G	1.20
6V6GT	0.60	75	1.00
6X4	0.45	75C1	0.75
6X5G	0.40	76	0.75
6X5GT	0.55	78	0.70
6Y6G	0.95	80	0.75
6Z4	0.65	85A2	0.75
6-30L2	0.90	803	6.00
7B7	0.80	805	18.00
7Y4	0.80	807	0.75
902	0.60	813	6.50
9D6	0.50	866A	1.60
11E2	6.00		
12A6	0.60		
12AT6	0.45		
12AT7	0.45		
12AU7	0.35		
12AX7	0.35		
12BA6	0.50		
12BE6	0.55		
12BH7	0.55		
12C8	0.60		

931A	6.00
954	0.60
955	0.50
956	0.50
957	0.50
1629	0.70
2051	1.00
5933	3.00
6057	0.80
6060	0.70
6064	0.60
6065	1.00
6067	0.80
6080	2.50
6146	3.35
6146B	4.00
8020	5.00
9001	0.40
9002	0.55
9003	0.70
9004	0.40
9006	0.40

C.R. TUBES

DG7-5	12.00
DG7-32	15.00
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MW13-35	35.00
VCR139A	8.00
5FP7	8.00
88J	9.00
88L	9.00

SPECIAL VALVES

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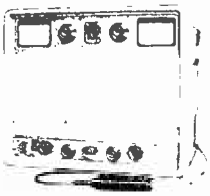
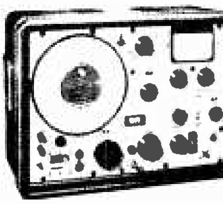
M503-2J4L	60.00
K301	7.00
KRN2A	6.00
725A	25.00
TY4-500	30.00
2J/192	140.00
2J/52A	75.00

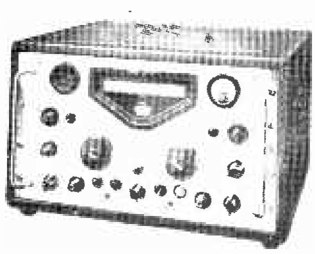


MARCONI TF 867 SIGNAL GENERATOR Range: 15KHz to 30MHz. Output 0.4µV to 4V at 13 or 75 ohms. Impedance with termination (supplied). Built in crystal check facility with handbook. **£138** including carr

TF144H SIGNAL GEN. Freq. range 10 KHz-72 MHz, R.F. output 2µV to 2V at 50 ohms 400 and 1000 Hz internal mod. Limited qty. only available. Full spec. and price on request.



TF 526B OSCILLATOR AND DETECTOR UNIT £50·00.



RACAL COMMUNICATION EQUIPMENT. On top of the above we are able to offer a comprehensive selection of this modern high class equipment including LF Converters, panoramic adaptors, transmitter driver units (export only) linear amplifiers can be built to customer's requirements

524B FREQUENCY COUNTER. Measures basically 10MHz Display on neop lamp 8 decibles P D A

DIVERSITY SWITCH TYPE MA168B. Solid state **£45.00.**

RACAL RECEIVERS MODELS. RA17L RA17W in fully working and tuned condition Prices on application RA98A SSB ADAPTOR **£85.00.**

HEWLETT-PACKARD OSCILLOSCOPES 175A with 1750A dual trace vertically plug-in and 1781B delay time base plug-in, 50MHz mini-meter band switch at 50 Mv/CM Modes of operation Single, mixed delaying Full spec and price on application

BOONTON

AM/FM SIGNAL GENERATOR. TYPE 202E & 202H 54-216MHz in 2 ranges **£275.00.**

BOONTON

SIGNAL GENERATOR TS. 497/URS 2-5Mz 13MHz, 30MHz, 78MHz, 180MHz, 400MHz 0 1v-1µv **£150** carriage £3.00

★ **Open 9-12.30, 1.30-5.30 p.m. except Thursday 9-1 p.m.** ★

CINTIL TYPE 1873 SQUARE WAVE & PULSE GENERATOR. Freq 5c/s to 250KHz Pulse 0 5 µsec, 0 3µ3 Output to 50v for 1000Ω& to 5v for 100Ω P O A

RADIOMETER TYPE MS111 SIGNAL GENERATOR. High quality Danish production 10KHz-110MHz **£200** carriage £5 00

CT480 SIGNAL GENERATOR. 7 KMC/S to 12 KMC/S mod C W , F M Pulse **£160** carriage £5 00

AVO NOISE GENERATOR CT 410 **£30** carriage £2 00

BRIDGE IMPEDENCE No 5. 0 1Ω-10MΩ 1pF-1µF 1µH-1H **£85** carriage £4 00

EDISWAN STABILIZED POWER UNITS. To 100v 50MA Type R1280 to 300v-150MA and, 300v 75mA

TEKTRONIX OSCILLOSCOPES 535 & 545. With plug in units CA (33MHz) (double beam). G(20MHz differential 50mV-20v) and D high gain differential 1MV-50v Price on application

TECHNICAL MATERIAL CORP EXCITER/TRANSMITTER MODE SELECTOR. Freq 2-32MHz M D and 10 crystal positions Vernier tuning USB, LSB var carrier insertion etc **£200** carriage £10 00
FSK EXCITER. Freq 1-6 5MHz 0 100Hz continued frequency shift up to 600Hz switched freq correction Modes FAX, FS, MSC, CW **£50.00** carriage £5 00
AMPLIFIER UNIT TYPE 1430. Dynatron Production Pulse amplifier with control 'Differential' and "Integration" time constant 0 08µs to 8µs Attenuation to 20db P O A
PULSE ANALIZER. Made by Dynatron with discriminator all meter reads, channel width threshold level P O A

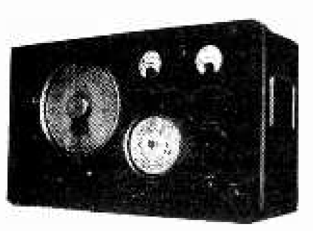
RHODE & SCHWARZ. Z-g DIAGRAPH TYPE ZDU 30-420MHz 50Ω Directly measures multiterminal net-works, phrase shift, phrase angle with complimentary POWER SIGNAL GENERATOR TYPE SMLM high freq resolution, internal external mod up to 3v out **£750.**
FREQUENCY SYNTHESIZER TYPE XUA. 30Hz-30MHz with FREQUENCY INDICATOR TYPE FKM 15-30MHz 30-100MHz **£1,000.**

SIGNAL GENERATOR NO 16. 8cm-11cm **£85** carriage £4 00

SIGNAL GENERATOR NO 13. 20MHz-80MHz, AM FM CW 1µv-1v **£65** carriage £4 00

KAHN SSB ADAPTOR TYPE RSSB — 62 — 18. Designed for receivers with 455-500KHz IF at 100mV (max) input Features electronic AFC carrier freq diversity to combat fading 20 sce R C memory to maintain tuning during severe fading Individual carrier meters, nuvishers 10W distortion production demodulator **£65** carriage £5 00

BEST PRICES PAID FOR TEST AND COMMUNICATION EQUIPMENT. Single items or quantities. Private or Industrial.



TF 801B/2. Spec as for 801D but minor circuit differences Few only left **£120** carriage £5 00

TF 867 SIGNAL GENERATOR. Range 15KHz to 30MHz Output 0 4µF to 4v at 13 or 75 ohms Impedence with termination (supplied) Built in crystal check facilities With hand book **£135.00** carriage £5 00

TF144H SIGNAL GENERATOR. Freq range 10KHz-72MHz R F output 2µV to 2V at 50 ohms 400 and 1 000Hz internal mod Limited quantity only available Full spec and price on request

TF 801D/1/S SIGNAL GENERATOR. Range 10-485MHz in 5 ranges R F output 0 1µV 1V source C M Dial calibrated in volta decibels and power relative to thermal noise Piston type attenuator 50Ω output impedence Internal modulation at 1KHz at up to 90% depth also external sine & pulse modulation Built in 5MHz crystal calibrator Separate RF and mod Meters Price on application

TF 893 AUDIO OUTPUT METERS. Up to 10W **£55** carriage £3 00

TF 995A/1 or A/2 or A/2M or A5 SIGNAL GENERATORS. Very high class AM/FM 1 5MHz to 220MHz Detailed spec and price on application

EMI OSCILLOSCOPE WM8 AC/DC to 15 mc/s Time base 0 15Msec 15Msec **£70** carriage £5 00

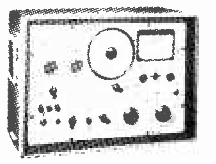
HR 23 TRIPLE DIVERSITY SSB RECEIVERS. Freq 3-275MHz V F O at 6 Xtal positions Reception of independent single or double side band transceivers Full spec on application **£350** carriage £35 00

TF 885A/1 VIDEO OSCILLATOR. 0-30KHz 5MHz 1Mv-31 6v **£85** carriage £4 00

TF 934 DEVIATION METER. 250MHz **£55** carriage £3 00

TF 1400S DOUBLE PULSE GENERATOR WITH TM 6600 SECONDARY PULSE UNIT for testing radad nucleonics scopes counters filters etc **£175** carriage £5 00

500/250 MEDIUM WAVE BROADCAST TRANSMITTERS. Export only Price and details on application



TF 958 VALVE VOLTMETER. AC voltage 1 5-150v at up to 100MHz DC voltage 1 5-150v **£25** carriage £1 00

PLEASE NOTE

Unless offered as "as seen"

ALL EQUIPMENT

ordered from us is completely overhauled mechanically and electrically in our own laboratories

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CD1400 OSCILLOSCOPE with wide band amplifier CX 1441 and general purpose time base x-amplifier CX 1443 Up to 15MHz d c 750KHz on X10 gain Sensitivity (max) 100 mv/cm 10v/cm on X10 gain **£130** carriage £3 00

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LM 14202. 2-2 5µv±1000v in 6 ranges Accuracy 0 05% of range i e ±1 digit, sensitivity 2 5µv per digit **£320.**
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Also available CD 1420 **£170.00.** CD 1440 2 **£220.**

AR88 D & LF SPARES. We hold the largest stock in UK write for list

RF METERS. 0 8 amp 2¼" (USA) brand new **£1.50** P&P 25p

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10 LINE MAGNETO SWITCHBOARDS
50 LINE AUTOMATIC PRIVATE TELEPHONE SWITCHBOARDS

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RCA ET 4336 TRANSMITTERS
Also modified version of increased output to 700W COLLINS TYPE 231D 4/5KW TRANSMITTER
10 channel, Autotone and manual tuning
C13 TRANSMITTERS, 38 62 TRANSCEIVERS NO 53 TRANSMITTERS, REDIFON 100SW SSB TRANSCEIVERS MULLARD C11 HIGH POWER INSTALLATION (1,000W)

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RELAYS

SIEMENS PLESSEY, etc. MINIATURE RELAYS

1	2	3	4	1	2	3	4
52	4-8	2c/o	75p*	700	16-24	4 M2B	65p*
58	5-9	6 c/o	85p	700	16-24	4 c/o	85p*
185	8-12	6 M	65p*	1250	18-36	2 c/o	65p*
230	9-18	2 c/oHD	75p*	2500	36-45	6 M	65p*
430	15-24	4 c/o	85p*	2500	31-43	2 c/oHD	65p*
600	10-20	6M	85p	15k	85-110	6 M	85p
700	12-24	2 c/o	65*				

(1) Coil ohms; (2) Working d.c. volts; (3) Contacts; (4) Price HD=Heavy Duty. All Post Paid. (*including Base)

OPEN TYPE RELAYS

6 VOLT D.C. 1 make con 45p. Post 15p.

9 VOLT D.C. RELAY 3 c/o 5 amp contacts 70 ohm coil **85p**. Post 15p

12 VOLT D.C. RELAY 3 c/o 5 amp contacts 120 ohm coil **85p**. Post 15p.

24 VOLT D.C. 2 HD c/o 700 ohm coil **85p**. Post 15p. 4 c/o 300 ohm coil **95p**. Post 15p. 100 VOLT a.c. 2 c/o **75p**. 3 c/o **85p**. Post 15p

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24V DC 3 c/o **85p**. Post 20p. Base 15p.

24 VOLT A.C. M.f.g. ITT 3 h.d. c/o contacts **65p**. Post 20p. Base 15p extra.

55 VOLT A.C. 3 heavy duty c/o contacts. Price **65p**. Post 20p. Base 15p

230 VOLT A.C. RELAY 240V A.C. heavy duty 3 c/o contacts. Price **85p**. Post 20p. Octal base 15p extra

220/240 VOLT AC RELAY 3 c/o 5 amp cont. Sealed M.f.g. ISKRA **£1.35**. Post 20p. Base 15p extra

ARROW 230/240V AC 2 c/o 15 amp contacts. Amp connectors **£1.10**. Post 20p

110 VOLT A.C. 2 c/o 20 amp. **£1.35**. Post 15p

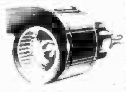
CLARE-ELLIOT Type RP 7641 G8 Miniature relay 675 ohm coil 24 volt D.C. 2 c/o **80p** P.P.

MANY OTHERS FROM STOCK. PHONE FOR DETAILS

LATCHING RELAY

Twin latching relay, 'flip-flop' 2c/o each relay. Mains contacts 115 volts A.C. or 50 volt D.C. operation or 240 volts A.C. with 2.5K resistor. **85p**. Post 20p.

PRECISION CENTRIGUGAL BLOWERS



Mfg. by Smiths Industries. Miniature model. Series SF/200. Size 95mm x 82mm x 82mm. Aperture 38mm x 31mm. 12 c.f.m. **£2.75**. Post 50p.

Mfg. by Airflow Developments Ltd. Precision made, continuously rated, smooth running 230/240v A.C. motor 80c.f.m. As illustrated but with round aperture. **£6.50**. Post 75p.

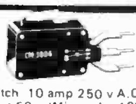
Mfg. by Woods. Extremely powerful 220/250v A.C. 0.3 amp 2,700 r.p.m. continuously rated. Capacitor start. Cast construction. Aperture 66mm x 50mm. O/A 200mm. **£12.00**. Post £1.00

230 VOLT FAN ASSEMBLY

Continuously rated, removable aluminium blades. Price **£1.25**. Post 50p.

VAT 25%

C/O MICRO SWITCH



VERY SPECIAL OFFER. Mfg. by C.E.M. 3 amp 250 volt, 10 amp 125 volt, 50 for **£3**. Post 36. 100 for **£5**. Post 50p. 1,000 for **£45**. Post paid.

DOUBLE POLE C/O or 2 make/2 break micro switch 10 amp 250 v A.C. With detachable roller assembly 10 for **£2.50**. Post 50p (Min. order 10)

MINIATURE ROLLER

M. switch OMRON type V15 FL 22-1C 10 for **£2.00** post 50p (Min. order 10)

230-250 VOLT A.C. SOLENOID

Similar in appearance to illustration. Approximately 1½ lb pull. Size of feet 1⅞" x 1⅜" Price **£1.00**. Post 25p.

SOLENOID HEAVY DUTY MODEL

230/250v A.C. Apprx. 10lb. pull, 4" long x 2⅜" wide x 3" high **£2.50**. Post 50p

24 VOLT DC SOLENOIDS

UNIT containing 1 heavy duty solenoid approx. 25 lb. pull at 1 in. travel, 2 solenoids of approx. 1 lb. pull at ½ in. travel. 6 solenoids of approx. 4 oz. pull at ¼ in. travel. Plus 1 24V D.C. 1 heavy duty 1 make relay. Price **£2.50**. Post £1.00. **ABSOLUTE BARGAIN.**

240 V A.C. SOLENOID OPERATED FLUID VALVE

Rated 1 p.s.i. will handle up to 7 p.s.i. Forged brass body, stainless steel core and spring. ⅛ in. b.s.p. inlet/outlet. Precision made. British mfg. PRICE **£2.25**. Post 50p. NEW original packing

600 WATT DIMMER SWITCH

Easily fitted. Fully guaranteed by makers. Will control up to 600 watts of all lighting except fluorescent at mains voltage. Complete with simple instructions. **£2.75**. Post 25p

1000 watt model	**£4.00**. Post 25p
2000 watt model	**£8.00**. Post 40p

VARIABLE VOLTAGE TRANSFORMERS

Carriage extra — INPUT 230 v. A.C. 50/60 — OUTPUT VARIABLE 0/260v. A.C.

BRAND NEW. All types.

200W (1 Amp)	£10.00
0.5 KVA (Max. 2½ Amp)	£11.50
1 KVA (Max. 5 Amp)	£16.50
2 KVA (Max. 10 Amp)	£30.00
3 KVA (Max. 15 Amp)	£33.00
4 KVA (Max. 20 Amp)	£60.00
(max. 37.5 Amp)	£102.50

LT TRANSFORMERS

0, 6, 12 volt @ 10 amp	£5.60 Post 70p
0, 10, 17, 18 volt @ 10 amp	£7.90 Post £1.00
0, 6, 12 volt @ 20 amp	£9.00 Post £1.00
0, 12, 24 volt @ 10 amp	£9.20 Post £1.00
0, 4, 6, 24, 32 volt @ 12 amp	£9.90 Post £1.00
0, 6, 12, 17, 18, 20 volt @ 20 amp	£10.40 Post £1.00

Other types to order at short notice. Phone your enquiries.

AUTO TRANSFORMERS

Step up step down 0, 115, 200, 220, 240 volts

At 75 watt **£3.00** Post 40p. 150 watt **£4.30** Post 50p. 300 watt **£6.20**. Post 60p. 500 watt **£9.20** Post 75p. 1000 watt **£13.50** Post 90p.

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Functional Versatile Educational

These multi-purpose Auto Transformers, with large centre aperture, can be used as a Double wound current Transformer, Auto Transformer, H.T. or L.T. Transformer, by simply hand winding the required number of turns through the centre opening. E.g. Using the RT 100 V.A. Model the output could be wound to give 8V @ 12½ Amp., 4V @ 25 Amp. or 2V @ 50 Amp., etc. Price

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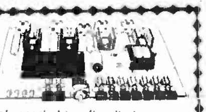
HY-LIGHT STROBE Mk. IV
Latest type Xenon white light tube. Solid state timing and triggering circuit. 230/240 volt A.C. operation. Speed adjustable 1-20 f.p.s. Designed for large rooms, halls, etc. Light output greater than many (so called 4 Joule) strobes. Price **£15.40**. Post 75p.

XENON FLASH GUN TUBES
Range of Xenon tubes available from stock. S.A.E. for full details.

ULTRA VIOLET BIG BLACK LIGHT
400 Watt. Mercury vapour ultra violet lamp. Extremely compact and powerful source of u.v. Innumerable industrial applications also ideal for stage display, discos etc. P.F. ballast is essential with these bulbs. Price of matched ballast and bulb **£24.00**. Post £1.50. Spare bulb **£8.00**. Post 65p.

ULTRA VIOLET BLACK LIGHT FLUORESCENT TUBES
4ft. 40 watt £6.00 (callers only). **2ft. 20 watt £4.60**. Post 60p (For use in std. bi-pin fittings) MINI **12in. 8 watt £1.75**. Post 25p. **9in. 6 watt £1.40**. Post 25p. Complete ballast unit and holders for either 9" or 12" tube **£1.70**. Post 30p (9" x 12" measures approx.)

SQUAD LIGHT



A new conception in light control. Four channels each capable of handling 750 watts of spotlights, floodlights, or dozens of small mains lamps. Seven programs all speed controlled plus flash modulation, effectively giving 14 different displays. Makes sound-to-light obsolete. Completely electrically and mechanically noise free. Price only **£58.00**

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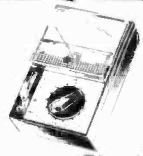

MULTI RANGE METER A.C. volts 2.5-500. D.C. volts 2.5-500 (Sensitivity 2000Ω/V DC & AC). DC current 0/1/10/100 mA. Ohms range. Sturdy compact moving coil instrument with 21 ranges. dimensions 120x 80x 44mm. Weight 0.32 kg. SERVICE TRADING CO. Price **£5.00**. Incl. leads and battery. Post 50p. (Total price inc. VAT & Post **£5.94**).

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90mm Diameter.
Type 65C5 2A D.C. M/C. 5A D.C. M/C. 10A D.C. M/C. 20A D.C. M/C.
Type 62T2 1A A.C. M.I. 20A A.C. M/I. 300V A.C. M/I. ALL ABOVE **£2.50**. Post 30p
Type 65L5 300V A.C. R/M/C **£2.75**. Post 30p

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VAT AT 8% MUST BE ADDED TO ALL ORDERS FOR THE TOTAL VALUE OF GOODS INCLUDING POSTAGE UNLESS OTHERWISE STATED

NICKEL CADMIUM BATTERY

Type VO22 1.2V 22AH height 210mm width 55mm depth 25mm weight 1050 gms **£1.75**. post 50p + 25p extra each additional cell.

GEARED MOTORS

100 R.P.M.

115 lb. ins. 110 volt 50Hz. 2.8 amp., single phase, split capacitor motor. Emense power. Continuously rated. Totally enclosed. Fan cooled. In-line gear box. Length 250mm. Dia. 135mm. Spindle Dia. 15.5mm. Length 145mm. ex-equipment **£14.00**. Post £1.50. Suitable transformer 230/240 volt tested **£8.00**. Post 75p

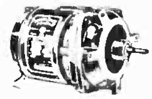
15 R.P.M.

Type SD48 15 r.p.m. 80 lb. ins. Input 100/120 volt A.C. Length incl. gearbox 270mm. Height 135mm. Width 150mm. Shaft drive 16mm. Weight 8.5 Kilos. BRAND NEW Price **£10.00**, carr. £1.00. Suitable transformer for use on 220/240 volt A.C. **£3.85**. Post 50p.

60 R.P.M. REVERSIBLE

220/240 volt A.C. Small, powerful, continuously rated motor. Mfg. BERGER (Germany). Size 80mm x 65mm x 65mm. Spindle dia. 6mm. Length 15mm. Weight 725 grams. **£6.50**. Post 50p

BODINE TYPE N.C.I. GEARED MOTOR



(Type 1) 71 r.p.m. torque 10 lb. in. **Reversible** 1/70th h.p. cycle 38 amp. **(Type 2) 28 r.p.m.** torque 20 lb. in. **Reversible** 1/80th h.p. 50 cycle 28 amp. The above two precision made U.S.A. motors are offered in 'as new' condition. Input voltage of motor 115v **A.C.** Supplied complete with transformer for **230/240v A.C. input.**
Price, either type **£6.25**. Post 75p or less transformer **£3.75**. Post 65p.
These motors are ideal for rotating aerials, drawing curtains, display stands, vending machines, etc. etc.

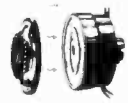
20 r.p.m. GEARED MOTOR

230/240 volt 20 r.p.m. motor. **£1.00**. Post 20p.

REVERSIBLE MOTOR 230V A.C.

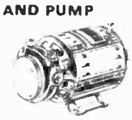
General Electric. 230v A.C. 1,600 r.p.m. 0.25 amp. Complete with anti-vibration mounting bracket and capacitor. O/A size 110mm x 95mm. Spindle 5/16" dia. 20mm long. Ex-equipment tested **£3.00**. Post 50p.

BENDIX MAGNETIC CLUTCH



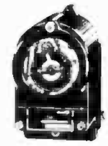
A superb example of Electro-mechanics! The main body is in two sections. The coil section is fixed and has a ⅜in sleeve. The drive section rotating on the outer perimeters. The uniting plate has ⅜in ID bearing concentric with main section and 18-tooth cog wheel.
When energized transmission is extremely powerful. 24V d.c. at 240MA. OUR PRICE JUST **£3.50**. Post 45p

ROTARY VACUUM AIR COMPRESSOR AND PUMP



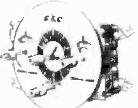
Carbon vane, oil-less. 100/115V A.C. 1/12 h.p. motor. 50/60 cycle. 2875/3450 r.p.m. 20" vacuum. 1.25 c.f.m., 10 p.s.i. (approx. figures). New unused surplus stock, with elect. connection data. Fraction of maker's price. **£12.00**. Post £1.00. Suitable transformer **£3.50**. Post 50p.

TIME SWITCH



Horstmann Type V Mk II Time Switch. 200/250 volt A.C. Two on/two off every 24 hours, at any manually pre-set time. 30 amp contacts. 36-hour spring reserve in case of power failure. Day omitting device. Fitted in heavy high impact case, with glass observation window. Built to highest Electricity Board spec. individually tested. Price **£7.75**. Post 50p. (Total inc. VAT £8.91.)

A.C. MAINS TIMER UNIT

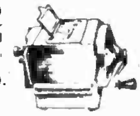


Based on an electric clock with 25 amp. single pole switch, which can be preset for any period up to 12 hrs. ahead to switch on for any length of time, from 10 mins. to 6 hrs. then switch off. An additional 60 min. audible timer is also incorporated. Ideal for Tape Recorders, Lights, Electric Blankets, etc. Attractive satin copper finish. Size 135 mm x 130 mm x 60 mm. Price **£2.25**. Post 40p. (Total inc. VAT & Post **£2.87**.)

POWER RHEOSTATS

New ceramic construction, vitreous enamel embedded winding, heavy duty brush assembly, continuously rated.
25 WATT 10, 25, 100, 150, 250, 500, 1k, 1.5k ohm. **£1.70**. Post 20p. **50 WATT** 1, 5, 10, 25, 50, 100, 500, 1k ohm. **£2.10**. Post 25p. **100 WATT** 1/10/25/50/100/250/500/1k/1.5k/2.5k/5k ohm. **£3.30**. Post 35p.
Black Silver Skirted knob calibrated in Nos. 1-9, 1½ in. dia. brass bush. Ideal for above Rheostats, 22p ea.

INSULATION TESTERS (NEW)



Test to I.E.E. Spec. Rugged metal construction, suitable for bench or field work, constant speed clutch. Size L. 8 in., W. 4 in., H. 6 in., weight 6 lb.
500 VOLTS 500 megohms **£36.00**. Post 80p.
1000 VOLTS 1000 megohms **£44.00**. Post 80p.

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MULLARD THYRISTOR TRIGGER MODULE

This produces pulses for phase control triggering it has two isolated outputs so one thyristor or two thyristor (in separate arms of bridge) may be controlled by one module The timing circuit is synchronised to the mains frequency and control is by an external variable resistor or from a voltage or current source Provision is made for feed-back where automatic control is required Price **£5.95.**

MAINS TRANSISTOR PACK

Designed to operate transistor sets and amplifiers Adjustable output 6v 9v 12 volts for up to 500mA (class B working) Takes the place of any of the following batteries PP1 PP3 PP4 PP6 PP7 PP9 and others Kit compromises main transformer rectifier smoothing and load resistor condensers and instructions Real snip at only **£1.50.** VAT and postage 60p

MULTI-SPEED MOTOR

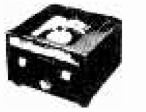
Six speeds are available 500 850 and 1 100 r p m and 8,000 12 000 and 15 500 r p m Shaft is ¼in diameter and approximately 1in long 230/240v Its speed may be further controlled with the use of our Thyristor controller Very powerful and useful motor size approx 2in dia x 5in long Price **£1.40** + 45p post and VAT

SPEED CONTROL SWITCH **50p** + 4

DC HIGH CURRENT PANEL METERS

3½in wound wide angle 240 movement meters flush mounting fitted with external shunts made by Crompton Parkinson brand new still in maker s cartons These are a real bargain at £5 50 each Reasonable quantities available in the following ranges 0 10 amps 0 20 amps 0-30 amps 0-40 amps 0 50 amps Post and VAT 80p each

TAPE DECK



In metal case with carrying handle heavy fly wheel and capstan drive Tape speed 3¾ Mains operated on metal platform with tape head and guide Not new but guaranteed good working order Price **£1.50** plus VAT and postage £1 50

SOUND TO LIGHT UNIT

Add colour or white light to your amplifier Will operate 1 2 or 3 lamps (maximum 450w) Unit in Box all ready to work **£7.95** plus 95p VAT and postage

OVEN THERMOSTAT

Made by the famous Diamond H Company this has a sensor joined by a capillary to a variable control and when fitted with a knob is ideal for many ovens or processes **50p** each + post and VAT 15p

HONEYWELL PROGRAMMER

This is a drum timing device the drum being calibrated to equal divisions for switch-setting purposes with trips which are infinitely adjustable for position They are also arranged to allow 2 operations per switch per rotation There are 15 changeover micro-switches each of 10 amp type operated by the trips thus 15 circuits may be changed per revolution Drive motor is mains operated 5 revs per min Some of the many uses of this timer are Machinery control boiler firing dispensing and vending machines Display lighting animated and signs Signalling etc Price from makers probably over £20 each Special snip price **£9.95.** £1 00 post and VAT Don t miss this terrific bargain

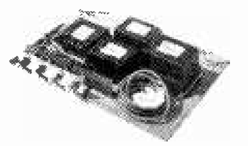
BREAK-DOWN UNIT

Contains hundreds of useful parts some of which are as follows – 66 silicon diodes equivalent OA 91 68 resistors mostly ½ watt 5% covering a wide range of values 4 x 1 mfd 400v infd condensers 15 x 01 mfd 100v condensers 2 RF chokes 8 x B9 valve holders 1 x 4H choke 1 x 115v transformer 1 boxed unit containing 4 delay lines also tag panels trimmer condensers suppressors etc on a useful chassis sized approx 9in x 5in x 7in Only 75p (the 66 diodes would cost at least 10 times this amount) This is a snip not to be missed Post and VAT 75p

THIS MONTH'S SNIP

250 watt Transformer is a very versatile transformer which can be used for many purposes Rated at 250 watts it is very well built with frames for upright mounting and is varnish impregnated Its primary is for 230 240 volts 50 cycles it has four secondaries each 10v very high current windings Just a few of the circuits it can power are 10 0 10v at up to 12 amps 20-0-20v at up to 6 amps single 10v at 25 amps single 20v at 12½ amps single 30v at 9 amps single 40v at 6 5 amps The transformer can be used for power circuits (charging etc) or for amplifiers there being an earth screen between primary and secondaries A transformer like this today would cost at least £15 from the makers however we are making a special offer at **£3.50** + 28p post £1 + 8p each Grab some while you can our stock may not last long

MULLARD UNILEX



A mains operated 4 + 4 stereo system Rated one of the finest performers in the stereo field this would make a wonderful gift for almost any one In easy-to-assemble modular form and complete with a pair of Goodmans speakers this should sell at about £30 – but due to a special bulk buy and as an incentive for you to buy this month we offer the system complete at only **£15.50** including VAT and postage

TWIN OUTPUT POWER PACKS

These have two separately R C smoothed outputs so can operate two battery radios on a stereo amp without cross modulation (they will of course operate one radio/tape cassette/calculator in fact any battery appliance and will save their cost in a few months) Specs Full wave rectification double insulated mains transformer – total enclosed in a hard P V C case – three core mains lead terminal output – when ordering please state output voltage 4½v 6v 7½v 9v 12v or 24v Price **£3.95.** Post and VAT included

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YOU MAY BE IN TIME

for a valve volt-meter at **£7.50** – a signal generator at **£8.50,** a frequency standard at **£19.50** as these and many other good buys were offered in our December Advanced Advertising News Send S A E for a copy today

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All standard 230-250 volt primaries

		£ p
1v	1 amp (special)	**1.75**
2 4	5 amp	**.85**
6 3v	2 amp	**1.25**
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9v	1 amp	**.95**
9v	3 5 amp	**2.50**
12v	1½ amp	**1.50**
12v	1 amp	**1.00**
6 5v 0 6 5v	1 amp	**1.50**
18v	1 amp	**1.50**
24v	2 amp	**2.25**
24v	3 amp	**3.50**
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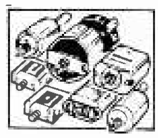

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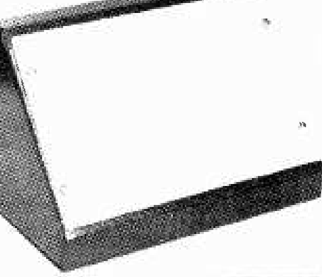

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Cases made from 20G. steel.
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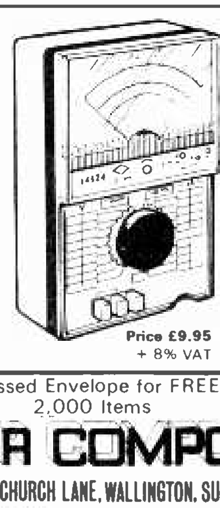

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FERRANTI

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WIREMAN-TESTER

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Please write for an application form to:—Young Electronics Ltd., 184 Royal College St., London NW1 9NN.

(5238)

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required for September, 1976, to take charge of full-time Radio, Television & Electronics Course and teach both theory and craft practical to parts 1 and 2 standard of the City & Guilds Mechanics 222 Course.

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NEWMAN APPOINTMENTS
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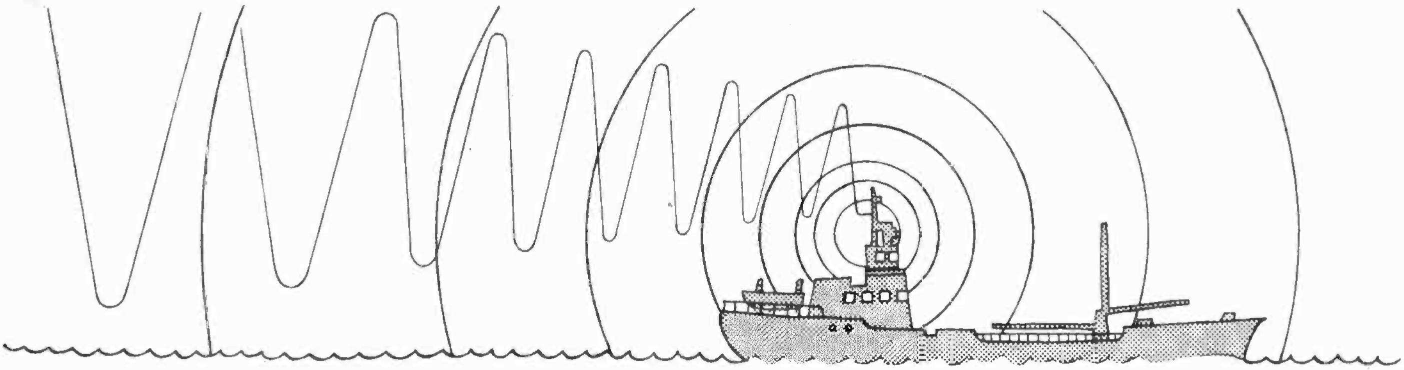

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A GEC-Marconi Electronics Company

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(5257)

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with extensive experience in digital techniques in one or more of the following areas:

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(5255)

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Single Men: 2 Year Contract — Return Fares Guaranteed.

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Medical Physics Department
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APPOINTMENTS

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Salary not a limiting factor

Project Engineer £3,000-£3600

Test Engineer £2500-£3100

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A Programming/Development Engineer is required to assist in the development of a range of audio visual and lighting control products based on the Intel 4040 microprocessor.
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Projects already in hand will involve the applicant in both hardware and software aspects of product design but it is anticipated that eventually the applicant will specialise in software and advise the Company in other areas of Computer application.

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Applications should be made by telephone or in writing to:
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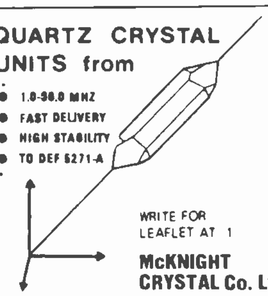

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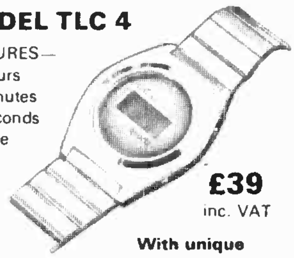

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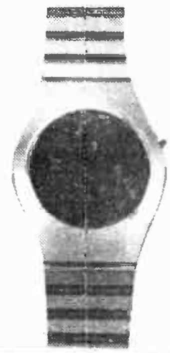

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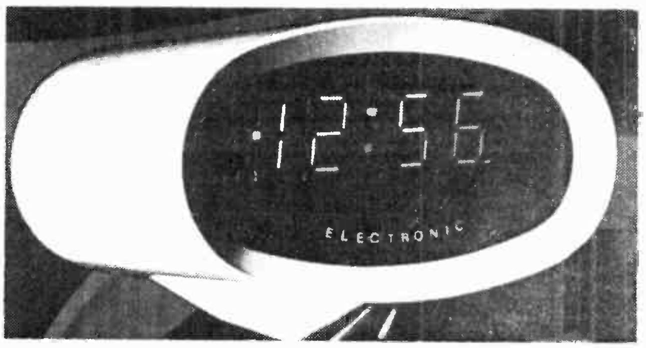

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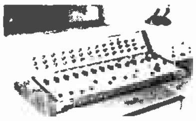

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INDEX TO ADVERTISERS

Appointments Vacant Advertisements appear on pages 130-142

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For the Great Names a Great Service

Bradley Electronics are well known as manufacturers of precision electronic instrumentation. But there's another important aspect of our business – we're also experts on other people's products.

For 21 years our Services Division has been providing a first-class repair and recalibration service for all types and makes of electronic test and measuring equipment – from simple meters to complicated systems. *Any* manufacturer's instrument in the frequency range DC to 18 GHz – and to 36 GHz in some cases – collected and delivered back to your door ready to plug-in.

The Services Division has its own 35,000 sq ft factory, expert staff, comprehensive spares, and a Standards Laboratory approved by the British Calibration Service. It will supply calibration certificates for AC, DC and RF measurements. And, of course, our standards are directly traceable to NPL and NBS.

So – when your calibrator won't calibrate anymore, your generator refuses to generate, or your counter stops counting – you know who to contact.

G & E BRADLEY LIMITED
Electral House, Neasden Lane,
London NW10 1RR
Telephone: 01-450 7811
Telex: 225583

A Lucas Company

BRADLEY electronics

WW—002 FOR FURTHER DETAILS

8 Hill Lane

Ersin Multicore- the international solder

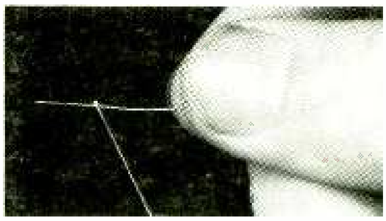
Ersin Multicore 5-Core Solder

The proved superiority of ERSIN Multicore Solder for over thirty years is due to many factors. We have specialised throughout this period in the manufacture of cored solders. Consequently our research and manufacturing staff have been able to devote all their energies to the development of Multicore Solders. All alloys are of highest purity, carefully formulated and checked.

Our unsurpassed ERSIN flux is rigorously tested before and after it is incorporated in the solder wire. Our five separate cores of flux ensure flux continuity, leave only an ultra-thin layer of solder separating flux from work for instant wetting and provide a more accurate ratio of flux to solder. It is therefore possible to use less solder and obtain greater reliability.

Our Quality Control at all stages of manufacture is guaranteed and recorded by the batch number on every reel.

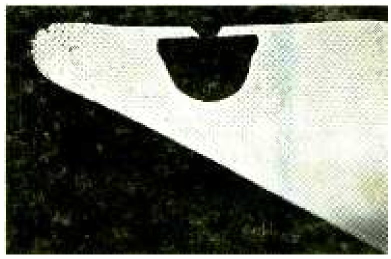
Needle fine gauges



In addition to our standard range of wire diameters (10-22 swg: 3.2-0.7 mm) supplied on 2½ kg and ½ kg reels we also mass-produce needle-fine gauges (24-34 swg: 0.56-0.23 mm) on 250 g reels for microminiature soldering applications—still with 5 Cores of flux.

Savbit Solder

One of our most popular special ERSIN Multicore Solder alloys is SAVBIT alloy. Compared with ordinary tin/lead solders it dramatically reduces the erosion of soldering iron bits, copper wires and printed circuit conductors. It also saves costs and increases reliability. SAVBIT alloy containing 5-Cores ERSIN 362 flux has received special Ministry approval—under DTD. 900/4535 for Military applications.



Sectioned iron-plated bit, after 40,000 simulated operations using 60/40 Solder.

Sectioned iron-plated bit, after 40,000 simulated operations using SAVBIT Solder.

ALLOY

Composition (nominal major elements)	Grade	Melting Temperature Solidus °C	Liquidus °C	Specification
50/33/17 Sn/Pb/Cd	TLC	145	145	DIN 1707
62/36/2 Sn/Pb/Ag	LMP	179	179	DIN 1707
62/35.7/2/0.3 Sn/Pb/Ag/Sb	Sn62	179	179	QQ-S-57 1E
63/36.7/0.3 Sn/Pb/Sb	Sn63	183	183	QQ-S-57 1E
60/40 Sn/Pb	K	183	188	B.S. 219
60/39.7/0.3 Sn/Pb/Sb	Sn60	183	188	QQ-S-57 1E
50/50 Sn/Pb	F	183	212	B.S.219
50/49.7/0.3 Sn/Pb/Sb	Sn50	183	212	QQ-S-57 1E
50/48.5/1.5 Sn/Pb/Cu	Savbit 1	183	215	DTD 900/4535 DIN 1707
45/55 Sn/Pb	R	183	224	B.S.219
40/60 Sn/Pb	G	183	234	B.S.219
40/59.7/0.3 Sn/Pb/Sb	Sn40	183	234	QQ-S-57 1E
30/70 Sn/Pb	J	183	255	B.S.219
20/80 Sn/Pb	V	183	275	B.S.219
15/85 Sn/Pb	—	225	290	—
Pure Tin	P.T.	232	232	B.S.3252
95/5 Sn/Sb	95A	236	243	B.S.219
5/93.5/1.5 Sn/Pb/Ag	H.M.P.	296	301	B.S.219

For full information on these and a Selector Guide to other MULTICORE products please write on your Company's letterhead direct to:

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