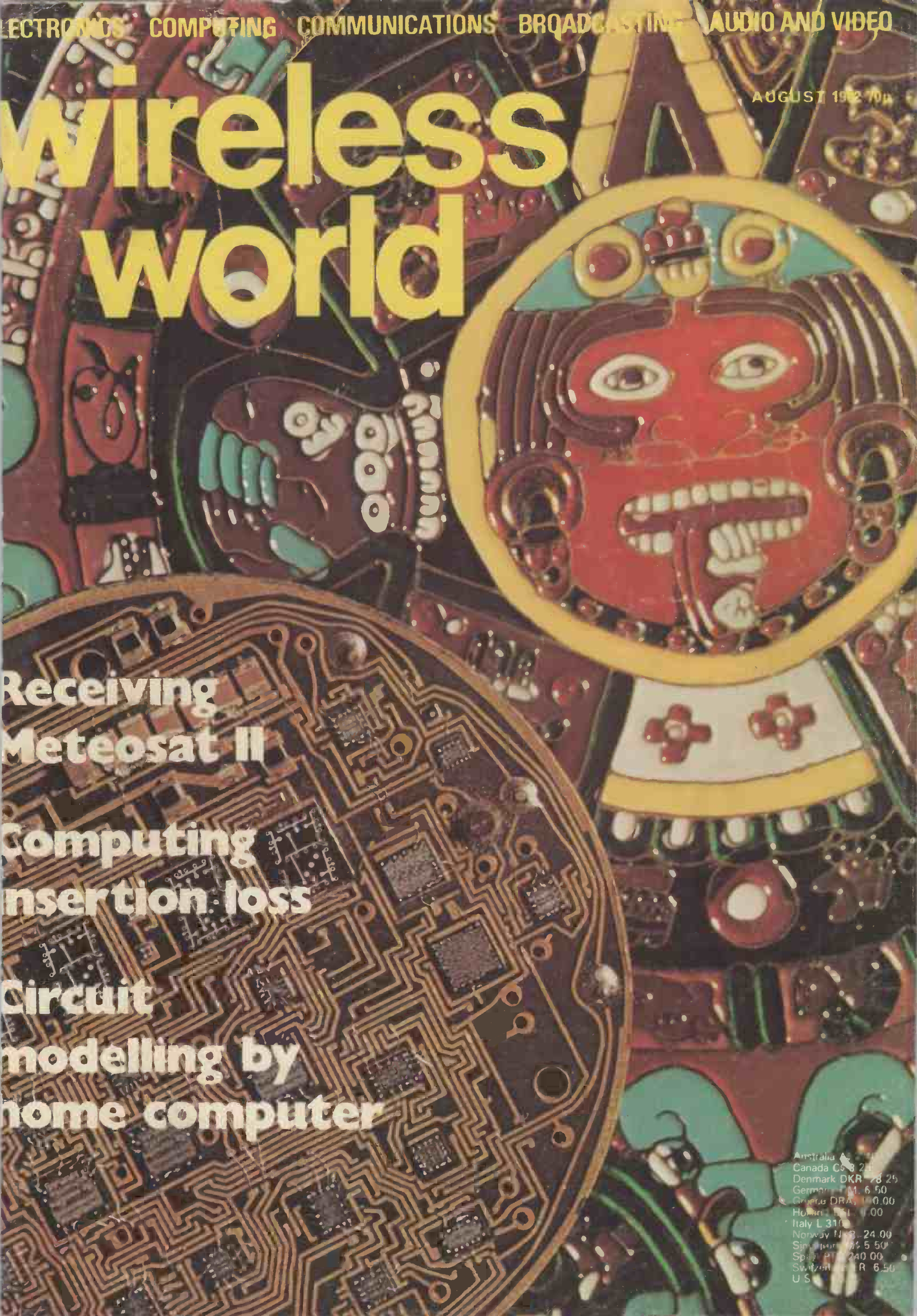

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AUGUST 1982 70p

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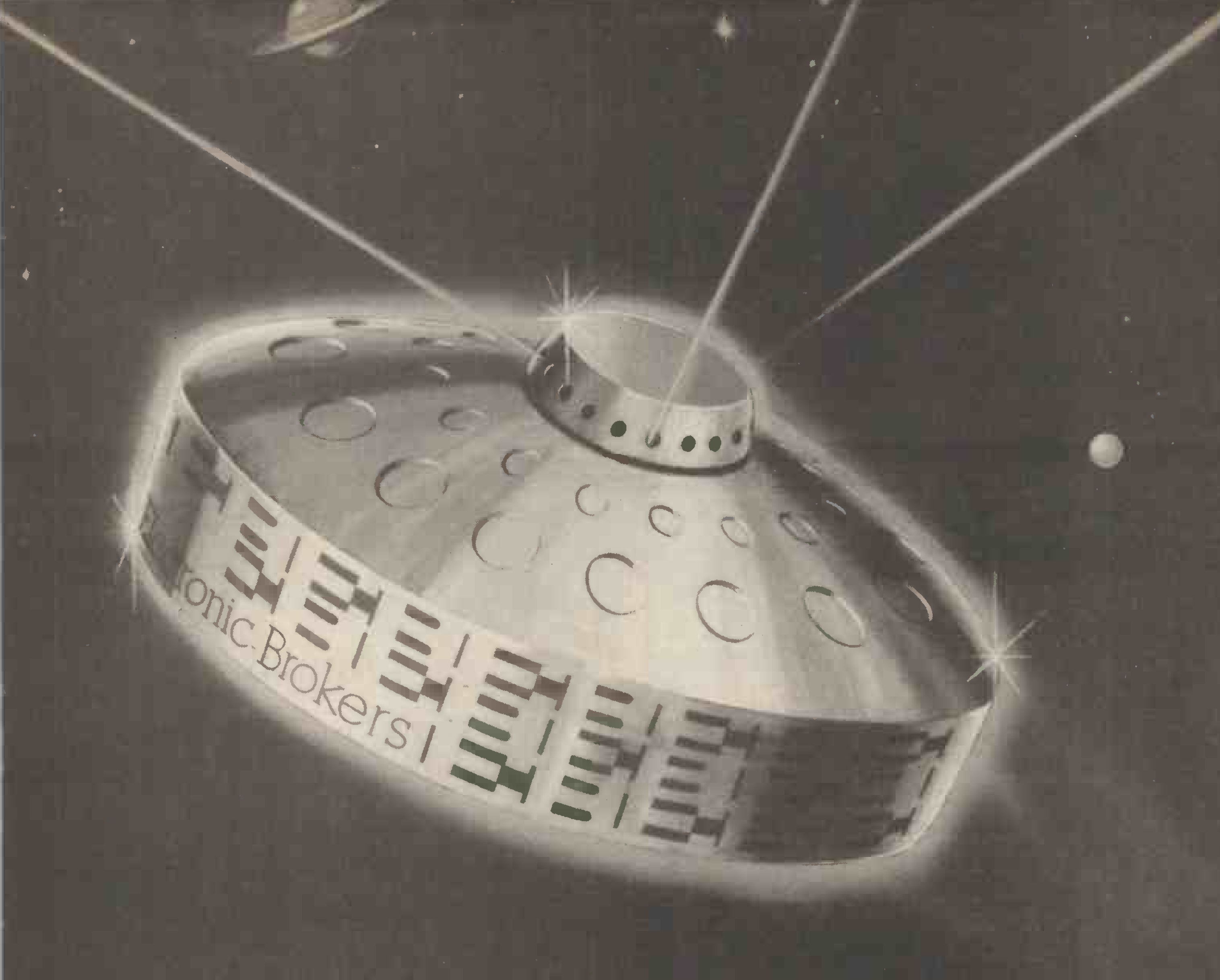

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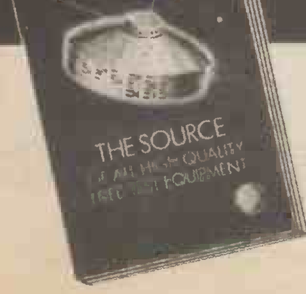

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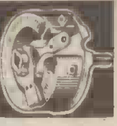

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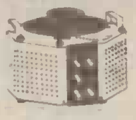

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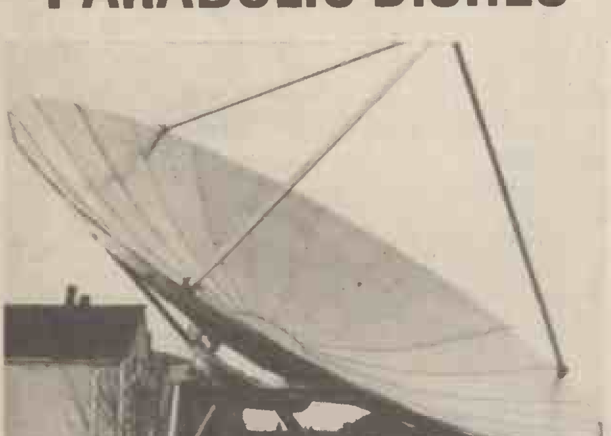

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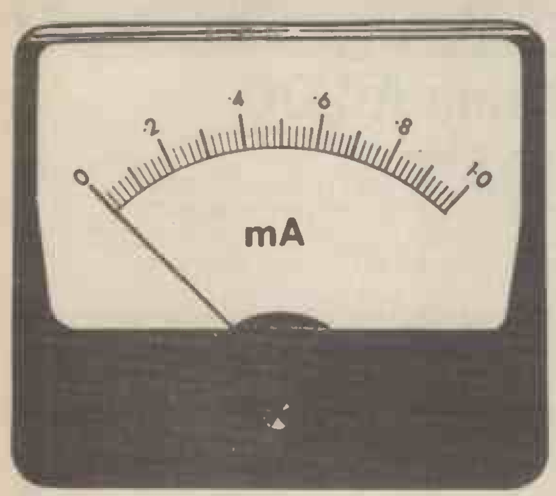

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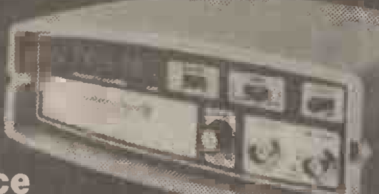

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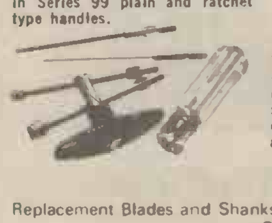

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7421	20p
7422	20p
7423	20p
7425	24p
7426	28p
7427	28p
7428	26p
7430	14p
7432	22p
7433	22p
7437	25p
7438	25p
7439	25p
7440	15p
7441	70p
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7443	90p
7444	90p
7445	50p
7446A	60p
7447A	40p
7448	45p
7450	15p
7451	15p
7453	15p
7454	15p
7460	15p
7470	36p
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7475	25p
7476	30p
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7482	70p
7483A	38p
7484	65p
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7492A	25p
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7497	90p
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74109	25p
74110	35p
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74116	50p
74118	80p
74119	80p
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74136	28p
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74145	50p
74147	90p
74148	70p
74150	50p
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74159	75p
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74163	48p
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74184A	90p
74185	90p
74186	500p
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74284	175p
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74LS170	75p
74LS173	70p
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74LS253	35p
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4086	55p
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4507	35p
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4516	50p
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TBA820	90p
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TBA950	225p
TC9109	900p
TCA210	350p
TCA220	350p
TCA940	175p
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ZN1040E	670p
ZNA234	850

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FIXED PLASTIC

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6V	7806	50p	7906	60p
8V	7808	50p	7908	60p
12V	7812	50p	7912	50p
15V	7815	50p	7915	50p
18V	7818	50p	7918	60p
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5V 100mA	78L05	30p	79L05	60p
6V 100mA	78L06	30p		
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10.5MHz	250p
10.7MHz	150p
12.00MHz	150p
14.318MHz	175p
14.756MHz	250p
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TIP32C	40p
TIP33A	70p
TIP33C	80p
TIP34A	90p
TIP34C	120p
TIP35A	120p
TIP35C	140p
TIP36A	140p
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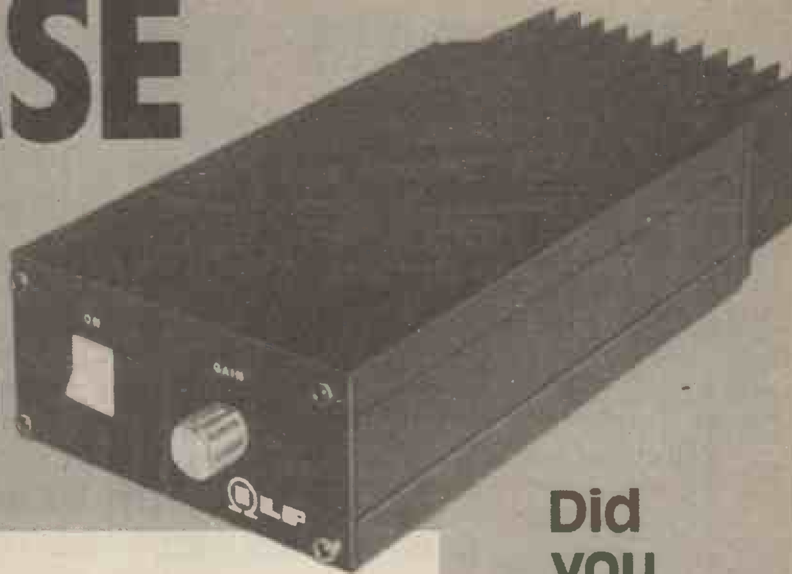

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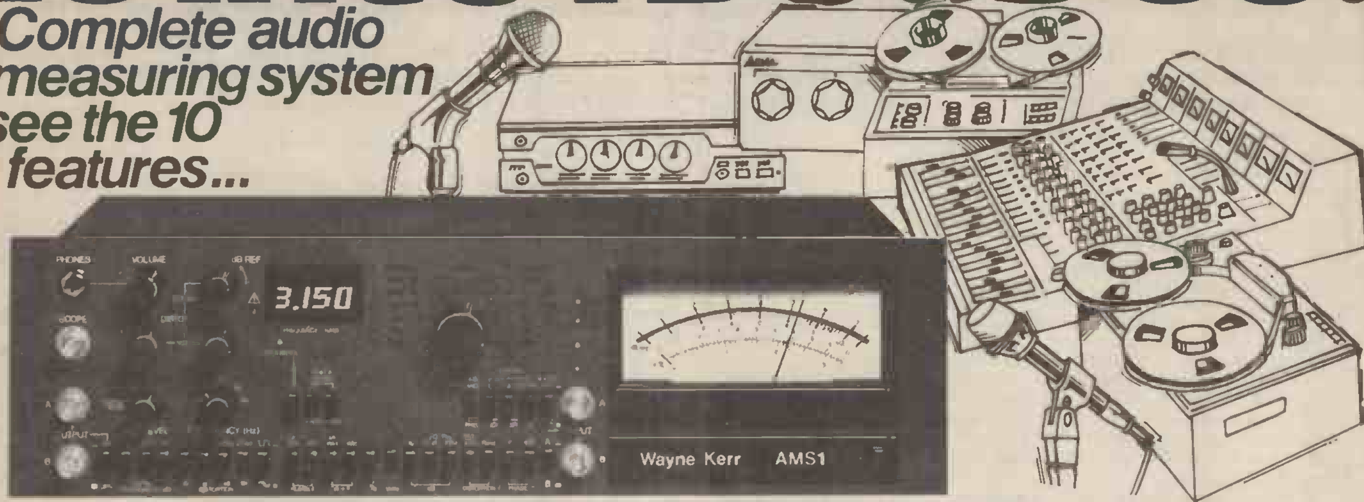

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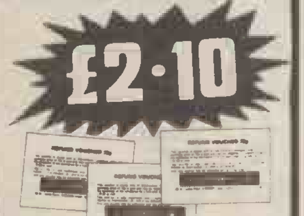

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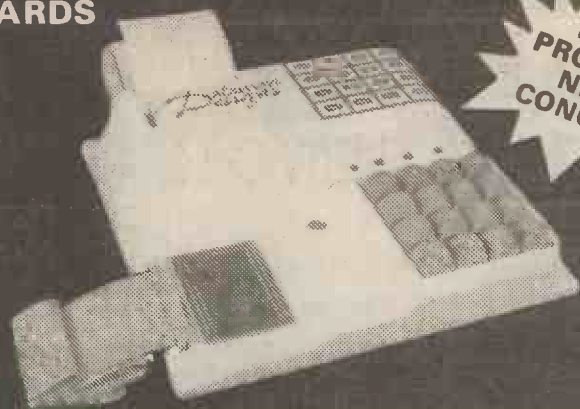

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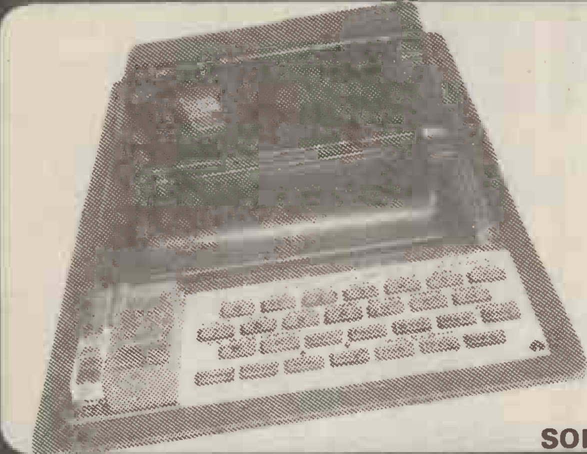

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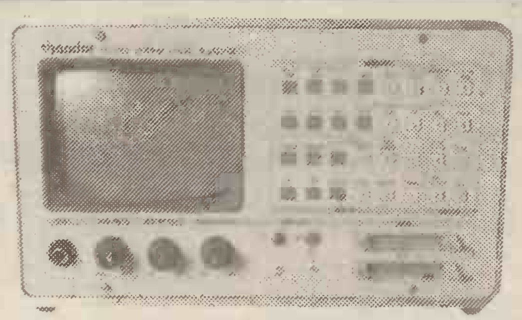

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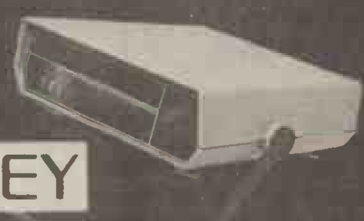

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In a recent Letter to the Editor, a reader described his feelings at seeing a copy of *Wireless World* for the first time after a long interval. On seeing the content, he felt impelled to write and suggest that the journal might benefit from a change of title, to take account of the fact that the World is now rather more computer-shaped than it was when wireless was the current miracle.

The letter constitutes cast-iron evidence to support the assertion, made by *WW* staff for seventy years, that one simply cannot produce a journal like this – the whole thing is logically impossible. Philosophy and printed boards, audio amplifiers and microcomputers, exposure meters and clocks do not, it must be admitted, appear to share much common ground. Neither, indeed, do the types of reader to whom our articles are addressed: the enthusiast making an amplifier on the corner of the kitchen table experiences but modified rapture at the prospect of an article on Rademacher-Walsh functions, though he may read it and be interested. The professional engineer does not require instruction in the design of an a-to-d converter, but he might want to build the digital voltmeter to which the article is an introduction. And one of the continuing arguments on basic physics possibly leaves both of them glassy-eyed, but nonetheless entertained.

The fact is, of course, that *Wireless World* is a hybrid in so many senses that it almost defies description. Both professionals and amateurs read it; the articles it contains are theoretical, or practical, or both; its topics cover the field from logic design to a discussion of the best material with which to stuff loudspeaker enclosures and from descriptions of optical-fibre communications systems to a design for an electronic cat-door.

In all this, the one common factor is electronics, in its wider sense. It leads us into any subject in which it is used – optics, chemistry, motoring, aviation – in addition to the more familiar area of telecommunications. Computers happen to be an important manifestation of electronic engineering and are therefore completely within our field of interest.

"Wireless" as a word disappeared in the forties or thereabouts, at around the time when "electronics" was born. But even then, *Wireless World* had been in existence for thirty-five years and its title was far too well known for Iliffe to risk causing an outcry by changing it.

Forty years on, computers, microprocessors and a mass of other digital circuitry have edged out the more traditional forms of electronic design – even sound reproducing is becoming digital in form. As this happens, it is clear that the content of the journal must change to meet new requirements, which is why a newcomer glancing at our contents page immediately after a look at the *Wireless World* logo might justifiably feel puzzled. If, however, a change of name after thirty-five years was felt to be too much of a shock for readers to bear, how much more of a jolt would it be after seventy-one?

The name is unimportant, except inasmuch as it sometimes misleads the casual bookstall browser and, perhaps, the not very well informed advertising agent. What is important is that the content should treat all aspects of electronics, which it will continue to do, no matter in what unexpected directions the subject leads us.

80-100W MOSFET AUDIO AMPLIFIER

The final section of this three-part article describes the complete amplifier circuit in detail, with the addition of a loudspeaker protection circuit.

by J. L. Linsley Hood

In the earlier parts of this article I discussed some of the design requirements of power mosfet audio amplifiers and described the evolution of a high-gain, symmetrical, class 'A' driver stage suitable for use with a power mosfet output. Inevitably, the final design of the gain stage, as shown in the completed power amplifier circuit of Fig. 14, shows some minor differences in comparison with the basic voltage-amplifier circuit, which underlines the point that any final design represents only the small tip of a large submerged iceberg of design effort. Unless one is lucky, or one's target performance is relatively modest, or one has considerable experience with closely similar designs, there is always a large amount of work necessary to convert a reasonably satisfactory basic design into a final version having, as nearly as possible, a blameless performance under all conceivable test conditions.

Design considerations

The choice of output power rating for any power amplifier is, inevitably, somewhat arbitrary and depends on the voltage ratings of the available components, and on the cost of the power transformer, smoothing capacitors and heat sinks which one is prepared to afford. However, in practical terms, the major considerations which limit the possible output power are the voltage ratings of the output devices, and of the available electrolytic reservoir capacitors.

The output power mosfets I decided to use are the complementary n-channel and p-channel devices from Hitachi, since they are readily available, are reasonably inexpensive, appear to be adequately rugged, and have useful power ratings. These particular mosfets are available in peak working voltages up to 160V. However, there are other similar devices, either available now or promised in the near future, from Fairchild, Motorola, Ferranti, Supertex, International Rectifier and Intersil, so it seems likely that a design based on complementary power mosfets will not restrict the user to a single source of components.

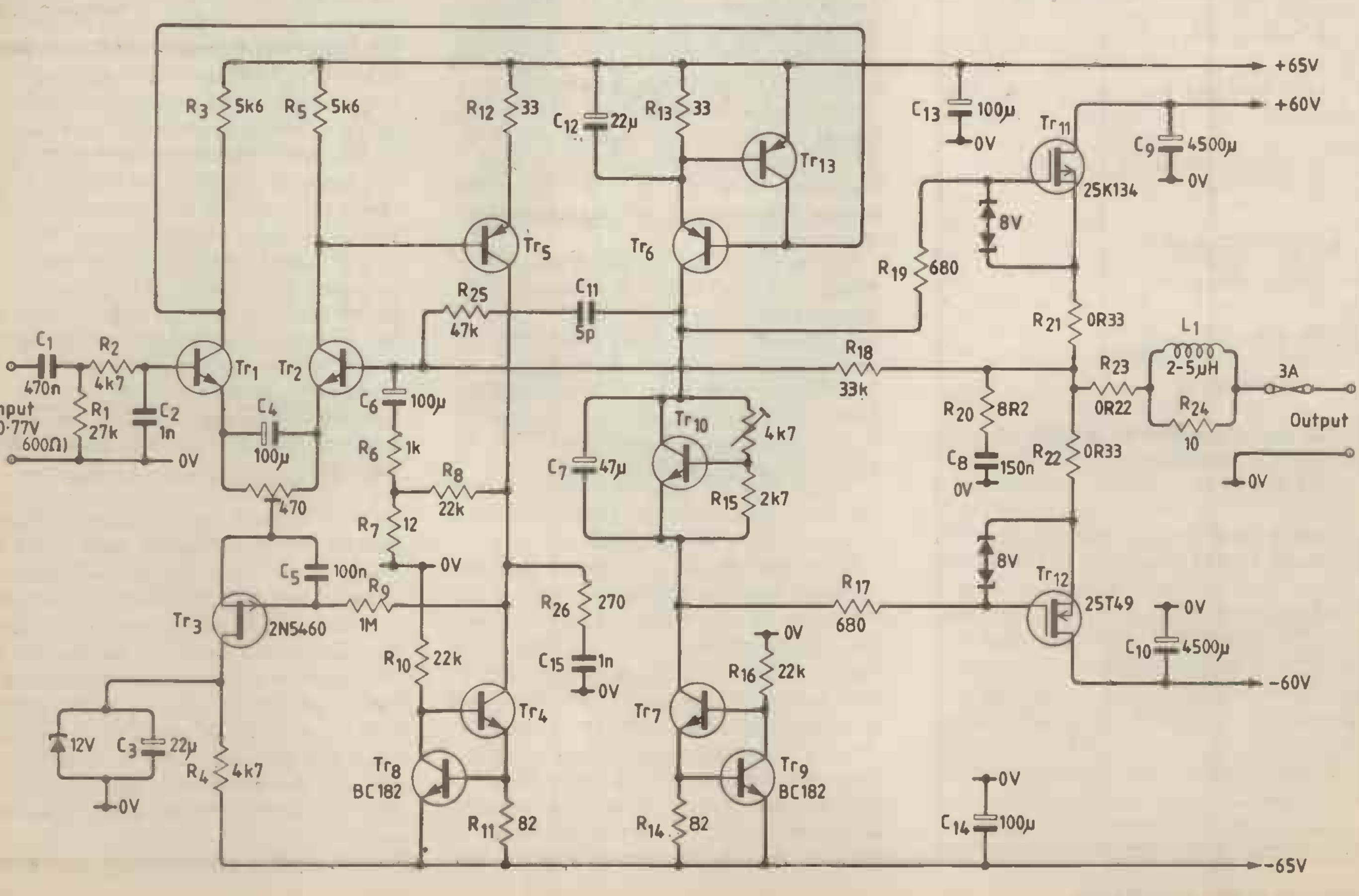
Some earlier experiments with mosfet-output audio amplifiers had shown that the r.m.s power output could be related to the available supply voltage in the manner shown in Fig. 15, over the range 25-100 watts. Since it had been decided, for various reasons, to use a symmetrical positive and negative supply, 63V electrolytic capacitors on each half would allow a safe working voltage, overall, of 120 volts, equivalent to a ±60V supply. In practice, the limited regulation of a simple rectifier/-capacitor power supply is likely to reduce this, on load, to some ±55V, giving an overall power output of 80 watts.

This output power requires a voltage swing of 25.3V r.m.s. across an eight ohm load, and if it is desired to drive this from an input voltage of '0VU' – which in audio-engineering terms implies 0.775V r.m.s. at a 600 ohm source impedence – the gain will require to be 32.6, which gives a suitable feedback resistor combination of 33k and 1041 ohms – though, in the event, for other considerations, it was decided to make this 1012, made up from a 1k and an 12 ohm series chain.

In the interests of d.c. symmetry, the input-circuit resistance should be also of the order of 33k. The values suggested are adequately close to this.

The performance of any feedback ampli-

Fig. 14. *Complete circuit diagram of the 100W amplifier.*



fier under transient (step-function or square wave) input conditions is helped if the input rise time can be limited. This can be done most easily by an input RC integrating network, R_2C_2, which gives a -3dB point at about 30kHz, allowing an adequate bandwidth for audio use.

A 470 ohm trimmer potentiometer in the emitter circuit of the input long-tailed pair allows accurate d.c. balance to be obtained with transistors having normal commercial spreads in V_{be} values and current gain. This is bypassed by a 100μF tantalum bead capacitor to avoid loss of open-loop a.c. gain. The output d.c. potential may be adjusted by means of this potentiometer to 0V, ±20mV.

Circuit performance depends strongly on the characteristics of the 'tail' of the 'long-tailed pair'. For correct operation of any such circuit, the dynamic impedance of the tail should be very large in comparison with the impedance as seen at the emitters of Tr_1 and Tr_2. Also, ideally, to minimize common-mode problems, the current from this source should be largely independent of the dynamic emitter potentials. Finally, the tail circuit should provide an adequate isolation from unwanted signal components on the supply line. A junction fet satisfies all these requirements very fully, and also allows, as explained above, control of the operating current in the second-stage class A amplifier. To allow a wider range of negative supply-line voltages, the negative-line supply to this fet is derived from a Zener-diode-stabilized -12 volt source. The use of a separate power supply for the driver stages is of considerable assistance in avoiding the performance degradation which can occur due to the intrusion of distorted signal potentials from the high-current output stage.

The second stage, class 'A', voltage amplifier is similar to that shown earlier in Fig. 13, except that conventional, two-transistor, constant-current sources are used as the loads for each half, and that a small amount of a.c. positive feedback is derived from the output of Tr_5, through R_8 and R_7, in addition to the current stabilizing d.c. negative feedback path through R_9 to Tr_3. The positive feedback restores the open loop a.c. gain to the 500,000 figure, over the frequency range 100Hz-3kHz, obtainable from the less d.c. stable configuration of Fig. 12.

The output power mosfets require a quiescent current value of 100mA for optimum performance – although it is difficult, because of the efficient operation of the n.f.b. loop, to see any significant change in the distortion residues, as this is adjusted, at any frequency below 10kHz – and this quiescent current is largely independent of the output device temperature. The 'amplified diode' circuit of Tr_{10} is not, therefore, used to sense the output transistor temperature, but used simply to generate a reasonably constant voltage drop.

Although the output devices present a very high l.f. input impedance, the effect of the 1200pF total gate-source capacitance cannot be ignored, and the current through Tr_6-Tr_7 must be enough to avoid any slew-rate limiting within the rise-time levels allowed by the input CR network, (R_2C_2). A current of 7mA is adequate for this, and permits worst-case dissipations of 900mW for $Tr_{4,7}$ and 450mW for $Tr_{5,6}$, which are within their limits.

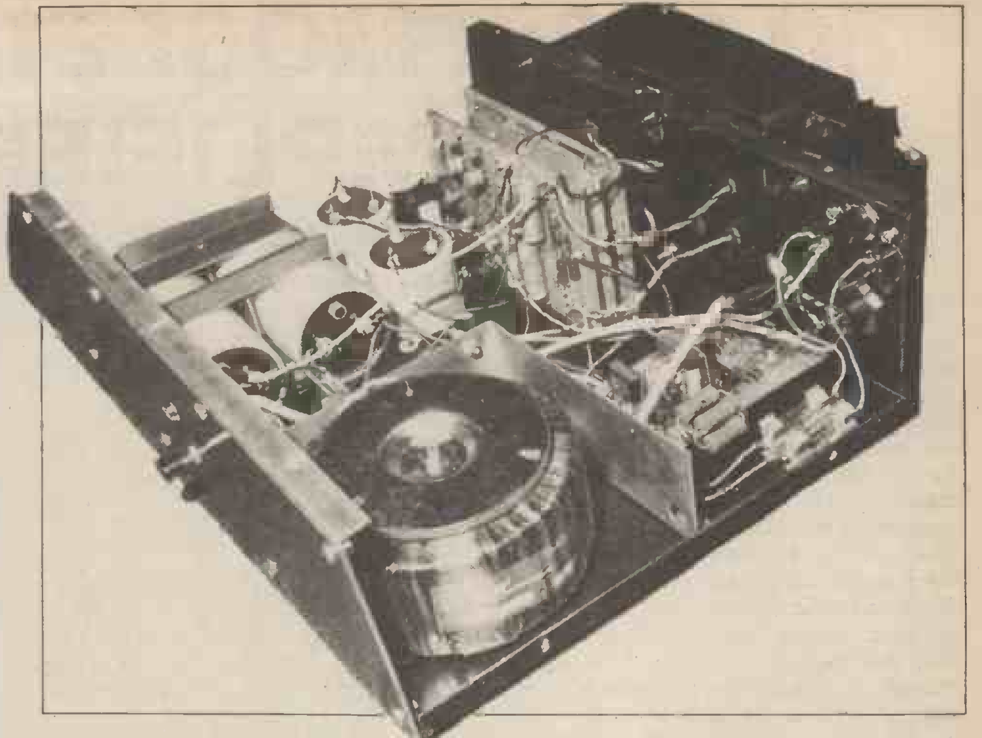
Since the Hitachi output devices are not protected by internal Zener diodes, it is unnecessary to exclude the possibility of reverse gate biassing, provided that this is within the ±14V gate-source breakdown voltage limits. This gate breakdown protection can therefore be provided by a pair of back-to-back 8V zeners, while the gate-source capacitance and the 680 ohm gate 'stopper' resistor will exclude the possibility of very rapid extraneous noise pulses which could escape Zener limiting due to lead inductance or turn-on time delays. Ideally, $R_{17,19}$ and the Zeners should be mounted close to the power mosfet pins.

Feedback loop, and loop stability

Although the use of a two-stage voltage amplifier will not automatically gurarantee, under all load conditions, that the internal phase shift will not approach 180° until the open-loop gain is negligible, the necessary conditions for an adequate phase margin, at unity gain, are very much easier to contrive in circuits in which only two successive gain stages are employed – provided that the additional phase shift of any other element in the feedback path is small enough to be neglected.

Unfortunately, in the case of the conventional junction-transistor Darlington or compound (p-n-p/n-p-n.) emitter follower this additional phase shift is significant, even at a few hundred kilohertz where the loop gain is still high, so this loop gain must be artificially reduced at higher frequencies to preserve closed-loop stability. Two basic methods exist for this, of which the first, and simpler, is simply to connect an external capacitor across the whole of the gain stage so that this acts as an integration network with a gain decreasing linearly by 20dB/decade from some l.f. break point. This has the advantage of allowing a wide phase margin of stability, and predictable performance characteristics. The second method is to tailor the h.f. performance so that it is maintained at as high a level as possible up to the point at which the loop phase shift approaches 180°, and then to reduce the gain rapidly, and in a manner chosen not to exceed the 180° stability threshold, until it is less than unity.

This method is commonly employed in



Prototype amplifier. Loudspeaker protection circuit is at rear right.

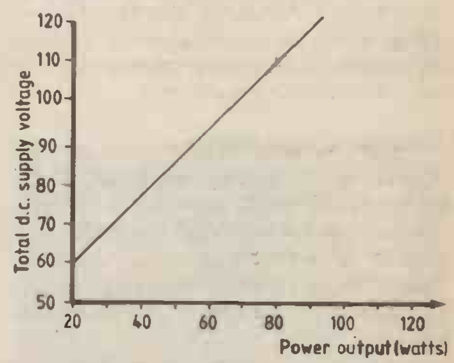


Fig. 15. *Amplifier output power as function of supply voltage.*

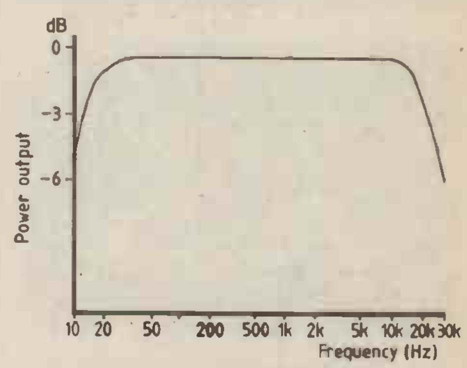


Fig. 16. *Power bandwidth of amplifier.*

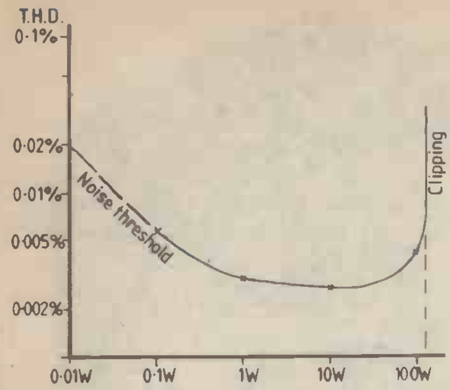


Fig. 17. *Harmonic distortion as a function of output power (1kHz, 8Ω load).*

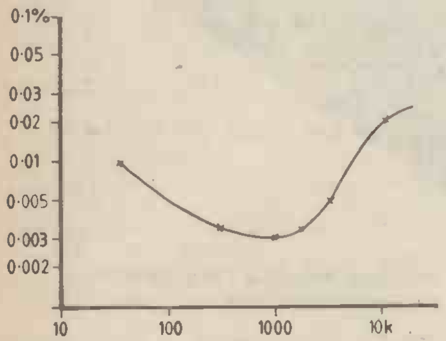


Fig. 18. *Harmonic distortion as a function of output frequency (80W, 8Ω load).*

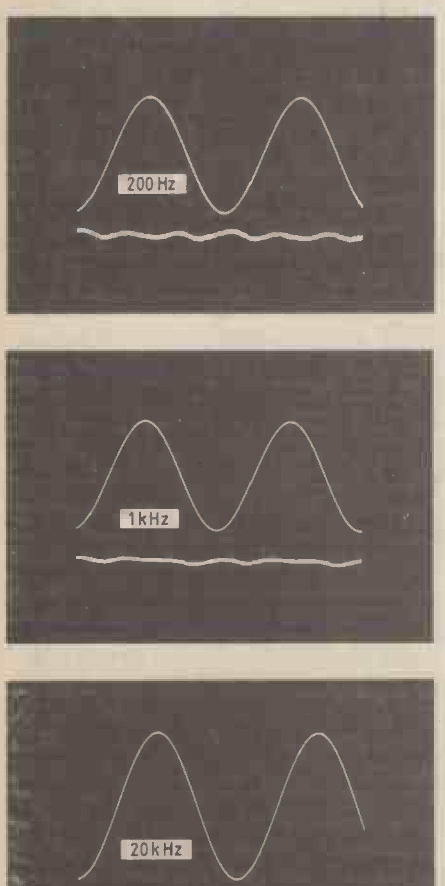


Fig. 19. *Harmonic distortion residues at 80W/8Ω for 200Hz, (0.004% mainly second harmonic), 1kHz (0.0025%) and 20kHz (0.025%).*

commercial transistor amplifier designs, often by the simple artifice of a capacitor between collector and base of the second stage amplifier transistor, because it allows better h.f. t.h.d. figures – and consequently better reviews in the 'Hi-Fi' journals. It does, however, carry with it the penalty that the phase margin of the amplifier is less good, with a consequently inferior transient response – manifest in respect of a less good 'settling time'[6] – and a less predictable performance with differing loudspeaker load characteristics. In addition, the intermal slew-rate limiting imposed by the second-stage collector-base capacitance (which is the mechanism by which the h.f. gain is reduced) leads to the predictable problem that signals accompanying large transient inputs will be blotted out during the period in which the amplifier is slew-rate limited. This is the phenomenon called 'Transient Intermodulation Distortion' by Otala[7]. This problem does not exist with the first method of h.f. compensation. A very good analysis of this problem was given by Jung[8] (with a small addendum by myself[9]).

The biggest advantage, in this respect, conferred by power mosfet output devices, is that the inherent phase-shift of the output emitter-follower impedance conversion stage is sufficiently small that it may be neglected up the megahertz region. This means that, with care, feedback audio amplifiers having high orders of negative feedback (open-loop gain) can be designed without the need for any external control of h.f. gain, and which will exhibit the desirable characteristics given by systems in which the gain decreases with frequency at 20dB/decade, and the loop phase shift does not significantly exceed 90°.

Influence of negative feedback

The use of negative feedback is, unfortunately, not as well understood, even among electronics engineers, as one might sometimes wish, and this misunderstanding has spilled over into the more emotive, and less logical, realm of the 'Hi-Fi' fraternity, where the ill effects attendant upon the improper use of this technique have encouraged the attempt to design amplifiers believed by their authors to employ no negative feedback whatever – a case of discarding the baby along with the bath water, if there ever was one.

The necessary conditions which must be satisfied if the potential benefits are to be gained have been examined both by Baxandall[10,11,12], in his series on audio amplifier design in this journal, and also, from a different angle, by *Wireless World*'s own Cathode Ray[13]. The message from all these contributions, if I may presume to precis, is that the amplifier in question must be made as linear as possible before negative feedback is applied; that the gain – at the frequency under consideration – must be enough, or the customary simplification of the mathematics will be inappropriate; and that a small amount of n.f.b., by injecting into the input an additional distorted signal, will worsen the harmonic distortion which would have been present without it.

Translated into design requirements,

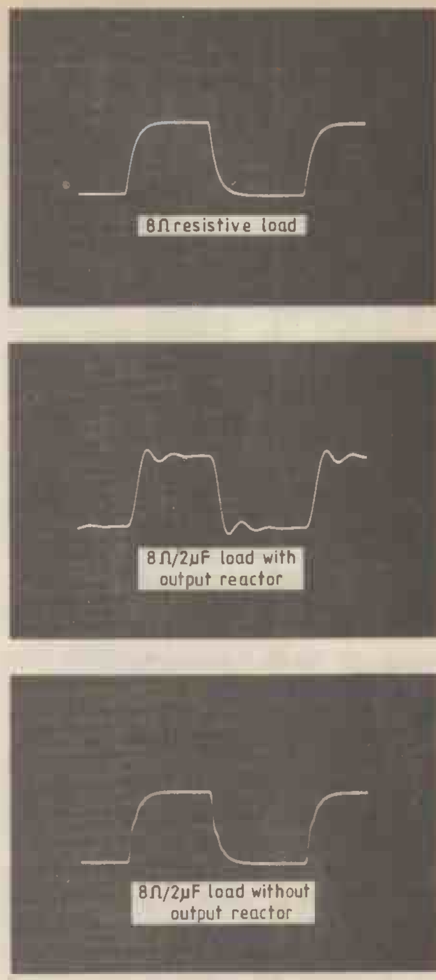


Fig. 20. *Response of amplifier to 10Vp-p 100kHz square wave on resistive and reactive loads, with and without output inductor.*

this implies that a high stage gain, coupled with good linearity and the lowest practicable phase shift, is the necessary design objective – most easily attained if not more than two gain stages are employed. The inclusion of a positive feedback path within the overall n.f.b. loop as a means of increasing the loop gain brings with it some supplementary requirements. These are that the phase shift within the positive feedback loop must be very small over the range of interest, since the p.f.b. will worsen it, and that the linearity of this part of the circuit must be much better than that of the remaining circuit outside the p.f.b. loop, or the benefits will be negated. Looked at in this light, the use of a bootstrapped driver load in an audio amplifier is not well advised, since the loop containing the 'bootstrap' will include the output devices whose linearity it is desired to improve.

In the particular case of the feedback loop built around Tr_2, Tr_5, R_8 and R_7, the linearity of this is very good because it is only driving a high-value resistive load, and the dominant phase shifts are those due to C_6 at the l.f. end, and the circuit stray capacitances in Tr_5 collector circuit at the h.f. end of the pass band. This gives a phase-linear bandwidth which is greater than that of the overall n.f.b. gain loop, and therefore satisfies the conditions for improving the overall amplifier performance.

Because of the capacitive nature of the load presented to Tr_6 by the gate-source capacitance of the power mosfets, the h.f. loop gain of the amplifier falls below unity at about 30MHz, which is sufficient to give an adequate margin of stability, while still allowing some 60dB of negative feedback at 30kHz, the chosen upper operating frequency limit. No additional h.f. roll-off components are required.

Stability with capacitative loads

A minor problem associated with power mosfets, discussed by Hitachi in their design note[14] is that the very high-frequency −3dB point of the mosfet used as a source follower (typically 30-40MHz for the Hitachi devices) allows the inductance of the internal gate-contact lead − some 70nH − to produce a negative resistance condition, with consequent parasitic oscillation, under conditions of small capacitative load (0.01μF-0.22μF). Oscillation, under these conditions, but due to other causes, is not uncommon in audio amplifiers, and can be the cause of amplifier failure when used with the so-called low-impedance loudspeaker cables, even when the amplifier is completely stable under the 8ohm/2μF load combination frequently chosen by reviewers. Needless to say, this possibility of parasitic oscillation should be avoided and this is most easily done in this type of design by the inclusion of a small inductor of some 5μH inductance, (20 turns of 24s.w.g. enamelled wire, wound round the case of a 10ohm, 1watt carbon-rod resistor) in the output lead to the loudspeaker load.

This output inductance has two practical effects, apart from the avoidance of parasitic oscillation. The first of these is to reduce the total harmonic distortion of the circuit, as measured at the output at high audio frequencies, simply because it acts as an output low-pass filter. The second effect, due to the same cause is a 'ripple' on the square-wave/reactive-load test waveform, which is an inevitable effect of any steep-cut, low-pass filter. Without this output inductor, the 8ohm/2μF test waveform is smoothly rounded and free of any overshoots.

Output stage protection

Because of the freedom of power mosfets from secondary breakdown, and because they have an inherent positive temperature coefficient of resistance, output stage protection can be much simpler than is the case with normal junction transistors, and a simple fuse in the output circuit is quite adequate. This has a practical advantage over many of the electronic protection methods normally employed, in that it avoids hard clipping under dynamic conditions when the amplifier is required to drive fast h.f. transients into loudspeakers having a low h.f. impedance.

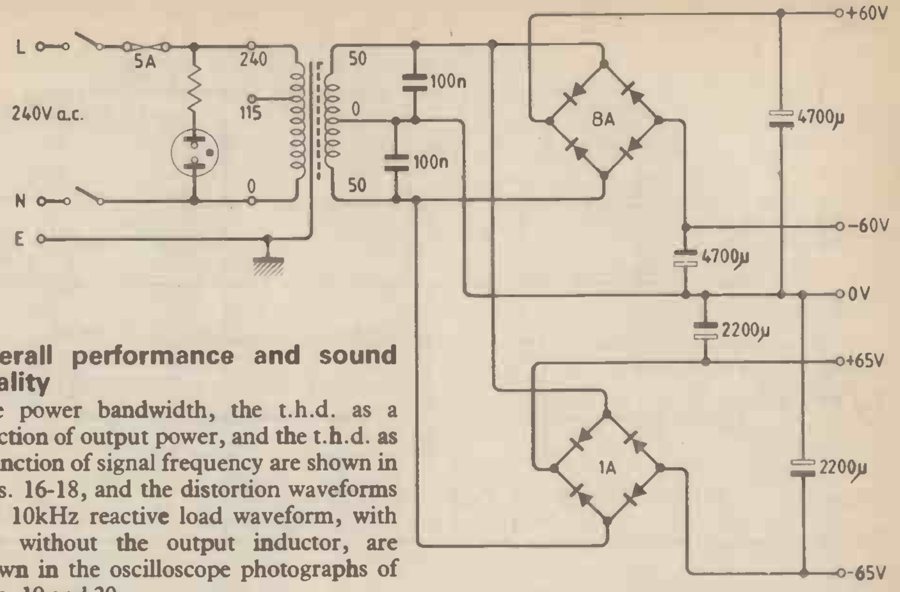


Fig. 22. *Power supply used in prototype.*

Overall performance and sound quality

The power bandwidth, the t.h.d. as a function of output power, and the t.h.d. as a function of signal frequency are shown in Figs. 16-18, and the distortion waveforms and 10kHz reactive load waveform, with and without the output inductor, are shown in the oscilloscope photographs of Figs. 19 and 20.

Inevitably, the question must be asked whether, in the event, the sound quality given by a well designed power mosfet amplifier is better than, or indeed noticeably different from, that given by an equally well designed power amplifier using junction transistors. The designer is not a good person from whom to seek an answer to this question, if only because his awareness of the inevitable design compromises in the circuit, and of the imperfections which remain as a result of the impossibility of achieving all design objectives simultaneously, colour his expectations in respect of its perceived performance. However, having said this, I believe that power mosfet output devices, in appropriately designed circuitry, can offer an improved performance in the upper-middle and top end of the audible spectrum, which is apparent as an improved clarity and transparency in tonal quality, particularly at low output levels, in comparison with equivalent junction transistor designs.

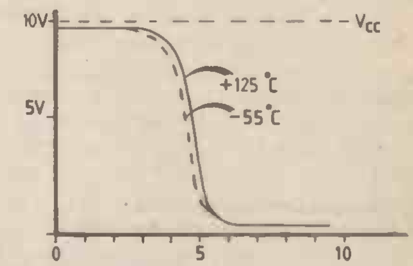


Fig. 23. *Typical transfer characteristic of c.m.o.s. gate.*

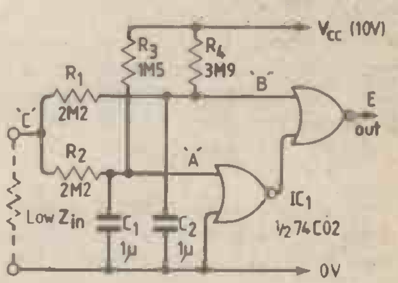


Fig. 24. *Input d.c. level monitor using c.m.o.s. Nor.*

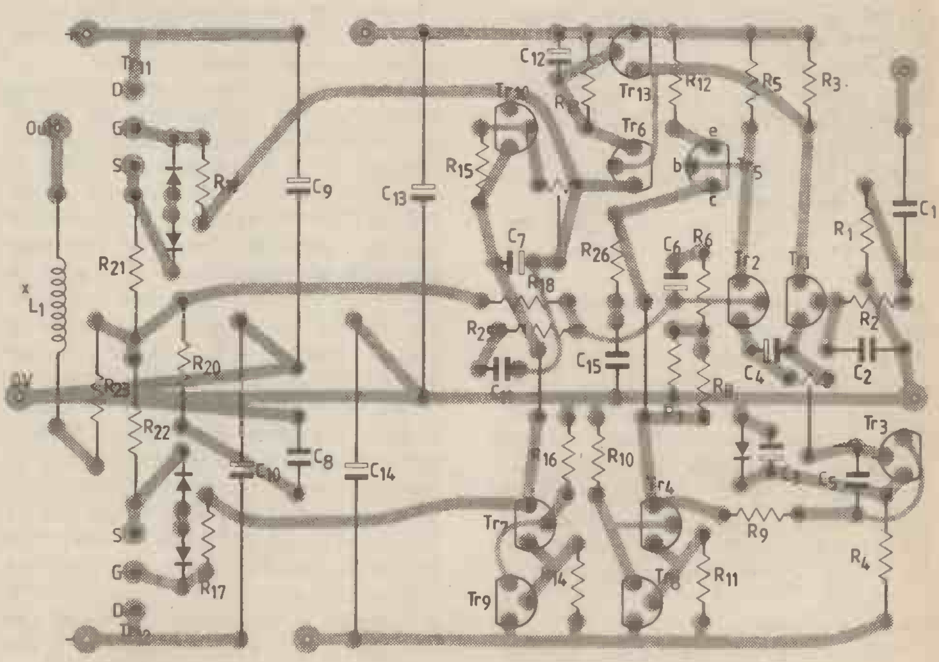


Fig. 21. *Printed-board for power amplifier.*

* L_1 is wound on R_{24}

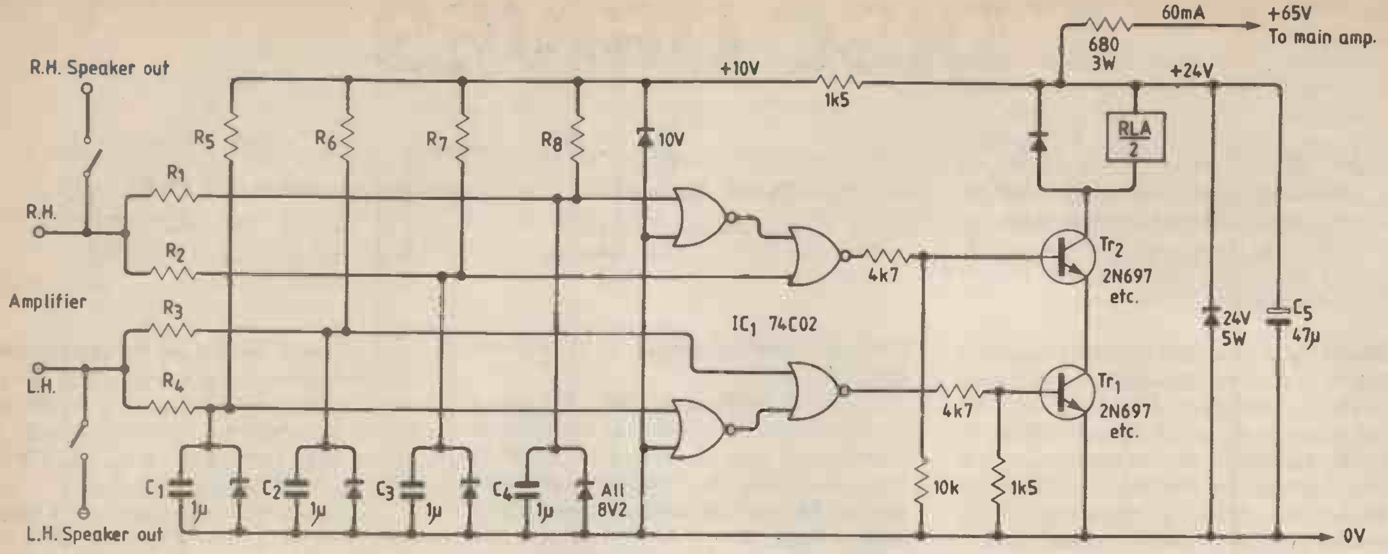


Fig. 25. *Complete two-channel loudspeaker protection circuit with switch-on delay.*

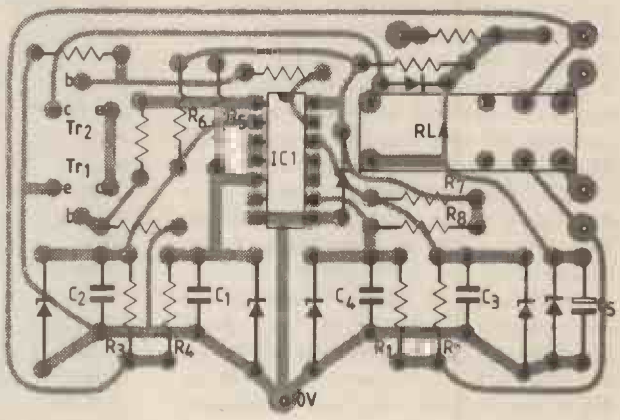


Fig. 26: *Layout of printed board for circuit of Fig. 25.*

Power supply

A suitable power supply circuit is shown in Fig. 22. As mentioned above, the output power of the amplifier depends almost entirely on the supply line voltages, and the original design was based on a conventional 'E' and 'I' cored transformer with a nominal 50-0-50 secondary winding, which gave a quiescent output d.c. voltage, after rectification, of ±62V. This was subsequently replaced by a 250VA 50-0-50V toroidal cored unit, in the interests of a lower residual 50Hz field, and this gave a d.c. output of ±65 volts, and increased the power output, at 1kHz across an 8ohm, water-cooled, resistive load, from 83watts/channel to some 105watts/-channel. It was thought prudent to uprate the reservoir capacitors to 80V types, but no other changes are necessary.

Loudspeaker protection circuit

Although the use of direct coupling between loudspeaker and amplifier output, together with the use of split positive and negative h.t. rails, undoubtedly helps in the economical design of high-powered audio amplifiers by limiting the necessary voltage rating of the reservoir capacitors, it does carry with it the implicit hazard that, in the event of a component failure within the power amplifier, the whole output of one or other of the supply lines may be switched into the output circuit, with expensive consequences.

The most elegant way of avoiding this hazard is to employ a small supplementary circuit to monitor the average d.c. potential of the amplifier output terminals, and to disconnect the loudspeakers in the event that an averaged d.c. offset of more than a volt or so is detected. Experiments over a periold of time have shown that the loudspeaker can be connected through a pair of gold-plated relay contacts without audible or measurable signal degradation. Silver-plated contacts are excellent when new and clean, but tend to become partially rectifying if sulphided by exposure to urban atmospheres, and should therefore be avoided if possible.

An inevitable problem in the use of an 'average d.c. potential' monitoring circuit is the necessity for some compromise between speed of response, in disconnexion following a fault condition, and the need not to diagnose a large but legitimate v.l.f. signal – especially if assymmetrical – as such a fault. My own choice is an integrating time-constant of about 2 seconds. This ignores all the normal l.f. signal components, at least at the largest signal levels I have so far used, but allows a switch-off in better than 80 milliseconds in the event of a large direct voltage being applied to the input. This should be adequate to avoid thermal damage to the loudspeaker.

In order to accommodate a fairly long integrating time-constant with the use of non-polarized capacitors, a high-input-impedance offset-detection logic circuit is essential. C.m.o.s. logic elements of the 74C or CD4*** series are well suited to this task, especially since the switching potentials are well defined in relation to the supply voltage line employed. Typical gate transfer characteristics are shown in Fig. 23. Because of this, if the gates are biassed by an input resistor chain, as shown in Fig. 24, so that one sits below and one sits above this threshold level, a pair of Nor gates will effectively act as an input-threshold d.c. monitor circuit, in which the output will only be high so long as input A is high and input B is low. With the resistor values quoted, this condition will be met while input C is within ±2V d.c., for a 10V supply line. The circuit also will provide a switch-on delay of a few seconds while C_1 charges up through R_3 to a potential above the $\frac{1}{2}V_{cc}$ level.

The complete, two-channel, loudspeaker protection circuit based on this arrangement needs only one Quad 2-input Nor gate, and a pair of switching transistors. The final circuit is shown in Fig. 25. It is 'fail-safe' in the sense that the relay contacts are normally open, and can only operate if the h.t. supply is present and both transistors are energized. The relay used is an RS Components p.c.b.-mounting, 24V unit, with 5A, 250V a.c.-rated gold-plated contacts, of d.p.d.t. operation. H.t. supply for this is best obtained from the output stage +65 volt line.

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Editor's note: *We understand that a kit of components for the amplifier is to be made available by Hert Electronic Kits, Ltd, Oswestry, Shropshire.*

A preamplifier design to match the mosfet power amplifier will be described later in the year. □

DISC DRIVES

When a read/write head's position is determined by information on the disc surface, data-storage capacity can be greatly increased. As shown here, there are different methods of applying this technique which, in the case of a drive with ten discs in one pack, can increase the storage capacity four times despite a loss of 5% in data storage area.

by J. R. Watkinson
B.Sc., M.Sc.,

Possibly the most significant event in the history of disc storage was the introduction of the servo-surface drive. Through the virtual elimination of thermal effects on head positioning, servo-surface drives, in which the head's position relative to the disc is determined by information on the disc surface, allow great increases in data storage density.

Changes of temperature in relatively simple disc-drive positioners, such as those discussed in the June issue of *Wireless World*, do not only affect accuracy through expansion and contraction in mechanical components such as head cantilevers. Thermal drift in the cylinder transducer and associated circuits also causes problems. How temperature changes limit the number of tracks on a given disc is illustrated in Fig. 1.

Because the position-error signal in a servo-surface disc drive is derived from a head reading the disc, these problems are drastically reduced. In a multi-platter drive, one surface of the pack holds servo information, which is read by the servo head. All of the read/write heads move with the servo head. In a ten-platter pack, this means that 5% of the usable data storage area is lost, but this is unimportant since the track density in a drive with a servo surface can be typically four times greater than in a drive without one.

Using one side of a single-platter cartridge for servo information would be unacceptable as it represents 50% of the usable data storage area so, in this case, servo information is interleaved with sectors on the read/write surfaces. Disc drives using this technique are usually referred to as 'embedded servo' drives.

Figure 2 shows the essential features of these two main categories of servo-surface drive, which will be described in turn.

Servo surface

As stated, one surface of the disc pack contains information to control the positioner. This surface is written when the disc is manufactured and, should it become corrupted, must be rewritten on special machine known as a servo writer.

The key to the operation of the servo surface is the way in which it is recorded by the servo writer. Recorded transitions are in adjacent pairs known as dibits, separated by a space, and Fig. 3 shows that there are two distinct types of servo track. On an A-type track, the first transition of the pair will cause a positive pulse on reading, whereas on a B-type track, the first pulse will be negative. In addition, the A-track dibits are shifted by one half cycle with respect to the B-track dibits. The width of the magnetic circuit in the servo head is equal to the width of a servo track.

During track following, the correct position for the servo head is with half of each type of track beneath it. The read/write heads will then be correctly centred on their respective data tracks. This relationship is illustrated in Fig. 4.

The amplitude of dibits from A tracks with respect to the amplitude of dibits from B tracks depends on the relative areas of the servo head which are exposed to the

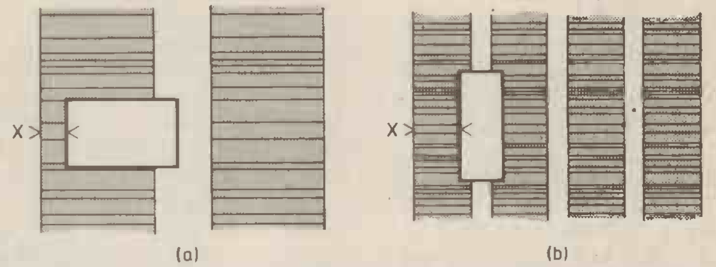

Fig. 1. At (a), misalignment x has little effect on the output signal, but at (b), the same misalignment in a system using four times greater track density causes unacceptable errors in the read signal. Distance x is not to scale.

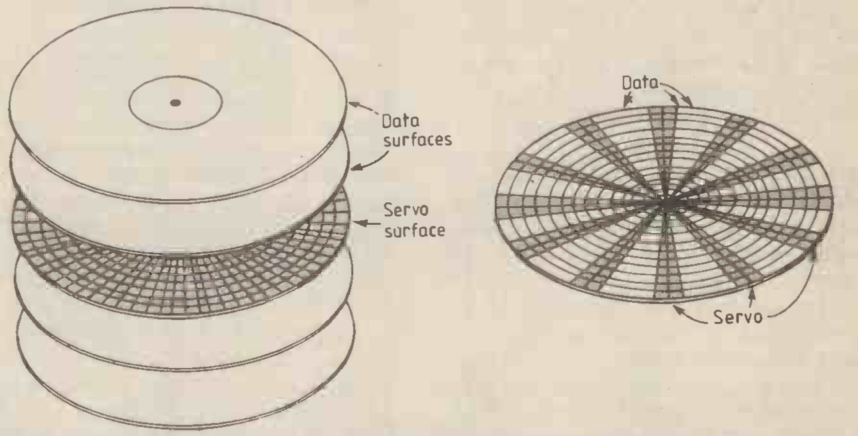

Fig. 2. In a multi-platter disc pack, one surface is dedicated to servo information, left, but as the number of platters in a pack falls, the percentage of data storage area lost to servo information rises. For this reason, some discs have servo information embedded in the data on the same side, as in the case of the single platter, right.

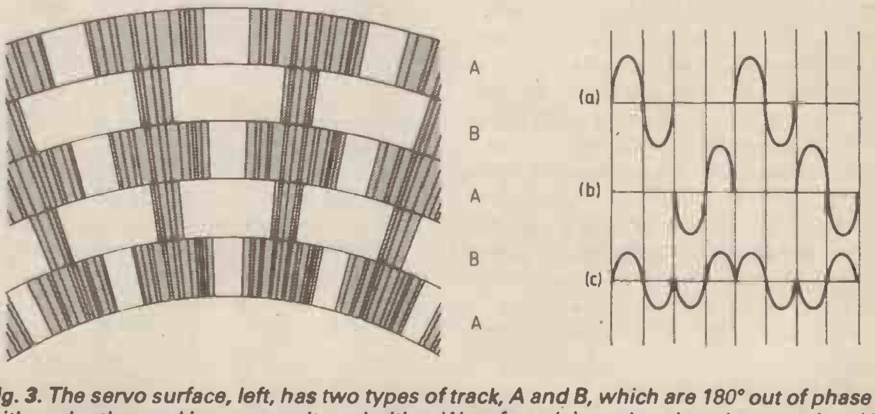

Fig. 3. The servo surface, left, has two types of track, A and B, which are 180° out of phase with each other and have opposite polarities. Waveform (a) results when the servo head is directly above track A, and waveform (b) appears when the head is above track B. When the head is correctly positioned, waveform (c) results.

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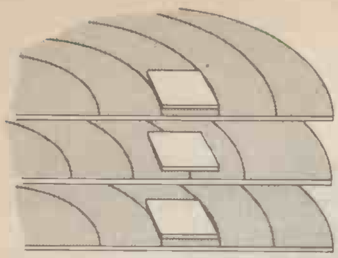


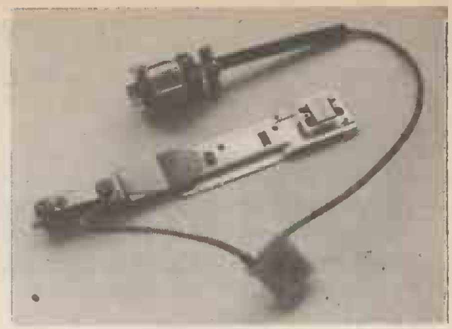
Fig. 4. When the servo head is straddling two servo tracks, the data heads are correctly aligned with their respective tracks.

respective tracks. As the servo head has only one magnetic circuit, it will generate a composite signal whose components will change with respect to one another as the position of the servo head changes. Figure 5 shows several composite waveforms obtained at different positions of the servo head. The composite waveform is processed by using the first positive and negative pulses to generate a clock. From this clock are derived clamping signals which permit only the second positive and second negative pulses to pass through. This resultant waveform has a d.c. component which, when filtered, gives a voltage proportional to the distance from the track centre. The position error reaches a maximum when the servo head is entirely above one type of servo track and further movement will cause it to fall. The next time the position error falls to zero will be at the centre line of the adjacent cylinder.

Cylinders with even addresses (l.s.b.=0) will be those where the servo head is detented between an A track and a B track. Cylinders with odd addresses will be those where the head is between a B track and an A track. It can be seen from Fig. 5 that the sense of the position error becomes reversed on every other cylinder. Accordingly, an inverter has to be switched into the track-following feedback loop in order to detent on odd cylinders. This inversion is controlled by the l.s.b. of the cylinder difference at the beginning of a seek, such that when the heads arrive at the target cylinder, the sense of the feedback will be correct.

Seeking across the servo surface results in the position error signal rising and falling in a sawtooth. This waveform can be used to count down the cylinder difference which controls the seek. As with any cyclic transducer there is a problem in finding an absolute position. This difficulty is overcome by making all servo tracks outside cylinder zero type A, and all servo tracks inside the innermost cylinder type B. These areas of identical servo tracks are called guard bands, and Fig. 6 shows the relationship between the position error and the guard bands. During a head load, the servo head generates a constant-maximum positive position error in the outer guard band. This drives the carriage forward until the position error first falls to zero. This, by definition, is cylinder zero. Some drives, however, load heads by driving the carriage at low speed across the disc until the inner guard band is detected, and then find cylinder zero by performing a full-length reverse seek.

Another, less common form of servo surface is shown in Fig. 7. In this type, there is a common sync. bit in both tracks, and subsequent servo bits at differen times afterwards. The position error is derived by opening sample and hold gates at different delay times after the sync. bit. As three distinct transitions can be seen in one cycle, the resultant waveform is known as a tribit signal.



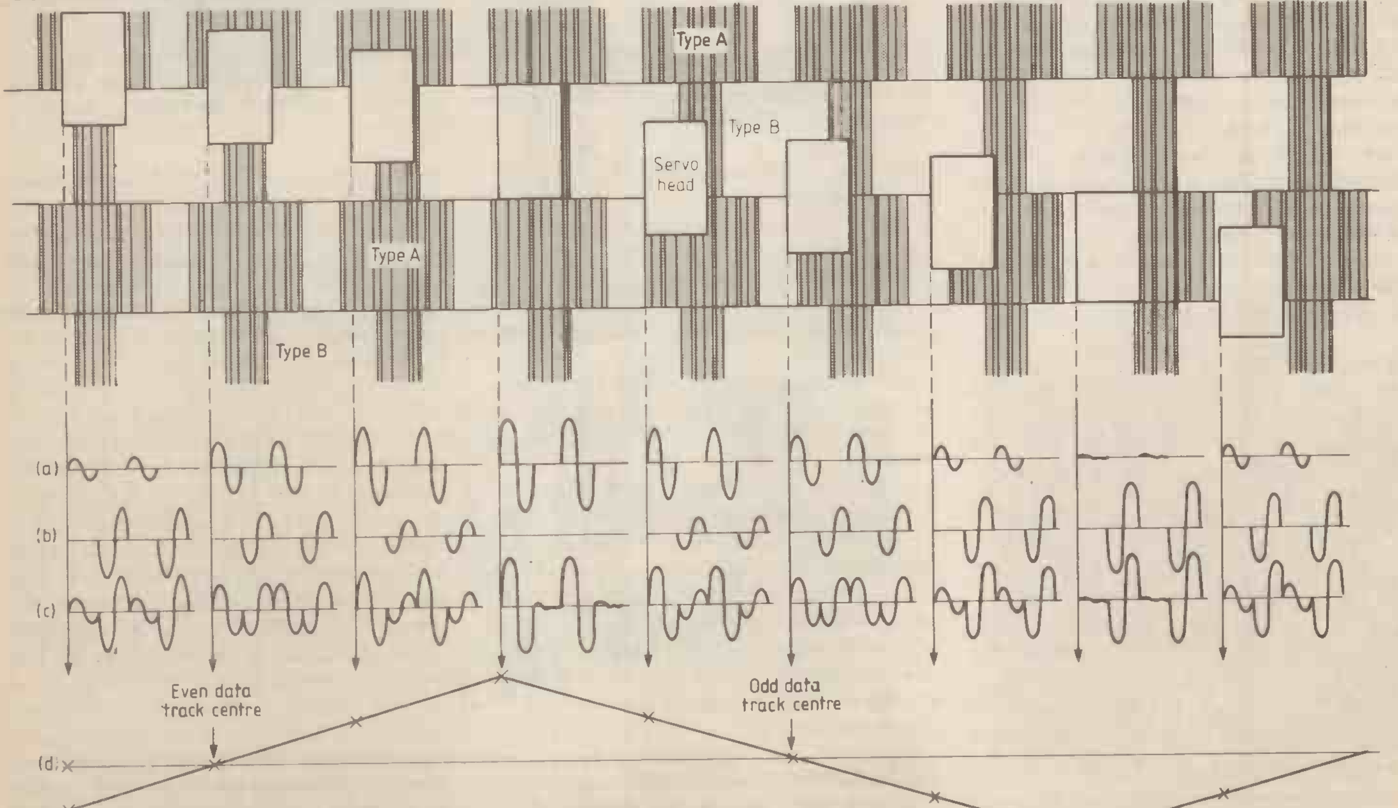
Servo head from a multi-platter disc drive. The rectangular plug is for mechanical support only.

We have seen that a position error and a cylinder count can be derived from the servo surface, eliminating the conventional cylinder transducer. The carriage velocity could also be derived from the slope of the position error, but unfortunately such a signal is only available while the servo head is above the disc, and velocity feedback is needed when the heads are retracted. Some form of velocity transducer is still therefore necessary.

As there are exactly the same number of dibits on every track, it is possible to describe the rotational position of the disc simply by counting them. All that is required is a unique pattern of missing dibits once per revolution to act as an index point, and the sector transducer can also be eliminated.

Unlike the read/write circuits, the servo circuits are active during a seek as well as

Fig. 5. Waveforms resulting from several positions of the servo head in relation to the disc. Amplitudes of waveforms (a) and (b), components of the actual waveform (c), are proportional to the area of the servo head over the track concerned. A position-error signal, (d), is obtained by comparing the second positive and negative peaks in the composite waveform, (c).



when track following, and so must be constructed in such a way that they do not suffer interference from pulse-width modulated e.m.a. drivers. The main problem comes when the index is due, where the presence of a noise pulse during a "missing" dibit could inhibit recognition of the index. There are two solutions to this problem. In the first, a preamplifier i.c. is incorporated in the servo-head cantilever, so that the servo signal leaves at high level and low impedance, making it noise immune. In the second approach, the sector counter predicts when an index pattern is due, by counting slightly less than the number of dibits in one revolution, and inhibits switching in the e.m.a. driver until index has been detected.

An advantage of deriving the sector count from the servo surface is that the number of sectors on the disc can be varied. Any number of sectors can be accommodated for by feeding the dibit-rate signal through a programmable divider, so the same drive may be used for storing, say, 22 sectors of 16-bit data for a minicomputer or 20 sectors of 18-bit words when connected to a main-frame (2 disc words are the same as 1 memory word).

In a non-servo disc drive, the write clock is usually derived from a crystal oscillator. As the disc speed can vary with supply voltage fluctuations, a tolerance gap has to be left at the end of each disc block to cater for the highest anticipated speed, to prevent overrun into the next block on a write. In a servo-surface disc drive, the write clock is obtained by multiplying the dibit-rate signal with a phase-locked loop. The write clock thus obtained is locked to the disc speed, and the recording density will be independent of supply fluctuations.

Most servo surface disc drives offer an offset facility, where a register written into by the system controls a d-to-a converter, which injects a small voltage into the track-following loop. The action of the servo is such that the heads move away from the theoretical track centre line until the position error is equal and opposite to the offset voltage. The position of the heads about the track centre line is thus program controlled, Fig. 8. Offset is only employed for the purpose of reading, if a write is attempted, the drive will return to the track centre line.

Head alignment. The servo-surface technique is also used for head alignment. On the data surfaces of the alignment disc, dibit patterns are written at the reference cylinder. A special test box is required for head alignment, and this usually contains an exact copy of the circuit board used by the drive to obtain a position error signal from a dibit signal. The module in the test box is fed not by the servo head, but by the data head to be adjusted. The position-error output drives a centre-zero meter which gives a direct reading of the head misalignment in micro inches. The selected head is adjusted radially in the carriage until the meter reading is within the specification. Precautions are taken to ensure that the alignment disc is not written over.

Program-controlled head-alignment measurement. In some test boxes, the position-error signal from the selected data head is compared with zero volts, to create a binary signal depending on the head position relative to the track centre line. This signal is fed back into the disc-control logic and becomes a bit in a register accessible to the system, known as 'sign change'. Under program control, the positioner is set to maximum offset, and then brought back until the sign-change bit changes state. The amount of offset needed to cancel the alignment error is equal to the error itself, Fig. 9. After sequentially testing all of the heads, the program can print out a table of the alignments. By comparison with the specification, an engineer can decide which, if any, heads need adjustment. The head alignment can also be checked at further reference tracks on both the innermost and outermost cylinders, as a check on carriage alignment accuracy.

Embedded-servo drives

In drives with few platters, the use of an entire surface for servo information gives a high percentage loss of data recording area. In the embedded-servo drive, servo information is interleaved with data on the same surface, causing a smaller loss of data storage area.

The embedded-servo drive heads will be reading data at some times and alignment information at others as the disc rotates. A sector transducer is required to generate a pulse which is true when the head is reading servo information and false when reading or writing data. Figure 10 shows the principle. On all disc drives, the width of the read/write head is less than the track spacing to prevent crosstalk. As the servo head is also the read/write head here, it is slightly narrower that the spacing of the servo information. This has the harmless effect of rounding off the peaks of the triangular position-error waveform. During the pulse from the sector transducer, the head sees alignment information, and the servo circuit develops a position-error signal in much the same way as any servo drive. Within the servo area there are two sets of alignment patterns, the second be-

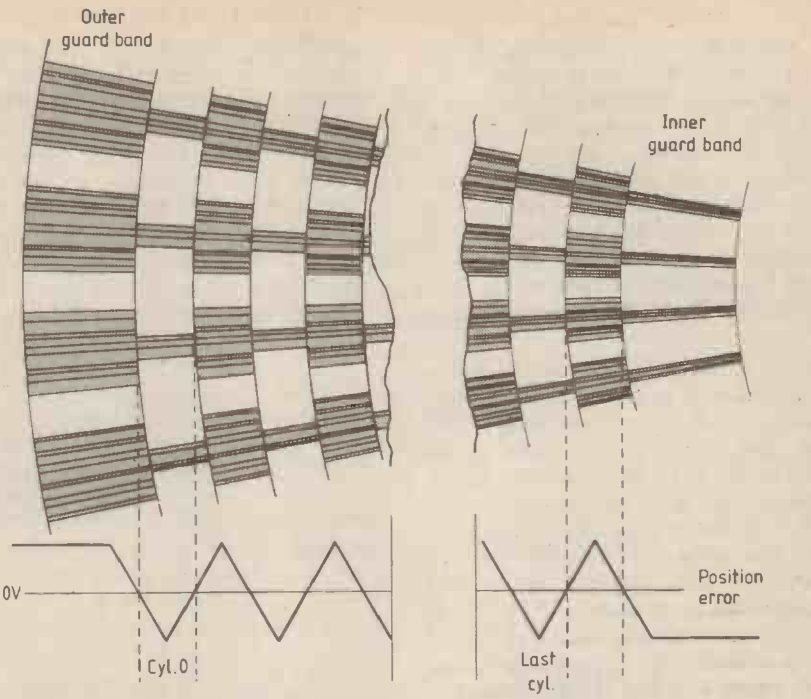


Fig. 6. The servo surface's working area is defined by the inner and outer guard bands, at which the position error signal is maximum.

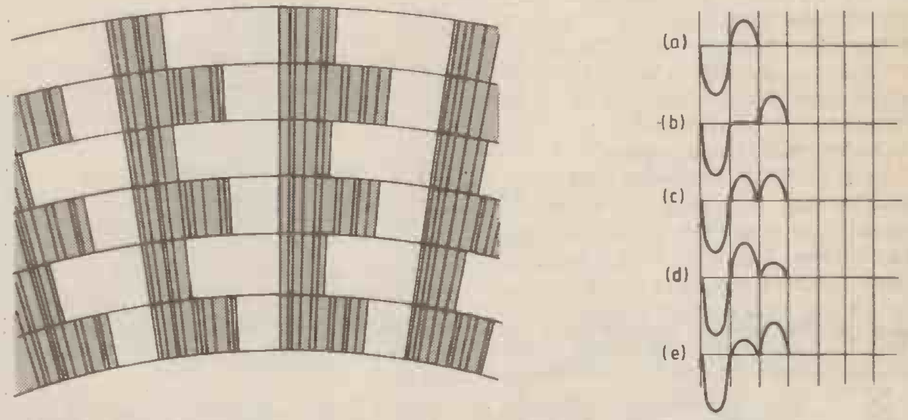


Fig. 7. The 'tribit'-type servo surface in which the position-error signal is derived from pulses from two types of track following a common negative synchronization pulse. (a) and (b) are obtained when the servo head is directly above one or other of the tracks, (c) is the correct waveform, and (d) and (e) show typical off-track waveforms.

ing positioned to a position error of zero when the first is at a maximum. The two bursts of information are known as S1 and S2. Sample-and-hold circuitry is used to carry over the position error when the head is traversing read/write data.

The discontinuous nature of servo information means that cylinder crossing cannot be counted directly during a seek, as the positioner is fast enough to cross several tracks between servo bursts. With reference to Fig. 11, the cylinder crossings are established as follows. During the S1 period, the position error is compared with zero volts to generate one data bit, whose state depends on whether the head was inside or outside the S1 null point. A similar process takes place during the S2 period, and the position of the head relative to the servo pattern is described as being in one of four places by the two bits. These bits are stored, and at the next servo bursts, two further bits are generated, describing the new position of the head. Figure 12 shows that there are a number of cases which can satisfy the same initial and final conditions. The only difference between the cases is the carriage velocity, so the output of the carriage-velocity transducer is digitized and used to resolve the ambiguity.

At every sector pulse, the two bits from the previous bursts, the two bits from the current bursts and the digitized velocity are fed into a rom which is pre-programmed to return the theoretically correct number of cylinders which must have been crossed for all combinations of inputs. This number is then subtracted from the cylinder difference counter which controls the seek. The calculation will only be valid for one disc rotational speed, so the disc motor requires a speed control. This is achieved by counting controller-clock pulses during the time between sector pulses, and developing a loop error by comparison with the desired number of pulses.

As the cylinder crossing count is deductive, there will be the odd occasion when the count is in error and the positioner comes to the wrong cylinder. In a conventional disc drive, this would be a mispositioning error which would warrant an en-

continued on page 46

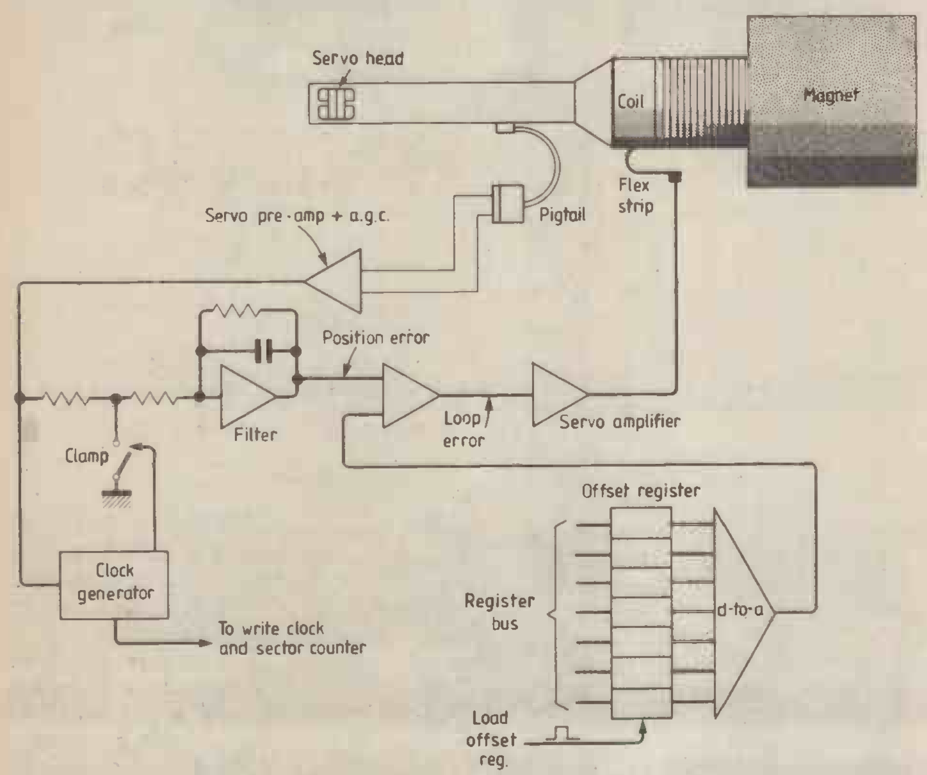
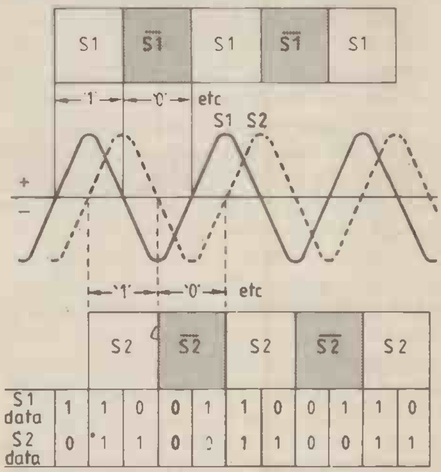


Fig. 8. Representation of servo-surface disc drive's feedback loop. The offset register drives a d-to-a converter which can modify the feedback loop, allowing the heads to be offset from the track centre line under control of the operating system.



S1 data	1	1	0	0	1	1	0	0	1	1	0
S2 data	0	1	1	0	0	1	1	0	0	1	1

Fig. 11. There are two basic types of servo track, S1 and S2, recorded in two different positions and staggered. During S1, a position error signal is generated from the relative areas of the two types of track (S1 and $\overline{S1}$) under the head as in the conventional servo-surface drive. This position-error value is stored in a sample and hold circuit. For track counting, the position error value is compared with 0V to obtain a data bit. During S2, another position error signal and data bit are generated. The four possible combinations of the two bits are shown here in relation to the two position errors.

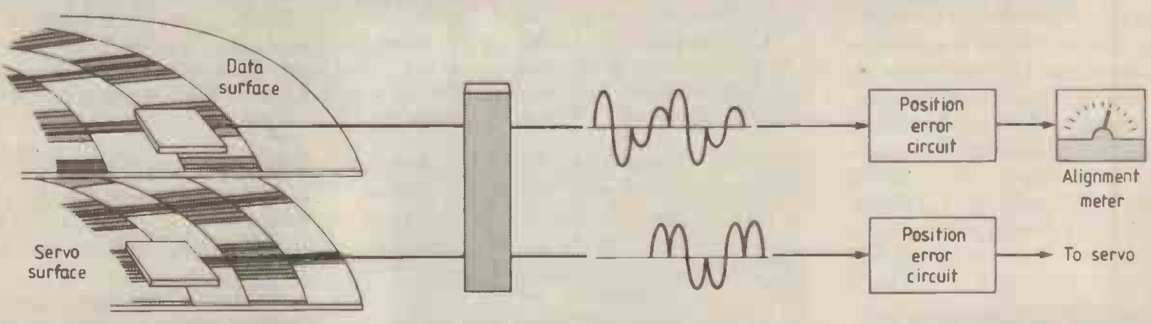


Fig. 9. Head alignment. An alignment disc with 'dibits' on its data surfaces is used in conjunction with a duplicate of the position-error circuit driving a head-alignment meter. Using offset, the program can move the servo head off track until the read/write head is in the correct position. The amount of offset necessary to achieve this is equal to the alignment error.

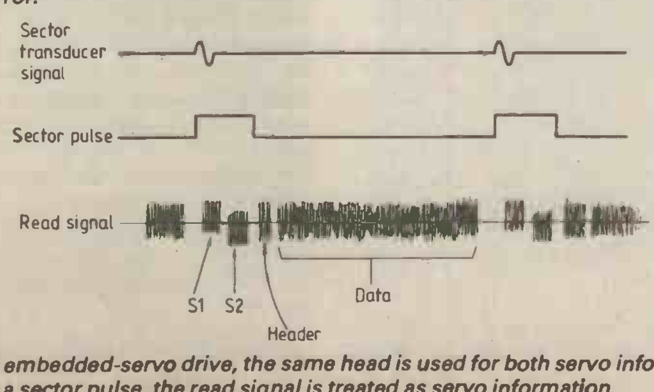


Fig. 10. In an embedded-servo drive, the same head is used for both servo information and data. During a sector pulse, the read signal is treated as servo information.

A Heretic's Guide to Modern Physics

THE ELECTROMAGNETIC ANALOGY

In his second article Dr Murray takes a dispassionate look at Victorian electromagnetic theory and finds that, contrary to popular belief and textbook wisdom, it had begun to go decidedly green around the edges before it was thirty years old – a fact that many otherwise worthy men have preferred to ignore.

by W. A. Scott Murray
B.Sc., Ph.D.

The earliest organized investigation of the physical properties of light was undertaken in the seventeenth century by Sir Isaac Newton. Despite the evidence of some of his own experiments, Newton himself remained convinced throughout his life that light consisted of showers of particles, or "corpuscles". His authority among scientists was such that much philosphical argument arose before Thomas Young's famous experiment – on the mutual interference of light rays after passing through a double slit – was accepted as conclusive evidence for the wave nature of light, largely through the mathematical ingenuity of Fresnel. Incidentally, the most convincing demonstration that I know of in favour of "light waves" is due directly to Fresnel, and lies in the fact that the shadow of a one-penny piece has a *bright* spot at its centre.

That light behaves as a wave system is one of the most thoroughly researched and supported conclusions in all science. By assuming waves of a definite wavelength one can calculate numerically how light will behave in optical apparatus of any complexity one chooses and, lo and behold, that is precisely the way light does behave in practice. The accuracy of the prediction seems to be unlimited, and to depend only on the accuracy with which we can measure the result. I want to place special emphasis on the precision with which the wave theory describes the behaviour of light as observed in Nature, because it is primarily that precision which makes the wave theory of light so convincing. As long as we stick to light which is bright enough to be seen, and of ordinary visible wavelengths, the theory works perfectly every time.

The next major step in the wave theory was taken in 1862 by James Clerk Maxwell, on the basis of his formulation of Michael Faraday's ideas of electricity and magnetism. Faraday had come to interpret his observations in terms of electric and magnetic fields of force, which Maxwell found could be expressed by exact analogy with the mathematical formulations of hydrodynamics – that is, the behaviour of incompressible fluids. Faraday's *field concept* conveniently bypassed the fundamental problem of action-at-a-distance (namely, how can one electric charge repel another when there is no connecting rod between them?). It suggested that the electric field permeated everything and everywhere, like a fluid throughout all space, so that such actions really took place locally, within the field, rather than "at a distance".

By this means action-at-a-distance came to be regarded as a non-problem, the first of many difficulties so handled in physical science. Note that the non-problem technique does not solve the philosophical problem to which it is addressed, but evades it. It is clearly legitimate as a technique, to permit us to maintain our momentum and get on with the next phase of the job, provided we put up a marker flag to remind ourselves that we have left behind us a fundamental problem unsolved. It is philosophically dangerous to omit this precaution. For example, there are those who have specialized in field theory so strongly that they *believe in* an electric field, as if it were a physical entity having an independent physical existence in its own right – like an electron perhaps, or a filing cabinet. Such folk do not envisage an electric field merely as a convenient mathematical trick for integrating a set of inverse-square-law forces.

I am discussing this concept of a "force field" at some length because it is the first instance we have encountered where an attractive product of romantic imagination has come to be treated, with no basis of experimental evidence whatsoever, as though it corresponded to an established or even a self-evident truth. It is in this romantic, unscientific way that doctrines arise in physics. (When a doctrine is subjected to criticism that it cannot withstand it usually turns into a dogma; it is then to be believed by faith rather than by evidence). In the present case the truth is that we know nothing of how or why one electric charge should be influenced by the distant presence of another, but only that it is so influenced and by precisely how much. It is another miracle.

These ideas may seem far removed from waves and light, but the connection between them was Maxwell's very great invention: he showed that a particular combination of his changing electric and magnetic fields, which can be written down mathematically in the form of a "wave equation", would propagate through space at the velocity of light. Thence it needed but one further, obvious step to the postulate

"Light consists of electromagnetic waves".

That step was taken. Combining as it did the three topics of electricity, magnetism, and light under the single concept of wave motion, it was extraordinarily satisfying aesthetically and it seemed to remain true when tested to any depth. It came to be believed by all scientists at the turn of the century and it is still believed by nearly all scientists today. Heinrich Hertz went on to cap it by generating radio waves electrically and showing that they belonged to the same family of phenomena.

Thus at the end of the "classical" period in physics all appeared superficially tidy. It was generally accepted that the entire spectrum of light from long-wave radio through and beyond the ultraviolet was a manifestation of electromagnetic waves of defined, invariant velocity c, whose "colours" were determined by their frequencies and corresponding wavelengths in accord with the general axiom of wave motion, frequency × wavelength = c. Those must have been happy days of self-satisfied Victorian complacency before the storms broke . . .

A couple of minor points arose. First, the physical energy transported by the light waves, which propagated at the speed of light, was taken to be the energy contained in the electromagnetic field as described by a simple formula of the theory. Once launched into space, this energy had an independent existence even though its source, a star for instance, should later explode as a supernova. So here one had an electric field and a magnetic field, neither of which (according to the theory itself) could exist without continuous connection to a source and a sink of fluence, while their combination, the *electromagnetic* field, did have an independent existence. These static and dynamic fields were therefore quite different in their intrinsic natures, yet there was nothing in Maxwell's equations to suggest that one type of field was more physically "real" (that is, had any more independent, objective and existence) than the other.

Second, and on a slightly larger scale of discrepancy, Maxwell's formulation of electric and magnetic fields was mathematically equivalent to the behaviour of incompressible fluids, as has been mentioned already; yet the waves in his *electromagnetic* field were *transverse* waves, of a type which in the mechanical case require a solid substance to transmit them and will not propagate in a fluid medium. Thus the medium involved, which became known as the ether, was required to exhibit physical properties which differed from moment to moment, according to whether the field it was supporting was static or in motion. This gave rise to much trouble.

In view of the intellectual triumph of Maxwell's work it would indeed have been churlish to have raised such apparently insignificant points as these at the time. Yet in retrospect one can see that they were real discrepancies whose incidence formed part of a pattern of discrepancy in electromagnetic theory. (Remember, please, that we are not attacking the theory, but examining a miracle: a physical occurrence for which we can offer no physical explanation). For physical waves as normally understood are mechanical waves; they are waves *in something* – in air, or water, or at the air-water interface, or in solid rock, or what-have-you. Their velocity is determined in relation to the medium in which they travel. Hence a careful measurement of the velocity of light in the laboratory, coupled with the assumption of the constancy of light velocity in its ether medium should, it was believed, reveal the velocity of the laboratory through the ether.

That experiment was duly performed, most famously by Michelson and Morley in a basement in the University of Chicago in 1887. The date is most interesting, being 25 years after the first publication of Maxwell's postulate of the electromagnetic nature of light, and 18 years *before* the publication by Einstein of the special relativity theory with which it is usually connected. That connection is something of a myth. Einstein did not refer to the Michelson-Morley experiment at all but assumed the velocity of light to be universally constant as a fact of nature (*it was not tested* in Michelson-Morley!). His other starting-point, the principle of relativity in the form of the denial of absolute motion, was in no sense new but had appeared in Newton's *Principia* just 200 years before.

Thus for contemporary thinkers the really shocking implication of Michelson and Morley's result was not that it might lead towards a new relativity theory some two decades later, but that it asserted, unmistakably and immediately, that *there was no ether* for the electromagnetic light waves to undulate in. It was of secondary importance that the medium in which electromagnetic waves travelled did not reveal any frame of reference of zero motion, or absolute rest. It was an equally red herring to say that it was merely the postulated electromagnetic waves that had no ether, because the experiment as performed was a straightforward experiment in light, having no reference to electricity or magnetism. The really crucial experimental result was that light waves, whatever their form, could not be waves in a physical medium. And if they were not waves in a physical medium, how could they be said to be waves at all? The answer to that question is *not* straightforward.

There was an immediate and almost instinctive reaction against the Michelson-Morley result. Some physicists (like Sir Oliver Lodge) simply refused to accept it, while others up to the present day have repeated the experiment with progressively more refined apparatus in the hope of proving it wrong. All such attempts so far have failed. Most of those experimenters believed themselves to be taking issue with Einstein and special relativity; only a discerning few have understood that they were really trying to save the electromagnetic theory, and with it the whole of the concept of fields of force of nineteenth-century physics. The Michelson-Morley experiment denies the existence of an ether, and there is no doubt about its finding: space is empty. There is nothing there.

In view of the admittedly overwhelming evidence that light consisted of waves (and very probably electromagnetic waves), physics at the turn of the centry refused to face the consequences of the Michelson-Morley result. Two lines of experimental evidence that seemed to be equally valid seemed also to be in absolute mutual conflict. The philosophical crisis was acute, and it has never been resolved. One approach has been to ignore the problem in the hope that in due course and in the light of later knowledge it will go away – this is the "don't care" or "too busy" reaction, which really means "too difficult" – but unfortunately this is a problem that *doesn't* go away. Another approach is to ask why a physical ether should be necessary for the waves to propagate in: why do they demand a *physical* medium? The answer would seem to be that according to the theory these "waves" carry physical energy in readily measurable amounts, so that they must be physical waves; and physical waves cannot be waves in nothing, unless we are to believe in miracles . . .

Then there are the semantic approaches, which seek to show that the problem is one of wording only and has no philosophical depth. "Very well", it has been said, "we have been denied a luminiferous ether; let us call the medium in which the waves travel 'space', or 'an inertial frame of reference' ". The trouble with such proposals is that space, insofar as we can *measure* its properties, is empty, a vacuum, having no physical content. (Do not let us get bogged down with arguments about the "permittivity" or "im-

Summary

History of the scientific concepts of light: Newton (corpuscles), Young and Fresnel (waves), Faraday (fields of force), Maxwell (electromagnetic theory). The philosophical problem of "action-at-a-distance" was not solved but bypassed, setting a precedent; this raised the question of the nature of a field theory and led to the emergence of related doctrine and dogma. Some minor discrepancies were inherent in electromagnetic theory as propounded: depending on scenario its fields possessed differing degrees of physical reality, and differing properties were required of the medium, or ether, in which the electromagnetic phenomena occurred. A major problem arose in consequence; when the issue was put to the test, the famous Michelson-Morley experiment unequivocally denied the existence of a physical ether for electromagnetic waves to undulate in. Attempts were made to evade this philosophical crisis by ignoring it, by semantic arguments, and by attributing physical properties to non-physical, mathematical equations. The last of these ideas, which began to take root in the 1890s, re-introduced mysticism into natural philosophy after a banishment of only 350 years. An alternative approach (which was not acceptable in the climate of those times) might be to regard electromagnetic theory as an analogy of Nature which although often extremely useful may not always be a perfect analogy.

pedance" of empty space, which are artifacts of electromagnetic theory). We cannot manufacture a physical medium having physical properties out of nothing merely by coining phrases or by re-defining space.

Yet another approach – and this one had far-reaching philosophical consequences – arose from the remark that the *mathematics* of wave propagation predicted results in accord with observation even though the physical requirements for wave propagation were not satisfied. The temptation became very strong to say that these light waves were not physical waves at all, but *mathematical* waves. Here at a stroke one seemed to have a potential solution satisfying both aspects of the experimental evidence: (a) light consists of waves (*c.f.* Young and Fresnel, and perhaps also Maxwell and Hertz), while at the same time (b) the waves are not physical waves in a physical ether (*c.f.* Michelson and Morley), but of a purely mathematical nature.

This was the first move in the takeover, by default, of theoretical physics by the Mathematicians' Union. It wasn't a complete takeover until the 1930s when the mathematics of the new quantum mechanics became so obscure and esoteric that the ordinary physicist gave up trying to follow the wilder ramifications of the theory. The nature of the physicists' default was their failure to insist sufficiently strongly on the physical reality of the physical world. In the case of light, energy is transmitted at a definite speed through a vacuum, and this energy is a physical entity which gives rise to measurable physical effects at its destination. Mathematical waves, being abstract and non-physical, cannot give rise to physical effects. If we accept mathematical waves as the basis for light, we are accepting miracles; for by our definition a miracle is a physical occurrence for which we can offer no *physical* explanation.

Mathematical explanations of physical events *will not do*. For those who believe that mathematics can take the place of physics, or who have merely failed to think about the suggestion deeply enough, I offer the following little mnemonic: Nobody ever became sunburnt as a result of exposure to a differential equation!

Thus in addition to being the first move in the general mathematical takeover, this was the beginning of the return of mysticism into Natural Philosophy after a banishment which had lasted no longer than 350 years. The evidence we shall put together will show that the process has continued steadily, until today the whole fundamentals area has become so permeated by mysticism that one can scarcely distinguish where the physics ends and the metaphysics begins. There is a way of making the distinction, but it calls for a certain old-fashioned ruthlessness in complying with physical discipline and rejecting unsupported mathematical speculation, however superficially attractive the latter may appear. The process will become easier and more sure as our long-neglected critical faculty is gradually re-developed and applied to these problems.

What other alternatives do we have for dealing with the quandary in which the Michelson-Morley result has placed us? There is one approach which always carried a budding promise, although in the face of the mystical takeover it has received little more than lip-service. It is that light does not in fact consist of electromagnetic waves but *behaves like* a system of electromagnetic waves. The distinction here between "is" and "behaves like" is not merely tautological or semantic, but fundamental. It tells us to treat the great electromagnetic theory as an analogy or mathematical model of nature, which probably reflects some features of physical reality but not necessarily all features, and which may prove to be a more accurate model of nature in some circumstances than in others. Therefore we do not say that electromagnetic theory is wrong; indeed, we make use of it successfully every day of our lives. We simply say that the area of its applicability may be limited.

Armed with that kind of philosophical background, which is much more restrained and cautious than that of our predecessors at the turn of the century, we are far better placed than they were to withstand the next shock to physical thinking, which was about to be delivered (in 1899) by Max Planck. □

Next month

2Kbyte eprom emulator/ programmer

A design for an emulator for 2516/2716 eproms, in which a ram, loaded with software by keypad, carries out the function of a rom and allows a program to be run and tested without the need for eprom reprogramming. Ram contents are easily modified, and the emulator plugs into the system eprom socket. When the program is satisfactory, the emulator transfers to eprom the tested ram contents.

Sélective call for c.b. radio

To call any one of 64K similarly equipped c.b. receivers, enter a number on a keypad to generate a 16 data-bit frame to modulate the carrier. Only the selectively called receiver will respond. The device is easily modified for high-security applications, such as remote access and data interrogation.

Simple, low-frequency oscilloscope

A very simple design, using a surplus radar tube. It uses easily obtained components, is straightforward and costs only around £40. Vertical bandwidth is up to 1MHz at 50mV/cm and the timebase is either astable or triggered.

Op-amp development

As a preliminary to a full description of his new, modular preamplifier, John Linsley Hood traces the development of the operational amplifier, from the early 741 types to the mosfet-input CA 3140 and the bipolar/fet TL071/2/4/ series, designed for use in audio work.

On sale August 18.

CIRCUIT MODELLING BY MICRO-COMPUTER

The small-signal a.c. properties of a circuit may be modelled on a computer. Here the implementation of a program uses techniques to reduce the computing time by 77%, or more, and to plot graphs of the frequency and phase responses.

A previous article on this subject[1] led me to implement circuit modelling on my home computer. I prefer to reserve the word 'analysis' for analytical, normally algebraic, methods such as complex variable theory. As home computers cannot do algebra, I have called the process 'circuit modelling'.

For the design of a 16-node active filter, I used a program to plot frequency responses on a printer, giving simultaneously phase and gain curves. The reduction of the infinite admittance determinant to a two-by-two was done for 50 frequencies in order to obtain enough points for a good curve. At first this took nearly two hours to run on my 4MHz Z80A microcomputer. The table shows a breakdown of the number of operations in Basic.

Operation Type	Number of Operations Originally	No. after Optimising Code
FOR X = . .	700	700
FOR P = . .	6650	6650
FOR Q = . .	74550	21150
ADDS	223650	43400
SUBTRACTS	298200	29800
DIVIDES	149100	14900
MULTIPLIES	745500	61000
ARRAY REFS.	1341900	86800
IF . . . THEN	0	28500
TOTAL	2840250	292900

Clearly any operation contained in the FOR . . . NEXT Q loop is carried out a far greater number of times than in any other position. The first step in reducing the running time is to move as many operations as possible outside this loop. The second step is to reduce the number of array references, as these take the longest time. Thirdly to eliminate any unnecessary computations: the determinant being evaluated is normally sparse because few nodes are interconnected. This causes many zero entries to appear and the computer dutifully subtacts zero for each unused node. This can be avoided by including a test for zero. For a typical 16-node circuit, these changes have reduced the number of computations ten-fold. The Basic interpreter code used is shown under. It uses the notation of A. S. Beasley's article[1] and cuts the time for a 50 frequency graph to 27 minutes, a saving of 77%. Note that the use of the exponentiation operator (**) has been avoided. I have used A=Y1*Y1+Y2*Y2 in place of A=Y1**2+Y2**2. Exponentiation is slower than multiplication and less accurate.

Further opimisation will be machine dependent, and the use of a Basic compiler

By R. I. Harcourt

```
      FOR X=N TO 3 STEP -1
      Y1=YR(X,X)
      Y2=YI(X,X)
      A=Y1*Y1+Y2*Y2
      IF A=0 THEN 1600
      FOR P=0 TO X-1
      Y3=YR(P,X)
      Y4=YI(P,X)
      IF (Y3 = 0 AND Y4=0) THEN 1300
      FOR Q=0 TO X-1
      Y5=YR(X,Q)
      Y6=YI(X,Q)
      IF (Y5 = 0 AND Y6=0) THEN 1200
      B=Y3*Y5-Y4*Y6
      C=Y5*Y4+Y6*Y3
      YR(P,Q)=YR(P,Q)-(B*Y1+C*Y2)/A
      YI(P,Q)=YI(P,Q)-(C*Y1-B*Y2)/A
1200  NEXT Q
1300  NEXT P
1400  NEXT X
      RETURN
1600  PRINT "NODE ";X;" UNUSED"
      GOTO 1400
```

such as that produced by Microsoft is the simplest method. I did not use Fortran because it is rather hard to plot graphs using the Fortran Format statements. It is also much harder to write a proper command decoder using Fortran rather than Basic. However, rather than spending money on a Basic compiler, I decided to re-code the FOR . . . NEXT Q loop, using assembler, and call the machine code subroutine from the Basic. I will not describe the assembler code in detail as it depends on the computer in use; but I will describe the macro-codes I used. Provided a Macro-assembler is available, the macro-code will be the same for any computer.

Macro-codes

A macro is a block of code which is invoked whenever the macro call is used. The macro-assembler sees the name of the macro called, and automatically inserts in its place the block of code defined. This would be useful even if it just saved typing, but the technique really comes into its own when the macro can have arguments.

If I define a macro for multiplecation, called, say, MPY, then I shall need to specify a multiplier, a multiplicand and a place for the answer. The macro MPY is used as follows:

MPY X,Y,Z is equivalent to Z=X*Y

It is defined by saying:

```
MPY MACRO A,B,C
*
* (code is entered here)
*
ENDM
```

The code for the multiplication is not shown but whenever MPY is used that code replaces the macro-call. The real arguments X, Y and Z are substituted in place of the dummy arguments A, B and C. It is now possible to use expressions like:

MPY X,Y,Z

MPY Z,W,Z

which is the equivalent of Z=W*X*Y, and

MPY X,X,X

this is the same as (LET) X=X**2

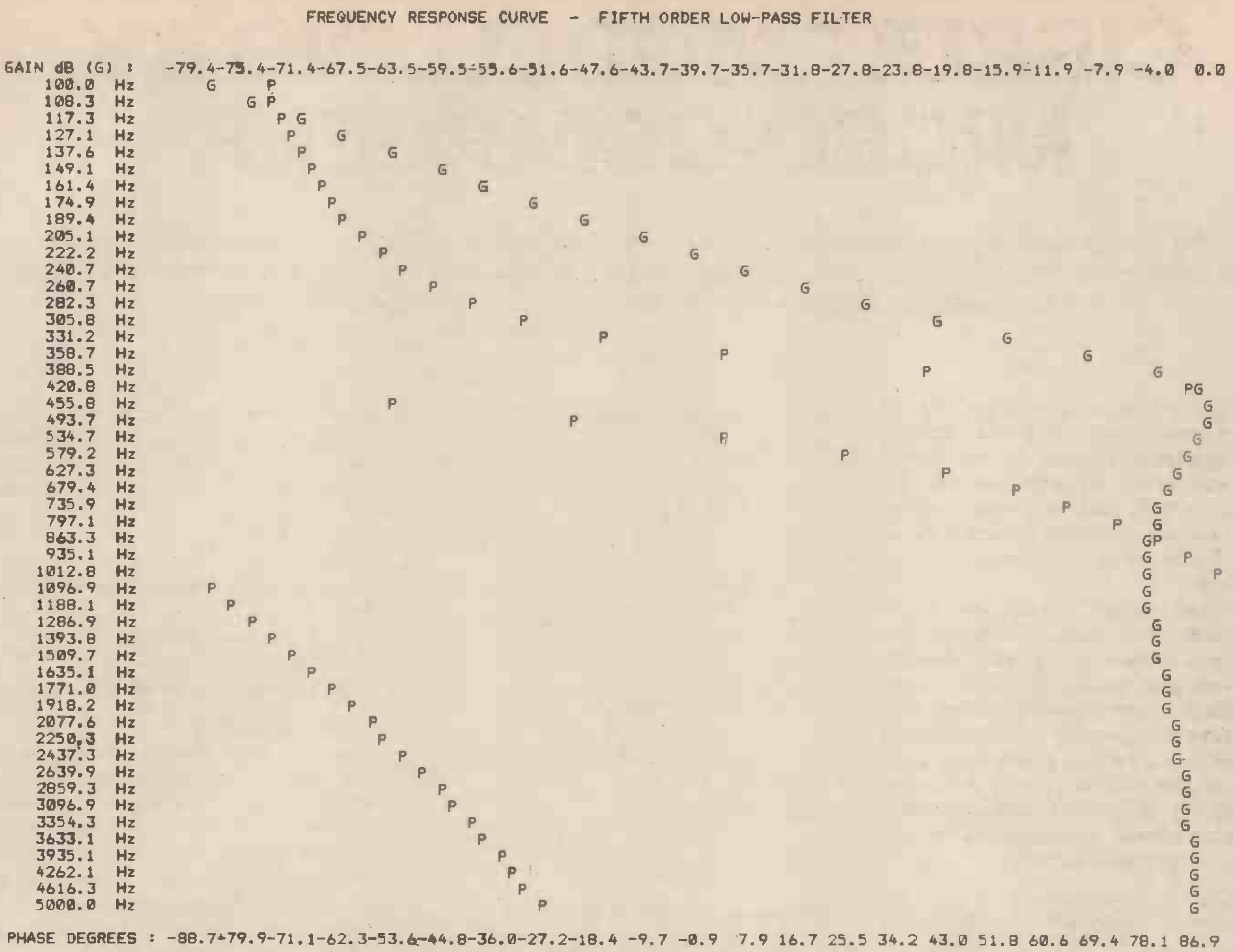
The macro-codes for use in the FOR . . . NEXT Q loop are shown in the appendix.

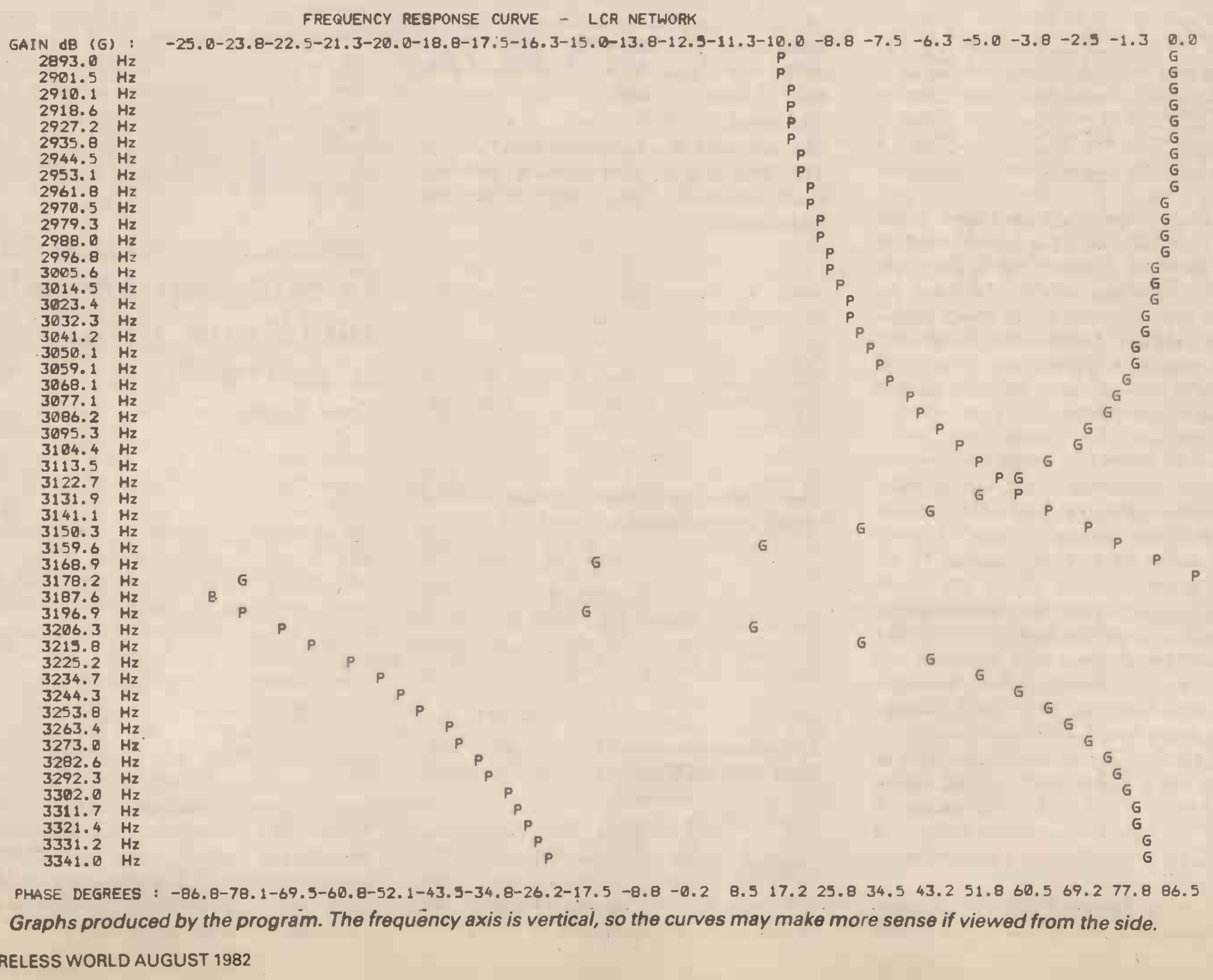
Graph plotting

Here is a Basic program for plotting gain and phase shift simultaneously on a line-printer or v.d.u. Examples are shown. It should be noted that both frequency and gain are plotted using logarithmic scales. Gain and phase axes are drawn so as to completely fill a page, with automatic scaling of axes. A gain point is plotted as a letter G, a phase point as a P, but if both coincide the letter B is used at that point. The code is as follows:

```
REM PLOT A GRAPH
INPUT "HEADING";C$
INPUT "FROM WHAT FREQUENCY";F1
INPUT "TO WHAT FREQUENCY";F2
INPUT "IN HOW MANY STEPS";NF
RA=EXP(LOG(F2/F1)/(NF-1))
LPRINT CHR$(12)                       'NEW PAGE
LPRINT TAB(30);"FREQUENCY RESPONSE CURVE - ;C$
LPRINT
MN=1E38 : MX=-1E38 : F=F1/RA
A1=-90 : A2=90
FOR I=1 TO NF
F=F*RA
FR(I)=F
GOSUB 20000                          'SETUP Y ARRAYS
GOSUB 21000                          'REDUCE TO 2 PORT
GOSUB 22000                          'GAIN AND PHASE
GOSUB 23000                          'CONVERT TO dB
IF MX<G THEN MX=G                    'MAX GAIN FOUND
IF MN>G THEN MN=G                    'MIN GAIN FOUND
IF A1<A THEN A1=A                    'MAX ANGLE FOUND
IF A2>A THEN A2=A                    'MIN ANGLE FOUND
GG(I)=G                              'ARRAY OF GAINS
AA(I)=A                              'ARRAY OF ANGLES
NEXT I                               'END OF GET GAINS
RN=MX-MN                             'GAIN RANGE
RA=A1-A2                             'ANGLE RANGE
ST=RN/20                             'HORIZ GAIN STEP
SA=RA/20                             'HORIZ. ANGLE STEP
LPRINT
LPRINT "GAIN dB (G) :   ";            'AXIS LABEL
FOR I=0 TO 20
LPRINT TAB(16+I*5) ;                  'AXIS STEP SIZE
LPRINT USING "###.#";(MN+ST*I) ;'AXIS MARKS
NEXT I                               'END GAIN AXIS
LPRINT
FOR I=1 TO NF                        'FOR EACH FREQ.
LPRINT USING "#########.#" ; FR(I) ;
LPRINT " Hz" ; TAB(20) ;
GS=INT(100*(GG(I)-MN)/RN)             'GAIN COORD
AS=INT(100*(AA(I)-A2)/RA              'ANGLE COORD
 IF GS>AS THEN S1=AS : C1$="P" : C2$="G"  :  S2=GS-AS-1
IF  GS<AS  THEN  S1=GS  :  C1$="G"  :  C2$="P" : S2=AS-GS-1
IF GS=AS THEN C1$="B" : S1=GS : S2=1 : C2$=" "
LPRINT SPC(S1) ;                      'PRINT SPACE 1
LPRINT C1$ ;                          'LETTER 1
LPRINT SPC(S2) ;                      'SPACE 2
LPRINT C2$                            'LETTER 2
NEXT I                               'FINISHED
LPRINT
LPRINT "PHASE DEGREES : ";            'AXIS LABEL
FOR I=0 TO 20
LPRINT TAB(16+I*5) ;
LPRINT USING "###.#";(A2+SA*I)
NEXT I                               'END
RETURN
```

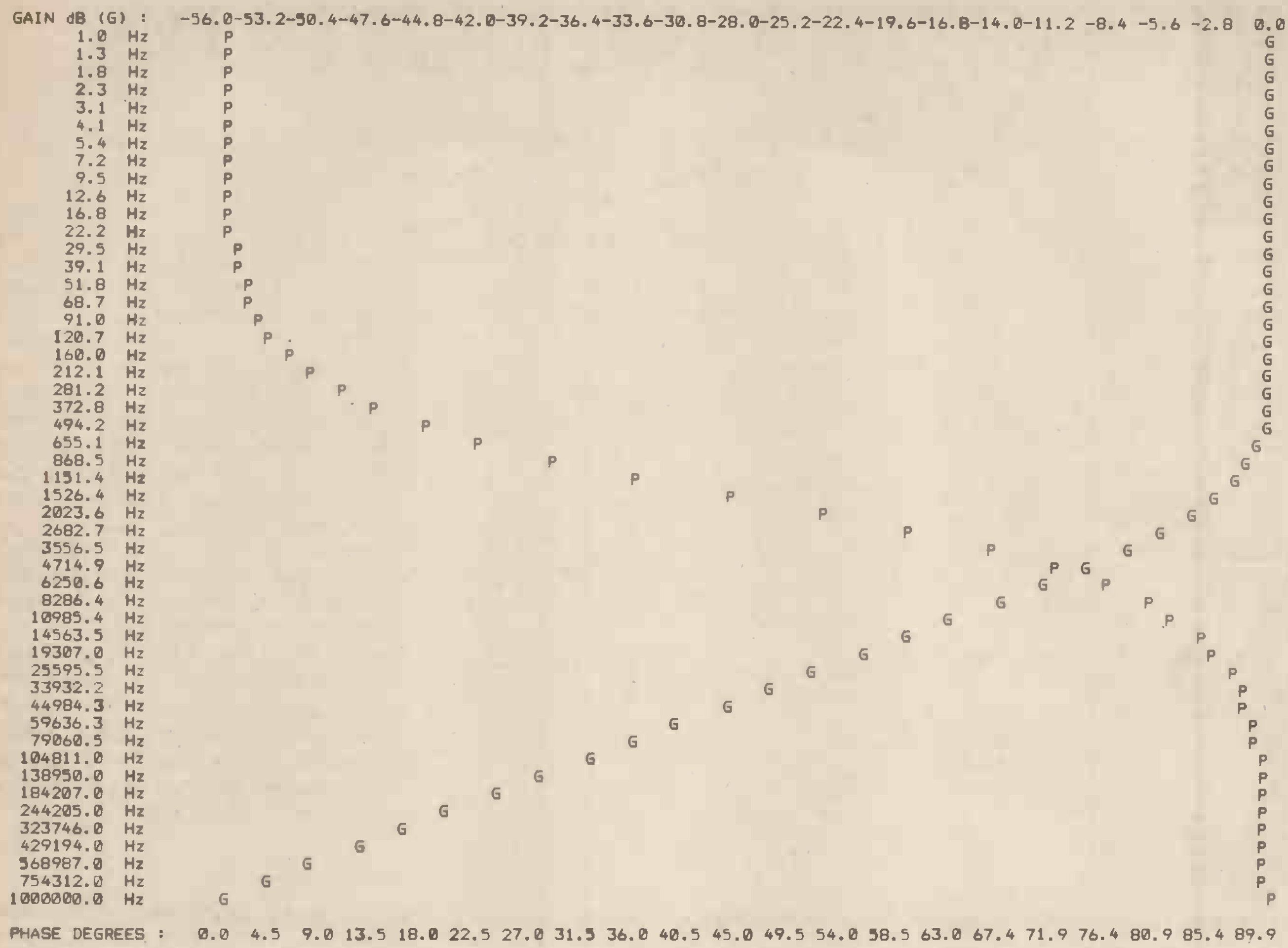
All the print statements can be seen to be LPRINT statements and a 132 column printer was used. If v.d.u. output is required, then PRINT statements should be substituted and the graph should be scaled according to the width available.





Graphs produced by the program. The frequency axis is vertical, so the curves may make more sense if viewed from the side.

FREQUENCY RESPONSE CURVE - TEST PLOT - CR LOWPASS - R=10K C=10N



While working on loudspeaker crossovers, I wanted to model a crossover feeding two drive units, one of which was connected out of phase. For speakers in phase it was easy to find the sum by specifying a summing network, but for an out-of-phase speaker, I found it necessary to invent a non-existent circuit element. I have called this an 'inverter' which is a two terminal device with the property of 'losing' any current flowing into it while taking in an equal current at its other end which is also lost. This violates Kirchhoff's law and the charge conservation laws, but the method works on the computer. The 'inverter' has admittance determinant:

$$\begin{matrix} +1E5 & +1E5 \\ +1E5 & +1E5 \end{matrix}$$

and the value used (always a positive value added to the YR array) was +1E5, so that the net effect was of a small resistor connecting an out-of-phase speaker to the output node.

Having cut the time for our typical 16-node circuit frequency plot to 16 minutes from two hours, I then tried the effect of a BASIC compiler and used the Microsoft compiler. This produces true machine code and the time for 50 reductions from 16 nodes to a 2-by-2 was now 2 minutes 48 seconds. With the addition of the macro assembler codes to the two inner loops (P and Q), this was cut to 2 minutes 6 seconds, a saving over the original running time of 98%.

So it can be seen that with a little effort, much time can be saved. The purchase of a Basic compiler compatible with the interpreter can turn the home computer into a useful designer's tool.

Appendix

Macro-codes for fast reduction

The macro-code used was as follows: Each operation is shown with its equivalent in Basic:

```
MSB   Y3,Y5,Y4,Y6,B    ;B=Y3*Y5+Y4*Y6
MAD   Y5,Y4,Y6,Y3,C    ;C=Y4*Y5+Y6*Y3
MAD   B,Y1,C,Y2,D      ;D=B*Y1+C*Y2
MSB   C,Y1,B,Y2,E      ;E=C*Y1+B*Y2
DIV   D,A,D            ;D=D/A
DIV   E,A,E            ;E=E/A
SUB   YRPQ,D,YRPQ      ;YR(P,Q)=YR(P,Q)-D
SUB   YIPQ,E,YIPQ      ;YI(P,Q)=YI(P,Q)-E
RET
END
```

The macro definitions, which should precede their use, are:

```
MAD   MACRO   M1,M2,M3,M4,ANS
      MPY     M1,M2,T1
      MPY     M3,M4,T2
      ADD     T1,T2,ANS
      ENDM

MSB   MACRO   M1,M2,M3,M4,ANS
      MPY     M1,M2,T1
      MPY     M3,M4,T2
      SUB     T1,T2,ANS
      ENDM
```

All other macro definitions (ADD, SUB,MPY,DIV) are machine dependant, and are not shown here.

Note: A version of the circuit modelling program, called ACM, suitable for TRS80 micro-computers, will be available from Molimerx Ltd, 1 Buckhurst Road, Town Hall Square, Bexhill-on-Sea, E. Sussex.

References

This article is an extension of "Circuit analysis by small computer," by A. S. Beasley, *Wireless World*, Feb. and April 1980. Photocopies of this are available from WW, Editorial, at a price of 90p inclusive. An interesting discussion of the theory may be found in "Two-port representation of multi-mode networks by matrix partitioning," by R. T. Kennedy, J.I.E.R.E. Feb. 1969. □

Orchestral sounds, halls and timbre — a correction

Denis Vaughan has kindly pointed out to us one or two misprints which crept into his article in the May 1982 issue: Just under the heading 'First reflections' on p.32, the phrase should read: "Their timing is exactly controlled by the width (1 foot ≈ 1ms)." In the middle of page 33, reference is made to Guildford and this should read Gilford. In the third column of the same page, there are two references to reflection times which should read: "this means that the effectively larger reflections start about 81ms after the original sound'. and; "Kingsway has quite a lot of powerful reflections to offer within the first 105ms. Because the larger reflections continue to return up to 147ms, the substantial and lengthy support of the musicians is assured". The figures printed (18 and 14ms) could be misleading, especially to those interested in modelling electronically the initial reflection pattern of the hall.

DIGITAL DIVIDERS WITH SYMMETRICAL OUTPUTS

The author uses Johnson counters with controlled feedback to give symmetrical even and odd-numbered divisions of a clock pulse.

By Cornelius van Holten

Time and again, in literature on digital circuitry, ideas are published on the problem how to obtain a 50% duty cycle when a regular pulse train is divided by an odd number. Some clever (and less clever) methods are proposed, e.g. the use of exclusive-or gates in the clock pulse lines, a separate flip-flop with a delay of half a pulse period, the output of which is combined with the normal flip-flops, etc.

In my opinion, the use of EXOR-gates in clock lines should be avoided, since spikes on the output-signals of the flip-flops may occur; a better way is to combine the outputs signals of the flip-flops. The ideas, found in Refs. 3 and 4 are broadened in this paper, and a generalized scheme is proposed which may be easily expanded. Moreover, the control input is pure binary and there is no attempt to change the (odd or even) sequence length. Standard i.cs are used.

The Theory

When a Johnson or Möbius ring counter is fed back, a sequence length of n or 2n is derived, depending on whether a straight or twisted loop is used. The maximum sequence-length is 2n for n bits, and sequences of 2(n-1) etc, are derived when outputs, other than the last, are chosen. When two adjacent outputs are fed back via an AND-gate and negated, (Fig. 1.) any length between 2n and 2 may be obtained.

If an auxiliary flip-flop is connected to the chain and is switched on the opposite pulse edge, the output is shifted over ½T, where T is the clock pulse period. It is necessary for the incomong pulse train to have a duty cycle of 50%; if not, a divider is needed which will halve the frequency. In Fig. 2. the outputs of 2 flip-flops, FF_1, the last in the chain, and FF_2, the extra flip-flop, are combined in an OR-gate to obtain an odd sequence length (9) with a symmetrical output. In this case, $\bar{D}$ and $\bar{E}$ are fed back (see Table 1).

Table 1. Feedback signals and sequence length.

Feedback	Sequence/length
A	2
AB	3
B	4
BC	5
C	6
CD	7
D	8
DE	9
E	10
EF	11
F	12
FG	13
G	14
GH	15
H	16

When an even sequence length is chosen, a symmetrical output is derived from the last flip-flop in the chain, only one (negated) output is fed back and no OR process is needed. In the Table 2, a list is given of all possible combinations; I through VIII are the controls signals which switch the (negated) I for $\bar{A}$, II for $\bar{B}$, . . . VIII for $\bar{H}$.

Table 2. Control inputs and corresponding sequence lengths.

Control inputs I	II	III	IV	V	VI	VII	VIII	Output (*T)
1								1 +1 = 2
1	1							1½+1½= 3
	1							2 +2 = 4
	1	1						2½+2½= 5
		1						3 +3 = 6
		1	1					3½+3½= 7
			1					4 +4 = 8
			1	1				4½+4½= 9
				1				5 +5 =10
				1	1			5½+5½=11
					1			6 +6 =12
					1	1		6½+6½=13
						1		7 +7 =14
						1	1	7½+7½=15
							1	8 +8 =16

Complete circuit

In Fig. 3, the complete diagram is given, consisting of 8 flip-flops (a shift register), a pulse circuit, an output, feedback gates controlled by the inputs I to VIII, and a decision making circuit with 4 full adders for odd and even lengths.

The latter operates as an EXOR-gate with 8 inputs: Y = I ⊕ III ⊕ IV. . . . ⊕ VIII and therefore Y = '1' for odd and '0' for even lengths; the unused input of the full adder at the bottom is permanently held at a logical '1' level.

In the output circuit, the function H + YZ is realized. For Y = O, the output becomes H (for even length sequences) and for Y = 1, the output is H + Z (for an odd length) as shown in the time charts in Fig. 4a and 4b respectively.

The flip-flops A to H are D flip-flops, operating in the leading clock pulse edge and Z (auxiliary flip-flop) reacting on the trailing edge of it. The P flip-flop is needed when the input pulses are not symmetrical, and a buffer gate is used for amplification. The correction and enabling circuit is described in the Appendix. In normal circumstances, this circuit is inoperative and the shift register is loaded with all zeros by the enabling input, and cycles via 10000000, 11000000, 11100000, . . . through 11111111, 01111111, etc. back to the all zero condition. This is the "normal" sequence, 1 out of the 16 possible cycles. Of course, other values of n than 8 are possible, this number has been chosen for comparison with the circuit described by Girolami and Bamberger[2].

Modification

In Fig. 3(a), there are 8 control inputs which are used separately (for even lengths) or in groups of adjacent pairs (for odd lengths). If one wishes to control the sequence length via a binary weighted control input, a decoder is needed as described in Table 3.

In Fig. 3(b), a read only memory is programmed as a decoder, and the input 1 may be used to control the output circuit: even or odd; the output function is H +

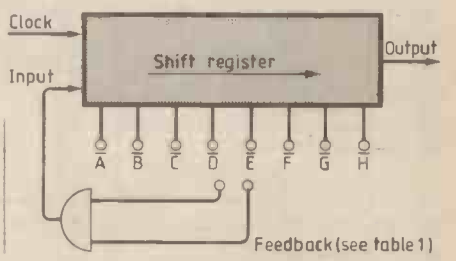


Fig 1. Basic principle of a variable length counter.

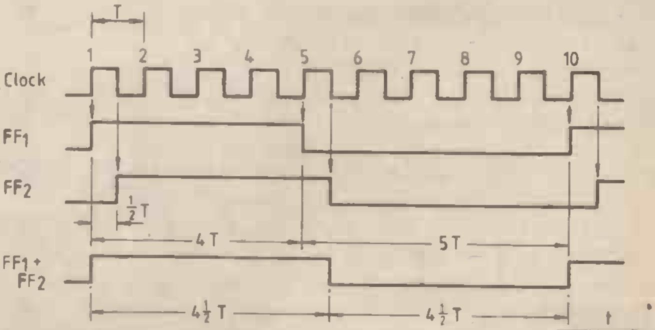


Fig 2. The addition of two asymmetrical flip-flop outputs leads to a symmetrical output.

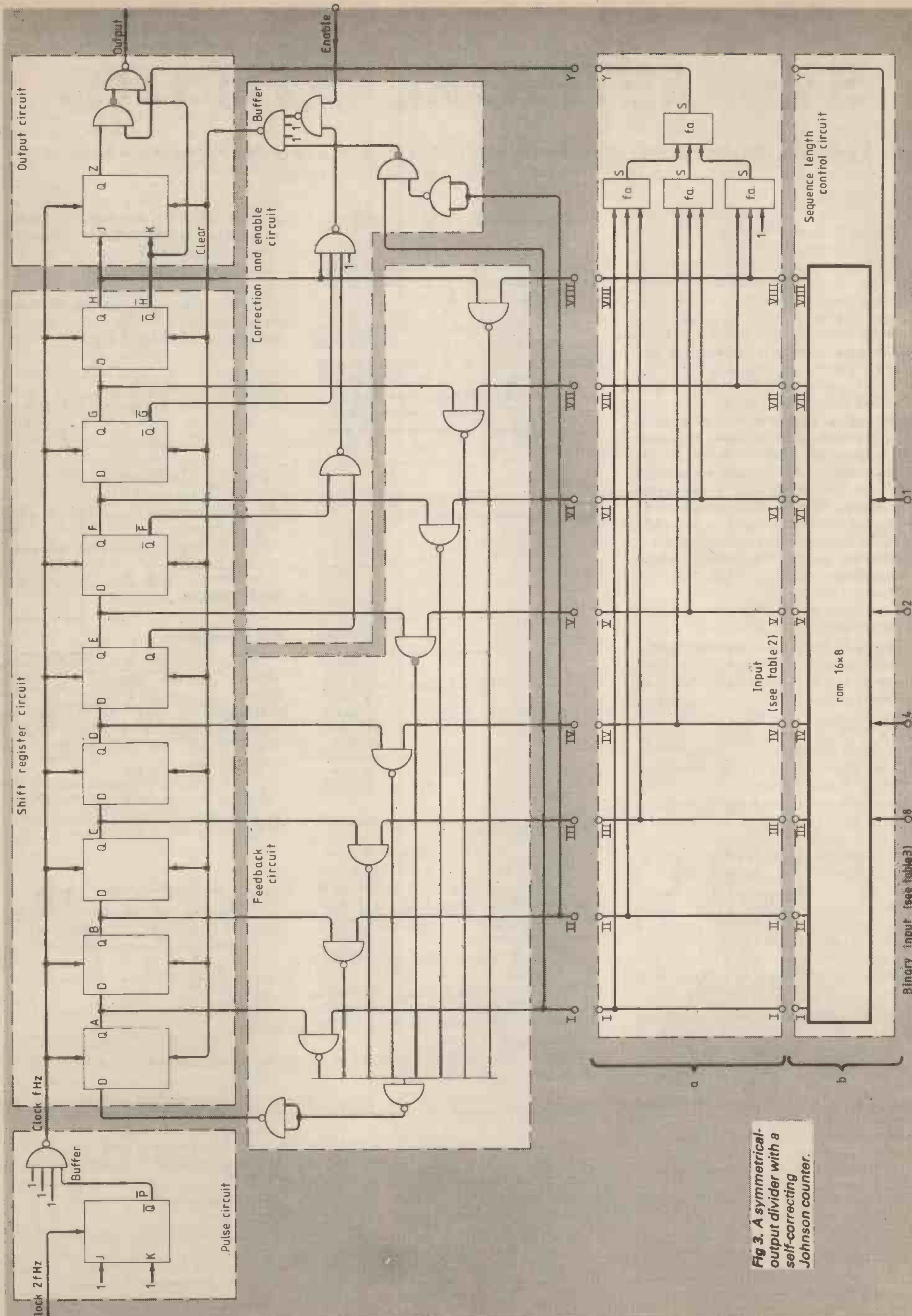


Fig 3. A symmetrical-output divider with a self-correcting Johnson counter.

Table 3. Binary weighted control inputs and corresponding signals and sequence lengths.

Input 8 4 2 1	I	II	III	IV	V	VI	VII	VIII	Sequence length
0 0 0 1				no sense					–
0 0 1 0	1	0	0	0	0	0	0	0	2
0 0 1 1	1	1	0	0	0	0	0	0	3
0 1 0 0	0	1	0	0	0	0	0	0	4
0 1 0 1	0	1	1	0	0	0	0	0	5
0 1 1 0	0	0	1	0	0	0	0	0	6
0 1 1 1	0	0	1	1	0	0	0	0	7
1 0 0 0	0	0	0	1	0	0	0	0	8
1 0 0 1	0	0	0	1	1	0	0	0	9
1 0 1 0	0	0	0	0	1	0	0	0	10
1 0 1 1	0	0	0	0	1	1	0	0	11
1 1 0 0	0	0	0	0	0	1	0	0	12
1 1 0 1	0	0	0	0	0	1	1	0	13
1 1 1 0	0	0	0	0	0	0	1	0	14
1 1 1 1	0	0	0	0	0	0	1	1	15
0 0 0 0	0	0	0	0	0	0	0	1	16

YZ, realized by NAND gates via the formula $\overline{H} \cdot \overline{YZ}$

Conclusion

A method is proposed by which in a straightforward manner any sequence length may be chosen via a binary weighted input. The circuits are normal s.s.i. or m.s.i. i.cs; for an 8 bit integrated shift register, the clock input is buffered as is the clear input. The buffers may be left out. The output is symmetrical and no spikes occur, since the Johnson principle is in fact a Gray code of sorts, changing only 1 output per clock pulse.

The number of flip-flops is ½n, when n is the sequence length, whereas for a normal counter $\log_2 n$ flip-flops are needed. There is little disadvantage, however, with low prices. In both cases the sequence is nonbinary.

Appendix

With n = 8, there are 256 possible zero-one bit patterns, of which only 16(8 × 1 and 8 ×0 in groups of 8) are valid. All other sequences have to be detected and corrected; since 00000000 is a valid combination, resetting of all flip-flops is an easy way to correct.

If one wishes to correct any invalid combination immediately, a rather complex circuit is needed; it turns out, however, that with certain combinations, the register may be reset; within 16 clock pulses any error will be removed.

In the normal sequence, no '0' is present between '1's; so 101 looks a good bit pattern to detect. However, not all sequences contain this combination; 1001 also occurs.

To check these sequences we write down any non-normal sequence, economizing space by writing the notation in a row, as follows:

e.g. $\underline{1}\,1\,\underline{1\,0\,1}\,\overline{1\,0\,1}\,0\,0\,0\,\overline{1\,0\,0\,\underline{1}}\,\underline{0}$

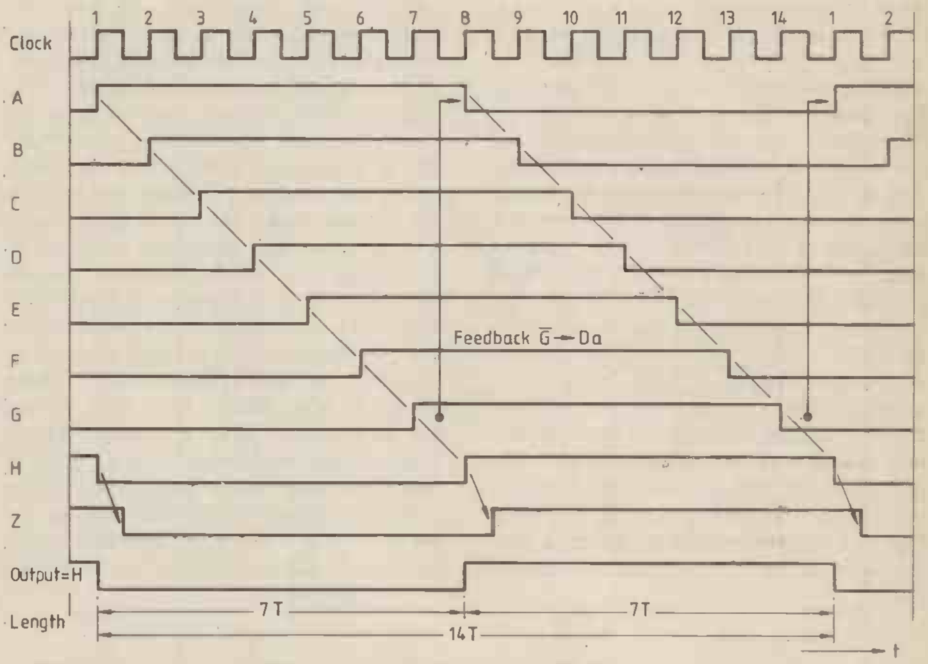


Fig 4a. Time chart for an even-numbered division (e.g. 14).

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He has written a self instruction course in digital circuitry and some 20 papers in periodicals.

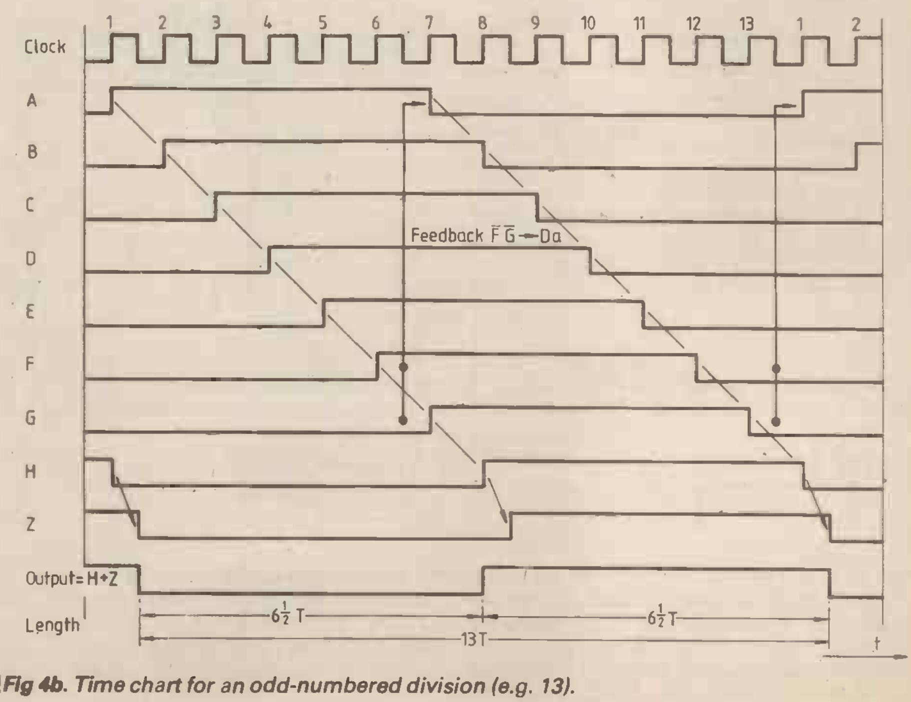


Fig 4b. Time chart for an odd-numbered division (e.g. 13).

The ends are in fact connected, so by checking 1 0 1 and 1 0 0 1 "over the edge" if needed, the result is:
1 0 1: (3x) and 1 0 0 1: (1x)
This means that $F\bar{G}H$ and $E\bar{F}\bar{G}H$ have to be used; simplification gives:
$(E\bar{F} + F)\ \bar{G}H = (E + F)\ \bar{G}H$ or rewritten in NAND-form:

$$\overline{E.F}.GH$$

Since reset is a 'O' signal, we invert this to: $\overline{E.F}.GH$; a buffer and an external enable (normally '1') signal results in the circuit as show in Figs. 3 and 4.

For a sequence of 2, however, this correction has to be corrected itself by an I.$\overline{\text{II}}$ signal (I is 1, II = 0) since this short sequence the detection patter occurs.

A	B	C	D	E	F	G	H	
0	1	1	0	0	0	0	0	
0	0	1	1	0	0	0	0	
1	0	0	1	1	0	0	0	(in A,B,C,D)
1	1	0	0	1	1	0	0	
0	1	1	0	0	1	1	0	
0	0	1	1	0	0	1	1	
1	0	0	1	1	0	0	1	(in E,F,G,H)

Detection and correction follows: there is no reason, to choose EFGH; any group of 4 consecutive outputs is valid. The reset is asynchronous, i.e. not controlled by the clock pulse, but within one period T the counter is ready and starts again, whatever the sequence length may be. □

References

1. L. E. Getgen. Divide symmetrical clock pulses by odd numbers, get a symmetrical output. *Electronic Design*, 5, March 1, 1980, p.110.
2. G. Girolami, P. Bamberger, Symmetrical-output dividers, *Wireless World*, February 1982, p.53, 54.
3. R. M. M. Oberman. Electronic Counters. Macmillan, London, 1973, p.151ff.
4. M. Morley. Two IC's restore symmetrical output to a ring counter. *Electronic Design*, February 18, 1982, p.206. □

continued from page 36

try in the system error log, as it indicates a malfunction. In the embedded-servo surface drive, however, the condition is handled differently. Figure 13 shows a flowchart for the control of the drive, which has no absolute cylinder-address register, and in which all seeks are relative. The system only knows where the heads are by reading a header. In order to reach a particular cylinder, the program has to read the first header it sees on the current cylinder, and calculate the cylinder difference required to get to the desired cylinder. This cylinder difference, which may be positive or negative, is sent to the drive, which performs a deductive seek. When this is complete, the program again reads a header. Most of the time the header will contain the desired cylinder address, proving that the seek was successful, but in the odd case where the cylinder count deduction was in error, the program simply loops and calculates a new difference value until the correct cylinder is reached.

Since each surface has its own embedded-servo information, the heads may be aligned using a normal data disc pack. As a new head is selected, it becomes the source of the position error, and as the heads are only aligned to one another within a certain tolerance, the positioner will adjust itself to eliminate any position error when head switching takes place. This process takes time, and further time is necessary to read a header to confirm that the desired cylinder is under the new head. The time taken by this process is the same as that needed to perform a one cylinder seek, such as might be necessary when all tracks of a cylinder have been written but there is still data to transfer. With a conventional disc drive format, both of these processes would cause the loss of an entire revolution of the disc, waiting for sector zero to come under the heads again. Having abandoned the concept of absolute cylinder addressing, which made it necessary to read headers to discover the head position, it is also possible to abandon the fixed index concept, as the sector number is contained in every header read. There is no index point on the disc, and all of the sector pulses are identical. The format of adjacent tracks is displaced to allow enough time for a seek or head change, and for a header to be read to confirm the position, before sector zero of the new track comes around. In the case of a long data transfer of many blocks, a significant transfer-time reduction achieved, since rotational latency is eliminated.

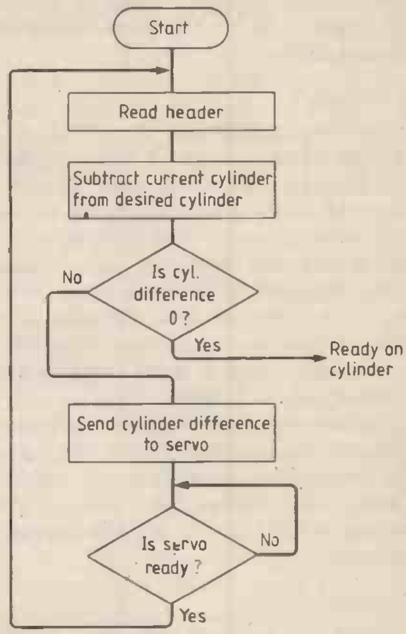


Fig. 13. Flow chart for an embedded-servo positioner system. An absolute cylinder-address register is not used, so all seeks are relative. Seek errors simply cause an extra execution of the loop.

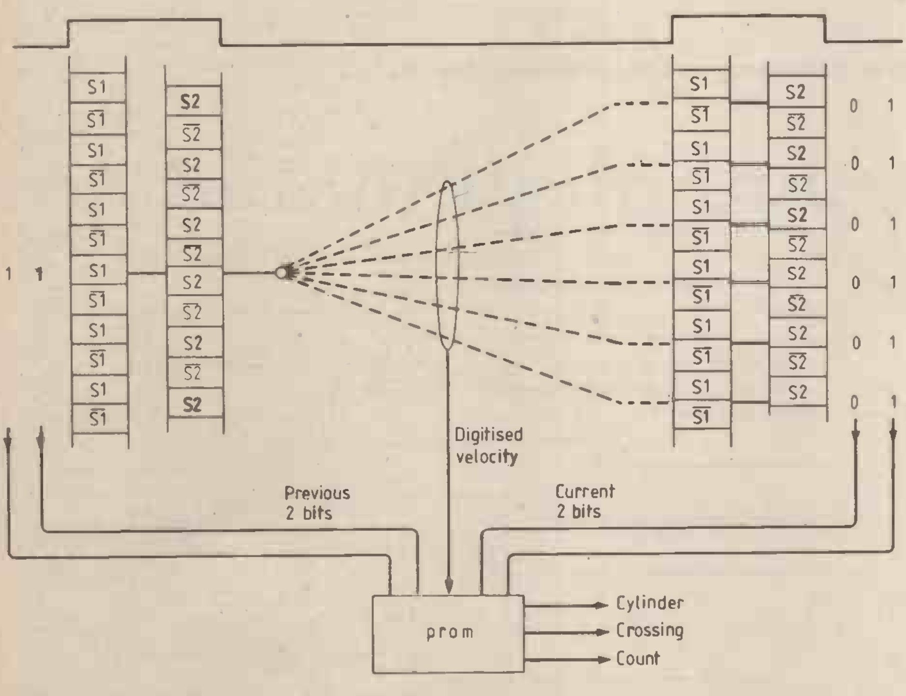


Fig. 12. Here, a seek is being carried out and value 11 from a servo sector has been stored for comparison with two bits from the next servo sector. As can be seen, there are many positions on the subsequent sector where the positioner appears to be on the correct cylinder. To avoid this ambiguity, digitized information from the carriage velocity transducer together with the two stored bits and two bits currently being read address a prom which returns the cylinder crossing count.

It is possible to build two versions of the drive. In the first, only the position error developed during S1 is used for track following. In the second, the position error from S1 is used for track following on even cylinders, and that from S2 used on odd cylinders. The second version obviously has twice as many cylinders as the first, but in other respects is basically the same.

Winchester technology and floppy discs and their drives are discussed in the next part of this series. □

DIGITAL FILTER DESIGN

Fast numerical operations using limited precision fixed-point arithmetic are now being provided by new types of microprocessors and l.s.i. circuits. This third article in a series of four outlines some of the problems of using fixed-point arithmetic and gives a brief survey of the new devices, concentrating on the Intel 2920.

by B. M. G. Cheetham and P. M. Hughes

Three types of operation are required for digital filters: multiplication of samples by constant coefficients, addition, and temporary storage for delaying samples. The digital filter shown in Fig. 1, a bi-quadratic section, represents the sequence of mathematical operations that must be carried out for each input sample x_n referred to as X to produce an output sample y_n referred to as Y. The sequence of operations may be summarized as

1. Calculate W by adding W′ multiplied by $-b_1$ and W″ multiplied by $-b_2$ to X. (W′ and W″ are values of W stored during previous executions of this algorithm – see steps 3 & 4).
2. Calculate the output Y by adding W′ times a_1 and W″ times a_2 to W.
3. Set W″ to the number currently stored in W′ for next time.
4. Set W′ equal to the number currently stored in W.

Recursive digital filters are generally implemented as cascades of biquadratic sections i.e. the required transfer function H(z) is expressed as the product of second-order transfer functions $H_1(z)$, $H_2(z)$ . . . each being realised by a distinct digital filter section of the type illustrated. A practical digital filter, therefore, would be a device or devices capable of performing the calculation sequence listed above for all biquadratic sections, for each input signal sample x_n. These calculations must be carried out accurately and within the time-span available between samples in real-time applications. Before looking at real-time digital filters, however, consider briefly their implementation on general-purpose digital computers.

Real-time processing

Although digital filters have been studied for many years, their use has until recently been mainly confined to research applications and computer simulations. This is likely to change rapidly with the development of special-purpose microprocessors and v.l.s.i. devices for signal processing. Such devices essentially execute the type of program discussed in the panel, but if the programmed filter is to be used for continuous signals sampled in the Nyquist rate, all numerical calculations must be completed for each input sample before the next one becomes available; otherwise an increasing backlog of samples would be built up. This imposes a speed requirement which is not present when processing blocks of stored data on a general purpose computer. Such processing would normally use the highly accurate floating-point arithmetic operations provided by high level languages but at great cost in processing time, typically 100µs per multiply or add. The necessary increase in processing speed required for real-time filtering is currently possible only at the expense of accuracy through the use of fixed-point arithmetic. It is thus necessary to represent all samples, coefficients and results of additions and multiplications by binary numbers of limited wordlength with the equivalent of the decimal point, i.e. the binary point, assumed fixed at some position within the word.

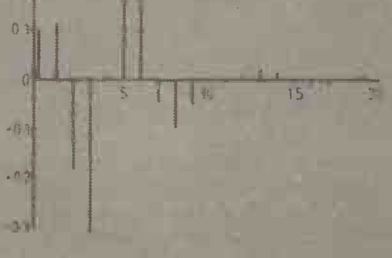
For example, the 16-bit number 0.110000000001101 with fixed binary point represents the decimal number 0.75040 correct to about five significant figures, whereas 0.0075040 must be written as 0.000000011110110 which gives only about three significant figures of precision. In contrast to floating-point numbers, the accuracy to which a fixed-point number represents a given number depends on its magnitude. Care must be exercised in positioning the binary point lest the addition of two numbers be allowed to overflow, producing a result too large for the chosen format. Negative numbers may be represented in two's complement form with a value obtained by subtracting 1.XXX . . . from the fractional part of the binary number. In this representation, the fixed-point numbers outside the range ±1 are not allowed and all numbers likely to appear within a digital filter would have to be scaled accordingly.

The use of fixed-point number representations clearly introduces complications in the design of digital filters and introduces

Programming on general purpose computers

Digital filters are often programmed in high-level languages such as Fortran or Basic and run on general-purpose computers or microcomputers to process blocks of signal samples stored as data arrays. This approach may be used to analyse experimental data where unwanted effects must be filtered out or where particular features must be extracted; you may have used the "trapezoidal rule" for numerical integration $y_n=y_{n-1}+(x_n+x_{n-1})/2$, without realizing that the formula represents a type of digital filter.

Programming a digital filter on a desk-top computer is a very useful way of testing its design before building it. In this application the programmed filter is a simulation of the system to be built, which may be tested by feeding in special test signals generated or captured as blocks of data by the computer. Programming digital filters in high-level languages is straightforward and a good way of learning about their capabilities.



As an example, a Basic program for a fourth-order digital filter is given in the first listing. The filter consists of two biquadratic sections with transfer functions

$$\frac{1-2z^{-1}+z^{-2}}{1-1.0524z^{-1}+0.6232z^{-2}}$$

$$\text{and}\quad\frac{1+2z^{-1}+z^{-2}}{1-0.1665z^{-1}+0.5348z^{-2}}$$

This filter has a Butterworth type band-pass response (passband $0.125f_s$ to $0.25f_s$ where f_s is the sampling frequency), as designed in the previous article. Each biquadratic section is implemented by calling a subroutine (GOSUB 800) with coefficients a_1, a_2, b_1, b_2, stored in the Jth elements of arrays A1, A2, B1, B2; J is 1 for the first biquadratic section and 2 for the second. The subroutine simply follows steps 1 to 4 derived from Fig. 1 with the Jth elements of arrays W1 and W2 holding W′ and W″ as required for subsequent calls to the subroutine. Arrays W1 and W2 are zeroed before the first call to the subroutine. Variables X and Y are the input to and output from the programmed biquadratic section. For this example, an array X loaded with 21 samples of the discrete time impulse δ_n is used as an input signal. Output samples are stored in a second array Y and are also printed out. Graph shows the output obtained from this program. This method may be generalised to digital filters of any order with input and output data arrays of much larger dimension.

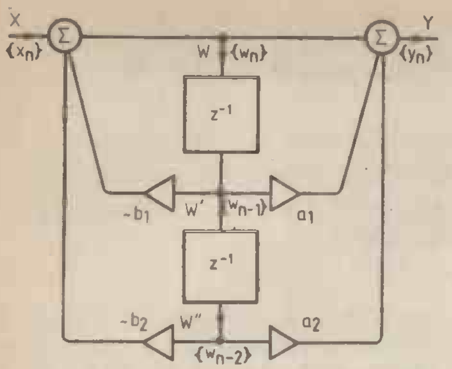


Fig. 1. Recursive digital filters are generally implemented as cascades of biquadratic sections, above. Diagram shows sequence of mathematical operations that must be carried out for each input sample $\{x_n\}$ to give output sample $\{y_n\}$.

innaccuracy which will tend to degrade performance as compared with the theoretical ideal. Some of the most important effects are next considered.

Quantization noise. The conversion of an analogue signal into digital form introduces a degree of distortion as a result of representing the sampled voltages as fixed-point binary numbers. This distortion effectively adds on error signal known as quantization noise to the original signal, as illustrated in Fig. 2. The level of this unwanted noise signal is determined by the wordlength available and the dynamic range allowed for the analogue signal i.e. its expected maximum and minimum voltages. It may be shown that an n-bit analogue-to-digital conversion (with $n>4$) results in a quantization noise signal of r.m.s. value $\Delta/2\sqrt{3}, \Delta=(V_{max}-V_{min})/2^n$, is known as the quantization step. In theory, the noise is spread evenly over the frequency spectrum 0 to $f_s/2$. For a zero-mean input of r.m.s. value σ, the signal to quantization noise ratio is

$$20\log_{10}(2\sqrt{3}\sigma/\Delta)$$
$$=20\log_{10}(2\sqrt{3}\sigma.2^n/2V_{max})$$
$$\approx 6n+10.8+20\log_{10}(\sigma/V_{max})\text{ dB}.$$

For this formula to be valid, input signal must not exceed the prescribed dynamic range. Ensuring that $\sigma \leq V_{max}/4$ achieves this to reasonable accuracy for noise-like signals, giving a maximum s-n ratio of

$$6n+10.8+20\log_{10}(0.25)=6n-1.2\text{ dB}$$

This formula may be used as a rule-of-thumb for a wide range of different types of input signal although higher ratios may be obtained by reducing σ/V_{max} for specific signals such as sinusoids. Clearly the maximum value depends on the number of bits in the digital representation, and increasing this number improves the figure by 6dB per bit.

Data wordlength. With fixed point number systems both the range and precision of the numbers which can be represented is limited. For convenience it is usual to think of all the signals within a digital filter as being in the range −1 to 1. Such signals require only one bit in front of the binary point, this being used as the sign bit to differentiate between positive and negative numbers. The precision of the number representation is determined by the number of bits available for storing data. A sixteen-bit data word, for example, with one bit used for the sign, gives a quantization step size of 2^{-15}. All data must therefore be rounded to the nearest integer multiple of 2^{-15}. In practice it is difficult to determine exactly how many bits are needed to satisfy particular performance requirements. The present generation of special-purpose signal processing devices employ basic wordlengths of between 16 and 25 bits.

Coefficient quantization. When a digital filter is implemented in real time its coefficient values as well as its samples must be quantized and stored to limited precision. The effect is to degrade the frequency response as illustrated in Figure 3. A wordlength of about 12 bits is typically used for coefficients. The second program listed calculates the amplitude-frequency response of a digital filter with original unquantized coefficients and with quantized values as they would be represented in the filter. The maximum difference over the relative frequency range 0 to 0.5 is printed out as a measure of the degree of degradation suffered.

Dynamic range limitations. Signal overflow, which occurs when the result of an addition or multiplication within a filter is out of range, will cause incorrect operation. The errors generated can cause self-sustaining oscillation of large amplitude which are highly undesirable. The simplest way of avoiding overflow is to multiply the input to each biquadratic section by a suitable scaling factor S. The aim is to reduce the input signal level sufficiently to ensure that the largest internal number likely to be generated is within range. For a sinusoidal input, S may be set equal to $1/G_{max}$ where G_{max} is the maximum gain between the unscaled input and any point in the second-order section. This ensures that no internal signal exceeds the input in amplitude. In practice, it is sufficient to examine only the overall gain of the section $G(\omega)$, and the gain $G_1(\omega)$ between the input and the internal signal W. It can be shown that

$$G_{max} \leq 2\max_{0\leq\omega\leq\pi}\{G(\omega), G_1(\omega)\}=2M$$

with $G(\omega)=|H_i(e^{\omega})|=$

$$\left|\frac{1+a_1e^{-j\omega}+a_2e^{-2j\omega}}{1+b_1e^{-j\omega}+b_2e^{-2j\omega}}\right|$$

$$\text{and } G_1(\omega)=\left|\frac{1}{1+b_1e^{-j\omega}+b_2e^{-2j\omega}}\right|$$

M may be calculated by evaluating $G(\omega)$ and $G_1(\omega)$ over the range $0\leq\omega\leq\pi$ and searching for the maximum modulus.

A Basic program for doing this is provided, see third listing. Choosing $S=1/2M$ will eliminate the possibility of overflow for sinusoidal signals, and in practice will normally prove satisfactory for other types of signal. In many cases this result may be unduly pessimistic and larger scaling factors S may be used depending on the particular filter being implemented and the type of arithmetic used. If G_{max} is significantly greater than the maximum value of $G(\omega)$ (overall gain) it may be necessary to scale up the output of a section to bring the overall passband gain to unity. Scaling factors are often approximated to the nearest power of two so that the required multiplication may be carried out by simply shifting the signal representation an appropriate number of bits to the left or right.

Example. Consider the scaling required for the first section of the bandpass filter whose impulse response is shown in the panel opposite. The coefficients a_1, a_2, b_1, b_2 for this section are −2, 1, −1.0524, 0.6232 respectively. By means of the program the maximum values of $G(\omega)$ and $G_1(\omega)$ are found to be 2.57 and 3.56 and hence $G_{max}\leq 2M=7.12$. A suitable scaling factor is therefore $1/7.12\approx 0.1404$. This would often be approximated to 2^{-3}, the nearest power of two, requiring the input to be shifted three bit positions to the right. As $G_1(\omega)$ is greater than $G(\omega)$ in this example, it would be necessary to scale up the output signal if a maximum gain of unity were required for the whole section.

Microprocessor implementation

In addition to its filtering task, a microprocessor may be required to control a-d and d-a converters, or alternatively interface with other digital devices as a means of signal input and output. When controlling converters it is necessary to provide some means of accurately maintaining a fixed sampling frequency.

The choice of microprocessor type depends mainly on the required sampling rate. The present generation of general purpose eight-bit microprocessors can provide digital filters with sampling frequencies of at most a few hundred hertz; the more powerful 16-bit microprocessors[1] enables this to be increased to about 5 kHz.

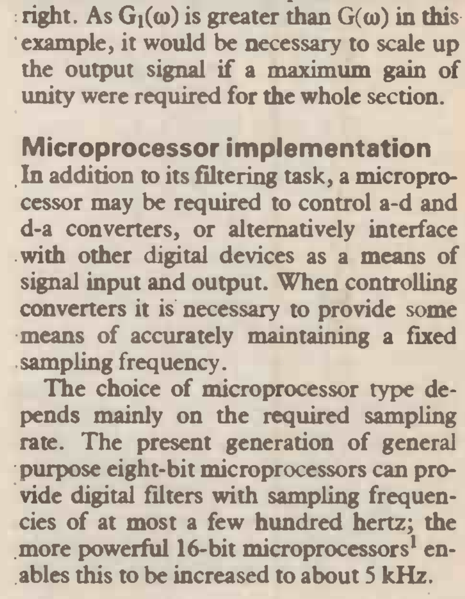


Fig. 2. Conversion of an analogue signal into digital form produces an error signal (quantization noise) which, in effect, is added to the original.

For the real-time filtering of audio bandwidth signals at sampling rates of about 8kHz and above, it has until recently been necessary to employ bit-slice microprocessors [2] or custom-designed hardware circuits which incur a high component count and circuit board complexity. The introduction in August 1980 of a microprocessor specifically designed for digital signal processing, the Intel 2920, significantly changed this position and marked the start of a new trend in digital signal processing. This is now being continued and emphasized by the introduction of a digital signal processor by NEC[3] and the fad[4], an l.s.i. digital filter designed by British Telecom. Details of other microprocessors intended for digital signal processing have been published[5] by Texas Instruments and Bell Laboratories.

The Intel 2920 incorporates both a-d and d-a converters on-chip and when programmed as a typical eighth-order digital filter has a sampling rate of approximately 30kHz. As such, the device can be used simply as a one-chip replacement for audio-bandwidth analogue filters. More recent devices differ from the Intel 2920 in that they do not incorporate the converters, but provide the means for interfacing with external converters. These provide more powerful arithmetic facilities than the 2920, including fast high precision multiplication. Large program and data memories are provided by the NEC, Texas and Bell devices which should allow them to implement not only fixed filters, but also adaptive digital filters which automatically modify their frequency response as the characteristics of the input signal change.

The Plessey/British Telecom fad (filter and detect) is not strictly a microprocessor, but sacrifices flexibility for simplicity of operation. It contains on one chip all the circuitry necessary to implement the biquadratic filter section shown in Fig. 1. Used as a single second-order section, the device can operate at a sampling rate of 64000 samples per second, with each input and output sample being up to 16 bits in length. The fully programmable filter coefficients are supplied in serial form by external memory. As an alternative to acting as a single second-order section, by using on-chip memory, the fad can be used in a multiplexed fashion to implement a cascade of eight second-order sections, providing a sixteenth-order filter with a sampling rate of 8000 samples per second. Cascades of between two and seven second-order sections can be implemented by modifying external connections.

To illustrate the full capabilities of microprocessor-implemented digital filters and to demonstrate how the techniques described may be applied to their design, consider in more detail the use of the Intel 2920. This device is now generally available, at gradually decreasing cost, and may be programmed by Intel users with a knowledge of digital filters without recourse to expensive design packages.

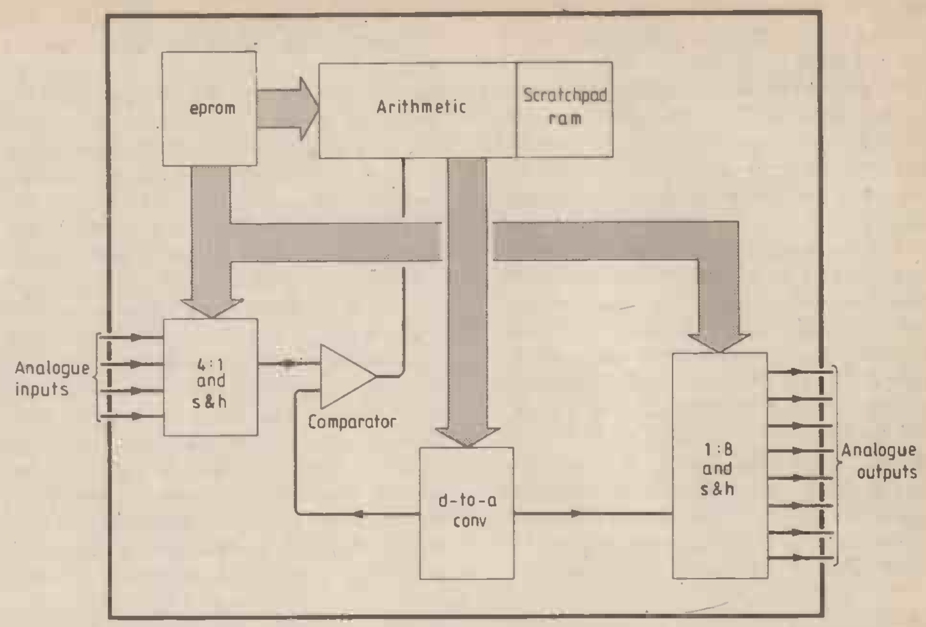


Fig. 4. Intel 2920 is basically a high-speed microprocessor connected to a nine-bit d-to-a converter, with eight multiplexed output channels under software control.

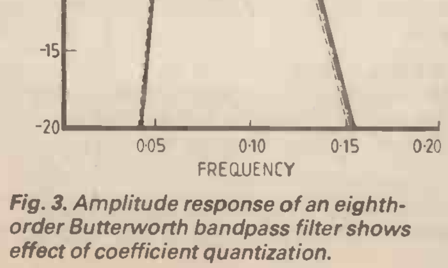


Fig. 3. Amplitude response of an eighth-order Butterworth bandpass filter shows effect of coefficient quantization.

Intel 2920

Shown schematically in Fig. 4, the Intel 2920 consists basically of a high-speed microprocessor connected to a 9-bit d-to-a converter. The output is connected to a one-to-eight line multiplexer which is under software control. Eight signal output channels are therefore available. The out-

Program to implement fourth-order digital filter on general-purpose computer used in example on page 47

```
 10 ! 4TH ORDER DIGITAL FILTER
 20 DIM X(20),Y(20)
 30 FOR J=1 TO 20 @ X(J)=0
 40 NEXT J @ X(0)=1
 50 FOR J=1 TO 2
 60 W1(J)=0 @ W2(J)=0 @ NEXT J
 70 A1(1)=-2 @ A2(1)=1
 80 B1(1)=-1.0524 @ B2(1)=.6232
 90 A1(2)=2 @ A2(2)=1
100 B1(2)=-.1665 @ B2(2)=.5348
110 A0=.0976
120 ! START FEEDING IN X(20)
130 FOR I=0 TO 20
140 X=X(I)
150 FOR J=1 TO 2
160 GOSUB 800 @ X=Y @ NEXT J
170 Y(I)=Y*A0 @ PRINT Y(I)
180 NEXT I
190 STOP
800 ! BIQUADRATIC SECTION J
805 W=X-B1(J)*W1(J)-B2(J)*W2(J)
810 Y=W+A1(J)*W1(J)+A2(J)*W2(J)
815 W2(J)=W1(J)
820 W1(J)=W
825 RETURN
```

```
 10 DIM P(100),Q(100)
 20 PRINT "NO. OF SECTNS")
 30 INPUT N
 40 PRINT "IDEAL COEFFS:"
 50 GOSUB 170
 60 FOR I=0 TO 100
 70 P(I)=Q(I) @ NEXT I
 80 PRINT "QUANTISED COEFFS:"
 90 GOSUB 170
100 PRINT "FREQUENCY  IDEAL   AC
    TUAL(DB)" @ M=0
110 FOR I=0 TO 100 @ F=I/200
120 PRINT USING "D.DDD,7D.2D,6D.
    2D" ; F,P(I),Q(I)
130 M1=ABS(P(I)-Q(I))
140 IF M1>M THEN M=M1
150 NEXT I @ PRINT "MAX DIFF=";M
160 STOP
170 FOR J=1 TO N @ K=J+J
180 PRINT J;": A1,A2,B1,B2="
190 INPUT C1(K-1),C2(K-1),C1(K),
    C2(K)@ NEXT J
200 FOR I=0 TO 100
210 W=PI*I/100 @ Q(I)=0
220 FOR J=1 TO 2*N
230 X=(1+C1(J)*COS(W)+C2(J)*COS(
    2*W))^2+(C1(J)*SIN(W)+C2(J)*
    SIN(2*W))^2
240 IF X<1.E-20 THEN X=1.E-20
250 Q(I)=Q(I)-(-1)^J*10*LGT(X)
260 NEXT J @ NEXT I @ RETURN
```

```
  5 DISP "A1,A2,B1,B2 ?"
 10 INPUT A1,A2,B1,B2@ A=1
 15 GOSUB 35
 20 DISP "MAX GAIN G(W) =",G
 25 DISP "MAX GAIN G1(W) =";G1
 30 END
 35 G=-1 @ G1=-1
 40 FOR F=0 TO .5 STEP .01
 45 W=2*PI*F @ W2=2*W
 50 R2=COS(W2) @ I1=-1*SIN(W)
 55 I2=-1*SIN(W2) @ R1=COS(W)
 60 N0=A+R1*A1+R2*A2 @ N=A1*I1
 65 N1=N+A2*I2 @ D=1+B1*R1+B2*R2
 70 D0=D @ D1=B1*I1+B2*I2
 75 ! NUM=(N0+J N1)
 80 ! DEN=(D0+J D1)-CVT TO EUL
 85 N=N0*N0+N1*N1 @ N=SQR(N)
 90 D=D0*D0+D1*D1 @ D=SQR(D)
 95 H0=N/D @ H1=1/D
100 IF H0>G THEN G=H0
105 IF H1>G1 THEN G1=H1
110 NEXT F
115 RETURN
```

Program left compares responses of recursive filter with ideal and with limited wordlength coefficients. That above calculates maximum values of $G(\omega)$ and $G_1(\omega)$ for a biquadratic section.

put is also connected to one input of a signal comparator, the other input being derived from a sample and hold network driven by one of four multiplexed analogue input channels. This arrangement allows up to four analogue inputs to be sampled and converted to digital form using the converter and the comparator under software control.

The microprocessor section of the device contains an eprom with space for 192 processor instructions, 40 words of ram and a specialist arithmetic unit. The basic wordlength of the arithmetic unit and the ram is 25 bits. All arithmetic operations provided, which include add and subtract but not multiply or divide, are performed in two's complement form. A special feature of the device which allows coefficient multiplications to be performed efficiently without a multiplication instruction is the binary shifter (sometimes known as a barrel shifter). Before being loaded into the arithmetic unit, one of the operands in an add or subtract operation passes through the binary shifter, which can be programmed to shift the number up to two places to the right or up to thirteen places to the left in one operation. Hence, a 'shift and add' process which can be used for programmed multiplication is combined into one instruction. Other features which simplify the programming of the device include a fixed instruction execution time (600 or 800 ns depending on device) and the absence of conditional jumps which are replaced by conditional operations. The latter ensures that there is only one path through the program and hence that the program execution time is constant. An 'end of program' instruction is included, which causes program execution to transfer to the first instruction in memory, providing continuous repetition of the program. As the input signal is normally sampled on each pass through the program, the sampling interval is equal to the product of the number of instructions and the instruction execution time. For example, a program containing 40 instructions run on a 600 ns device produces a sampling interval of 24μs i.e. a sampling rate of approximately 41666 samples per second giving a signal bandwidth of almost 21 kHz. This represents the theoretical upper limit and it is prudent in a practical system to allow some measure of oversampling and limit the signal bandwidth to say one third of the sampling frequency.

A technique based on the canonical signal digit code used for coefficient multiplications on the 2920 together with details of digital filters implemented using this device will be given in a subsequent article. □

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Appendix to June article

To calculate $\sqrt{x}$ where $x=a+jb$.
Convert x to Euler form $x=re^{j\theta}$, where $r=\sqrt{a^2+b^2}$, $\theta=\arctan b/a$.
Take square root $\sqrt{x}=\sqrt{r}\,e^{j\theta/2}$.
Convert $\sqrt{x}$ to Cartesian form
$\sqrt{x}=\sqrt{r}(\cos \theta/_2+j \sin \theta/_2)$.

EVENTS

August 5-6
Computational physics on the distributed array processor. Institute of Physics Conference at the University of Glasgow. Details from the Institute of Physics, 47 Belgrave Square, London SW1X 8QX.

August 14-17
Harrogate International Festival of Sound and Video at the Harrogate Exhbition Centre and at various hotels close by.

August 21-27
15th International Congress on high speed photography and photonics. San Diego, California, USA. Organised by the International Society for Optical Engineering, Washington 98227, USA.

August 26-September 5
Firato 82. Biennial exhibition and trade show for consumer electronics. At the RAI Exhibition Centre, Amsterdam.

September 2-6
SIM HI FI IVES: International exposition of music and high fidelity has been extended this year to include a video and consumer electronics section. Milan Fair Centre, Italy.

September 6-7
Seventh annual microprocessor workshop at the University of Liverpool Computer Laboratory.

September 6-10
Annual Meeting of the British Association for the Advancement of Science. To be held at the University of Liverpool. BAAS, 23 Savile Row, London W1X 1AB.

September 6-9
Enrolment for course for the **Radio Amateurs examination.** Brixton College for Further Education, Brixton Hill, London SW2.

September 6-10
Microcoll 82: Seventh Colloquium on microwave communication. Budapest. Sponsored by the International Union of Radio Sciences and the Hungarian Academy of Sciences. Details from Microcoll, 1252 Budapest, 114, PO Box 15, Hungary.

September 7-10
6th International conference on computer communication. London. Details from ICCC 82, PO Box 23, Northwood Hills, Middlesex HA6 1TT.

September 7-8
Semiconductor 82: Exhibition at the Bingley Hall, Birmingham.

September 7-9
Compec Scotland: Exhibition of computers, systems, peripherals and software. Sponsored by *Computer Weekly*. City Hall, Glasgow.

September 9-10
Microprocessors and their applications. Symposium at Bristol Polytechnic, Ashley Down Road, Bristol BS7 9BU.

September 9-12
The 5th Personal Computer World Show. Barbican Centre, London.

September 8-10
Eurographics '82: International congress for computer graphics. UMIST. Conference details from Andrew Yates, University of Manchester Institute of Science and Technology, PO Box 88 Manchester M60 1RD.

September 13-16
12th European solid state device research conference, Munich. Details from Dr Zerbst, Siemens AG, Otto Hahn Ring 6, D-8000 Munchen 83, FRG.

September 13-17
12th European microwave conference, Finlandia Hall, Helsinki, Details from Microwave Exhibitions, 43 Dudley Road, Tunbridge Wells, Kent TN1 1LE.

September 14-16
ElectroWest; West of England electronics exhibition, Bristol. Exhibitions for Industry Ltd, 157 Station Road East, Oxted, Surrey RH8 0QF.

September 18
Computer Fair; Prestatyn High School PTA, Prestatyn, Clwyd.

September 18-21
International broadcasting convention: IBC82, Metropole Hotel, Brighton. Details from the IEE, Savoy Place, London WC2R 0BL.

September 19-24
Human aspects of computer systems: A short course at the Department of Human Sciences, University of Technology, Loughborough.

September 19-24
Industrial digital and microprocessor-based control systems. IEE vacation school at Baliol College, Oxford.

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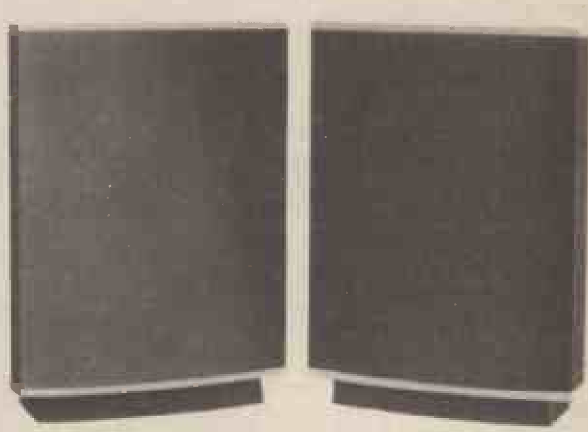

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Also available (not shown): ● VM10 Video monitor – £99; ● UV141 EPROM Eraser with timer – £78; ● GP100A 80 column Printer – £225; ● PI100 interface for EP4000 to GP100A – £65.

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WW – 023 FOR FURTHER DETAILS

MICROCOMPUTER LINE PRINTER

This is the second of two articles describing an interface for driving a 40-column dot-matrix printer mechanism from Z80 signals. With the mechanism, addressing and interrupt sections covered, the author explains the controller i.c., power circuits, running the printer and modifications required to drive a 12V mechanism.

by P. L. Woods

Turning now to Fig. 3, the rest of the controller circuit can be considered. IC$_2$ is a bidirectional buffer designed to isolate the controller-board internal data bus from any noise on the system data bus, and *vice versa*. It is enabled only when the controller board is addressed, and the direction in which it passes data is determined by the $\overline{WR}$ line buffered by IC$_{1a}$ and IC$_{3a}$. To reduce noise problems, IC$_{1a}$ is a Schmitt trigger, and similar buffers are used on the other control bus lines.

The control bus is connected to the printer controller chip, IC$_{14}$, and through three-state buffers, IC$_{13}$, to the status outputs of the controller i.c. It is also connected to IC$_9$, the interrupt reply byte circuit. Note that D0 from IC$_9$, pin 18, should go to D0 on IC$_2$, pin 2, and so on up to D7, pin 9 on IC$_9$ to pin 9 on IC$_2$.

A 6.0MHz clock for the controller i.c. is provided by an HC18/U or HC25/U crystal, XL$_1$. IC$_{14}$ contains the character generator for the printer, and the output for the currently selected character appears on PS1 to $\overline{PS7}$ (pins 27 to 33 respectively). High-voltage open-collector line drivers, IC$_{16}$ and IC$_{17}$, are used to send the signal to the solenoid drivers.

Two additional signals have to be sent to the printer; one is a paper advance signal, $\overline{FS}$ (at pin 21 of IC$_{14}$), the other is to turn the drive motor on and off, $\overline{MT}$ (pin 34).

Three status signals are needed back from the printer for correct operation. The first of these comes from a timing coil which allows the controller to correctly space the dots for each character. If no timing pulses are found within 0.2s after the motor is turned on, the circuit assumes that the motor has stalled, so an error status is set ($\overline{Error}$ at pin 22), and the motor stopped to prevent it from burning out.

The second signal is from a reed relay which indicates when the printer carriage has reached the 'home' position, and that the motor may be stopped as it has finished printing a line.

The third status line is from a normally-closed pushbutton, connected to ground, which serves two functions. If the switch is depressed (open) when the $\overline{Reset}$ line goes high then the controller enters a test mode and prints lines of characters until the switch is closed. Otherwise, pressing the switch when the printer is idle advances the paper through the mechanism.

Solenoid and motor drivers

Figure 4 shows a solenoid drive circuit. Seven of these circuits are required for the

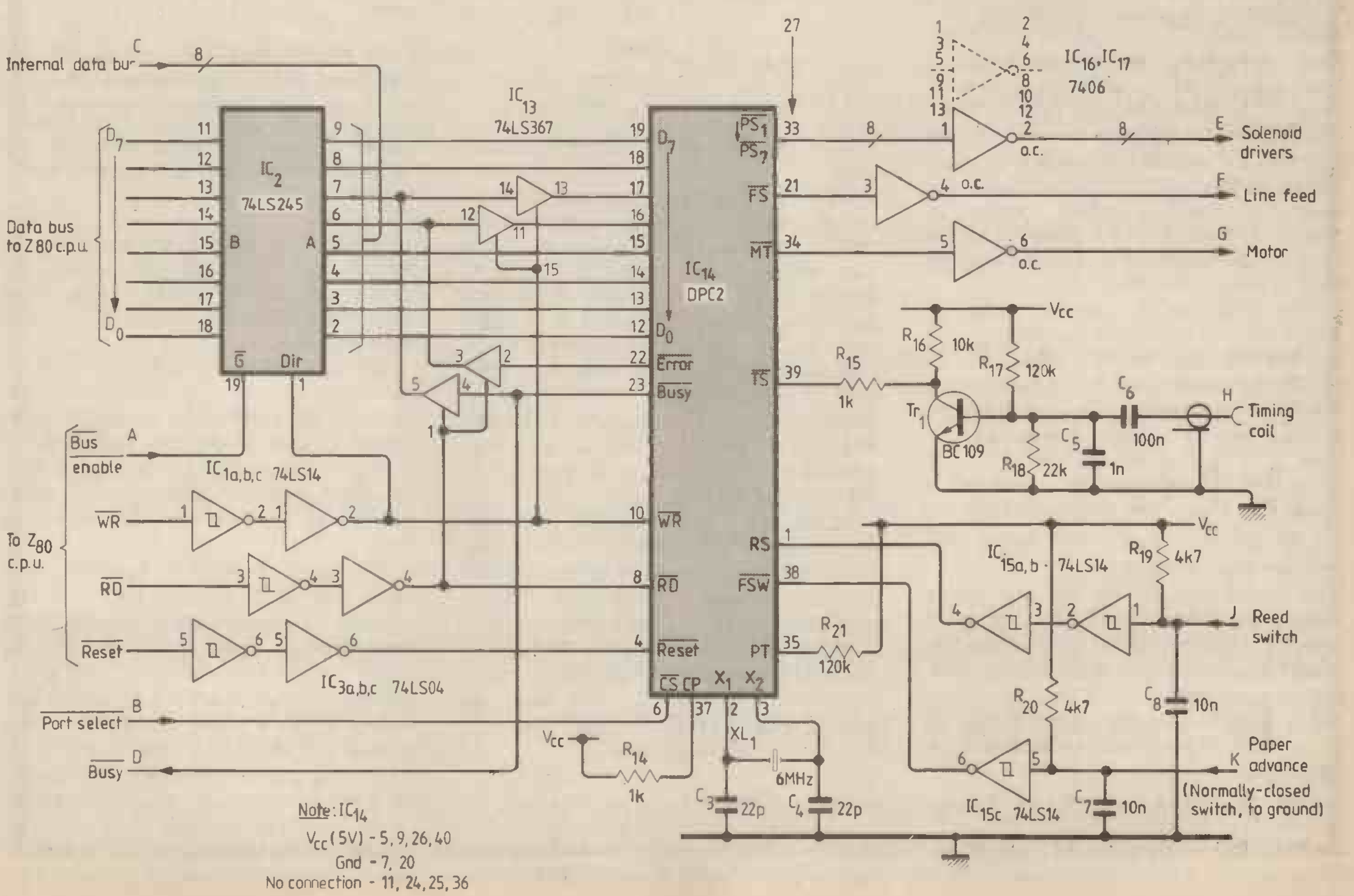


Fig. 3. *Controller i.c. and buffers. Mr Woods informs us that the controller, IC$_{14}$ is not the DPC-2 as given here and in last month's parts list, but is the DPC-4.*

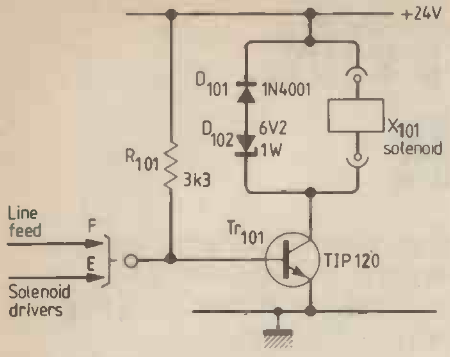


Fig. 4. Eight of these solenoid driver circuits are required, one for each of the seven needle drives and one for the line-feed solenoid. Tr_{101} is a power Darlington transistor.

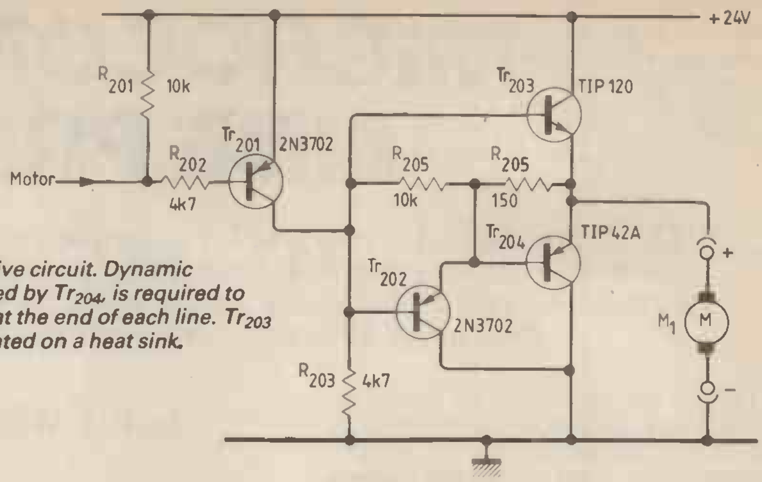


Fig. 5. Motor-drive circuit. Dynamic braking, provided by Tr_{204}, is required to stop the motor at the end of each line. Tr_{203} should be mounted on a heat sink.

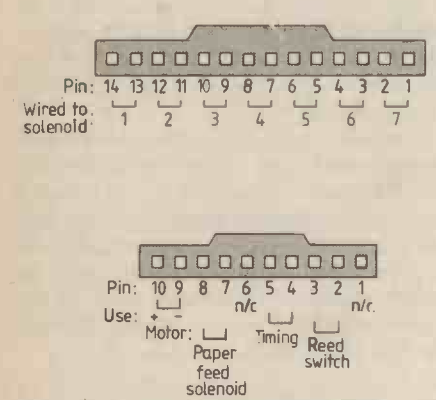


Fig. 7. Edge connector diagrams for the printer mechanism.

head solenoids and one for the line-feed solenoid.

As the circuit consists of only one Darlington transistor, it needs no discussion. One point worth mentioning though is that, should the circuit's input become open, as happens when the cable between the interface and printer board is disconnected, the solenoid is turned on. The effects of this will be explained later. No heat sink should be needed because, although the peak current is high (3.2A), the duty cycle is low. Diodes D_{101} and D_{102} are used to protect the transistor.

The driver for the motor is shown in Fig. 5, and is a little more complex because dynamic braking (through TR_{204}) is used to stop the motor at the end of each line. A Darlington transistor, Tr_{203}, is used to power the motor and will need a small heat sink. As with the solenoids, the motor will be turned on when the circuit's input is open.

Printer power supply

The circuit diagram for the two power supplies needed is shown in Fig. 6. Careful separation of the interface logic from the needle drivers has the advantage that each part of the circuit requires only one power rail. That for the interface logic (Figs 2 and 3) is 5V at about 300mA, supplied by a 7805 voltage regulator, IC_{301}.

The 24V supply requires a little more explanation. A voltage doubler circuit is used because I only had a 12V, 2A transformer; a 24V, 1A transformer used with a

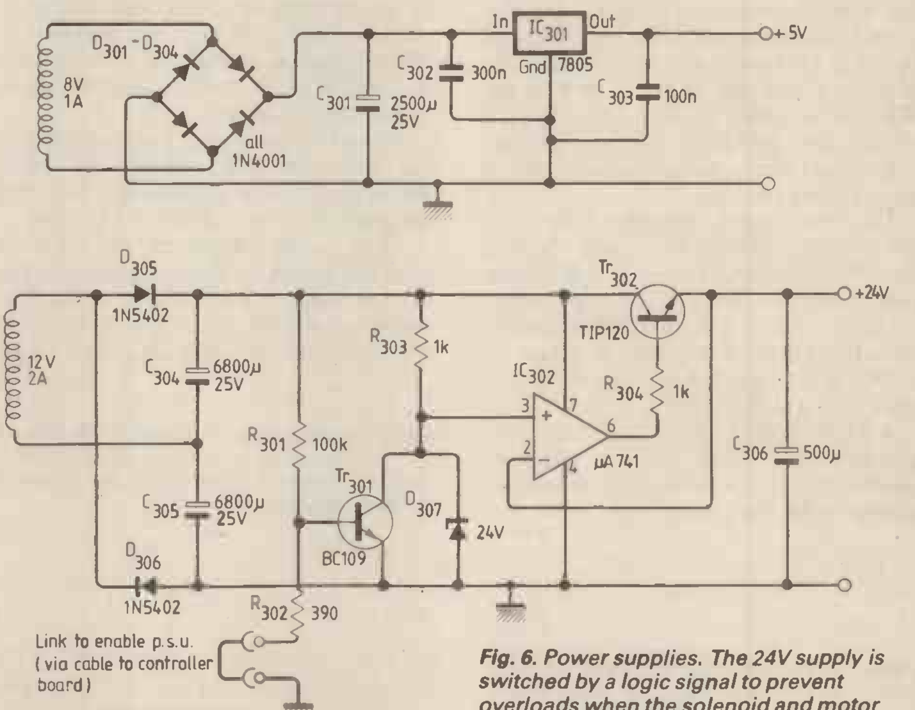


Fig. 6. Power supplies. The 24V supply is switched by a logic signal to prevent overloads when the solenoid and motor driving circuit inputs are open. The author had a 12V transformer in his 'junk box', hence the voltage doubler. Heat sinks are required for IC_{301} and Tr_{302}.

bridge rectifier would perform equally well.

If the action of Tr_{301} is ignored, then the circuit is an op-amp, IC_{302}, connected as a voltage regulator, with Tr_{302} as the series pass element. The purpose of Tr_{301} is to shut down the 24V rail should the control cable from the interface board to the solenoid drivers become disconnected. As mentioned above, in this event all the solenoid drivers, together with the motor driver, turn on. The resulting prolonged 30A current demand is sufficient to destroy the rectifier diodes, as happened during testing of the prototype.

So the link to enable the 24V rail is not on the supply board, but on the interface board, and two of the wires in the connecting cable are used to connect the link between the base of Tr_{301} and ground. Using a multipole connector ensures that if the flying lead is not plugged into the interface board, then the link will not be made, so turning off the 24V supply. Both IC_{301} and Tr_{302} will require heat sinks.

Construction

The circuit was constructed in two parts: the first is the interface board which was built to fit into a slot in one of the computer's cards. The solenoid and motor drivers were built on a second board which, together with the 24V supply, was mounted in the base of the box containing the printer mechanism.

The interface board should be carefully laid out, i.e., with a good ground mesh, and with the ground pin of each i.c. connected to that of the i.cs around it. A decoupling capacitor is needed for each i.c., 10µF tantalum-bead capacitors alternating with 10nF ceramic disc capacitors being suitable.

The layout of the driver board is a little more difficult as it carries both t.t.l. signals and the heavy currents associated with the solenoids. Because of the solenoid surge currents mentioned earlier, a substantial cable is needed to connect the emitter of each driver transistor to the ground side of the 24V power supply. To avoid noise caused by the solenoids getting back into the interface, the digital ground return should be separate from the 24V-supply return, although it need not be as heavy. Once again, everything should be

Table 1: Program to display printer character set. This program was written to demonstrate the operation of the printer, and act as a confidence test for it. It is loaded at location 4000 (hex.) in memory, and should be entered, after the stack pointer has been set up, using a CALL instruction. This listing was produced on the printer described in this article, as was its result, shown in Table 2.

```
                     ; LISTING ONE.
                     ;
                     ; DISPLAY PRINTER
                     ; CHARACTER SET.
                     ;
                     ; COPYRIGHT.
                     ; PL WOODS.    1982.
                     ;
                     MAIN:   EQU  4000H
                             ORG  MAIN
                             LOAD MAIN
                     ;
                     ; PRINTER PORT ADDR.
                     PRT:    EQU  11H
                     ;
                     ; RESET PRINTER
4000 CD5E40                  CALL RESET
                     ; VALUE OF FIRST
                     ; CHARACTER TO PRINT.
4003 3E20                    LD   A,32
                     ;
                     ; PRINT 14 LINES, EAC
                     ; BEGINING WITH THE
                     ; VALUE OF THE CHAR
                     ; IN HEX.   EACH LINE
                     ; CONSISTS OF FOUR
                     ; GROUPS EACH OF FOUR
                     ; CHARACTERS.
4005 060E                    LD   B,14
4007 CD3140          LINE:   CALL PRTHEX
400A CD6540                  CALL SPACE
                     ; SET UP FOR GROUPS.
400D C5                      PUSH BC
400E 0604                    LD   B,4
4010 CD6540          GROUP:  CALL SPACE
                     ; SET UP FOR EACH
                     ; CHARACTER.
4013 C5                      PUSH BC
4014 0604                    LD   B,4
4016 CD6540          CHAR:   CALL SPACE
                     ; PRINT CHARACTER.
4019 CD4C40                  CALL PUTPRT
                     ; NEXT CHARACTER.
401C 3C                      INC  A
                     ; END OF GROUP?
401D 10F7                    DJNZ CHAR
                     ; END OF LINE?
401F C1                      POP  BC
4020 10EE                    DJNZ GROUP
                     ; TERMINATE LINE.
4022 CD2940                  CALL NEWLIN
                     ; ALL LINES DONE?
4025 C1                      POP  BC
4026 10DF                    DJNZ LINE
                     ;
                     ; ALL DONE.
4028 C9                      RET
                     ;
                     ; START A NEW LINE.
4029 F5              NEWLIN: PUSH AF
402A 3E0A                    LD   A,0AH
402C CD4C40                  CALL PUTPRT
402F F1                      POP  AF
4030 C9                      RET
                     ;
                     ; PRINT 'A' AS TWO
                     ; HEX DIGITS.
4031 F5              PRTHEX: PUSH AF
                     ; HIGH DIGIT.
4032 0F                      RRCA
4033 0F                      RRCA
4034 0F                      RRCA
4035 0F                      RRCA
4036 CD3E40                  CALL PRTHX
                     ; LOW DIGIT.
4039 F1                      POP  AF
403A CD3E40                  CALL PRTHX
403D C9                      RET
                     ;
                     ; PRINT LOW 4 BITS OF
                     ; 'A' AS A HEX DIGIT.
403E F5              PRTHX:  PUSH AF
                     ; MASK BITS
403F E60F                    AND  0FH
4041 B7                      OR   A
                     ; CONVERT TO ASCII
4042 27                      DAA
4043 C6F0                    ADD  A,0F0H
4045 CE40                    ADC  A,040H
4047 CD4C40                  CALL PUTPRT
404A F1                      POP  AF
404B C9                      RET
                     ;
                     ; PRINT THE CONTENTS
                     ; OF THE 'A' REG.
404C F5              PUTPRT: PUSH AF
                     ; LOOP UNTIL PRINTER
                     ; READY.
404D DB11            PRLP:   IN   A,(PRT)
                     ; CHECK ERROR STATUS.
404F CB67                    BIT  4,A
4051 2808                    JR   Z,PRTERR
                     ; BUSY BIT.
4053 CB57                    BIT  2,A
4055 20F6                    JR   NZ,PRLP
                     ; SEND CHARACTER.
4057 F1                      POP  AF
4058 D311                    OUT  (PRT),A
405A C9                      RET
                     ;
                     ; HERE IF THERE IS
                     ; A PRINTER ERROR.
405B 76              PRTERR: HALT
405C 18FD                    JR   PRTERR
                     ;
                     ; RESET PRINTER
                     ; CONTROLLER.
405E F5              RESET:  PUSH AF
405F 3E11                    LD   A,11H
4061 D311                    OUT  (PRT),A
4063 F1                      POP  AF
4064 C9                      RET
                     ;
                     ; PRINT A SPACE.
4065 F5              SPACE:  PUSH AF
4066 3E20                    LD   A,' '
4068 CD4C40                  CALL PUTPRT
406B F1                      POP  AF
406C C9                      RET
                             END

CHAR    4016 GROUP   4010 LINE    4007
MAIN    4000 NEWLIN  4029 PRT     0011
PRTHEX  4031 PRTHX   403E PUTPRT  404C
PRLP    404D PRTERR  405B RESET   405E
SPACE   4065
```

Table 2: The printer's character set. This listing shows the result of running the program in Table 1. The first four lines (values 20 to 5F inclusive) are an upper case ASCII character set, while the last six lines (from A0 to FF) are a Kata Kana (Japanese) character set. The middle four lines are not specified for the controller chip used and so represent 'noise'.

20		!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
30	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
40	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
50	P	Q	R	S	T	U	V	W	X	Y	Z	[	¥	]	^	_
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A0	[illegible]	。	「	」	、	・	ヲ	[illegible]	¢	½	[illegible]	[illegible]	ャ	ュ	ョ	ッ
B0	ー	ア	イ	ウ	エ	オ	カ	キ	ク	ケ	コ	サ	シ	ス	セ	ソ
C0	タ	チ	ツ	テ	ト	ナ	ニ	ヌ	ネ	ノ	ハ	ヒ	フ	ヘ	ホ	マ
D0	ミ	ム	メ	モ	ヤ	ユ	ヨ	ラ	リ	ル	レ	ロ	ワ	ン	゛	゜
E0	[illegible]	[illegible]	[illegible]	ト	[illegible]	[illegible]	[illegible]	[illegible]	オ	[illegible]	[illegible]	[illegible]	[illegible]	ニ	[illegible]	[illegible]
F0	ス	セ	ソ	タ	チ	ツ	テ	ト	ナ	ニ	ヌ	ネ	ノ	ハ	ヒ	フ

Conversions for a 12V printer mechanism

After this article had been completed, a version of the printer mechanism for use with a 12V supply, the DP-824F-12, and associated controller, the DPC-4A, were introduced; this section describes modifications required to accommodate these.

Pin connexions on the 12V mechanism are exactly the same as those on the 24V model. The DPC-4A i.c. can be used to control either version of mechanism by altering the signals on certain pins.

On the 12V mechanism, the solenoids require a 730µs pulse, as opposed to 400µs for those of the 24V version. This pulse length is determined by the controller and depends on the logic state at pin 35, the 'printer type' terminal (PT). When this pin is tied to the +5V rail, as shown in Fig. 3, the pulse length is 400µs. For the 12V mechanism, R_{21} must be changed to 1kΩ and wired to ground instead of +5V.

Current requirements for the 12V mechanism's solenoids and motor are higher because of the lower supply voltage, hence, R_{101} of Fig. 4 should be reduced to 2.2kΩ in all eight solenoid-driver circuits, and R_{302} of Fig. 5 reduced to 3.3kΩ.

Finally, the voltage doubler used in the 24V supply, Fig. 6, can be replaced by a bridge-type rectifier and single smoothing capacitor (say, 10 000µF, 25V). The zener diode, D_{307}, should be replaced by a 18V type.

Both the 24V and 12V mechanisms mentioned are friction-feed types but sprocket-feed versions, available from the same manufacturer, may be used.

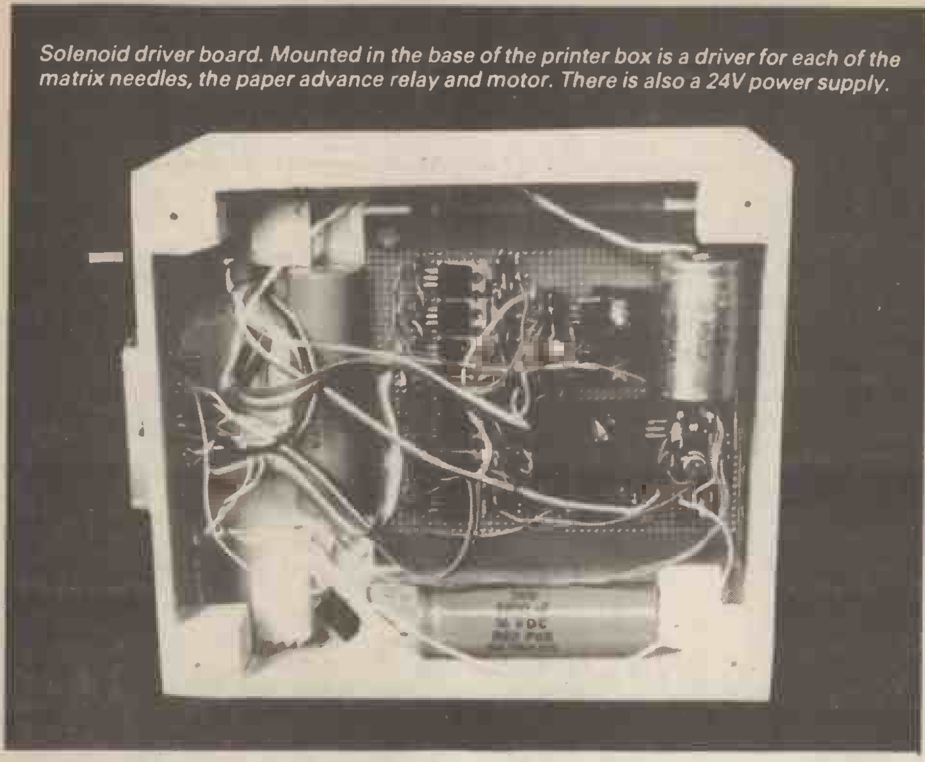
well decoupled for best performance, using 20µF, 36V electrolytic capacitors connected between the 24V side of each solenoid and ground.

Connexions to the matrix printer itself are through a pair of non-reversible connectors, the mating halves of which are suppled with the printer. One of the connectors is 14 way and supplies the solenoids, while the other is 10 way and carries the motor, paper feed and timing signals (Fig. 7).

The two boards (interface board and driver board) were interconnected by multi-core cable and sub-miniature 25-way 'D' connectors. The precise allocation of the pins to the various signals does not matter too much provided that there are ample ground-return lines. Cable length should not matter too much either, as the signals are all relatively low in frequency, but anything over 1m in length could cause noise problems. The screen of the connecting cable should be earthed to improve reliability.

Demonstration program

Table 1 is a program, written in Z80 assembly language, which is designed to test the printer by causing it to display its complete character set. The results of this program are shown in Table 2. The program is loaded into memory at 4000 (hex.), a convenient location in my system, and is entered from a system monitor which first sets up the stack pointer (SP register), and then pushes a return address onto the stack (e.g. by the use of a CALL 4000 instruction). The test program exe-



Solenoid driver board. Mounted in the base of the printer box is a driver for each of the matrix needles, the paper advance relay and motor. There is also a 24V power supply.

cutes a RET instruction when finished.

This article is not the place to introduce assembly language programming, and so instead of a detailed description of the program, notes are given to assist those wishing to use all, or part, of the program for their own purposes.

The port address of the printer is declared in an EQU pseudo instruction at line 14. This address must correspond with the address used by the hardware.

There are three interface driver routines of interest, namely RESET, PUTPRT and NEWLIN. Starting at line 118 is a subroutine called RESET. The purpose of this is to 'set' the printer controller should a previous program error have left it in an unacceptable state. The same effect may be achieved by using the RESET bus signal. As good practice, a CALL to RESET should be made at the start of each program which accesses the printer. No registers are modified by this subroutine.

The second subroutine of note, PUTPRT at line 96, may be regarded as causing the character sent to it from the 'A' register to be printed. PUTPRT waits until the printer is ready, then transfers a character from the 'A' register to a print buffer in the printer controller i.c. If the printer error bit is set, the subroutine will halt at address 405B. Normally this point would contain a code to alert the operator to a printer problem. If there is no error the subroutine returns, leaving all registers unmodified.

The third and final subroutine to inspect is NEWLIN, at line 60. The purpose of this is to cause printing of the line in the controller print buffer, which it does by sending an 0A character (line feed) to the printer. Once again, this routine does not change any registers. It should be noted that this subroutine must be called at least once every 40 characters to avoid the print buffer becoming full, in which case, overflow characters will be lost.

Conclusion

In this article it has been shown that it is possible to build a low-cost printer for a home-computer system. Although this design was originally intended as a means of printing programs from a Z80-based system, it may easily be adapted to make it compatible with any popular microprocessor and for use in any application where a permanent printed record is required, such as data logging. That the controller only allows upper-case graphics characters to be printed is not a problem for the majority of applications. □

BOOKS

Computing

From Hardware to Software
by Graham Lee
454 pages, paperback/hardback
MacMillan, £8.95/£16.00
This is an introductory text, albeit an extremely thorough one, and covers both equipment and programming at a level suitable for A level or first-year university courses. The author has used a computer model – the Simple Digital Computer – throughout, with which to illustrate his points more generally than would have been possible with a commercial design.

Advanced 6502 Interfacing
by J. M. Holland
190 pages, paperback
Prentice-Hall, £9.05
This book is practical in its approach to the subject of persuading 6502 microprocessors to perform useful functions in timing, control, data acquisition and high-current load driving. It is written for those who are already familiar with microprocessors.

Introduction to 6800/6802 Microprocessor Systems
by R. J. Simpson and T. J. Terrell
238 pages, paperback
Newnes £6.95
For readers who may not be versed in the language of logic and binary arithmetic, the authors have included a useful first chapter on basics before embarking on a description of the 6800/6802 devices and their use. This is followed by chapters on programming and on input/output signals, the practical approach being the province of the final two chapters on the MEK6802D5 evaluation system, with some investigations to carry out with its help.

Microcomputer Data Communications Systems
by F. J. Derfler, Jr.
129 pages, paperback
Prentice-Hall, £9.70
Microcomputers can serve as terminals in a data communication network to provide information at home, as an alternative to what the author calls the 'time tyranny' of radio, television and newspapers. The book describes such systems, including sections on modems and terminals, and going on to show how Apples, TRS-80s and others can be employed in this way. There is also a piece on using the CP/M disc operating system with S-100 bus computers and others.

Video

Video-Tape Recording
by J. F. Robinson, revised by S. Howe
362 pages, hardback
Butterworth, £12.00
The third edition of a well known text, this covers the whole field of professional and domestic video tape recorders from the engineering point of view. New information is presented on the helical B and C formats, and the domestic type of machine, with additional coverage of timebase correction. Those familiar with television engineering are led easily into the subject by the way of a first chapter on tape recording in general terms.

Video Techniques
by G. White
299 pages, hardback
Butterworth, £10.95
Although the blurb says that this is for the engineer or technician in television or ancillary industries, it hardly seems detailed enough for that purpose. It is a descriptive book, which is well suited to readers in other fields who want to obtain a working knowledge of television, both broadcast and recorded, studio equipment, transmission, reception (including teletext and viewdata) and digital techniques.

LETTERS

BRITISH HI-FI

I'm informed by John Crabbe of *Hi-Fi News/Record Review* that the Acoustical manufacturing company's claim that the QUAD FM4 brings 'Home the world's best broadcasting system at the touch of a button' is ethically justified, as Acoustical, in contributing to the support of the Philharmonica, helps to pay the piper.

Most other British high fidelity manufacturers do not, and subsist upon music making of all kinds parasitically, and thus have no prestige or reputation internationally amongst serious consumers of reproduced music.

By and large, British high-fidelity products are not materially competitive or competitive in terms of dazzling or convenient features. But they are perhaps more competitive qualitatively. Unhappily, however, recognition of their qualities is pretty well reserved to engineers, technicians, and 'hi-fi fans'. Most serious consumers of reproduced music, here and abroad, don't know about them, and have precious little opportunity to learn.

Thus, while the programming and technical quality of the world's best broadcasting system is revered – and envied – internationally, British high-fidelity products are known about and coveted only by the membership of tiny audiophilic cults, here and abroad.

I have at hand No 1 of the 1982 Edinburgh Festival newsletter. It's publication was apparently entirely supported by the advertisements of hoteliers, restaurant-keepers, one or two insurance companies, and a bank or two. Many people who will attend Festival events, or wish to, and many who – due to privation or remoteness – are dependent upon broadcast reception and recordings for musical enjoyment during most of the year, will remain in ignorance of the products of Linn, Syrinx, Strathclyde Transcription Devices, the makers of the Systemdek, and even Tannoy – not to mention KEF, B&W, Sugden, Castle, Celef, Mitchell, Acoustical, Naim, Riga, C&J Walker, MB Creek, Boothroyd, Stuart-Meridian, and even Wharfedale, south of the border.

It would be too charitable to say that the British high-fidelity industry has its head in the sand. A harsher but more appropriate judgement would suggest that it is contemplating its own navel from the inside, is unwholesomely involved and beguiled subjectively by its own entrails.

John F. Withey
Pollockshields
Glasgow

SCIENTIFIC COMPUTER

Please could you note in your records that I am the new Editor of The Sci. Comp. 80 monthly newsletter for users of the scientific computer designed by John Adams, M.Sc., details of which were published in your magazine.

Any of your readers who built the SC80, who are not members of the group, would find it well worth joining. Back issues, still available, contain a plethora of hardware, software and firmware. Mr Adams contributes articles monthly, and has developed no less than five versions of the BURP high level language, an excellent 64K d.o.s. (CP/M compatible), a standard Basic interpreter and some excellent hardware improvements. These include a 32K dynamic memory expansion, 64K mapping circuits, interrupt vector circuits, ASCII character generator modification and a floppy disc controller p.c.b. Details of all these are in the newsletter. One year's subscription is £6.50 for U.K. members, £8 for the continent, and £8.50 for elsewhere. Cheques sent to the address below.

I would like to take this opportunity to thank Mr Philip Probetts for the past two years of excellent newsletters under his editorship. I hope I can do as well.

John Hodson
189 Trent Valley Road
Oakhill
Stoke-on-Trent, ST4 5LE

AMATEURS AND CB

C. G. Howard's comments in the June issue of *WW* under 'Amateurs and c.b.' highlighted the indifference of the Home Office towards illegal c.b. amateur operations. But what about the specific identifiable violations where the Home Office attitude is downright irresponsible?

I am referring to the illegal pirate radio stations that flagrantly operate in the v.h.f./f.m. broadcast band. There are a number of them, but two examples serve to illustrate the general case – 'Thameside Radio' and 'Liberation Radio'.

I asked British Telecom why these stations were not closed down and imagine my surprise, as a legal broadcasting operator, when I was told that the Home Office would not give the necessary authorization for British Telecom to do so. Must a campaign be mounted privately to ensure that the law of the land is upheld when a government department refuses to do so? Continual violation of the law in this way is a form of anarchy, in principal every bit as bad as other, more subversive, movements.

The Home Office, in supporting the violation of statutory laws by its non-action is encouraging further escalation. This is yet another of a growing number of examples of where government legislation controls the actions of responsible citizens but not those who chose to flout the law of the land.

H. Clayton
Northwood
Middlesex

CARTRIDGE ALIGNMENT

Referring to P. E. Cryer's letter in the June 82 issue, I found some difficulty in understanding the layout instructions in his second paragraph together with the associated diagram on the next page. However, it is of course quite true, as he says, that it makes no difference to the geometry whether you think of the stylus traversing over the record, or the record traversing under the stylus; all that matters is the relative moment of the two.

Two or three points seems to warrant comment: firstly, there is nothing particularly new or useful in finding out that the *proportion* of tracking angle errors depends on the choice of setting radii – of course it does. It is necessary, in the interests of minimizing tracking error *distortion*, for the angular error to vary inversely with radius, and as Cryer's figures indicate, this is exactly what does happen. The relationship of tracking angle errors at both outer and inner radii to the error at the radius for minimum angle (my R_{min}) depends on the amount of dip in the curve of angle across the record, as is obvious from my Fig. 1.

Secondly, I cannot understand Cryer's statement that my own factors "would place B on the other side of the datum line". If the datum line is defined as a line through the two points where the stylus cuts the circles having radii p and q as in his diagram, then obviously the intersections at both inner and outer record grooves (his B and A) must necessarily lie on one side of the said datum line, and none of my 'factors' can alter this condition.

Thirdly, Cryer's roundabout method of calculating p and q as described in his last paragraph, cannot work. The expression $pq/p=(p+q)-p$, is meaningless, a mere identity which reduces to $q=q$. Obviously it cannot be used to separate q from p when $(q+p)$ is known. The whole point of my final paragraph, in the Oct '81 issue, was to show that one did not need to go through the whole procedure based on formula 4(b) every time, in the light of the linear $y=a+bx$ relationship ascertained at middle of paragraph. The final outcome, which cannot be simplified or improved, was to evaluate p and q (my r_0 and R_0), from the empirical expression $R_0=79+hC/84$ and $r_0=12+hC/71$ or ideally L^2-C^2/R_0. For the recommended overhang value of $h=2600/C$, this reduced further to $R_0=110$ and $r_0=49$ (ideally 48.81, but the 0.19 discrepancy is insignificant in practice).

If one uses a protractor, or my setting gauge, as in the November 1981 article, there is no need to evaluate the offset angle O (my B), but if desired it can be very easily obtained, within about 0.1° accuracy, from my empirical expression 4380/C.

R. J. Gilson
Winchester
Hampshire

HERETIC'S GUIDE TO MODERN PHYSICS

I was delighted to see you are still providing a forum for open and constructive criticism of modern theory.

That Dr Murray should need to assure his colleagues that he has "no wish to cause you offence" is a sad comment on the state of physics. Doubtless his article is the result of a long and critical investigation of modern theory, and he would welcome any constructive criticism of his article. Equally doubtless, a few of his colleagues know his investigation is a deliberate attempt to revive the flat earth theory and Maxwell's wave theory of light – an insult to Newton's corpuscular theory of light.

I predict Dr Murray will soon learn to appreciate the truth of the supreme investigator, Michael Faraday's bitter response to the hostility to his theories of the self-satisfied mathematicians of his day – "A man who makes assertions, or draws conclusions, regarding any given case, ought to be competent to investigate it."

Many Nobel prizes were awarded for contributions to the basic premise of relativity – that nothing in the universe can travel faster than the speed of light. Cerenkov received the 1958 prize for his experimental proof that "when charged atomic particles pass through water or other media at a speed in excess of that of light itself, a bluish light is emitted."

LETTERS

Aspden, Dingle, Essen, MacCausland and other critics of relativity are dismissed as cranks and crackpots by the Establishment. Is there any member of the Establishment competent to investigate the strange case of why the crank Cerenkov received a Nobel prize?
M. G. Wellard
Kenley
Surrey

WALSH FUNCTIONS

I write with respect to the recent articles on Walsh Functions by Mr T. Roddam (*WW* Dec. 1981, pp 31 *et seq.* and *WW* Jan. 1982, pp 47 *et seq.*) to raise the following points.

The Rademacher functions, shown in Fig. 4 of this series correspond to Wal (1,θ), Wal (3,θ), Wal (7,θ), Wal (15,θ) . . . The associated intermediate Walsh functions may be derived by "exclusive Or" processing all combinations of the Walsh functions. Thus, for example referring to Fig. 3, the Wal (2,θ) function is derived from Wal(3,θ)⊕Wal(1,θ) and should be inverted in the Figure. Several other derived Walsh functions have been inverted in Fig. 3. A correctly-signed set is enclosed for reference.

There is also an error in Fig. 5.

Wal(5,θ)=Wal(2,θ)⊕Wal(7,θ)

which does not hold for this diagram. I enclose a modified diagram which will satisfy this requirement. Incidentally, the paper by Barratt, Gordon and Brammer also contains these errors.

I mention these slips since many people seem to be becoming interested in these functions that valuable introductory articles, such as Mr Roddam's are worth these small corrections in the interests of accuracy.
R. T. Irish
Swindon,
Wilts.

Mr Irish enclosed an amended set of functions, which we have regretfully been obliged to omit for reasons of space. They can be obtained from this office – Ed.

FUNCTION OF FUNCTIONS

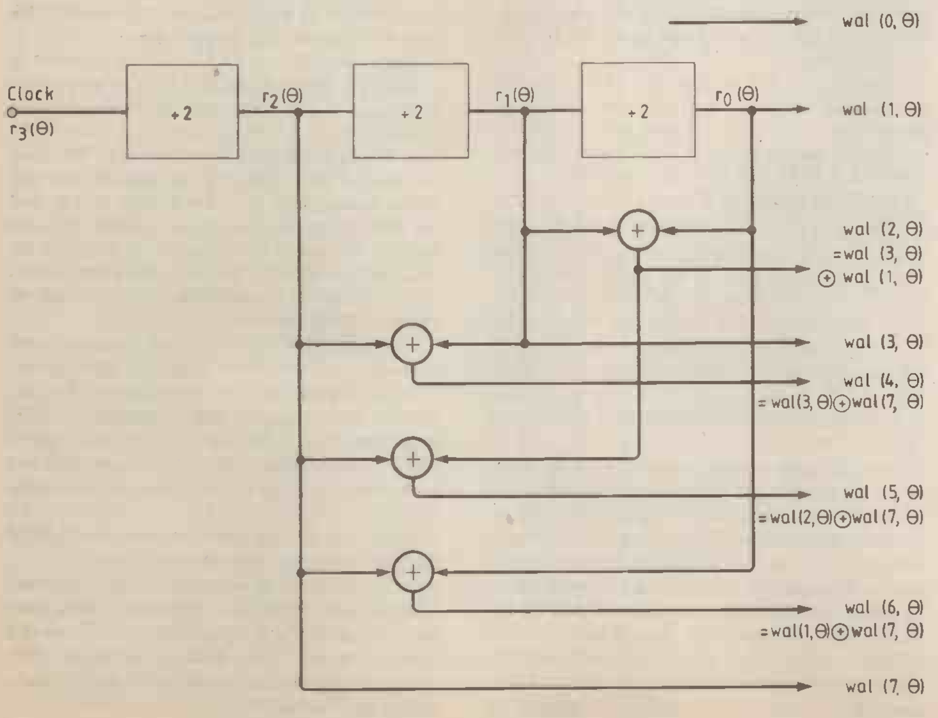
With reference to Mr Sutherland's letter (June), I think that the view of sidebands as mathematical fiction is not entirely unfounded. I believe that a periodic complex waveform and it's Fourier series expansion are not one and the same thing in the sense of somehow being freely interchangeable without the active involvement of suitable physical devices to perform the complex series and conversion and vice versa. On this view a modulated radio transmission propagates in its complex form and there is no need to postulate any sidefrequencies at the transmitter end. The sidefrequencies are generated at the receiving end by tuned circuits. These have the capability to store energy and thus perform integration, thereby generating the continuous waves known as Fourier series components or sidefrequencies. The physical process by which a sidefrequency is generated can be understood by considering the following experiment:

Suppose that a high "Q" tuned circuit is adjusted for resonance at 110kHz and placed near a 100kHz oscillator. Clearly, the tuned circuit will not begin to oscillate since any such oscillations would move in and out of phase with the oscillator, thus receiving just as much help as hindrance. However, should the amplitude of the oscillator be decreased whenever out of phase with the tuned circuit and increased when in phase, then the tuned circuit would receive more help than hindrance and would build up oscillations. It would oscillate at 110kHz whilst receiving it's energy in burst of 100kHz. Assuming a very high "Q", the inertia of the tuned circuit would be large enough to smooth out any amplitude variations and it would appear to receive a continuous wave input (i.e. one of the sidefrequencies). In fact it would be generating the continuous wave.

For the above process to take place the amplitude of the oscillator would have to be altered (i.e. modulated) at 10kHz which is, of course, the appropriate modulating frequency for the 110kHz sidefrequency.

It is interesting to note that it would not be essential to alter the amplitude of the oscillator in order to generate the 110kHz response. The same effect could be achieved by alternating the phase of the oscillator at 10kHz, which suggests how sidefrequencies are generated in the case of suppressed carrier, frequency and phase modulation systems.

So, although the sideband concept is a very useful, even essential part of radio theory, it is not necessary to assume that sidefrequencies have physical existence prior to the complex waveforms arriving at the receiving equipment. As explained by the *Wireless World* contributor Cathode Ray (September 1955, under the heading "Fourier – Fact or Fiction") continuous sinewaves are not the only possible form into which complex waveforms may be "decomposed", and hence it makes sense to assume that the sine form occurs simply because of the sinewave nature of oscillations in tuned circuits at the receiving end of transmitter – receiver link.
G. Berzins
Frimley
Surrey



REMOTE CONTROL FOR HI-FI

I read Mr. Kirby's article on a remote control hi-fi system (*WW*, March 1982) with some interest, as I was at that time busy designing a similar system. I too used the Mullard voltage-controlled potentiometers for control of the audio signal path, but found a much simpler and cheaper remote control system.

The major drawback of Mr Kirby's system seem to be the fact that the Plessey receiver (ML 922) only has three analogue control outputs; hence the need to use a 'stepped' volume control. The Motorola remote control system (MC 14497 – transmitter and MC 6203 – receiver) has four analogue channels and a host of other useful features. For example, toggle action volume mute and a single button operation which sets three of the analogue channels to 50% and the fourth to 30%.

This system is the same as that used on Grundig remote control television and so the modifications for hi-fi applications are quite simple. I wondered whether Mr Kirby was aware of this possibility and if not, and he was interested, I could send him some details.
D. F. Lovely,
Bioengineering Unit,
University of Strathclyde.

The author replies:
It seems from Dr Lovely's comments that we are heading in opposite directions. I regard the use of the two analogue outputs on the Plessey ML 922 as a necessary evil! I would much rather have used all digital tone level setting controls. The reason I did not was my inability to design a stereo bass and treble control circuit using less than four of the Analog Devices AD7110 chips. These cost around £8 each and the extra expense compared to the use of the Mullard analogue tone control i.e. seemed unwarranted.

I chose the Plessey remote control chip set (after looking at several alternatives) because of the analogue and digital outputs available on the ML922, and their use of an infrared photodiode to logic level integrated preamp, which saves much trouble with discrete high gain amplifiers.

Also a whole family of receiver chips are available, including one with a 5 bit latched output for a microcomputer interface, all operated by the same transmitter.

There is a toggle output on the ML922; this is used to switch the loudspeaker headphones relay, a quite effective mute control. In practice the 3/8 full scale normalised level of the analogue outputs is not a disadvantage; I rarely alter the tone by more than 1/8 of the scale.

My choice of the AD7110 was for the relative simplicity of driving it from a single chip microcomputer (the Zilog Z80), which can be programmed in Basic, as well as machine code. Then the interface between the controlling computer, and the controlled preamp/tuner/record deck can be some simple buffers. All the decoding from the received codes to the sequences necessary to drive, say, a synthesising tuner could be handled in software. This would make it easily adaptable to the various units commercially available. The prom decoding and sequencing logic used in the published design are an interim solution.

D.C. INPUT OR R.F. OUTPUT?

In "Amateur radio" for June, 1982, Pat Hawker laments the replacement of "d.c. input power" regulations by new limitations on "dBW carrier power" in the revised Amateur Licence Schedule. While I tend to agree that the dBW is not particularly welcome, the change to an "r.f. output" criterion is long overdue.

"D.c. input" was firmly rooted in the days of valve transmitters and constant-carrier modes, when both h.t. voltage and anode current were metered, and the meter needles would stay still to be read! For most radio amateurs – like it or not – those days are gone. Either our transmitters tend to be solid-state and have only r.f.-output metering, or they are primarily designed for s.s.b. In both cases it makes more sense to measure r.f. output, and this can be done with acceptable accuracy for the Amateur Service. At low powers, the accuracy requirement is minimal (at least for regulatory purposes), and at higher powers either commercial power meters can be used, or extremely simple home-made equipment, such as an existing s.w.r., meter can be calibrated accurately by transfer.

Although a d.c.-input limit does encourage high-efficiency amplifiers, is that what we really need? In today's crowded bands, the most important characteristic of a signal is its quality, and an r.f.-output limit allows amateurs to operate their transmitters in a more linear, though less efficient, manner.

The demise of d.c.-input limits is a welcome advance, but other relics of the past remain in the new Schedule: for example, the 6dB difference between the power limits for c.w. (A1A/B) and for s.s.b. (J3E). Can anyone explain how a c.w. signal with a well-shaped keying waveform differs significantly in interference potential from an s.s.b. (J3E) signal of the same peak envelope power, and why the power limits for the two modes should not be the same? The 6dB penalty against c.w. is a legacy of the transition to s.s.b. from plate-and-screen modulation, and has no current relevance. In any further revisions of the Schedule it deserves a decent burial, alongside d.c. input limits.

Ian F. White, G3SEK
Abingdon
Oxfordshire

THE NEW ELECTRONICS

It is at least eight years since I shared the responsibility for selecting graduates for employment in an electronics development laboratory, and I read with interest and dismay Mr Jaques' article in the January issue.

I was interested in that some of Mr Jaques' questions were similar to the ones I put to interviewees, and dismayed because the responses he obtained mirrored so closely those that I obtained all too often. True, my own efforts were rewarded by the occasional interviewee who did *understand* some of the principles with which he had been presented and could perhaps even describe his final-year project clearly and accurately! Indeed a few such went on to become much respected colleagues.

However, it is not Mr Jaques' article which prompts the writing of this letter, but rather the contradictions and inconsistencies in the letters about this article which appeared in the March and April issues. In a letter of reasonable length I can only draw attention to a few of these.

There is much to agree with in Mr Graham's letter – I too would reach for my text books to deal with Tensor analysis etc., etc., etc., and must agree entirely with his reference to "learning by rote" – but what is the relevance to Mr Jaques' article?

Mr Jaques' questions are all of an elementary nature – for example, surely a qualified electronics engineer might reasonably be expected to derive the expression for the gain of the amplifier configuration in thirty seconds flat, even if didn't remember "$-R_2/R_1$". Does it really require a text book on op-amps to deal with this? (Why does it have to be an op-amp anyway?)

Perhaps Mr Graham would tell us – I really would love to know – which text book does he reach for when he wishes to remind himself about Ohm's Law?

Surely the point is that an elementary *understanding* of circuit theory and device fundamentals is all that is required to answer most of Mr Jaques' questions? That is, are they not nearly all designed to avoid testing the mere ability to recall tabulated data from the candidate's memory?

Even if a graduate cannot recall a precise expression governing the current/voltage relationship for a semiconductor device, is it not reasonable to expect him to understand that it is a function of temperature, for example?

On the subject of final year projects, my experience was that students got involved in much too complex systems without any hope of fully understanding them in the limited time available! Whilst I am sure that Exeter students have written many good final year reports, does Mr Graham really believe that the result of a few weeks project work is to produce an "expert specialist"?

Turning to Mr Wehner's letter, I will ignore the first part as being totally irrelevant, and in any case, highly suspect. However, he goes on to make my point for me very well. He takes Mr Jacques to task for not drawing his (Mr Wehner's), "standard" amplifier circuit. One might quibble with the precision of Mr Jaques' "the gain between X and Z" but there is no ambiguity. Mr Wehner wants to define the gain referred to some point not even present in the circuit – why? Even if "input impedance" is not given its normal meaning, the circuit shown does have an infinite "source" impedance – so why the complication?

Whilst I do not see any ambiguity in Mr Jacques' Figure 2, surely a graduate might be reasonably expected to spot and question any such ambiguity?

It is my own belief that extraordinary progress in electronics has led to the very thing that Mr Graham objects to: learning and examination by rote. Inadequate emphasis is given to understanding and applying fundamentals. This may not matter for certain systems "designers". However, one would hope that some of the electronics engineers we are educating might actually be capable of designing the "guts" of those fascinated multilegged black boxes we all love so dearly. New processes, new devices, new circuits, all require an understanding of, and an ability to use, the fundamentals of which Mr Graham is so scornful – or have we already left it to the Americans and the Japanese?

Whilst writing this letter, I asked my son (who graduated with first class honours in Electronics Engineering and Physics about five years ago), to read and comment on your contributor's article and letters as I thought it appropriate to obtain a perhaps more modern view than my own. (Although I do not actually qualify for Mr Graham's unnecessary reference to "Grandpa".) My son's reaction was not inconsistent with my own, but I feel inclined to give him the "last word". He recalled a comment he made to his examiners – "I could have done better if I had spent more time simply memorizing information rather than trying to understand it all . . . the examination questions all too often merely required the regurgitation of chunks of lecture notes . . . a computer programmed to do the same in response to a few key words, could have got a degree."

C. W. Ward,
Yelverton,
Devon

THE DEATH OF ELECTRIC CURRENT

After Dermond O'Reilly's second blistering attack, May 1982, perhaps Ivor Catt should slink away with his tail between his legs.

When discussing a TEM wave, it is common practice to use the formula O'Reilly objects to, $E/H=\sqrt{\mu/\epsilon}$. See for instance Bell, *Wireless World*, August 1979, page 44, and also A. F. Kip, "Electricity and Magnetism", page 332, equation 12.34. Kip uses the popular convention, where vectors are written in bold type and the amplitudes of vectors are written in faint type. In *Wireless World*, July 1979, page 73, the diagram immediately above my equation (a) that O'Reilly objects to makes it clear that amplitudes are being discussed.

Para. 3. Where is it said by anyone but O'Reilly that a wave is called transverse EM because displacement current flows across it? On the contrary, a wave is described as TEM because E (not dD/dt) and M are transverse. dD/dt has nothing to do with it, and will not even exist in the case of a steady TEM signal. O'Reilly makes this very point earlier in the same paragraph, that the bulk of a steady TEM wave contains no displacement current.

Following your publication in the December 1980 issue of my article 'Death of electric current', you published a letter by R. T. Lamb and my reply to his letter, both in the March 1981 issue. The following quotations from my reply show that I found Lamb's letter muddled;

"I think Mr Lamb has reversed physicists and engineers."

"Lamb seems to call Theory N 'the current model' and Theory H 'e-m theory'."

Lamb himself wrote, among other things;

"This is a broad generalization and, like all such, has exceptions, so please don't rush to quote them at me!"

You then published R. T. Lamb's reply to my reply in September 1981. Here the plot really thickens. For instance, I have no idea what "principal assertion" he refers to in his first sentence:

"I was pleased to note that Ivor Catt, in his reply to my letter (March issue), gave yet another example of the truth of its principal assertion."

Presumably he is promoting a particular philosophical position in the matter of theory, fact, hypothesis, truth and so on. If he is, then he should give us references to the originator of his philosophical view, or if it originates with himself, he should state it clearly.

Which model of Kepler's is he discussing in his second paragraph, September 1981, when he says:

"Kepler's problem was that the central construct of his model . . ."?

There should have been more information, or reference to the literature where the particular activity of Kepler is discussed. Lamb may be talking about the ellipse, or the Harmony of the Spheres, or something else. Again, we see Lamb's ability to pitchfork confusion into a discussion.

In the December 1981 issue, you published my reply to Lamb's September letter. Then in April 1982 you published his reply. Again, Lamb confuses the issue. Even though in my latest reply, December 1981, I wrote, "If Lamb thinks (unlike me) that a mere model is in dispute, why the tenacity?", Lamb comes back with the reply, April 1982; " . . . [Ivor Catt] seems to acknowledge that we are discussing models of reality and not reality itself."

A dialogue, or debate, between two parties is of little value if the debaters ignore what the other man is saying.

Lamb's apparent assertion in paragraph three that it can be experimentally established that RC discharge current does not continue for ever I find astonishing. Also, in the last sentence of that paragraph, what does he mean by "an e.m. wave model"? Is that phrase yet another misnomer for a theory of mine? I don't know. I always name my theories clearly.

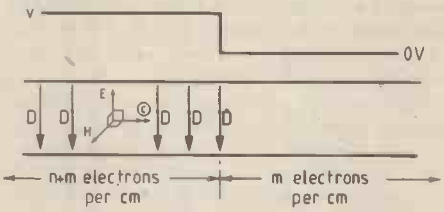
In his second paragraph, April 1982, it is unacceptable, because muddling, if he does not clearly specify which "other correspondents" have shown that the " 'insurmountable difficulties' introduced by ρ and J exist only in Mr Catt's mind." No one has retrieved classical electromagnetism from the death-blow dealt to it by the question in my letter of August 1981. It is of crucial importance to establish whether classical electromagnetism collapsed in August 1981, so I am sending a personal request to each of the following experts to submit an answer to *Wireless World*; Professors Mott, Dirac, Salaam, Brown, Lindsay, Bleaney, Gosling and Mr G. G. Scarrott.

The internal contradiction in classical electromagnetism is contained within this set of axioms;

1) A transverse electromagnetic wave (TEM) travels without change at the speed of light in a vacuum, guided by two perfect conductors.
2) Lines of electric flux terminate on electric charge. (This is one of Maxwell's equations.)
3) Electric charge cannot be created or destroyed.
4) Electric charge travels slowly in a conductor significantly slower than the velocity of light in a vacuum.

Now consider a TEM voltage step travelling to the right between two perfect conductors.

Behind the step, the D lines from the upper (more positive) conductor terminate in electrons, n per cm length of conductor, in (on) the lower conductor. These electrons are in addition to the electrons, m per cm, which neutralise the holes in the molecules of the lower conductor.



Ahead of the voltage step, m electrons per cm length of lower conductor are present, neutralising the holes. During the next 1/30 nanosecond, the voltage step moves forward by 1 cm (approx.), so that n new electrons appear in this section of the lower conductor, to terminate the newly appearing tubes of D flux between the two conductors. Where do they come from? Not from the upper conductor, because by definition, displacement current is not the flow of electrons. Not from somewhere to the left, behind the voltage step, because such electrons would have to travel at the speed of light in a vacuum.

Ergo, classical electromagnetism, which for this purpose includes both Theory N and Theory H, is dead.

Ivor Catt
C.A.M. Consultants
St. Albans

AMATEURS AND BAND 1

My attention has just been brought to the fact that the BBC is intending to use band I frequencies, channels B1 and B2, for schools broadcasting. As a radio amateur with a keen interest in the 50MHz band I find this very unsettling. It leads me to believe that there really is something wrong with the way frequencies are allocated in the UK, since if the whole 88 to 108 MHz band were available for broadcast, the BBC could have far more suitable channels tunable on existing receivers with existing antennae.

I had very much hoped that radio amateurs in the UK would eventually get an allocation at 50MHz. We would not require a band MHz wide; 50 to 50.5MHz would be quite adequate. If, however, the BBC intends to use these frequencies, I would ask that they leave a "listening hole" from 50.0 to 50.2 at least, and 50.5MHz if possible, since these frequencies are of scientific value.

I and many others have spent a lot of time, money and effort in the study of this most interesting part of the spectrum, and propagation there is not confined to the sunspot maximum: only the other week I was able to hear the PYZAA beacon in Brazil for the first time.

Therefore it would be very sad indeed if all of our efforts were to come to nothing and we were unable to even listen on 50MHz in future.

BBC please take note.

Mr G. M. Pheasant
Great Wyrley
Walsall

BLUMLEIN AND STEREO

I have followed with interest the correspondence in your columns relating to the invention of stereophonic disc recording.

It now seems that the earliest existing stereophonic discs are by Arthur Keller at Bell labs in America made using dual groove techniques in December 1932.

The earliest known orthogonal monogroove stereophonic discs were cut at EMI for A. D. Blumlein in 1933 and early 1934. This work was covered by his classic patent 394.325 which was applied for in December 1931.

On recording this document I was drawn to the conclusion that Blumlein probably had carried out research on stereophonic disc recording before its application was made. As a result I have made some effort to find whether work was done by Blumlein before the merger of the Columbia Gramophone Co and the Gramophone Co to form EMI in 1931. Unfortunately I found that his co-workers at Columbia are no longer with us and EMI were unable to confirm or deny the possibility of such earlier work. There are however to my knowledge seven references to such work and among these there are which I feel are important.

One by James Moir was based on a discussion between Moir and Blumlein during World War II and the other by Clark, Dutton, Vanderlyn who were co-workers of Blumlein. H. A. M. Clark worked with Blumlein at Columbia from 1929 and was therefore in a position to write with authority.

I have found it most frustrating that the work of probably Britain's finest electronic electronic engineer is not proclaimed to the world at large and that his long promised biography has not yet appeared.

It does no credit to EMI that they have done so little to publicise the work of Blumlein whose efforts so enriched our knowledge in such fields as sound recording, television, radar, measurements, and electronic circuitry that we still make use of his ideas forty years after his tragic death.

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R. Maude
Dalton
Huddersfield

METEOSAT HIGH-RESOLUTION IMAGES

Enhancements for receiving high-resolution pictures from Meteosat II on a home-built station. The original weather-satellite receiver, designed for Tiros-N high-resolution images, was described towards the end of last year.

by M. L. Christieson

This article describes additional equipment required to receive Meteosat primary data on the basic Tiros high-resolution receiving system outlined in a recent article.[1] Meteosat-2, which is in geosynchronous orbit at zero degrees longitude, transmits digital data in shared time with the analogue Wefax service.

The Wefax service transmits data by means of an amplitude modulated 2400Hz f.m. subcarrier, and the reception of this has been described before.[2] It is, however, important to understand how the Meteosat system as a whole operates, and how each service fits in. The spacecraft has a mirror radiometer similar to that used in the Tiros series, but because of its stationary position, the mechanics of the scan system are different. The spacecraft spins about its vertical axis at a rate of 100 rev/min. The radiometer looks out of the side of it and thus the spin provides the line scan. The frame scan is obtained by tilting the mirror from south to north over a period of about 25 minutes. There are five sensors; two are infra-red, two are visible-light sensitive, and one is sensitive in the water-vapour band. Their spectral bands are

visible (vis.)	0.4 to 1.1μm
infra-red (i.r.)	10.5 to 12.5μm
water vapour (w.v.)	5.7 to 7.1μm

Since the amount of data that may be transmitted in 25 minutes is limited, only one of each type of sensor, or one infrared and two visible-light sensors may be used at once. The basic image format is

infra-red	2500 lines × 2500 pixels
water vapour	2500 lines × 2500 pixels
visible	2500 lines × 2500 pixels or 5000 lines × 5000 pixels

This data, called the raw image, is sent in digital form to the Meteosat ground computer system at the European Space Operations Centre (ESOC) at Darmstadt in West Germany. Here it is stored and certain processing carried out, such as the registration of the two visible channels. The images are then sectored and retransmitted using Meteosat's S-band transponders as analogue Wefax data for secondary data-user stations (s.d.u.s), and as full-resolution digital data to p.d.u.s.

There are two types of digital images sent from ESOC – 'A formats' which cover the full earth disc, and 'B formats' which cover the eastern Atlantic and Europe. Both A and B formats are sent at regular times throughout the day according to the current Meteosat dissemination schedule[3] and contain, at various times, data from all the sensors. The transmissions are coded on the schedule by A or B followed by the sensor data that they contain; for example AI contains full-disc infra-red data and BIV contains the sectorized data from the infra-red and both visible sensors. BIVW contains infra-red and only one visible channel because the water-vapour image is also transmitted.

Transmission duration varies, depending on the amount of data being sent, from a few minutes to 29 minutes. The shortest format at present is BIW and the longest AV. In general terms BIV and AI are sent every half hour during daylight, with water vapour replacing visible during darkness. AV is sent four times a day. This schedule is however subject to changes. These transmissions can occupy up to six consecutive four-minute slots in the schedule and normally take place on only one of the transponder channels. The general characteristics of the p.d.u.s. transmissions are shown in Table 1.

Antenna and receiver design

The basic receiver described for a.v.h.r.r. is used with some modifications.[1] The frequency is very close to that of the h.r.p.t. from NOAA-6, and in the prototype station the down-converter and demodulator are common to both systems. Suitable crystals are used to retune the down-converter to either of the Meteosat frequencies. Both frequencies are available because an s.d.u.s. demodulator is used to receive Wefax formats in addition to the p.d.u.s. data. It is useful to have the Wefax facility in order to receive ESOC administration notices.

A completely separate antenna and preamplifer are used and system selection is by means of a coaxial relay at the input to the down-converter. The preamplifier design is similar to that used on the h.r.p.t. system, except that the combiner section is not required since a single dish antenna is used. Due to the removal of combiner loss, the noise figure can be reduced to around 1dB. This corresponds to a noise temperature of 75K. The antenna noise temperature is the same as before, 70K, so the value of the system noise temperature, T_{sys}, is approximately 70 + 75 = 145K. The recommended G/T for a p.d.u.s. is 11.5dB/K, so the antenna gain, G, should be 21.6 + 11.5 = 33dB.

The gain of a parabolic dish is given by approximately

$$G=\frac{4\pi AE}{\lambda^2}$$

where A = aperture area, E = efficiency (usually about 0.5) and λ = wavelength.

Rearranging this, to obtain a gain of G (expressed as a real number), the required diameter is

$$\sqrt{\frac{G\lambda^2}{E\pi^2}}$$

or for this frequency, approximately $0.0766\sqrt{G}$ metres. For a gain of 33dB this gives a diameter of 3.4 metres.

This size of dish is recommended for commercial use, but a significantly smaller one may be used without a large increase in error rate. The prototype uses a 2.1 metre dish, which gives a gain of about 29dB, (G/T = 29 – 21.6 = 7.4dB/K).

The exact design of the prime feed for

Table 1. General characteristics of the p.d.u.s. transmissions.

Transmission frequency	– (ch.2) 1691.0MHz (analogue and digital) (ch.1) 1694.5MHz (analogue only)
Polarization	– linear
Effective radiated power	– 18.2dBW
Modulation type	– digital split-phase-L
Modulation index	– 1.2 radians
Bit rate	– 166.66kbit/s
Bandwidth	– 1MHz
Bits/word	– 8
Words/frame	– 364
Frames/subframes	– 8 (A formats), 4 (B formats)
Frame sync.	– first three words
Recommended G/T	– 11.5dB/K

Feedback Instruments Ltd

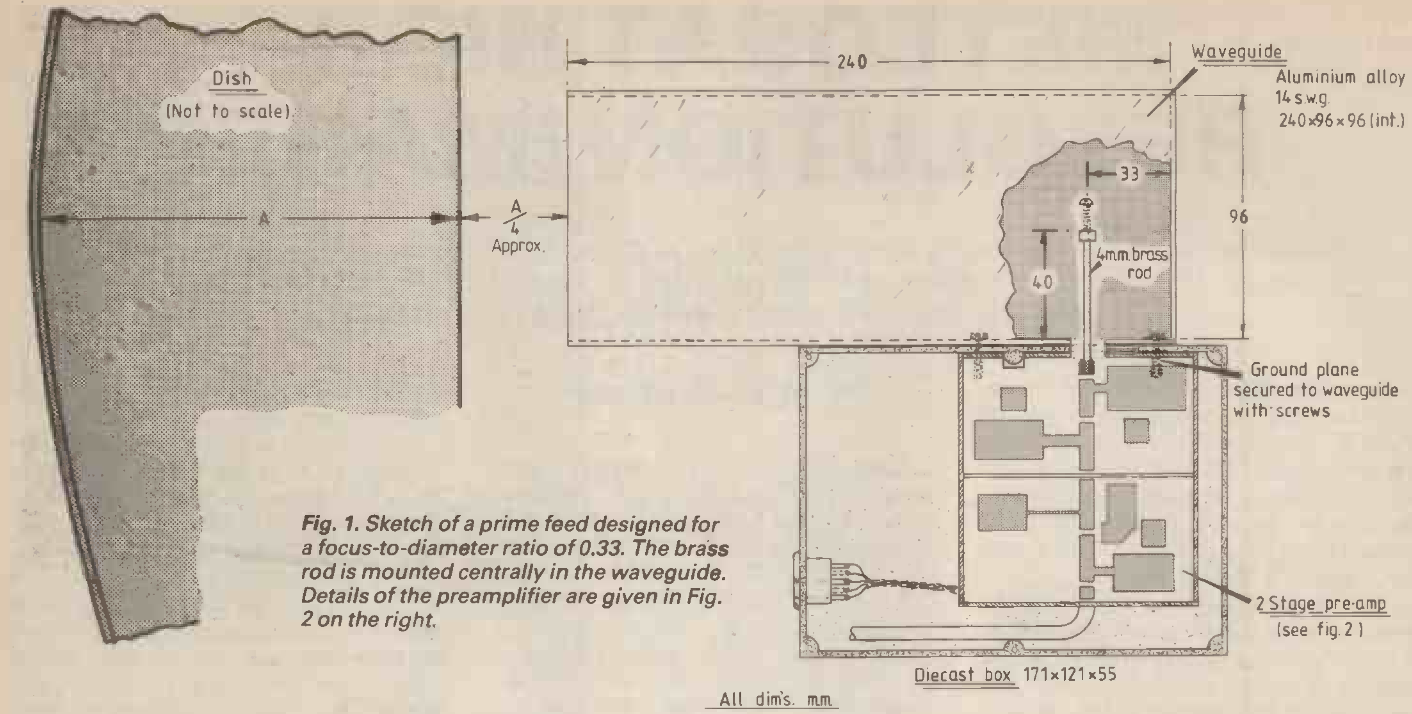


Fig. 1. Sketch of a prime feed designed for a focus-to-diameter ratio of 0.33. The brass rod is mounted centrally in the waveguide. Details of the preamplifier are given in Fig. 2 on the right.

the dish will depend on the focus-to-diameter ratio which determines the beam width that will fully illuminate the dish, but without spill-over. Figures 1 and 2 show a design which was optimized for a f/d ratio of 0.33. A smaller ratio presents an almost impossible design problem. A square section wave guide was used rather than a circular one because a slightly wider beam width can be obtained before the wave guide becomes too small to support wave transmission. If a dish with a larger f/d ratio were used a suitable circular section, sometimes known as a 'beer can feed' could be used. Construction of the preamplifier is identical to that used on the Tiros h.r.p.t. station except that the small receiving element is connected immediately before the first chip capacitor. The length of the element is adjusted, by means of the brass screw in the top, for optimum noise performance by pointing the waveguide, without the dish, in the general direction of Meteosat and adjusting it using the s.d.u.s. transmissions. A usable but rather noisy facsimile picture could be obtained on the prototype.

The dish mounting may be rigid because the beam-width is not narrow enough for the satellite to move off beam during its daily movement of about two degrees. A reasonably unobstructed view of the sky must be available and the direction may be estimated from a nomograph or calculated.[4] Once the signal has been acquired, final adjustment of direction, focus and polarization may be achieved.

Conversion to 10.7MHz is by the same converter system used for h.r.p.t. which was in turn based on one for Meteosat s.d.u.s. Careful adjustment of the interdigital filter is needed if it is required to pass h.r.p.t., as well as the Meteosat transmissions, without significant differences in performance on the four frequencies.

If the maximum benefit is to be gained from the lower bandwidth of the Meteosat transmission, the i.f. bandwidth should be reduced to about 1MHz. The simplest way to do this is to remove the 2.2kΩ damping resistor across the tuned circuit in the mixer mosfet drain. The remainder of the wideband i.f. amplifier may be used without modification.

Table 2. P.d.u.s. frame format. The first three words of each 364-word frame are always the same.

3 words	1 word		24 words		
Sync.	Format ident	Frame number 0000	Label	Spare 40 words in 'A' 8 words in 'B'	Data
Sync.	Format ident	0001	Data, radiance values sent m.s.b. first		
etc.	etc.	0010	Data		
All syncs. are 3 words 00000101 00001100 11011111	Most significant 4 bits 0111 = A format 0011 = B format	0011	Data 202 words	Further data in 'A' formats 158 words grid in 'B'	
		0100	Data (only exists in 'A' formats		
		0101	Data	Note: IR & WV have 8 bit resolution v.i.s. is 6 bit (to l.s.b s filled by zeros)	
		0110	Data		
		0111	Data 44 words	Grid, 316 words (2500 grid bits plus 28 spare)	
4 words		360 words			

1 Sub-frame; B formats (frames 0000–0011); A formats (frames 0000–0111)

Phase demodulator

The method of modulation and the modulation index are identical to those used on the h.r.p.t. transmission and so the phase-locked loop demodulator may be used without change. The base bandwidth of the p.d.u.s. signal is considerably lower than the h.r.p.t., for which the post-detection filter was designed, and therefore a further filter must be added before the signal is applied to the p.d.u.s. decoder. This filter is placed after the existing filter output, in parallel with the existing connection to the h.r.p.t. decoder, and has a 3dB cut-off point of 280kHz, Fig. 3.

Data decoding

At this point in the system it is convenient to separate the p.d.u.s. chain from the h.r.p.t. system because the differences between the two become progressively more extensive. As before, the next step is to convert the s.p.l. data to n.r.z. and clock, in a manner that avoids most of the noise. The principle of s.p.l. decoding was covered before and the same definitions apply here. The h.r.p.t. system uses a digital integrator as a bit conditioner, and although this method could have been used again, because of the lower data rate a more conventional analogue implementation was used. Far simpler methods could be used to decode s.p.l., but it is well worth making the extra effort at this point because the decoder and front-end performance determines the overall error rate.

A complete circuit diagram of the decoder is shown in Fig. 4, and it operates as follows. Raw s.p.l. data is divided into two chains, one of which is clipped, and both positive and negative transitions used to regenerate the clock by pulsing a tuned

Table 3. The 24-word frame label broken down.

Word number	Meaning
1 & 2	Number of frames per subframes
3 & 4	Number of subframes in transmission
5 & 6	Current subframe number
7 & 8	Image line number (headers are zero)
9 – 12	Image number from mission start
13	Format indicator. A = 00 B = FF (hex)
14	Vis 1 indicator } 00 = Data not present, F0 = 1st half line present, 0F = 2nd half line present
15	Vis 2 indicator
16	IR indicator } 00 = Data not present, FF = Data present
17	WV indicator
18	Grid. 00 = No grid present
19	Reserved (00 on current operations)
20	Scan direction (normally 00 = S-N/E-W)
21 – 24	Spare (all zeros)

circuit at twice the data rate. Two c.m.o.s. phase-locked loop i.cs provide logic level clocks both in phase, and at 90° to the s.p.l. 'bits'. Two D-type flip flops generate clocks at data rate both in phase and at 90° to the incoming data. The two clock dividers can be initialized externally by the clock-error signal which goes high if a phase error is detected by the frame synchronizer. The clock signals are gated to produce the enable and reset pulses that operate the integrators and sampling circuits. At the end of each data bit the integrated values of both associated s.p.l. bits are held at the inputs of a comparator, the output of which is clocked into a further D-type flip flop. This forms the n.r.z. output. Both 180° and 90° clocks are used by the sync. detector. The waveforms marked on the circuit diagram are timed over a single data bit.

P.d.u.s.-frame format

Like the h.r.p.t. from Tiros the data stream is divided into blocks of words called frames. Each frame consists of 364, eight-bit words and the first three words of each frame are always the same; they form the synchronizing sequence. The transmission is structured as a number of sets of the frames, each set containing four frames in a B format and eight in an A format. These

Background

The launch of Meteosat-2 on 19 June, 1981, began a new era of European space exploitation. It was the major part of the first active payload for Ariane, the European Space Agency's launch vehicle. After launch, the satellite was placed in a transfer orbit and then lifted into a near geosynchronous orbit by the apogee boost motor. On 20 June it was 86° W and drifting slowly eastwards at a rate of 2.8° per day. During the drift-phase, test transmissions were carried out and by the time it arrived on station on the morning of 21 July, most of the telecommunications system had been checked out. The first image scan in visible light was performed at 1030 GMT on 28 July, and in infrared on 30 July. The scheduled Wefax analogue service commenced on 17 August and the primary-data user station (p.d.u.s.) service on 15 September.

One of eight registered primary data users, Mike Christieson, at his station. From left to right are colour-display electronics, computer-terminal and v.d.u. with colour monitor above it showing p.d.u.s. full-disc image, and the PDP9 mini-computer with four tape drives. The white panel below the tape drives is the satellite interface.

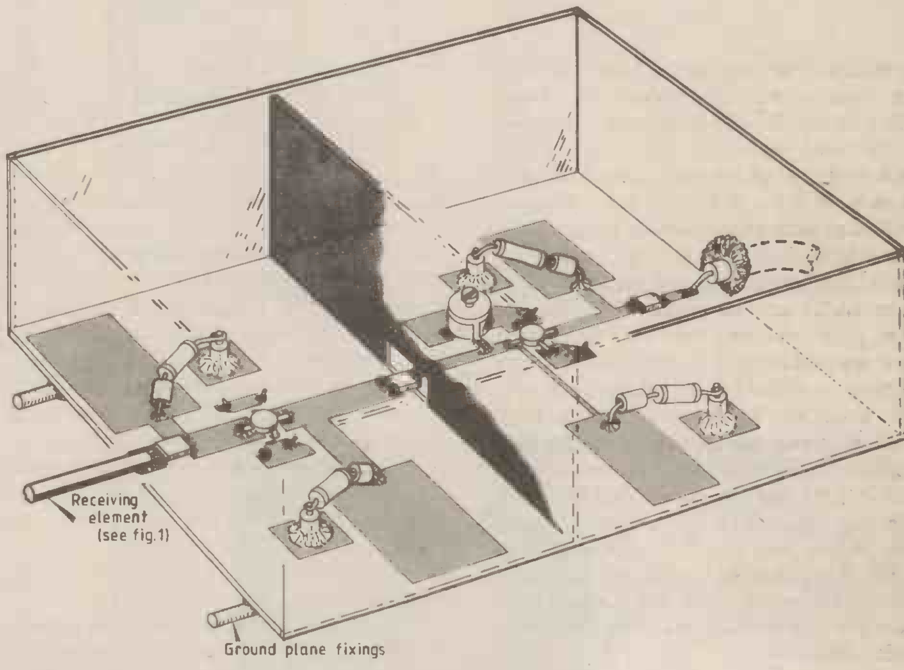


Fig. 2. Details of the two-stage preamplifier shown in Fig. 1. This is a slightly modified version of the one designed for receiving h.r.p.t. using the signal from NOAA-6, as described in the November 1981 issue of Wireless World.

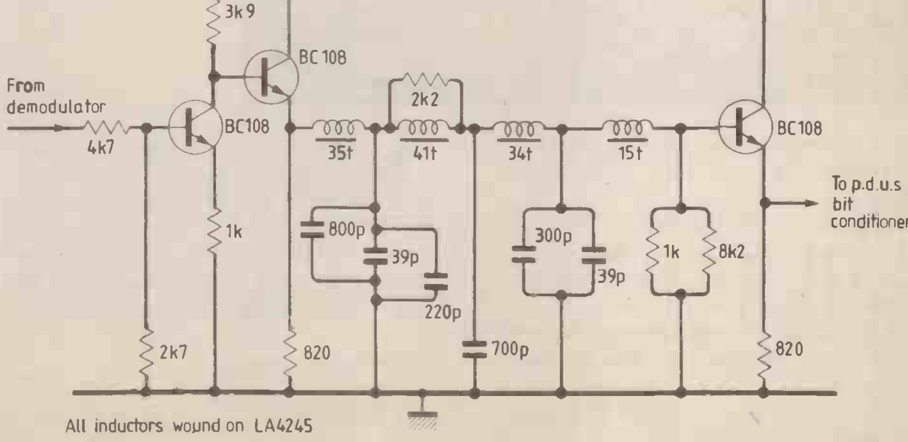


Fig. 3. Post-detection filter for p.d.u.s with 3dB cut-off point of 280kHz.

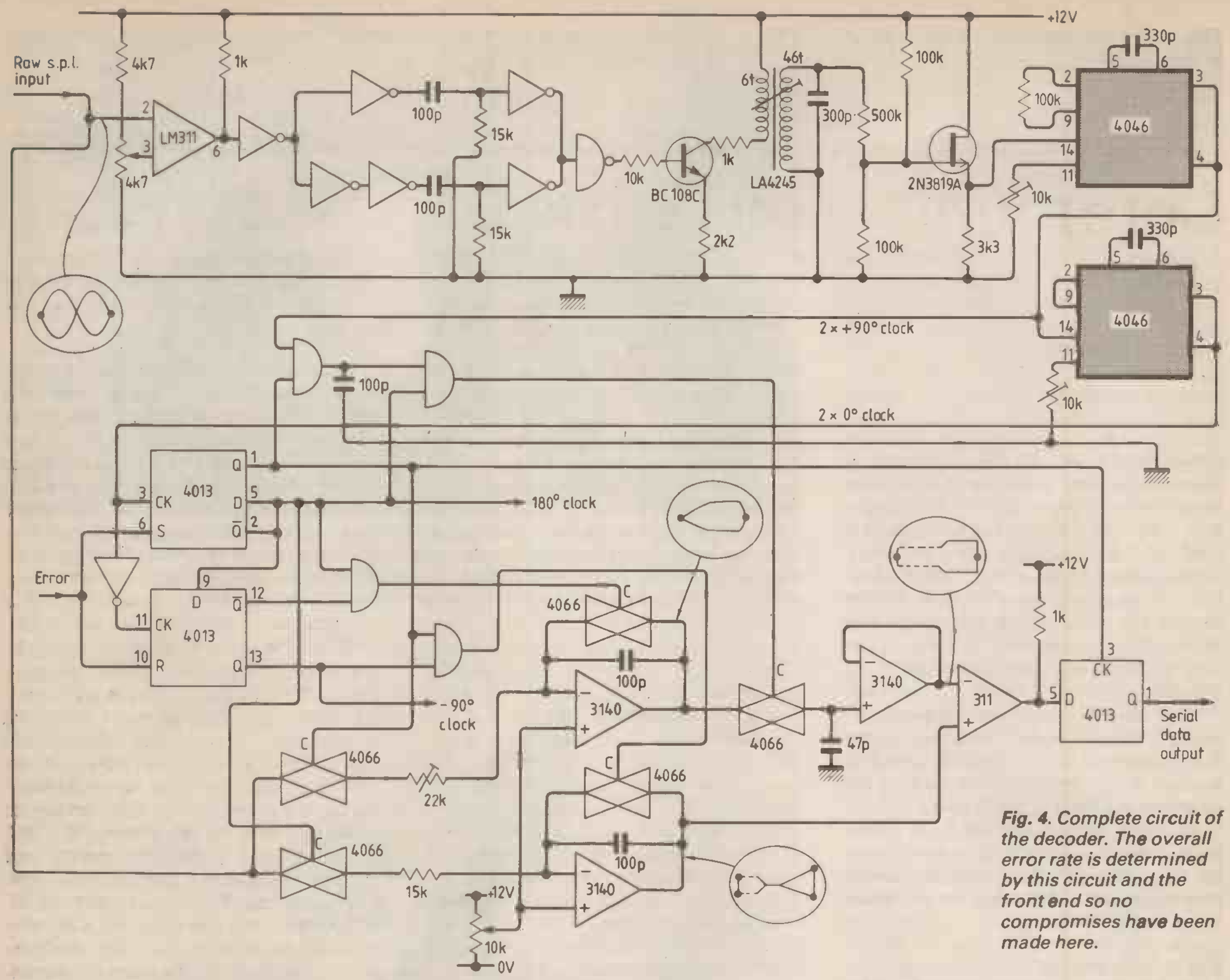
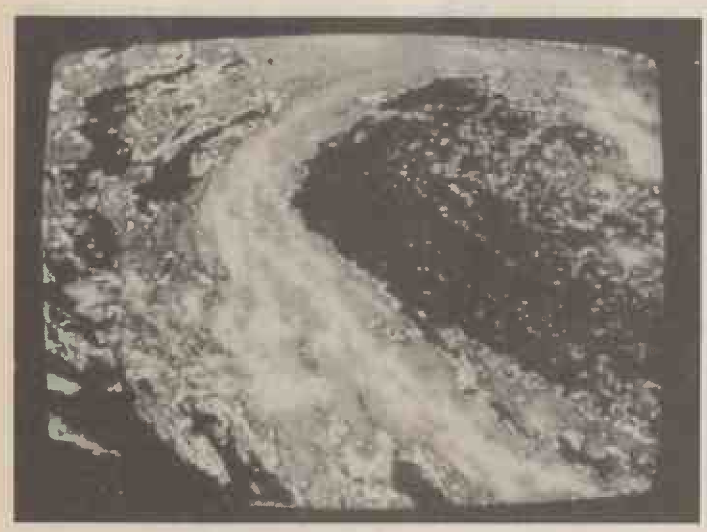


Fig. 4. Complete circuit of the decoder. The overall error rate is determined by this circuit and the front end so no compromises have been made here.



A depression in the eastern Atlantic scanned by one of the satellite's two visible-light sensors

sets are rather confusingly referred to as subframes. There are three types of subframes

- heading, which contain identification and interpretation information
- data, which contain the image, and the grid-coastline bit map
- conclusion, which are similar to heading subframes but may contain updated information.

Table 2 shows the construction of a data subframe for both A and B formats. Each subframe has a 'label', consisting of 24 words, and its contents are shown in Table 3. The data from one line of infra-red or water vapour is sent in one subframe, but one line of visible data requires two consecutive subframes. When formats containing more than one image are sent the lines are interleaved in the following priority

– infra-red line one
– visible line one
– visible line two or water-vapour line one
– infra-red line two
– visible line three, etc.

Note that when both visible channels are scheduled and only one channel is available, lines are duplicated.

All digital transmissions are preceded by a series of frames containing random data (with the label zero) to synchronise the receiver. The heading is then repeated 42 times in an A format and 84 times in a B format. Data then follows and the sequence is ended by one or two conclusion sub-frames. There is insufficient space here to describe fully the contents of the identification and the reader is referred to the ESA publications for this essential information.[5,6,7,8]

References

1 High-resolution weather satellite pictures, M. L. Christieson, *Wireless World*, Nov., Dec. 1981, Jan. 1982

2 Meteosat earth station, M. L. Christieson, *Wireless World*, June, July 1979

3 Meteosat dissemination schedule, (published regularly) ESA.

4 *Meteosat dissemination news letter*, No 81/2, July 1981, ESA

5 Meteosat high-resolution image dissemination, ESA

6 Definition of h.r. format interpretation data, M. Jones, 79 06 11, ESA

7 Meteosat calibration reports, (published occasionally) ESA

8 Special response data for Meteosat-2, Meteosat systems guide annex B1, ESA

To be continued

NEWS

Communications crisis

A pressure group, consisting members of companies and associations connected with the communications industry, has been set up to try and persuade the Government to speed up their liberalization of telecommunications. Many of the companies have invested money in anticipation of the liberalization and are now suffering financial hardship. The group calls itself the Communications Crisis Committee and its members include; Professor Lou Schnurr of the Chelmer Institute of Higher Education; The Mobile Radio Trade Association (MRTA); The Independent Telephone Supplies Association (ITSA); The Federation of Communications Services (FCS); The Mobile Radio Users' Association and the National Committee for the Legalization of Citizen's Band Radio (NATCOL-CIBAR).

They have put their opinions together into a document called the Report of the Communications Crisis Committee which consists of contributions from each of the corporate members of the Committee.

Professor Schnurr sets the scene by decrying the self-perpetuating monopoly of the present system. Even where free enterprise agreements exist, they are bound by licensing and technical approvement procedures. A particular area for discontent is the allocations of the radio-frequency bands, especially the constraints on commercial development of the spectrum "controlled by an organization insensitive to market demand and without the philosophy of optimizing available spectral bandwidth for the purpose of services development. So long as such practices are contained within the moated walls of establishment privilege and internal decision making, the marriage of telephony and wireless cannot exist". This, he implies, impedes the whole of the diffusion of information technology throughout commerce.

Contributions from the other committee members also press for the liberalization of the use of British Telecom's network; to give access to mobile radio users, so that advanced data services for communication to mobile traffic. MRUA suggests that mobile services should have access to frequencies below 1,000MHz, frequencies above that being reserved for radio location and navigation. They also press for private network communications which would also have access to the public switched networks.

In a specific case study, Godfrey Wilson of Digital Paging Ltd bitterly complained about the inability to gain from BT the exchange facilities required for direct dial-in capability, available on his companies paging service. The unrealistic pricing of BT's radiopaging service; the "extortionate delays in obtaining services, and servicing from BT; excessive delays from the Home Office in obtaining frequencies." Wilson feels it is unacceptable to be forced to compete with the body that issues the licences.

In conclusion, the committee puts forward several points for "direct, immediate action": Government departments should be asked to take steps to break the cycle of "time wasting tactics by BT and the Home Office Radio Regulatory Department; licensing powers should be transferred from BT to the Department of Industry; BT management to give fair and equitable access to BT competitors of the same facilities enjoyed by BT's own services and at the same price; require BT to set up self-accounting in all areas where there may be competition, ensuring public accountability. Pending the division of such areas, BT should suspend further commercial development; The Cabinet Office should take action to allocate some 60MHz of the radio frequency spectrum below 960MHz for private sector mobile radio services in conformity with the allocations of the 1979 WARC. There should be support and funding available to a private sector coordinating group. This would assist the administration and allocation of radio communications services, enabling medium-term commercial development of information technology and telecommunications services.

Arthur C. Clarke, on the right, is receiving the Marconi Fellowship Award for 1982 from HRH Prince Claus of the Netherlands. Arthur Clarke was awarded the prize particularly for his pioneering ideas in the field of satellite communication. He originated proposals for the use of 'Extra-terrestrial relays', first published in an article in Wireless World *in October 1945. Since then he has worked in similar proportions in both science fact and science fiction.*

Old brain, new hat?

First announced as long as two years ago, the "hand-held" Newbrain personal computer emerged recently under the new parentage of Grundy Business Systems. Following Newbury Laboratories dropping of the project in 1980 – itself then only three years old – Bob Smith and colleagues left to seek new backing, ending up with a Grundy:BTG share arrangement of 70:30%. At the same time, the specification of the machine was improved so that Grundy now claim it is designed for "business, scientific and educational use as well as home computing". Now with its resident random-access memory increased to 32K (plug-in modules of 64, 128, 256 or 512 can take it to 2M) and 28K of read-only memory, it is designed to operate with a range of interchangeable and expandable program modules, or firmware. The hand-held claim is based on the built-in 16-character 14-segment vacuum fluorescent display together with optional one-hour battery module of the AD version, designed chiefly to occupy minimum desk space. But an MDB model with on-

board nickel-cadmium cells will allow display in its editing mode for four hours and preserve memory for 20 hours and should be available in six months time. The cheapest version, model A at £199 + vat, comes without this display but with tv and monitor ports instead, as well as dual cassette port, RS232/V24 printer and bidirectional ports. The screen display can provide, unusually, 40 or 80 characters per line and a resolution of 250 dots vertically by up to 640 dots, and may be mixed with a separately scrollable character-mode display. The 512 character fount includes viewdata mosaics, upper and lower case Greek letters, arc, and line drawing graphics, as well as the 96 ISO printing characters.

Firmware consists of interchangeable modules, communicating via hardware-independent interfaces, and may be expanded without interference with the hardware. The enhanced-ANSI Basic allows for user proofing of programs, direct interrupt handling, device-independent i/o, chaining and external calls. The screen editor claims novelties for a microcomputer: backwards scrolling, multi-screen ability and direct cursor addressing. The operating system provides for peripheral device drivers to the processors – the cassette device involves a second processor which uses a learning algorithm to accommodate tape speed fluctuations. Additional rom slots are available in a buffer expansion module that accepts Z80 assembler, Comal structured Basic, statistics and text processing packages. The buffer module also has memory paging circuitry, parallel i/o ports, analogue ports, two multi-speed V24 ports, as well as rom space, which will be included onboard in the M models available later. Proprietary software packages may be used from cassette or *via* disc under control of the CP/M module, available September. A communications module, also available September, contains 32 V24 ports to give flexibility in sharing peripheral devices and connecting computers together. Unfortunately, a videotext module takes only low priority, and is planned for "some time next year".

Meeting Grundy's price targets meant adopting n.m.o.s. circuits instead of the more expensive c.m.o.s. types. Switch-off circuitry was incorporated to keep the circuits cool and power consumption within reasonable limits. "Other machines do have problems in this respect," says Grundy's Mike Wakefield, who is pleased to be able to claim a 0 to 45° C temperature range.

Welsh Dragon

The Dragon 32 computer is the first product of a new company, Dragon Data Ltd, a subsidiary of the toy manufacturers, Mettoy. Aimed at the first user, Dragon Data have concentrated their publicity in marketing a 'family home computer' where the children might use it for learning and games playing while the parents can compute family budgets, or index a collection.

The Dragon 32 is based on a Motorola 6809E which has an internal architecture so designed that it needs far fewer instructions to operate it than many other microprocessors and is very fast. It has a 16K rom with extended Microsoft colour Basic, which gives high-resolution graphics of up to 256 x 192 pixels: there is a modulated output to a domestic tv and there is also a monitor output. The basic computer includes a Centronics-type interface, so a 'professional' printer may be plugged in directly. The keyboard is similar to that used on DEC equipment and offers typewriter-style keys, guaranteed for 20 million key depressions. There is a 32K ram with the ability to expand to 64K. In addition there is a games cartridge slot with sockets for two joystick controls for the playing of games;

The Dragon 32 home computer, made in Wales.

cartridges for the more popular amusement arcade games, space invaders, a 'Pac-man'-type game and others, are available. Programmes may be stored on cassette tape. Dragon Data say that they have paid particular attention to the cassette interface so that the computer will work with a wide range of cassette recorders.

Some software on cassette is already available, particularly the Dragon Special Selection tapes which are games programs which explain how they work and so give some insight into their programming.

Especially useful for educational programs is the ability to switch sound from a cassette player through to the tv sound. Program and a sound commentary can be included on the same cassette. A language lesson could show the words on the screen while they are spoken through the speaker. The Dragon can also generate sound with five octaves of musical notes with selectable duration and volume. This too comes out through the tv speaker.

Future expansions and developments include a disc operating system, an RS232 port, a second microprocessor and an operating system together with Prestel and teletext facilities. Other operating languages can be added, including Pascal, 'C' and Basic compilers.

Program cassettes and cartridges are planned for a wide range of applications. The Dragon is all British, designed by Dragon Data with the co-operation of the PATs Centre, and Motorola, whose chips, manufactured in Scotland are used in the computer.

Comparisons are always difficult but the nearest competitor to the Dragon is the Sinclair ZX Spectrum. The Dragon 32 has more memory and a particular advantage in having a 'professional' keyboard. The Centronics interface is also a big advantage. The Sinclair has more colours available at high resolution and the big (so far theoretical) advantage of the Microdrive; the miniature, low cost disc memory. However, there is a big difference in 'feel' with the ZX Spectrum feeling like a toy computer and the Dragon and its keyboard with the touch of a 'real' computer.

The Dragon 32 is in production at the Mettoy factory in Swansea, it will be on sale in the High Street early in August for just under £200.

Banking on video

Barclays Bank has found that the best way to keep their staff informed is through video programmes, shown on tv sets at the place of work. They have invested in a £1M recording studio and insist that their programmes should be of the highest quality both in content and presentation. So they have hired tv producers and popular tv performers to make the programmes look as much like the programmes the staff might watch at home, as possible. Such subjects as 'How to spot fraudulent use of Barclaycard' or the implications to the staff on the opening of the banks to the public on Saturday mornings, have been produced and are examples of the training and information functions. In order to generate enough copies of the video films for distribution, Barclays have a computer-controlled copying suite with quality monitoring also controlled by computer.

The next phase of the video network is to extend it to 2,300 outlets. Barclays have awarded a £3.5M contract to Soundcraft Network Video to install 700 additional Type 5 Sony U-Matic video cassette recorders and 1,900 Trinitron monitors, and to maintain the whole system.

Mike Pogson, the managing director of Soundcraft, told us that his company had made considerable investment in providing servicing back-up for such a system. He described the lack of fully-trained broadcast engineers who were necessary to diagnose as well as rectify any faults in the field. He saw the role of his company as removing all the technical problems from the client's shoulders so that they can 'get on with producing and distributing the programmes'.

The Soundcraft deal is claimed to be the biggest contract by a corporate organization in Europe.

New technology and the graduate

The Department of Education and Science has approved the co-operation between the Science and Engineering Research Council and the Open University for a series of programmes of 'technological topping-up' courses. It is intended to provide a re-education for those graduates who have been working in industry for periods of 5 to 15 years. The SERC became aware of a need for such courses and have commissioned the OU to produce them.

The courses will use the OU's techniques for home study with tutorial support and study centre facilities for practical work. Two areas in particular have been identified for priority treatment, which are computer applications (including real-time monitoring and control systems), and manufacturing.

The computer applications course is expected to consist of a 'foundation' module on software engineering, computer systems architecture, and operating systems. This would be followed by a number of 'core' modules on monitoring systems, systems modelling, control systems and project management. There would also be optional modules on robotics, man/machine interactions, and computer-aided design. The full course will be the equivalent of one year's full time study. Certificates would be awarded for each module of the course and a diploma for the successful completion of the whole course. Students may then be able to undertake a further project in a related area which would lead to an M.Sc.-level qualification.

Telecom showcase

British Telecom's new exhibition centre is not a museum, stressed Peter Benton, the Deputy Chairman of BT, although it does trace the history of telecommunications from the early days of telegraphy. The centre's full title is Telecom Technology Showcase and in addition to the historical aspect which is well covered with many working examples of, for example, a Strowger telephone exchange of 1940s vintage, there is an exhibition of BT's latest equipment and techniques. Currently these include many digital techniques, displays about optical fibres and satellite telecommunications with examples of some of the latest equipment. It is planned to change the displays regularly to keep them up-to-date.

The Showcase is situated in Queen Victoria Street, London, in part of BT's Baynard House and is next door to the Mermaid Theatre. Lord Miles, formerly Sir Bernard Miles, officially opened the showcase and pointed out the role that the Mermaid's Molecule Club had played in educating young people in science and technology. He hoped that the Showcase would also contribute towards the edification of the young. He also looked forward to the micro revolution which he felt would release us from the 'work ethic' and allow us to get on with living, without the encumbrance of work.

CIRCUIT IDEAS

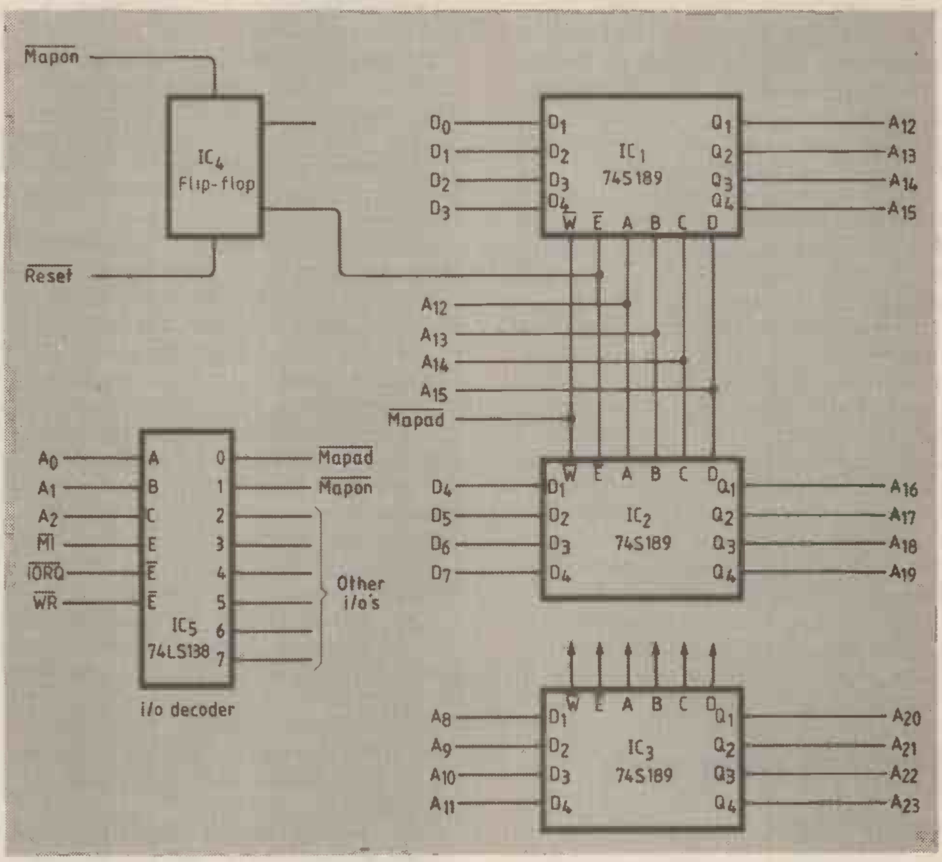
Extended addressing for the Z80

Current 40-pin memory-mapping i.cs are expensive and difficult to obtain. As this circuit shows, it is possible to extend the addressing capability of a Z80 to more than 16 bits using readily available 74S189, 64-bit t.t.l. rams.

The microprocessor's four most significant address lines are not used for memory access, but instead address one of 16 stores of eight or 12 bits which are used as most significant address lines; in essence the same function as carried out by dedicated memory-mapping i.cs.

Each store is loaded using an OUT(C),r instruction which, with the Z80, results in the contents of the B register being placed on the upper half of the address bus. To load a particular store, the program has to put the eight address bits into the A (or D, E, H or L) register, the store addressing the top four bits of B, then load C with the i/o address of the mapping circuit and issue an OUT(C),A (or D, E, H or L) instruction. If 12 address bits are to be generated, the top four bits must also be placed in the bottom four positions of B.

Sixteen different stores are used so that various parts of the program can be allocated one or several locations, allowing each store to work on its own ram. For example, interrupt routines may be run without upsetting background pointers.



Initially, bistable IC_4 disables the stores, whose outputs are held high by resistors until a switch-on signal is generated using a spare i/o line. This gives a fixed value on start up while the initializing program loads the 16 stores.

Brian Dillon
Dublin

Low-current voltage regulator

Standby consumption and output rating of this low-power regulator are 50µA and greater than 10mA respectively. Current limiting is included, brought about by gate-to-source voltage starvation in the 4007, and the output is short-circuit proof. Components used are cheap and readily available.

With the components shown, the output voltage is 12.78V, given by

$$V_{out} \approx V_{BR(Tr1)} + V_R$$

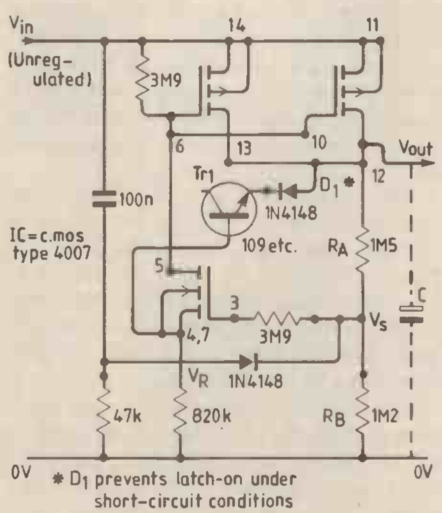
where $V_R = V_S - V_T$ and $V_T \approx 1.5V$. And

$$V_{RA} = V_{F(D1)} + V_{BR(Tr1)} - V_T$$

such that $V_{out} = V_{RA} + V_{RB}$. In this case, assuming a typical BC109 breakdown voltage of 8.2V for Tr_1, a forward voltage for D_1 of 0.4V and a threshold voltage of 1.5V, V_{RA}=7.1 and V_{RB}=5.68. Therefore $V_{out} = V_{RA} + V_{RB}$.

With a maximum input voltage of 20V, with V_R at around 4V, the c.m.o.s. device will be operating at around 16V which is inside its rating.

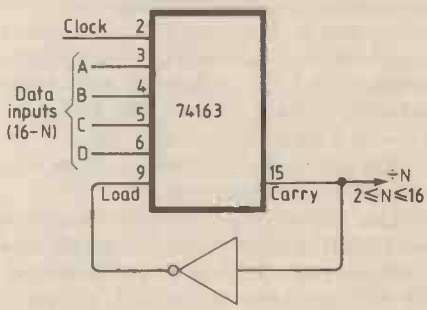
D. Roffey
Bromley

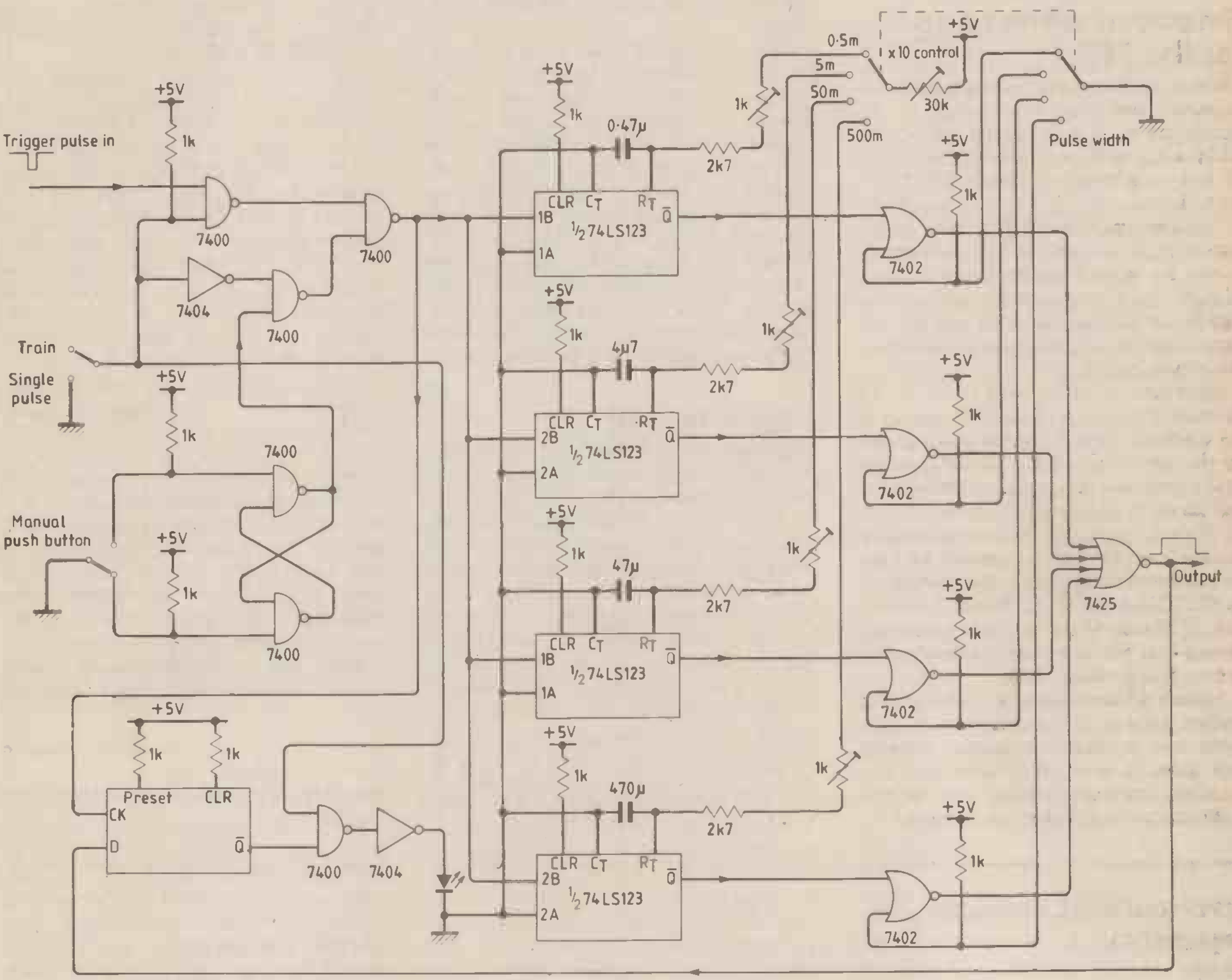


Programmable frequency divider

The 74163 4-bit binary counter may be used to divide the clock frequency by N, where 2≤ N≤ 16, by applying binary (16−N) to the data inputs and connecting the load input to the inverted carry output.

N. H. Sabah
American University of Beirut



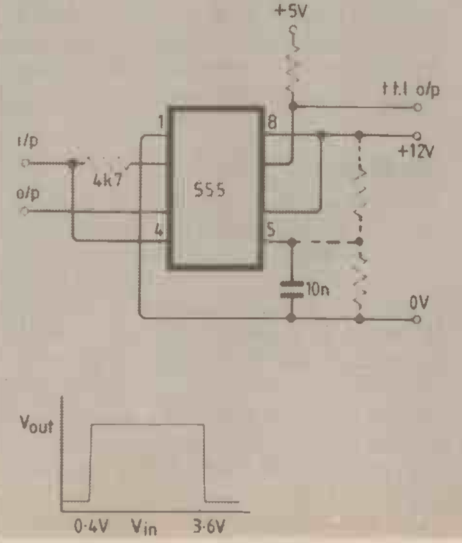


Pulse-generation using t.t.l.

Variable-pulse control using t.t.l. i.cs is not unusual, but most circuits use non-retriggerable monostables since they are less prone to false triggering from noisy supply lines and stray signals. However, when a 100% duty cycle is reached, output jitter occurs and above 100%, the pulse repetition frequency is reduced.

This circuit uses separate retriggerable monostables and is not prone to false triggering. Jittering near the 100% duty cycle does not occur and at and above 100%, an l.e.d. lights and the output becomes static. Further stages may be added.

A. R. Millichope
Birmingham



Window discriminator

Two op-amps and numerous close-tolerance resistors used in conventional window discriminators are replaced by this circuit at the expense of convenient adjustment.

Designed to lift the pen of an X-Y recorder when the Y input exceeded the range 0.5 to 4.5V, the circuit uses the 555's control-voltage input to trim the trigger level. A potential divider was used at the input to change the voltage range to between 0.4 and 3.6V. Predictable operation is ensured by tying the threshold input to the positive rail and if a t.t.l. output is required, the open-collector output, pin 7, can be used in the conventional manner.

R. M. Jones
County Durham

Howard Hughes

I watched the recent two-part EMI film on Howard Hughes (BBC 2) with interest – though it seemed a great pity that so much emphasis was placed on his extraordinary idiosyncrasies, so little on the remarkable contributions made to technology by the companies controlled by his secret telephone calls in the middle of the night. Hughes was undoubtedly the fruitiest of fruit-cakes – though if he had been born in Chipping Sodbury, rather than Houston, Texas, he might have passed as the last of the great eccentrics. Fruit-cake or eccentric he has the distinction of being one of the few men ever to take on and defeat the European telecommunications "establishment" led by the British Post Office.

Wireless World has always been proud of the fact that the potential of the geostationary orbit as a unique parking place for microwave and broadcast relay stations was first pointed out in its columns in 1945 by Arthur Clarke. But the means of implementing this in 1963 by a transfer orbit and position-keeping jets were entirely the work of the Hughes Aircraft team led by Harold Rosen, Tom Hudspeth and Don Williams. An equally difficult job was to convince the Post Office. BPO were ranged solidly behind the concept of a series of station-keeping satellites some 12,000 miles above the Earth, involving all the problems of tracking and hand-over. The Post Office engineers attacked the geostationary orbit on the grounds of excessive time delay and pointed out the impracticability of conversation between two nervous speakers reduced to a hopeless tangle by the delays. Indeed the first transAtlantic call I made over Early Bird (Intelsat 1) in 1965 did seem to bear out their gloomy prognostications – it was only later, when they had virtually admitted defeat, that it emerged that the real villain of the piece was the inadequate design of echo-suppressor then in use. It is often forgotten that it was not until well after the launching of Early Bird in 1965 (following the experimental ATS series) that Intelsat/Comsat became firmly committed to the synchronous orbit. In the struggle, which lasted some 3-4 years, Hughes Aircraft was not adverse to using the lavish hospitality that had earlier brought Howard Hughes before a Congressional Committee. I have to declare an interest as I was a bemused member of a party of European journalists taken to Culver City, Los Angeles and the fabulous Hughes Research Laboratories out at Malibu Beach – a trip that remains indelibly in the memory as one of the most lavishly endowed press parties of all time! I can plead only that it was not the trip that subverted me to support the geostationary orbit but a previous more modest meeting with Harold Rosen, at the conclusion of one of his many efforts to convince European PTT organizations that their future was to be found 22,300 miles above Earth.

No mention was made in the EMI film of communications satellites or lasers though the dying recluse was shown playing with a model of the CIA-backed Global Explorer, the remarkable deep-sea recovery ship which came very near to success and which one day may itself be recognized as contributing to the technology of reaping a richer harvest from the sea bed. In his later days Hughes was close to madness – but as an old-style entrepreneur he did more to advance communications and aviation technology than whole battalions of eminently sane bureaucrats!

Easily nicked

The emphasis on lightweight, microminiature complex equipment in communications and broadcasting is not without its problems. High-cost equipment that can be easily carried, can easily be carried away by other than the rightful owners. It is not without reason that e.n.g. (electronic news gathering) television equipment has earned the sobriquet "easily nicked gear". During the past few years several crews have returned minus many thousands of pounds worth of equipment. Nor is it only portable electronic gear that vanishes. In April a BBC crew in South London lost £25,000 worth of film equipment from the back of an estate car while taking a lunch break in Stockwell. Another anonymous company has been advertising (under a box number) for information on a loss of a complete Sony e.n.g. unit including BVP330P camera, BVU110P recorder, battery charger, radio microphone, etc. This was not the first e.n.g. unit to disappear in the UK.

Communications equipment – professional, amateur and c.b. – has become very vulnerable to car thieves. But the thieves need to be careful in their choice of vehicle. I heard of a case recently where what looked like a standard broadcast car radio was taken from a Special Branch police vehicle. It was in fact a disguised control unit for a boot-mounted two-way radio!

Stable at s.h.f.

Although semiconductor devices, including Gunn diodes and Impatt diodes, make possible relatively simple self-excited oscillators at s.h.f., it remains essential for many applications to provide some form of stabilization. A good deal of effort, for example, has been put into developing cavity resonators, including low-cost types that can be used in association with the front-ends of 12 GHz satellite receivers where the circuit elements may take the form of punched out metal sheet.

Recently much interest is being shown in small dielectric resonators which can be used in connection with cavity resonators to improve greatly the temperature characteristics or, for example, to stabilize monolithic GaAs fet oscillators.

In conjunction with a conventional cavity it is claimed that commercially available dielectric resonators using a disc of doped barium titanate in the cavity can reduce the temperature drift of a 10 GHz cavity-stabilized oscillator from 3 MHz per °C to only 3 kHz per °C. A new Mullard range of dielectric-stabilized oscillators within the 4 to 16 GHz frequency range includes the facility to tune over 1 per cent of the lowest frequency limit without degrading stabilization, or 8 per cent when rather lower stability and higher noise is acceptable.

A French team at Laboratoires d'Electronique et de Physique Appliquée (LEP) has reported (*Electronics Letters*, April 15, 1982 Vol 18 No 8, pp 345-347) the development of a monolithic X-band GaAs fet oscillator stabilized by means of a barium titanate dielectric resonator which delivers more than 30mW output power at 10.8 GHz with a frequency drift better than 1 p.p.m/K from -20°C to 80°C, and a maximum chip efficiency of about 20 per cent. The oscillator chip measures 1.2 by 1.4mm^2 with a chip thickness of 300μm. It can be used as a voltage-controlled oscillator.

Long waves, high power

The BBC is currently carrying out a £2-million refit to the Droitwich 200 kHz (1500 m) long-wave station at Droitwich, taking the opportunity to increase transmitter output power from 400 kW to 500 kW. The transmitters now in use are two of the four 200 kW units originally supplied by Marconi for the special wartime 800 kW station near Hull. The use of the Marconi "Pulsam" high-efficiency technique will make the higher power units more economical to run.

500 kW is a long way from the first long-wave (1600m) BBC station at Daventry. This was completed in 1924 and had a power of 25 kW following tests on a Marconi 15 kW long-wave transmitter in the Chelmsford factory. At that time the intention was to supplement the local regional transmitters (1.5 kW plus 0.12 kW relays) by a single transmitter providing "a reasonable field strength over most of the British Isles" – as indeed it appears to have done at a time when most listeners used outdoor aerials, electrical interference was reasonably low and there were none of those infuriating signals emanating from the line time-bases and switched-mode power supplies of colour television sets. Indeed in the 1930s it was firmly recognised in the UK that high-power stations of the order of 500 kW "may be a doubtful blessing".

American broadcasters, who have never used the long-wave broadcast band, have been limited even on medium-wave "clear channels' to a maximum of 50 kW and yet have traditionally achieved extensive and excellent night-time coverage using directional aerials to minimize mutual interference.

However this coverage is now under severe threat from Cuba who have stated an intention to install two 500 kW transmitters with omnidirectional aerials, plus over 180 other transmitters of various powers – and have withdrawn from a key Region 2 planning conference. It could be argued that the Americans have brought this problem on themselves by their intention to transmit programmes to Cuba on medium-waves – yet another example of how it is often external broadcasting for government agencies that has been the prime cause of the transmitter power race and excessive interference.

AMATEUR RADIO

Satellite scene

Several of the balloon flights being organized this year by the South African Radio League as a preliminary to an amateur satellite project have been completed successfully, including two flights to 100,000 ft with simple recovery beacons and a 10-hour flight to this height carrying a linear transponder as well as telemetry and recovery beacons. During the flight about 20 amateur operators had s.s.b. and morse contacts through the beacon over distances of several hundred kilometres. A later flight will be aimed at keeping a transporter at 100,000 ft over an extended period with power derived from solar panels. The whole project is enjoying the full co-operation of a number of universities and electronics firms.

During April, a false command initiated by the main computer on board the University of Surrey's UOSAT satellite inadvertently switched on both the 145 MHz and the 432 MHz beacons at the same time, resulting in desensitizing both command receivers so that the satillite was no longer under ground control. The normal fail-safe software in the computer had previously been temporarily over-written, with the result that the malfunction persisted for an extended period.

Ron Broadbent, G3AAJ, secretary of Amsat-UK, has complained of the many demands directed to the society, stemming not from radio amateurs but from school and university staffs seeking detailed information on what they regard as a "British Schools Satellite".

Vintage valves

A few months ago the turning over by Mullard Ltd of their Blackburn factory from the manufacture of domestic valves to other products led to nostalgic backward glances to the heyday of the "red" EF50 of wartime radar, the EF39 used in many communications receivers, and other once familiar small-signal valves.

Across the Atlantic the process of closing down production lines of "vacuum tubes" has been going on for several years, without many tears being shed. But surely a note in *QST* will touch the hearts of every old-time amateur and professional communications man: RCA have discontinued manufacture of a further batch of glass-envelope transmitting valves including such famous types as the 807, 811A, 813, 829B – valves that found their way into innumerable transmitters since they were first introduced well over 40 years ago – and still do yeoman service in many transmitters even today, although presumably the demand for replacements has dipped. Transmitters needed to be large to accommodate them and the ceramic types with (often noisy) forced-air cooling were displacing them, years before the semiconductor era began to deliver the knock-out blow. The 813 needs a hefty 5 amps at 10 volts just to keep the filament energized; but was – and remains – a magnificent workhorse for Class C service. Show me a transistor that will provide a comfortable 300 watts r.f. output at 20 MHz with a similar freedom from parasitic oscillation and ease of design – but until then many will regret the gradual passing of the thermionic era.

Perhaps not quite passing – Mullard, for example, tell me they have no plans to discontinue their range of transmitting valves, including near equivalents of a number of the axed RCA types. Indeed I hear rumours of European manufactured valves being sent across to the States and then returning to find sockets in European transmitters.

Here and there

The regulations introduced by the FCC on January 1, 1981, limiting the amount of r.f.i. generated by new computing devices marked for the home to limits calculated not to interfere with broadcast reception are having an effect on manufacturers. Although initially many manufacturers applied for waivers, the regulations must be complied with by October 1983, and recently the FCC laboratory has been rejecting less than 15 per cent of devices compared with 25-30 per cent in early 1981. FCC are now investigating the amount of interference produced by other digital devices including digital clocks using synthesized speech.

A number of candidates who took the Radio Amateur's Examination in May appear to have been less than happy with the multichoice paper and support the view, expressed on a number of previous occasions in this column, that the City & Guilds Institute should carefully consider updating the aims and scope of the examination – and contributing to the reduction of the administrative time it takes in the UK to sit the exam and acquire a licence.

With the help of a small grant from the Science Research Council, the R.S.G.B. Propagation Studies Committee is to assist in the collection over the next four to five years of data on Sporadic E propagation on frequencies above 100 MHz. North/south propagation paths on 50 MHz were open on many occasions during March and April 1982. An unusually large number of South African stations were received in the U.K. on April 12.

In brief

The boom in walkabout audio tape cassette players has encouraged the marketing in Japan of miniature 50 MHz "walkie-talkie" units, such as the Standard "Talkman" with headphones and miniature boom microphones. In future someone "talking to themselves" in the street may or may not be a first sign of madness . . . . David Adams, VE3BHF (G4NWA) of Sutton West, Ontario has been walking the length of Britain, from the Scilly Isles to the Orkneys with a backpack that includes a 144 MHz hand-held transceiver . . . Callsign of the 70.05 MHz beacon transmitter on Harpur Hill, near Buxton, Derbyshire has changed from GB3SU to GB3BUX as part of the plan to use two-letter GB callsigns for repeaters and three-letter ones for beacons. Similarly, for example, the beacon high on the IBA's concrete aerial support tower at Emley Moor, West Yorkshire has changed from GB3EM to GB3MLE . . . Tropospheric 10 GHz contacts across the English Channel to amateurs in France and Holland continue to be reported over distances up to about 250 km . . . A "very slow rise" in membership is reported by the R.S.G.B. who state that of members resigning "the vast majority gave the present economic climate and unemployment as the main reason". . . Forthcoming mobile rallies include: July 25, Anglian Mobile Rally, Stanway School, Colchester; Scarborough A.R.S. at Spa Ocean Room. August 1, R.S.G.B. National Mobile Rally at Woburn. August 8, 25th annual Derby Mobile Rally, Lower Bemrose School, off Derby Ring Road. August 15, Preston A.R.S. at Walton-le-Dale County High School, Brindle Road, Bamber Bridge, Preston. August 22, Bromsgrove A.R.C. picnic at Avoncroft Art Centre, Bromsgrove.

PAT HAWKER, G3VA

NETWORK ANALYSIS WITH A ZX81

Extensive insertion loss and group delay computations of ladder filters are faster with an inexpensive microcomputer than with a programmable calculator

by L. E. Weaver

The specification of the ZX81 reveals that it is also potentially a 'super-calculator' capable of handling much more extensive programs at a far higher computing speed than, for example, the Texas TI59. The 9½-digit accuracy is admittedly less but nevertheless perfectly adequate for a wide range of practical problems. The program described was written not only to fulfil a professional requirement, but also to test the capabilities of the ZX81 fitted with the 16K ram.

The menu it provides is as follows.

- Compute and display the insertion loss and group delay of a passive ladder network with up to 10 branches, excluding the terminations. For a frequency base in MHz the group delay is computed over an increment of 1kHz.
- Each branch can consist of a single inductor or capacitor, or a series or parallel tuned circuit. More complex structures can be handled by means of a simple device.
- A chosen value of dissipation can be assigned to the components.
- Component values entered can be listed and corrections made before computation starts.
- At the end of a calculation, individual frequencies and element values can be modified without re-starting the program from the beginning. This is invaluable for estimating the effect of component tolerances or for 'zooming in' on any particular area of the network response.
- Up to five group-delay equalizer sections can be added and the total resultant delay displayed. The display is in the form of the zero-frequency delay, followed by the differences from that value at the other points.
- Because the group delay values of the network are held in an auxiliary array, re-computation of the group-delay response after changes to the equalizer parameters is fast.
- Added loss due to dissipation in the equalizer can be displayed.

To give an idea of the running time, the ZX81 in the fast mode displays the insertion loss and group delay of a seventh-order elliptic-function filter at 15 points in around 75 seconds. Each successive attempt at group-delay equalization takes around 12 seconds, not including the time taken to enter values.

Because many users will not need the group-delay equalization routine, the procedure for use is conveniently divided into two portions.

Computation of network response

First some general remarks. As I am principally concerned with video filters, the units chosen are Ω, μF, μH, MHz and μs. These can be replaced by any other self-consistent set, but obviously minor changes to the print statements will be needed.

It is assumed that the network is unbalanced and contains no bridged-T sections. The group-delay equalizers are dealt with quite differently. The branches are numbered from the input to the output, and the component values are entered in the same order so that for example, the fourth branch will contain L(4) and C(4), or perhaps L(4) or C(4) alone. As shunt and series branches alternate in a ladder network it is only necessary to specify the nature of one of these. This is chosen to be the branch facing the input termination.

The dissipation is expressed by D, which is the reciprocal of the Q factor, and must be specified at some frequency. This will often be the cut-off frequency or possibly one of the points of nominally infinite rejection. Because of the simplification in the expressions for the impedances, the standard device is employed of assuming that both the inductors and capacitors have the same dissipation, and that in a resonant circuit D is the sum of these. However, experience shows that provided D is less than about 0.02 (Q>50) the individual dissipations do not need to be equal. It follows that if the capacitors can be considered as dissipationless, D can be taken as one half of the value which would otherwise apply. This may not sound very satisfactory but in practice it works surprisingly well.

With such a long program and only 16K of storage the display prompts necessarily have to be kept very short, so it seems desirable to set out the procedure in detail. Each input will, of course, be followed by NEW LINE.

Prompts	Inputs
FO?	Starting frequency
FM?	Maximum frequency
DF?	Frequency step
D?	Dissipation constant
FD?	Dissipation frequency (if D=0 then a nominal positive value must be entered)
RI?	Input termination
RO?	Output termination
NO. OF BRANCHES?	Total excluding terminations
L+C? N=1	YES for a resonant circuit, NO for a single resistor or capacitor
SER OR PAR?	When previous input was YES, input SER for a series and PAR for a parallel resonant circuit
L? N=1	Enter L(1)
C?	Enter C(1). If only one L or C the other must be entered as zero

L. E. Weaver, B.Sc, M.I.E.E. is the author of three well-known works on television measurements, and of a number of monographs and papers both on that subject and on aspects of network design. Now a television engineering consultant, he was previously head of the measurements laboratory in the BBC designs department. While in that position he also used the experience previously gained in network design at STCs transmission laboratory to produce high-quality video filters, some of which have been commercially manufactured on a considerable scale.

This process will continue until the last branch has been entered. Then

SHUNT IN?	YES for a shunt input, NO for a series
9/695	GOTO CHECK. This will then list the entered values. Modify by, for example, LET L (4) = 5.25. Do not enter RUN or CONT. When satisfied enter GOTO LOSS, which starts computation. After completion values can be modified and the network re-calculated by again using GOTO LOSS.

Group delay equalization

The insertion loss of a filter is usually required over a frequency range wide enough to cover both the pass and stop bands, but with delay equalization the situation is totally different. As a rough guide the important area in that instance lies between zero frequency and the 6dB point for a lowpass network, and between the 6dB points for a bandpass. It follows that a new set of frequencies must be selected up to the allowable total of 15, achieved by entries such as LET FM = 6 and LET FD = 0.5. The initial computation is then repeated by means of GOTO LOSS, which takes very little time as the component values do not have to be re-entered. The read-out must be completed, indicated by a 9 code.

The program allows for one first-order equalizer section followed by up to four second-order. Alternatively, up to five second-order sections may be used. Each is defined by a resonant frequency and a shape factor K, which must be made zero for the first-order section. The first-order section, if present, must be entered before the others.

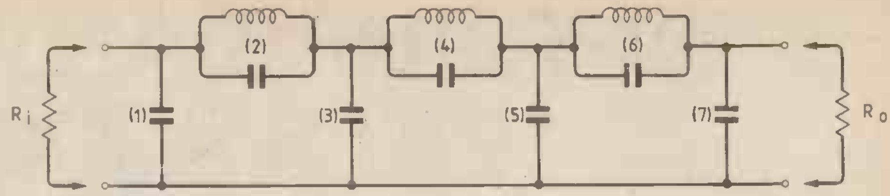
The procedure is then as follows.

Prompts	Inputs
9/1590	CONT
V?	Total number of sections
FR? M=1	Resonant frequency of first section
K?	K-parameter of first section
FR? M=2	Resonant frequency of second section
K?	K for second section

As soon as the parameters for M=V have been entered the computation starts.

The initial attempt is not likely to be successful, so it will then be necessary to modify the equalizer parameters by inputs of the form LET F(2) = 2.2 and LET K(3) = 1.2. This must be followed by GOTO EQU, which repeats the calculation with the new values.

At the end of the equalization process, GOTO DISS will provide a read-out of the equalizer dissipation corresponding to the value of D. This does not need to be the same as the D used for the insertion loss but may be re-entered before calling up the DISS routine.



Loss section

UNITS: Ω, μH, μF, MHz

$R_i = R_o = 75$

N	1	2	3	4	5	6	7
L	0	1.58	0	3.09	0	1.67	0
C	315.5 E-6	53.8 E-6	655 E-6	150 E-6	564 E-6	379 E-6	126 E-6

Group delay equalizer

M	1	2	3
FR	2.0	3.0	4.5
K	0	1.3	0.7

Fig. 1. Component values of a 5MHz elliptic function lowpass filter in the form recommended for program entry. Suggested initial parameter values are included for a three-section group delay equalizer.

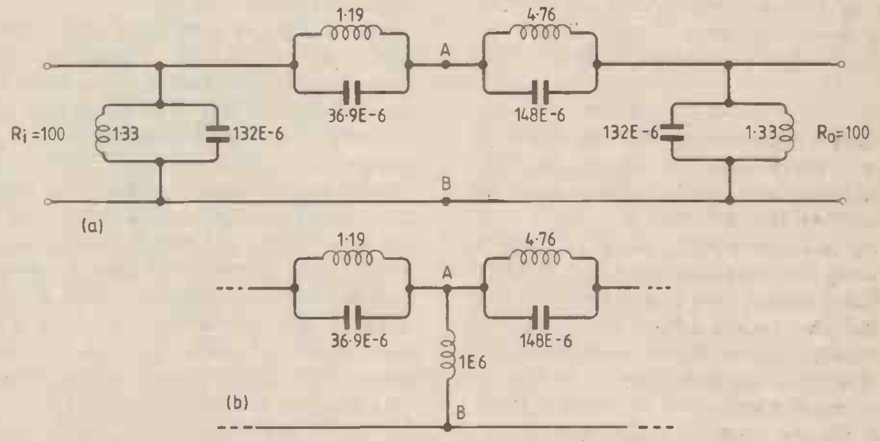


Fig. 2. Use of a dummy shunt branch where a series arm contains more than two components. Values shown are for a 10MHz bandpass filter with midband frequency 12MHz and rejection points at 6 and 24MHz. Original configuration at (a), dummy shunt branch inserted at (b).

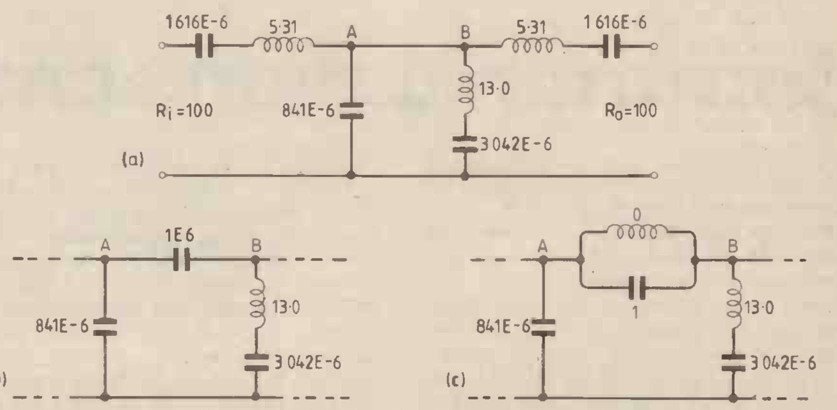


Fig. 3. Use of a dummy series branch where a shunt arm contains more than two components. Values shown correspond to a 3MHz bandpass filter with midband frequency 2MHz and a single rejection point at 0.8MHz. Original configuration at (a), dummy series branch suitable for bandpass structures only (b) and universally applicable dummy series branch (c).

In the absence of enough ram to run an optimization program, a graphical method has been found effective. This consists in plotting the combined group delay responses for successive parameter changes from some initial set of values, taking care not to try to deal with too many simultaneous changes. Some of these will inevitably be in the wrong direction, but one quickly gets a feel for the way in which moves have to be made. Remember that the aim must be to minimize the absolute error, that is the positive and negative deviations must tend to equality, subject to the condition with video filters that the error may be allowed to increase with frequency. The display provides the deviations directly, which saves a great deal of

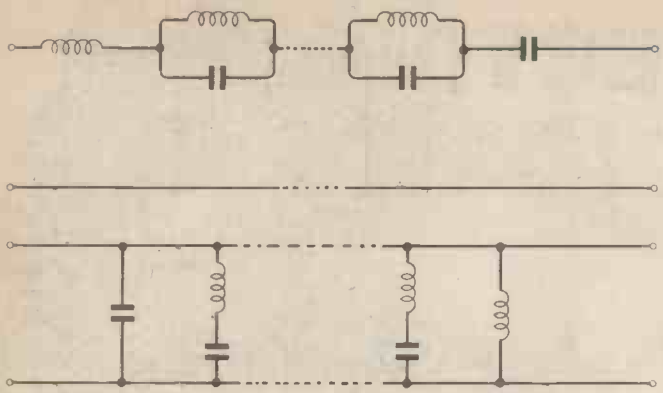


Fig. 4. Pair of canonical two-terminal reactance arms.

tedious plotting especially in the earlier stages of the process, since it is simple to note the maxima and minima at each stage without drawing the complete curve.

A brief guide to the shape of the delay equalizer responses may be found useful. The first-order network provides a group delay which falls steadily starting from the zero-frequency value. On the other hand, there is a very useful analogy between the response of a second-order section and the amplitude response of a parallel tuned circuit. The parameter K performs much the same function as the Q in the last-mentioned case, and the delay maximum roughly corresponds with FR.

The seventh-order elliptic function lowpass filter given in Fig. 1 may be found useful for a trial run. The loss is about 4dB at 5MHz. The delay equalizer parameters do not represent an optimum, but merely a suggestion for an initial trial. The component values are listed in the order of insertion into the program, with the capacitors provided in exponential notation, thus avoiding strings of zeros.

Before leaving the subject of insertion loss calculation, one still has to deal with the problem of network branches containing more than two reactances such as may be encountered in bandpass filters. In fact it can be very easily solved by the use of dummy branches as the following examples will make clear.

Fig. 2(a) shows a bandpass filter with a bandwidth of 10MHz, a mid-band frequency of 12MHz, and rejection frequencies at 8 and 24MHz. The series arm has the form of two parallel tuned circuits in series, i.e. a total of four reactances, usually the maximum number likely to be met with. The device in this instance is to add between points A and B a shunt inductor of such a magnitude that it cannot possibly have any practical effect on the loss and delay responses, Fig. 2(b). The original three-branch network is now converted to a five-branch ladder which can easily be handled by the program.

A shunt branch yields to similar treatment, as is illustrated by the bandpass filter of Fig. 3(a). This has a bandwidth of 3MHz with a mid-band frequency of 2MHz and a rejection frequency at 0.8MHz. Because it has a bandpass characteristic it is possible to employ the analogue of Fig. 2(b), that is the series insertion of a very large capacitor, Fig. 3(b). The resulting five-branch ladder can now be treated normally. In this instance, there is an alternative which applies equally to lowpass structures, that is the insertion of a parallel tuned circuit with a zero-valued inductor and a capacitor of any nominal size, Fig. 3(c).

It is worth stressing that the dummy branch technique can always be applied, subject to the limitation of a total of ten branches imposed by the present program. The justification for this is the theorem that a two-terminal reactance arm can always be transformed into one of the two configurations of Fig. 4 (ref. 1), for which reason they are sometimes called canonical networks. Of course, not all of the inductors and capacitors have to be present, so the two examples given above are obviously included. It will sometimes involve the transformation of one configuration into another, but this is comparatively simple provided a reference table of equivalent circuits is available[2].

References

1. R. M. Foster, Reactance theorem. *Bell System Technical Journal*, vol. 3, April 1924, pp. 259-67.

2. A. Zverev and H. Blinchikoff, Network transformations for wave filter design. *Electronics*, June 26 1959, pp. 52-4.

To be continued.

Communications crisis—a reply

On our news pages this month is a criticism of the Government's liberalisation programme for the telecommunications industry. John Butcher, the Parliamentary Under Secretary of State for Industry has made the following reply, listing the progress made to date.

A licence was granted in February to Cable and Wireless PLC on behalf of the Mercury Communications Limited to run a telecommunications system in the UK the first independent system of its kind outside North America. By the middle of next year the first subscribers should be connected to Mercury, surely an astonishing achievement in the time.

On the liberalisation of attachments progress has been remarkable. Already some 50 attachments, including about 25 telephones, 20 modems and five telex teleprinters can be supplied competitively which under the old regime would either have been completely unavailable or supplied only through BT.

November 1981 – Interim approved scheme for extension telephones from BT's special range. The latter have been added to since then and all of BT's special range telephones can now be supplied in competition with BT. The first approvals under this interim scheme have now been made and more will follow shortly.

May 27 – An extension of this scheme to include callmakers, repertory diallers and apparatus incorporating integral modems. The Department is now considering applications for further evaluation. Now that BSI's new laboratory can undertake some of the test work, it shoule be possible to deal with more telephones more quickly.

March 31 – Orders made requiring apparatus to be marked to tell customers whether or not it is approved for connection to BT's networks. This is vital information for users if they are to choose apparatus that will not cause damage and produce inferior service.

Six draft standards have been written and made available for public comment in record time and further drafts will follow shortly. So far all standards are meeting their target dates.

May – The British Approvals Board for Telecommunications (BABT) was incorporated and will begin to accept applications for approval when the first standards are published.

The Department and BT have agreed on arrangements allowing BT's present suppliers of telex teleprinters to supply the models they now sell to BT direct to customers. This makes five models available competitively if the manufacturers wish to take advantage of this arrangement.

"The Government has a duty" he continued "to make sure that apparatus connected to BT's network does not endanger consumers who use this equipment or BT's engineers and does not impair the quality of service that the network is able to provide to all. Much of the preparations that have been made over the past 12 to 18 months have been aimed at avoiding such dangers.

"In many cases little of this progress is visible to the outside observer but all of it is necessary if liberalisation is to be fair and to work. Critics do not do justice to the immense amount that has already been achieved."

"Since April private operators have been able to apply to the Department of Industry for a licence to provide services over the network. The provision of these value added network services (VANS) will help to satisfy the demand more quickly than at present and encourage the growth of a wider range of services, providing jobs and helping business in Britain to become more competitive.

COST-EFFECTIVE ELECTRONIC IGNITION

The popularity of Rod Cooper's ignition circuit design, published in the March issue, led to many requests for a component location diagram. In response, here is a component layout – regrettably held out of the last issue – designed to complement the board pattern originally given. A resistor and decoupling capacitors were omitted from the published circuit, so a corrected version is reproduced herewith, which now corresponds with the board design.

Printed boards to an alternative layout, with components horizontally arranged, is available from M. R. Sagin (see advertisement), who may also be able to supply wound transformers and discharge capacitors. Ferrite and bobbins are also available from Mullard stockists.

The graphs showing the relation between combustion efficiency and spark were originally published in an article entitled Ignition Design Trends by K. Garrett, in *Automotive Engineering*, April-May 1977. Oscilloscope traces were produced from equipment kindly loaned by Hewlett Packard. □

Components for ignition circuit

Resistors

1	180
2	10k
3	180
4	33M
5	270
6	180
7	4.7k
8	2.2k
9	27k
10	2.2k
11	22k
12	1.2k
13	1.2k
14	330

Transistors

1	TIP3055,MJE3055
2	BFY52
3	2N3903
4	2N3903
5	TIP2955,MJE2955
6	BFY52

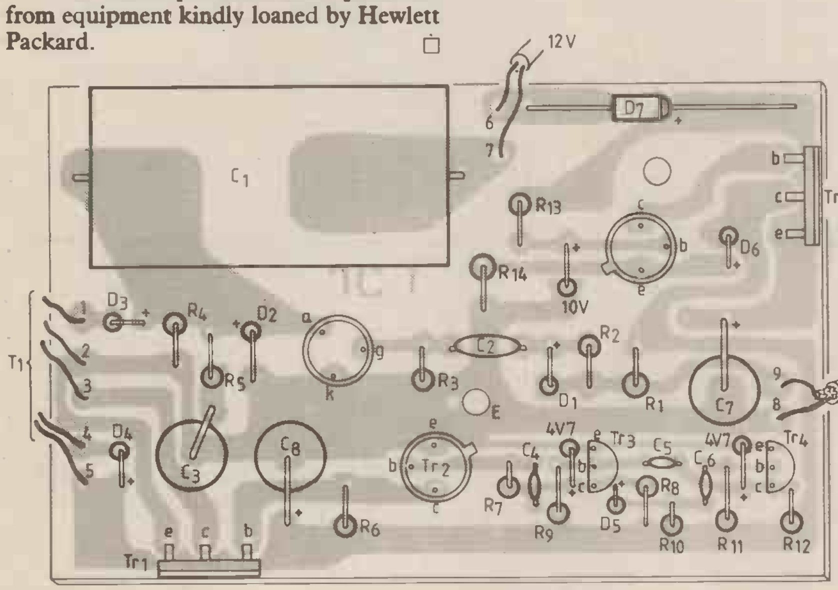
Capacitors

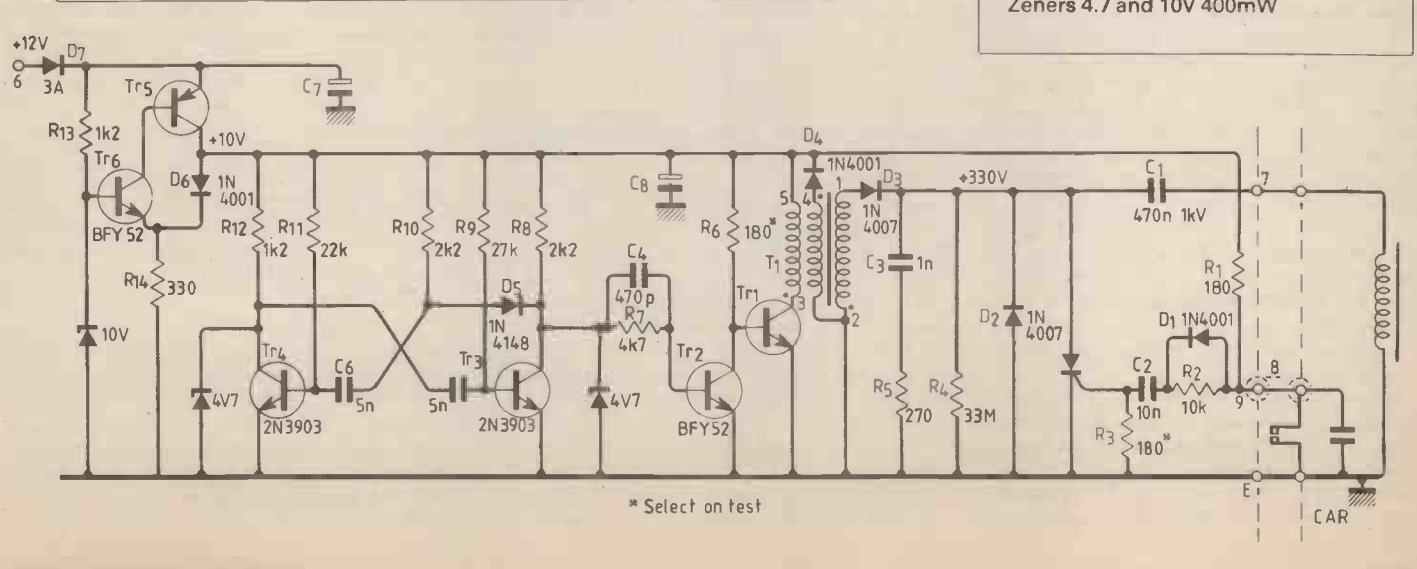
1	470n 1kV polypropylene (RS)
2	10n
3	1n 1kV polypropylene
4	470p
5	5n polyester
6	5n polyester
7,8	100 to 500μ 10V electrolytic

Diodes

1	1N4001
2	1N4007
3	1N4007
4	1N4001
5	1N4148
6	1N4001
7	1N5402 or similar 3A rec.

Zeners 4.7 and 10V 400mW





DESIGNING WITH MICROPROCESSORS

Step-by-step procedures for implementing microprocessor systems with commercially-available i/o chips – illustrated by a design problem – conclude this series of articles.

by D. Zissos and Jane Pleus

The most effective design strategy is to choose those i/o chips whose terminal characteristics can be programmed to match those of the peripheral in question. But such an objective however would be unrealistic because in practice the microprocessor system will have its own programmable i/o chips already interfaced to the microprocessor chip, as illustrated in Fig. 1. In situations like this a good starting point is to derive a simplified programming model of the i/o chip, omitting those features that are not likely to be used. Initially, a programming model should contain the ports, typically two per chip, the control and status registers. Programming models of the Intel 8155, p.i.a. and v.i.a. are shown in Fig. 2, 3 & 4.

The next items to be specified are

1 – how the interface initiates an m.p.u. read operation for moving data into a microprocessor (from peripheral 1 in Fig. 1)

2 – how the p.i.o. chip signals that the requested read operation has taken place to the interface.

For example in the case of the p.i.a., when programmed with control word 26 to move an item of information from a peripheral into the microprocessor, all the interface has to do is to pull terminal CA1 in Fig. 3 high. When the microprocessor reads the item the signal on terminal CA2 is pulled low.

The third and fourth items to be specified involve the reverse process, namely moving data from the m.p.u. into a peripheral, in which case the designer needs to know

3 – how the interface initiates an m.p.u. write operation for moving data from the microprocessor to a peripheral m.p.u. (peripheral 2 in Fig. 1)

4 – how the p.i.o. chip signals that the requested write operation has taken place.

In the case of the Intel 8155 chip, when programmed with control word 99 data is requested from the m.p.u. by pulling the STROB terminal in Fig. 2 low when the m.p.u. responds when the requested item of information has been loaded into the 8155, the signal on terminal BBF changes to 1.

5 – the final item to be specified is the status flip-flop for each of the ports, as this is the signal looked at by the programmer in the test-and-skip mode.

For example in the case of the 8155, SFFA

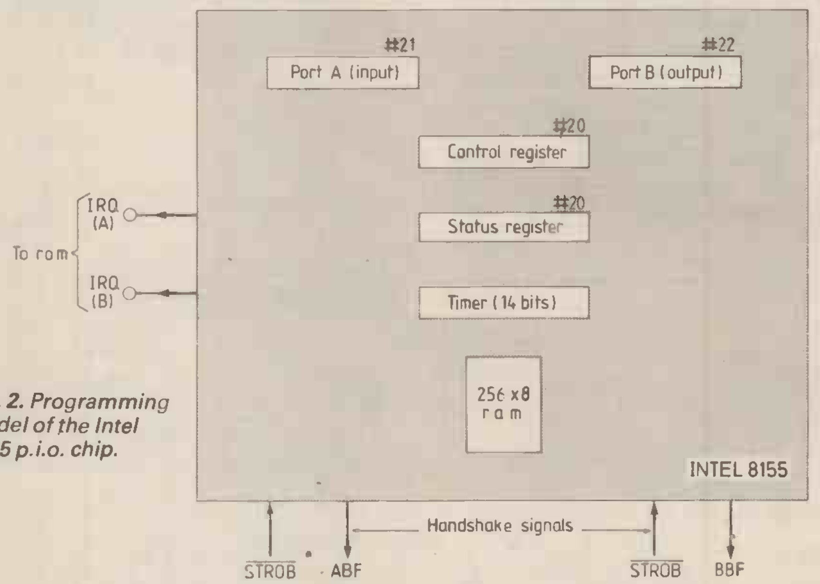


Fig. 2. Programming model of the Intel 8155 p.i.o. chip.

Control register (write only) #20

Timer	EI (B)	EI (A)	Handshake signals	Data direction bit (B)	Data direction bit (A)

Status register (read only) #20

Not used	TMR	EI (B)	SFFB	IRQ (B)	EI (A)	SFFA	IRQ (A)

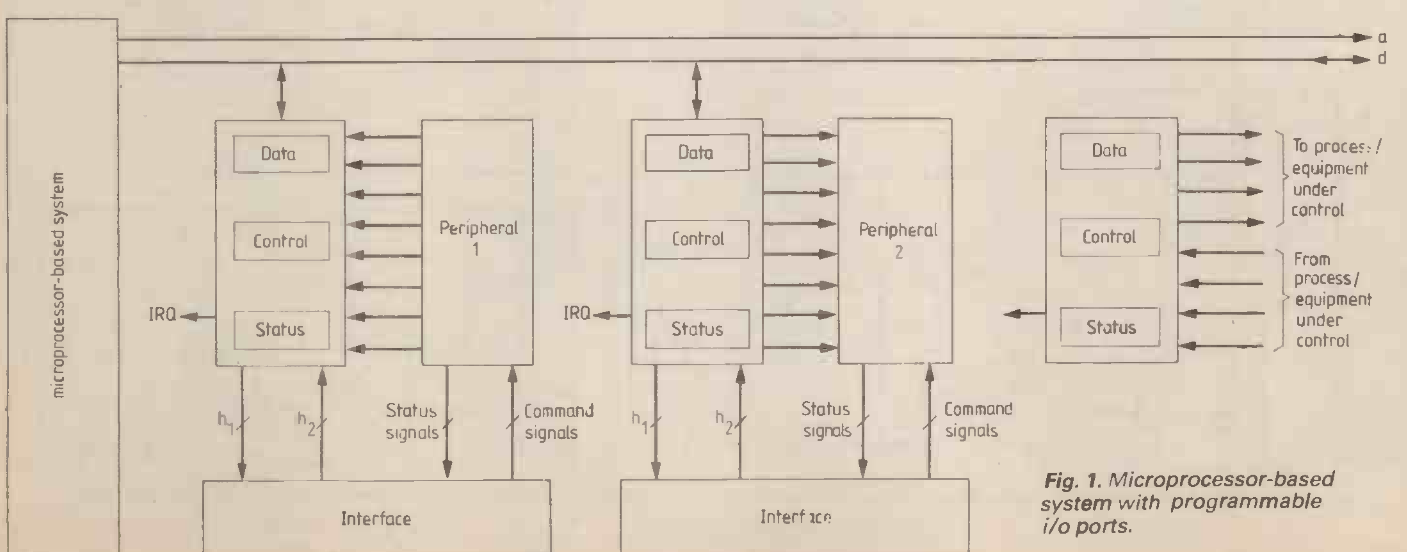


Fig. 1. Microprocessor-based system with programmable i/o ports.

Mnemonic and hex listings of the PRINT problems using programmable i/o chips and test-and-skip.

8085 & 8155					6800 & PIA					6502 & VIA					Comments
		Machine code					Machine code					Machine code			
Label	Mnemonics	Address	Opcode	Operand	Label	Mnemonics	Address	Opcode	Operand	Label	Mnemonics	Address	Opcode	Operand	
	LXI SP, 20C8	2020	31	C8 20											Initialize
	CALL I0PRT	23	CD	00 20		JSR I0PRT	0200	BD	01 00		JSR I0PRT	0300	20	00 02	–
	LXT H, 2080	26	21	80 20		LDX #0300	03	CE	03 00		LDX #00	03	A2	00	–
	MVI B, n	29	06	n		LDAB #n	06	C6	n		LDY #n	05	A0	n	–
X0:	DCR B	2B	05		X0:	DECB	08	5A		X0:	DEY	07	88		Decrement character count
	JM X2	2C	FA	3D 20		BMI X2	09	2B	13		BMI X2	08	30	11	If no more characters, go to X2
X1:	IN 20	2F	DB	20	X1:	LDAA F003	0B	B6	F0 03	X1:	LDA A00D	0A	AD	0D A0	Read status register port
	ANI 10	31	E6	10		ANDA #80	0E	84	80		AND #10	0D	29	10	Erase all but status flip-flops
	JZ XI	33	CA	2F 20		BEQ X1	10	27	F9		BEQ X1	0F	F0	F9	If data not printed, go to X1
	M0V A, M	36	7E			LDAA 00, X	12	A6	00		LDA 0400, X	11	BD	00 04	Otherwise, get next character
	OUT 22	37	D3	22		STAA F002	14	B7	F0 02		STA A000	14	8D	00 A0	Print
	–					LDAA F002	17	B6	F0 02		–				Dummy clear to clear SFF of PIA
	INX H	39	23			INX	1A	08			INX	17	E8		Point to next character
	JMP X0	3A	C3	2B 20		JMP X0	1B	7E	02 08		JMP X0	18	4C	07 03	Go to X0
X2:	RST 1	3D	CF		X2:	SWI	1E	3F		X2:	BRK	1B	00		Return to monitor

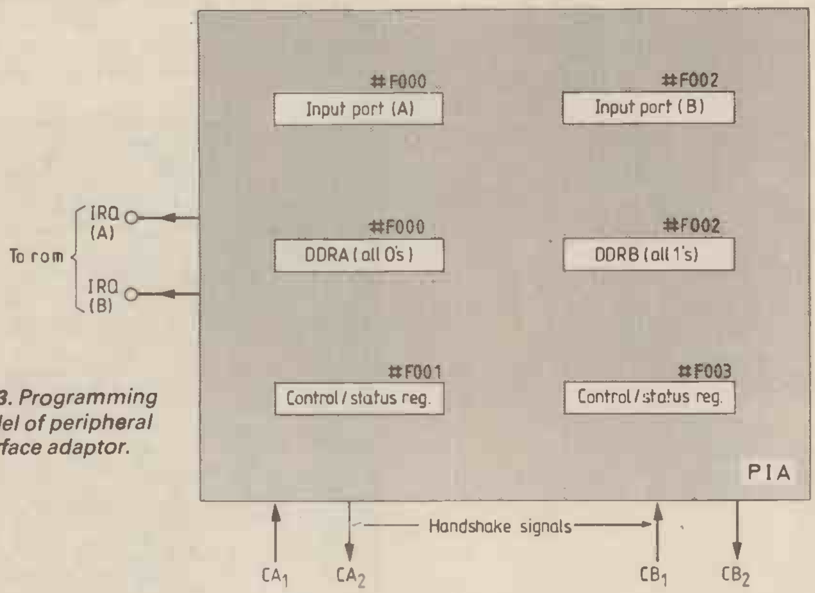
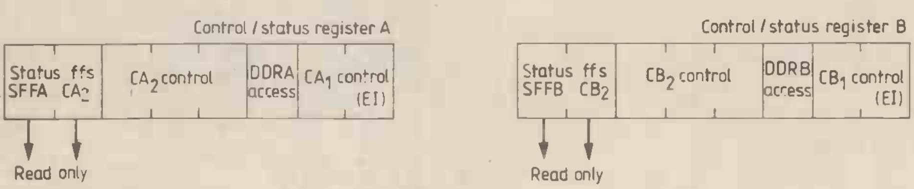


Fig. 3. Programming model of peripheral interface adaptor.



and SFFB are bits 1 and 4 of the status register – see Fig. 2. Status flip-flop signals are normally made available on terminals for use as interrupt flags if desired. Such flags can be disabled by program; bit 2 in Fig. 2, when 0 disables interrupt flag IRQ(A).

Programming models of the 8155, the p.i.a. and v.i.a. are shown in Figs 2 & 3.

Design problem

Objective: to consolidate the design steps described in the previous article.

Using programmable i/o chips, design a test-and-skip system that would allow the programmer to print a block of characters stored in consecutive memory locations. Implement the design using an action/status character printer and (a) the 8155 interfaced to the 8085 and (b) the p.i.a. interfaced to the Motorola 6800.

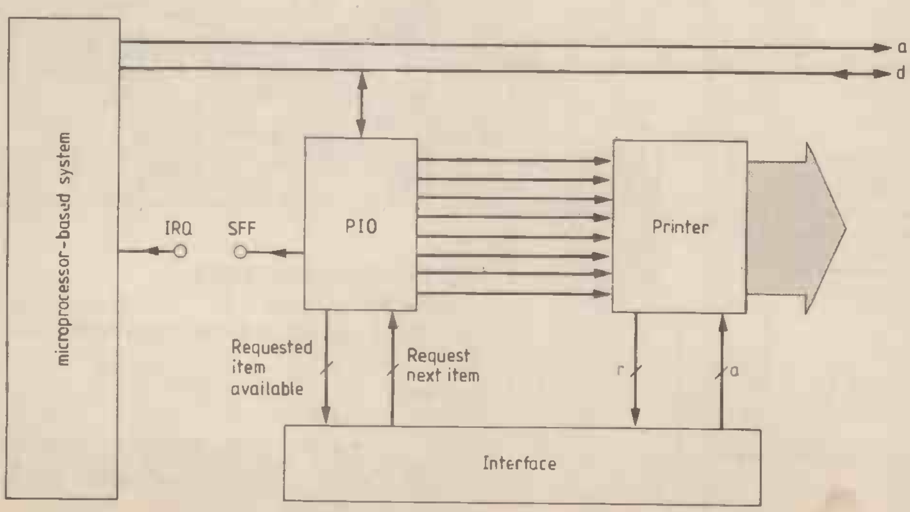


Fig. 4. Block diagram of the PRINT problem.

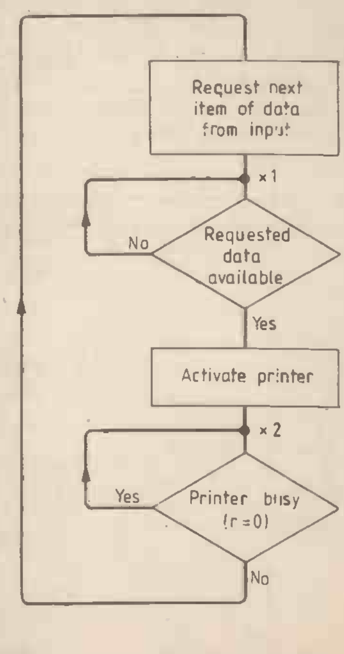


Fig. 5. Flow-chart of our solution to the PRINT problem.

Solution

Handshake signals Fig. 1

h1 – 1 indicates that the port is full (has new data) and 0 that the port is empty (data has been read).

h2 – 0-to-1 change requests an m.p.u. read cycle.

h3 – 0-to-1 change requests new data from the m.p.u.

A test-and-skip system that transfers blocks of data of specified length, byte-by-byte, from memory to a peripheral device through an i/o port using a microprocessor-based system with at least one programmable i/o port is shown in the block diagram of Fig. 4, derived directly from Fig. 5 of the previous article. Its step-by-step operation is shown in the flow chart of Fig. 5. The hardware design consists of implementing the interface equations derived for each of the p.i.o. chips. The software design is the self-explanatory programming flow chart of Fig. 6. Ignore at this stage the statements to the sides of the boxes.

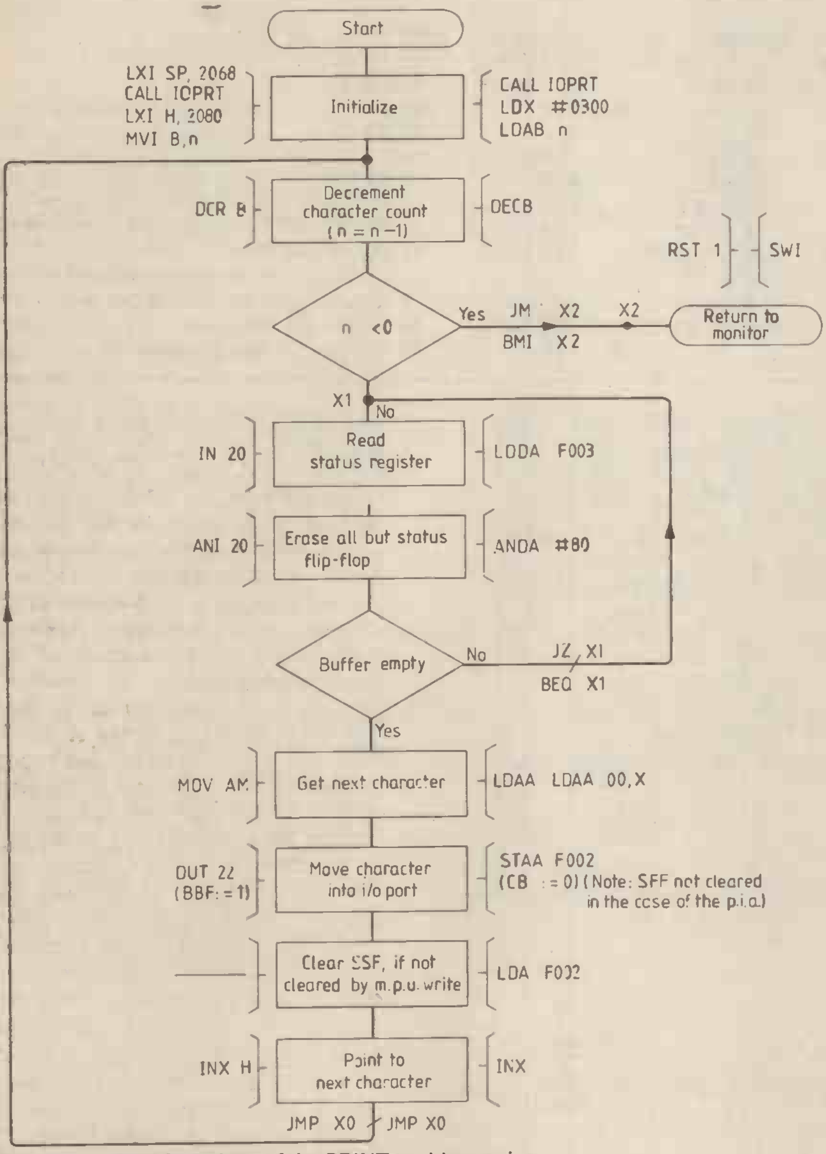


Fig. 6. Programming flowchart of the PRINT problem using programmable i/o chips and test-and-skip

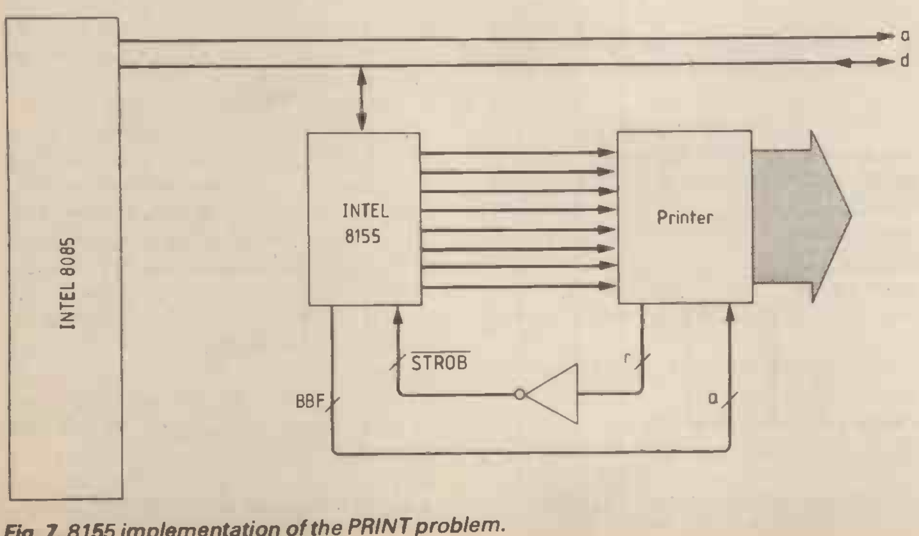


Fig. 7. 8155 implementation of the PRINT problem.

8155 implementation

By direct reference to the data sheet of the Intel8155 and to the definitions of handshake signals h1 and h2, we obtain

$$h1 = BBF$$

and

$$h3 = \overline{STROB}.$$

The implementation of these equations constitutes the hardware component of our solution, Fig. 7.

Next refer to the 8085 instruction set to derive the mnemonic statements that implement the flowchart in Fig. 6. For ease of reference we list them to the left of each box. Finally, we tabulate these statements with the corresponding machine codes and comments on page 77.

8155 data

Programming model, Figure 2. The control word 0A disables the interrupt terminals and to program the 8155 i/o chip to function in the following way.

Section A – input port

An m.p.u. read is requested by a 1 to 0 change in $\overline{STROB}$

When m.p.u. responds (reads) ABF* changes to 0

ABF pulled high by a 1 to 0 change on STROB

ABF pulled low by an m.p.u. read of port A

Status flip-flop (bit 1 of the status register)

set by a 1 to 0 change on STROB

reset by an m.p.u. read of port A

Section B – output port

New data requested from m.p.u. by a 1 to 0 change on STROB

When m.p.u. responds (writes) BBF changes to 1

BBF* pulled high by an m.p.u. write operations

BBF pulled low by a 1 to 0 change on STROB

Status flip-flop (bit 4 of the status register)

set by an m.p.u. write operation

reset by a 1 to 0 change on STROB

*ABF = 1 indicates new data in input port
BBF = 1 indicates new data in output port

PIA implementation

Referring to the p.i.a. data sheet and the definitions of handshake signals, we obtain

$$h1 = CB2$$

and

$$h2 = CB1.$$

Implementing these equations gives the pia implementation of our solution, Fig. 8.

continued on page 80

ELECTRIC FIELDS IN A SOLENOIDAL COIL

— often forgotten, more often misunderstood

The time-varying magnetic field in a coil gives rise to electric fields that in turn determine the terminal or circuit properties of the coil

*by F. S. Chute and F. E. Vermeulen

Since the time of Michael Faraday's experiments, researchers have sought to understand the electromagnetic behaviour of the solenoidal coil, but a complete field solution has proved a difficult and elusive goal. While it is well known that the magnetic field within a long, multi-coil is predominantly axial and azimuthally symmetric, the associated electric fields are less clearly defined. However, a few fundamental points can be made regarding these electric fields without having to resort to a complete boundary-value solution.

When excited by an alternating current, the time variations of the axial magnetic field within the coil must, in accordance with Faraday's law of induction, produce an electromotive force around any closed loop linking the magnetic field. The result is an induced electric field in the circumferential direction, and it is just this field that gives rise to the eddy current that circulates whenever the coil is wound around a core of lossy material. However, the existence of this circumferential electric field at the surface of the coil causes a redistribution of charge along the helical conductor forming the coil, such that the negative charge is concentrated towards the opposite end of the coil. This separation of charge creates a secondary electric field that in the interior region of a long solenoid is predominantly axial. The redistribution of charge is precisely such that the sum of the magnetically induced circumferential electric field and the secondary axial electrical field arising from the charge separation is just equal to zero along the surface of the coil winding.

The relative magnitudes of these circumferential and axial components of the electrical field are easily estimated for a long solenoid of length l and radius a, comprised of N turns. If the magnetic flux linking a cross section of the coil of area πa^2 is defined as Φ, the electromotive force around a closed loop of radius a must in phasor form be given by

$$\text{e.m.f.} = j\omega\Phi$$

where ω is the angular frequency. An average value for the circumferential electric field at radius a can now be obtained by dividing this e.m.f. by the circumference of the coil. In other words,

$$E_{\phi a} = \frac{j\omega\Phi}{2\pi a}$$

where $E_{\phi a}$ is the average induced circumferential electric field at the surface of the coil. Alternatively, since the terminal voltage, V, of the coil is just N times this e.m.f.

$$E_{\phi a} = \frac{V}{2\pi a N}$$

Neglecting end effects, an average value for the axial electric field, at radius a, can be obtained by dividing the terminal voltage by the length of the coil. Thus,

$$E_{za} = \frac{V}{l}$$

where E_{za} is the average value of the axial electric field at radius a.
Taking the ratio of E_{za} and $E_{\phi a}$ yields

$$\frac{E_{za}}{E_{\phi a}} = \frac{2\pi a N}{l} = \frac{2\pi a}{d} = \cot\psi \qquad (1)$$

where d is the separation between turns and ψ is commonly referred to as the pitch angle of the winding.

For coil configurations commonly used this pitch angle is only a few degrees and the secondary axial electric field is typically more than an order of magnitude greater than the circumferential electric field! Moreover, the axial field E_z is nearly independent of distance from the axis of the coil, whereas the circumferential electric field E_ϕ decreases to zero at the coil centre. At interior points then, the dominating influence of the axial electric field will be even more pronounced than near the surface of the coil winding.

All too often this surprising result is not fully appreciated although it was pointed out as early as 1928 by Townsend[1] in conjunction with an investigation of gaseous discharges, and again in 1969 by Contaxes[2]. It is of interest to note that both of these authors comment, more than 40 years apart, that the existence of such a large axial electric field is remarkably unknown.

It is only by virtue of the fact that the secondary electric field of the coil (whose source is the charge distributed along the winding) is much larger than the circumferential electric field (produced directly by the time-varying magnetic field), that a *unique* value of potential difference between the terminals of the coil can be defined. For a loosely wound coil with a large pitch angle ψ, the magnitudes of the two fields are more nearly equal and no unique value will exist for the terminal voltage. In this case the *measured* value of potential difference will depend upon the placement of the leads of the voltmeter that is used to measure the voltage across the coil.

In some earlier work[3, 4], the authors have described a technique for visually displaying electrostatic fields and electromotive force by utilizing the heat-sensitive colour changes of cholesteric liquid crystals. In this technique, Mylar sheets coated with encapsulated liquid crystals are bonded to a sheet of Teledeltos resistive paper. Currents induced in the resistive paper in the presence of an electric field will cause heating, and produce a temperature variation that is characteristic of the distribution and intensity of the electric field vectors lying in the plane of the resistive paper. The apparent colour of the liquid crystal sheets used by the authors[3] is black below about 25°C. Between 25°C and 30°C, the colour of the sheet changes with temperature from red, through yellow and green, to blue at about 30°C. Above 30°C, the apparent colour is again black. Regions of a uniform coloration represent regions of constant temperature or field intensity. While the limited thermal sensitivity of the liquid crystals and their nonlinear temperature response make serious quantitative measurement impractical, the liquid-crystal display does serve to provide the viewer with an immediate appreciation of the overall electric field distribution.

To display the axial and radial electric fields of a coil carrying a time-varying current, a sheet of resistive Teledeltos paper was bonded to a 3.2 mm thick, 60 × 60cm sheet of Perspex with spray adhesive. Four 30 × 30 cm sheets of liquid crystal were then similarly bonded to the resistive paper. This three-layer sandwich combination was then carefully drilled with 40 holes of 2.5 mm diameter to serve as a support plate for a 20 turn coil of No 14 A.W.G. copper wire. A continuous length of wire was then threaded through the holes in the support plate to create a coil of length 40 cm, diameter 10 cm, and turn spacing 2 cm, having a pitch angle so that $\cot\psi = 15.7$. The coil, which has an induc-

*Department of Electrical Engineering
University of Alberta

Fig. 1. *Equipment used by the author to show the electric field distribution on the coated perspex sheet on the right.*

tance of about 12 μ H, was series-connected to high-voltage capacitors to resonate at 3 MHz. The coil circuit was fed at 3 MHz from an Electronic Navigation Industries A-300 RF Power Amplifier driven by a Hewlett-Packard 651A Test Oscillator. Figure 1 is a photograph of the apparatus showing the distribution of the dominant secondary electric field surrounding the coil.

When the coil is energized, the liquid crystal sheets change colour almost instantly, in response to the current induced by the radial and axial electric fields around the coil, to produce the display. The interior region is a uniform shade of blue except near the coil extremities, clearly indicating the uniform nature of the field within the coil. Indeed, the temperature differs by less than 2-3°C over the entire central region of the photograph, which ranges through various shades of blue to shades of green in the original display. Near the ends of the coil, where all the field solutions quoted in this paper are modified by end effects, and hence, are only approximate, the axial electric-field intensity has decreased just enough so that not enough heating is produced to cause a perceivable liquid crystal response.

References

1 J. S. Townsend and R. H. Donaldson, "Electrodeless discharges," *Phil. Mag. J. Sci.*, vol. 5, pp. 178-191, 1928.

2. N. Contaxes and A. J. Hatch, "High frequency fields in solenoidal coils," *J. Appl. Phys.*, vol. 40, No. 9, pp. 3548-3550, 1969.

3. F. S. Chute and F. E. Vermeulen, "A visual demonstration of two-dimensional electrostatic fields," *Amer. J. Phys.*, vol. 24, pp. 1075-1077, Dec. 1974.

4. F. E. Vermeulen and F. S. Chute, "Visual demonstration of electromotive force and induced current," *Amer. J. Phys.*, vol. 45, pp. 309-310, Mar. 1977.

continued from page 78

The Motorola 6800 statements that implement the flow chart are obtained by referring to the 6800 instruction set (see Sept. 1980 issue). As in the case of the 8085, we list them in mnemonic form to the right of each box, and then tabulate them with their machine code, page 77.

Note that a write operation does not reset the status flip-flop, so in the case of the p.i.a. we need to execute a dummy read to clear SFF.

Invitation. *Additional problems and solutions in this area are available from Professor D. Zissos, Department of Computer Science, University of Calgary, Calgary, Canada T2N 1N4.*

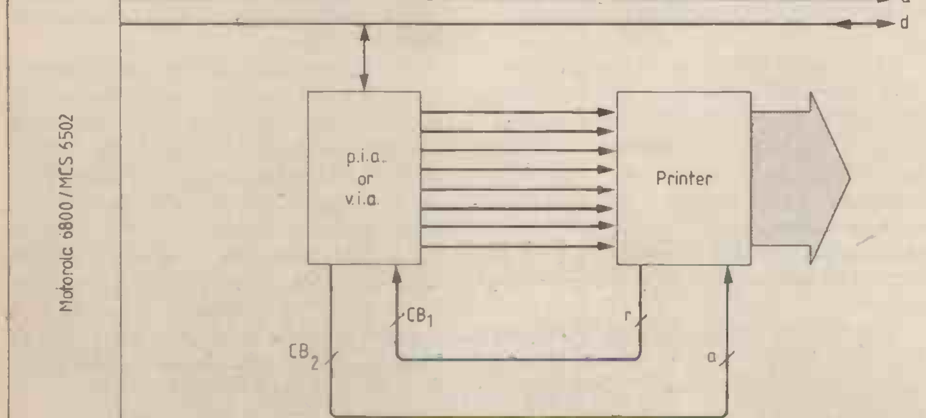


Fig. 8. PIA implementation of the PRINT problem.

PIA data

Programming model, in Fig. 3. Control word 26 for both sections disables the interrupt terminals and programs the PIA chip to function in the following way.

Section A – input port
An m.p.u. read is requested by a 0 to 1 change on CA1
When m.p.u. responds (reads) CA2 changes to 0
- CA2 pulled high by a 0 to 1 change on CA1
- CA2 pulled low by an m.p.u. read of port A

Status flip-flop (bit 7 of control/status register)
- set by a 0 to 1 change in CA1
- reset by an m.p.u. read of port A

Section B – output port
New data requested from m.p.u. by a 0 to 1 change of CB1
When m.p.u. responds (writes) CB2 changes to 1
- CB2 pulled high by a 0 to 1 change on CB1
- CB2 pulled low by an m.p.u. write into port B

Status flip-flop (bit 7 of control/status register)
- set by a 0 to 1 change in CB1
- reset by an m.p.u. read of port B

NEW PRODUCTS

LOW-COST PRINTER FOR HOME COMPUTERS

Graphics and lower-case letters are possible on the Amber 2400 printer costing £69.95 excluding v.a.t. The unit prints 24 characters per line on a 58mm-wide plain-paper roll some 90 feet long. Data rates are selectable between 75 and 9600 bits/s. Four horizontally-aligned print solenoids oscillate from side to side, each covering ¼ of the paper width, under control of the unit's microcomputer, which also handles software routines and allows data input options. The 2400 is primarily intended for use with home computers. Amber Controls Ltd, Central Way, Walworth Industrial Estate, Andover.

WW301

WW301

FREQUENCY MEASURING D.M.M.

The main difference between this and Fluke's previous hand-held digital multimeters is the inclusion of a frequency measurement function – one of a number of additional facilities made possible by the inclusion of a Sharp 4-bit microprocessor and a cmos measurement-processing circuit designed and manufactured 'in house'. Frequencies from 12Hz to 200kHz are measured on the 8060A in four automatically-selected ranges, with 0.01Hz resolution on the lowest range (200Hz), and indicated on a 4½-digit l.c.d. Alternating voltages may be displayed directly in V r.m.s., in dBm (referred to 600 ohms), or in volts or decibels relative to a previously stored reference. This offset facility may be used with other measurement functions. Direct and alternating voltage, a.c. and d.c. functions are in five ranges, resistance in seven, and decibels in four. Basic d.c. accuracy is 0.04% and sensitivities are 10μV, 10nA and 10mΩ. A 200nS range may be used to measure resistances up to 10GΩ. Further functions include diode test, audible/visual continuity test and self test. Normally, input impedance on the direct-voltage ranges is 10MΩ, but on the 200mV and 2V ranges, an input impedence of greater than 1GΩ may be selected. Fluke (GB) Ltd, Colonial Way, Watford, Herts WD2 4TT.

WW302

ANALOGUE/ SWITCHING INTERFACE

This IEEE-bus-controlled interface, manufactured by CIL Microsystems, provides eight analogue inputs, four analogue outputs and four relay-activated change-over switches, for general-purpose control and monitoring applications in research and industry. A concise set of ASCII commands are handled by a 6502 microprocessor, which can also run specific operating programs loaded from the main computer into an optional 4K of ram. Two versions of the PCI 6000 are available, one with eight-bit resolution and one with 12-bit resolution. Facilities include differential inputs and programmable gain, and the relay-contact ratings are 240V and 1A. CIL Microsystems Ltd, Decoy Road, Worthing, Sussex BN14 8ND.

WW303

WW303

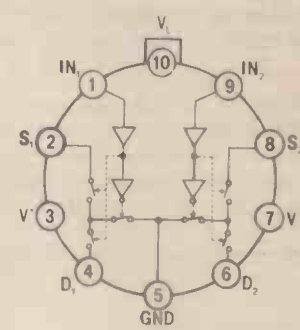
64K EPROM PROGRAMMING ADAPTER

Any eprom programmer suitable for Texas 2532-type devices may be used to program 64K eproms by adding an adapter made by Elan Digital Systems. The E6 adapter has a z.i.f. socket for 2564 or 2764 devices and a ribbon cable terminated by a plug which fits into the existing programmer. Each half of the 64K, selected by a switch, is programmed separately by the existing programmer in the usual manner. All automatic test or editing functions of the existing programmer are retained and an additional feature allows Intel 2732 or 2732A i.cs to be read through the adapter. Elan Digital Systems Ltd, 16-20 Kelvin Way, Crawley, West Sussex RH10 2TS.

WW304

CMOS R.F. SWITCH

The IH5341 is a dual-channel r.f. and video switch with t.t.l.. and c.m.o.s.-compatible control inputs, manufactured by Intersil. Each channel has three switch elements, connected in a series/shunt formation, giving an $R_{DS(on)}$ of less than



75Ω, flat response from 0 to 100MHz and 70dB isolation at 10MHz in the off state. Isolation between the two channels is greater than 60dB at 10MHz. Supply current is less than 1μA and switching speeds are 150ns, on and 80ns, off, giving break-before-make operation. A TO-100 package is used. Intersil Datel Ltd, 9th Floor, Snamprogetti House, Basingstoke, Hants.

WW305

NEW PRODUCTS

EPROM ERASER

Both models in Northern's eprom eraser range cost under £60 excluding vat and can be used to erase up to six devices at once. The latest of these, the UV1T, is basically the same as the earlier UV1B, but with a 10 to 60-minute time switch fitted. Lamp life is quoted as being in excess of 3000h and all models, i.e., those mentioned for 220 to 240V operation and two others for 110 or 240V mains, comply with appropriate British Standards. Northern Electronics Ltd, 51 Arundel Street, Mossley, Lancs OL5 OLS.

WW306

CODED ROTARY SWITCHES

Miniature rotary switches with ten or 16 positions, giving b.c.d. or hexadecimal outputs, have been added to the Elma range of ceramic wafer switches marketed by Radiatron. Measuring 10 by 10 by 11mm, these switches can be obtained for mounting either horizontally or vertically on a p.c.b. and with either a screwdriver slot or spindle. Gold-plated contacts are used, giving a contact resistance of less than 50mΩ and the contact rating is 50V at 0.2A between −40 and 85°C. Radiatron say that these switches have a life expectancy of more than 10^4 rotations. Radiatron Components Ltd, 76 Crown Road, Twickenham, Middx.

WW307

32 × 8 BIPOLAR PROM

A 'washed emitter' process has been used to produce two 256-bit Schottky bipolar proms with typical access times of 9ns. One, the 63S080 has open-collector outputs and the other, the 63S081 has three-state outputs. Applications of these 32 × 8-bit proms include address decoders, priority encoders and random-logic elements in high-speed systems. Monolithic Memories Ltd, Lynwood House, 1 Camp Road, Farnborough, Hants GU14 6EN.

WW308

DISPOSABLE TEMPERATURE INDICATORS

Adhesive dots and strips for recording maximum temperatures are available from Cobonic Ltd. Within a second of reaching the temperature marked on it in both °C and °F, one of five different areas on the labels, or one area on

the dots, changes irreversibly from white to black. There are 40 different temperature levels in the range, from 40 to 260°C, and each sensitive area changes colour at within 1% of the specified temperature. These products are useful for monitoring and recording maximum temperatures in hazardous and inaccessible areas. Cobonic Ltd, Lantern Yard, Ludlow Road, Guildford, Surrey GU2 5NW.

WW309

BROADBAND R.F. PREAMPLIFIER

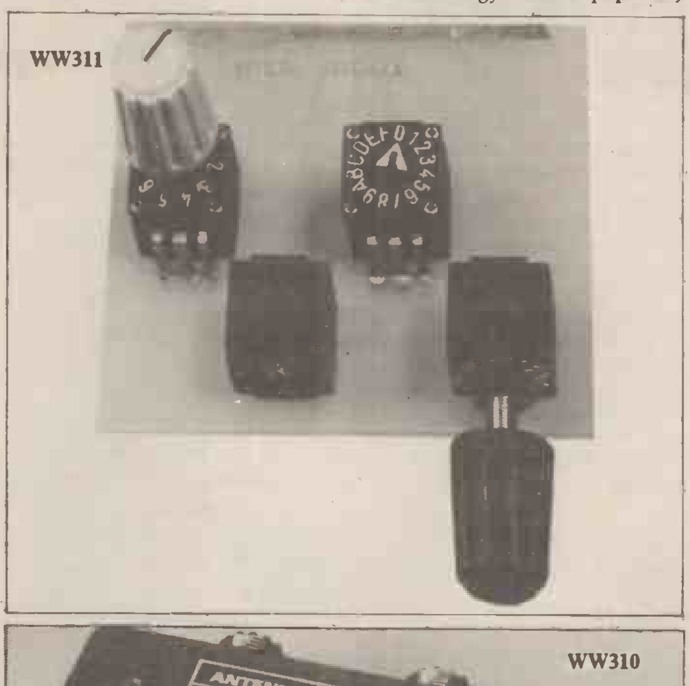
An r.f. preamplifier providing 9dB gain and suitable for use with low-power transceivers in the range 5 to 200MHz can be obtained from Datong. Send/receive switching is automatic, using r.f. sensing and an internal bypass relay, and the unit is claimed to handle large signals well (intercept point + 20dBm). Applications of the model RFA include private mobile v.h.f. transceivers, marine and aeronautical band reception, scanning receivers and antenna-loss compensation. Datong Electronics Ltd, Spence Mills, Mill Lane, Bramley, Leeds LS13 3HE.

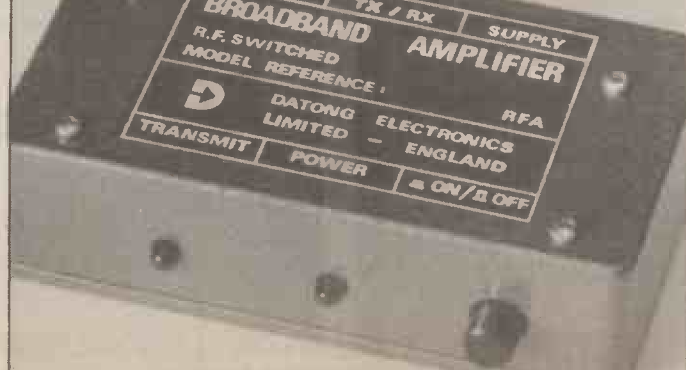
WW310

NON-INVASIVE X-RAY METER

An electronic system for non-invasive measurement of radiation intensity and exposure time in diagnostic X-ray equipment has been developed in Sweden by three researchers at the Chalmers Institute of Technology. The equipment, produced by HB Innova Electronic and called Digi-X, consists of a measurement unit, with parameter, threshold and mode controls, and a detector which is attached to the patient. Peak kilovolt readings are indicated digitally and actual exposure time is calculated from previously stored threshold values selected by the operator. The system may also be used to check beam quality and, with an option, be used to calculate current and mAs values. HB Innova Electronic, Box 25062, S40031 Gothenburg, Sweden.

WW311





METALLIZED-FILM CAPACITORS

Extensions in Rifa's range of metallized polypropylene capacitors have been made to include the PHE425 series. These components, with values ranging from 1.5 to 135nF, are relatively small since they incorporate a 4µm-thick metallized film. Capacitance tolerances are 1%, 2%, or 5% and insulation resistance is claimed to be better than 200GΩ at 20°C, 10V. Working voltages, dependent on value, may be 200, 100 or 63V, direct. Rifa AB, Market Chambers, Shelton Square, Coventry.

WW312

T.T.L.-OUTPUT PATTERN GENERATOR

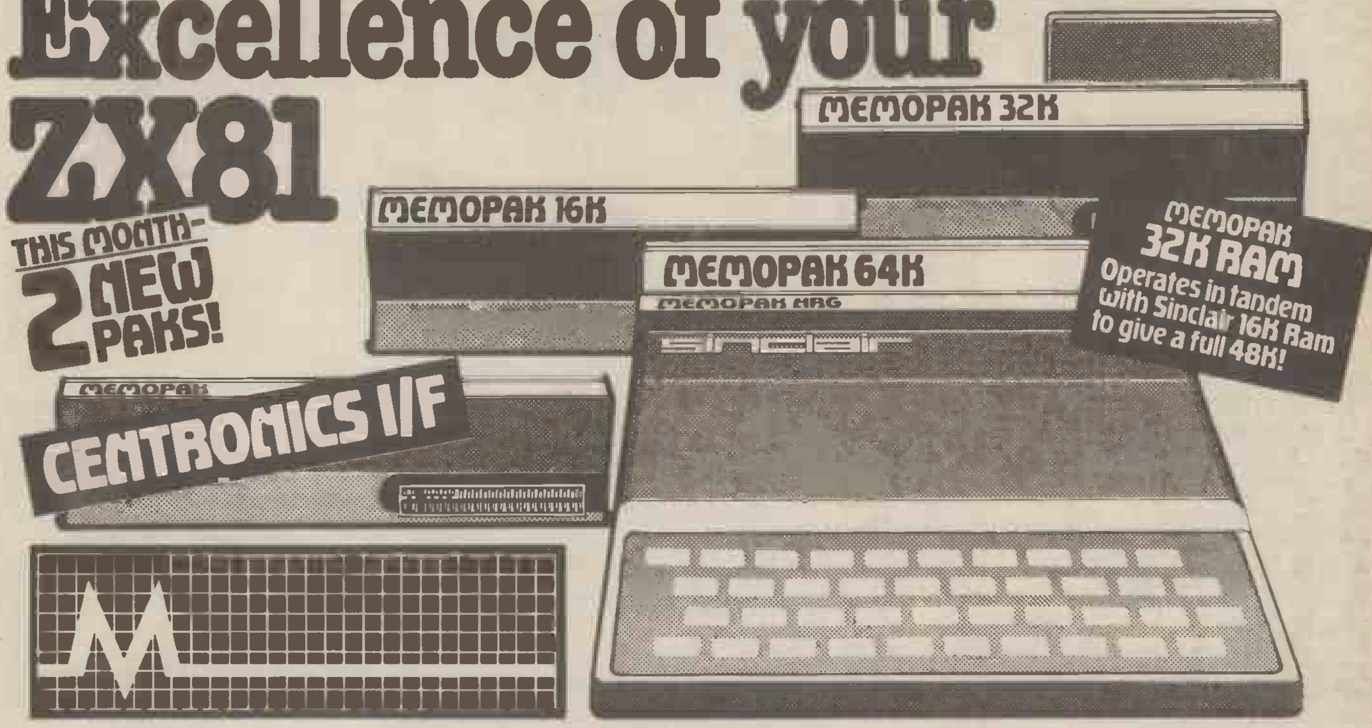
A hand-held pattern generator providing t.t.l.-compatible red, green and blue signals for servicing monitors and video displays is manufactured by Sadelta. Eight patterns are produced, colour bars, red, green, blue and white rasters, grey scale, cross-hatch and vertical lines, and the unit may be used for

up to four hours from one battery charge. The RGB11 is intended for servicing of commercial and hobby v.d.us, including video games, and c.c.t.v. monitors. House of Instruments, Clifton Chambers, 62 High Street, Saffron Walden, Essex CB10 1EE.

WW313

Professional readers are invited to request further details on items featured here by entering the appropriate WW reference number(s) on the mauve reply-paid card.

MEMOTECH Explores the Excellence of your ZX81



Memotech's Memopak Range

All five of the currently available Memopaks are housed in elegant black anodised aluminium cases, and are styled to fit wobble-free onto the back of the ZX8I, allowing more add-ons (from Memotech or Sinclair) to be connected.

£68.70 plus VAT

MEMOPAK 64K MEMORY EXTENSION

The 64K Memopak extends the memory of the ZX81 by 56K, and with the ZX81 gives 64K, which is neither switched nor paged and is directly addressable. The unit is user transparent and accepts commands such as 10 DIM A(9000).

Breakdown of memory areas...0-8K-Sinclair ROM. 8-16K-This area can be used to hold machine code for communication between programmes or peripherals. 16-64K-A straight 48K for normal Basic use.

£43.43 32K / £26.00 16K plus VAT

MEMOPAK 32K and 16K MEMORY EXTENSIONS

These two packs extend and complete the Memotech RAM range (for the time being!) A notable feature of the 32K pack is that it will run in tandem with the Sinclair 16K memory extension to give 48K RAM total.

£52.00 plus VAT

MEMOPAK HIGH RES GRAPHICS PACK

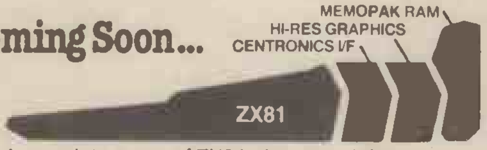
HRG Main Features — • Fully programmable Hi-Res (192 × 248 pixels) • Video page is both memory and bit mapped and can be located anywhere in RAM. • Number of Video pages is limited only by RAM size (each takes about 6.5K RAM) • Instant inverse video on/off gives flashing characters • Video pages can be superimposed • Video page access is similar to Basic plot/unplot commands • Contains 2K EPROM monitor with full range of graphics subroutines controlled by machine code or USR function

£34.70 plus VAT

MEMOPAK CENTRONICS TYPE PARALLEL PRINTER INTERFACE

Main Features — • Interfaces ZX8I and parallel printers of the Centronics type • Enables use of a range of dot matrix and daisy wheel printers with ZX8I • Compatible with ZX8I Basic, prints from LLIST, LPRINT and COPY • Contains firmware to convert ZX8I characters to ASCII code • Gives lower-case characters from ZX8I inverse character set

Coming Soon...



A complete range of ZX81 plug-in peripherals

Digitising Tablet RS232 Interface

We regret we are as yet unable to accept orders or enquiries concerning the above products, but we'll let you know as soon as they become available.

Access/Barclaycard Holders Please Tel. Oxford (0865) 722102 (24 Hrs)

©R. Branton & G.A.C. Boyd 1982

Please make cheques payable to MEMOTECH Ltd.

Please Debit my Access/Barclaycard* account number

*Please delete whichever does not apply

Please send me	Price	No	Total
64K RAM £68.70 + £10.30 VAT	£79.00		
32K RAM £43.43 + £6.52 VAT	£49.95		
16K RAM £26.00 + £3.90 VAT	£29.90		
HRG £52.00 + £7.80 VAT	£59.80		
CENTRONICS I/F £34.70 + £5.20 VAT	£39.90		
Packaging & Postage £2.00 per unit			
TOTAL ENC			

SIGNATURE ____________ DATE ____________

NAME ____________ ADDRESS ____________

____________ TELEPHONE ____________

We want to be sure you are satisfied with your Memopak – so we offer a 14-day money back Guarantee on all our products.

Memotech Limited, 3 Collins Street, Oxford OX4 1XL, England Tel: Oxford (0865) 722102 Telex: 837220 Orchid G

WW – 019 FOR FURTHER DETAILS

U.K. RETURN OF POST MAIL ORDER SERVICE, ALSO WORLDWIDE EXPORT SERVICE

BSR DE LUXE AUTOCHANGER £20

Plays 12", 10" or 7" records, Auto or Manual. A high quality unit backed by BSR reliability. Stereo Ceramic Cartridge. AC 200/250V. Size 13½×11¼in. 3 speeds. Above motor board 3¾in. Below motor board 2½in.
Post £2 Cut Board £1 extra

HEAVY METAL PLINTHS Post £2

Cut out for most BSR or Garrard decks.
Silver grey finish, black trim. Size 16x13¾in. **£4**

DECCA TEAK VENEERED PLINTH. Post £1.50 **£5**
Superior finish with space and panel for small amplifier. Board is cut for B.S.R. 18¾in.×14¼in×4in. Black/chrome facia trim. Also with boards cut out for Garrard £3. Tinted plastic cover £6

TINTED PLASTIC COVERS Post £2

17⅞×13⅛×3¼in.	£6	18¼×12½×3in.	£6
17¼×9⅜×3½in.	£3	14⅜×12½×2⅞in.	£5
13¾×12×2¼in.	£5	16⅝×13×4in.	£6
15¼×13½×4in.	£6	14½×13⅛×2¾in.	£5
17×12⅞×3½in.	£6	17¼×13¾×4⅛in.	£6

Callers Only (not suitable for post)

21½×14¼×2½in.	£6	21×13⅞×4⅛in.	£6
23¾×14×3⅞in.	£6	30¾×13⅜×3¼in.	£6

BSR SINGLE PLAYER DECKS

BSR P232 BELT DRIVE QUALITY DECK
Manual or automatic play.
Precision ultra slim arm.
Cueing device. Bargain price
With stereo ceramic cartridge
£24 Post £2

BSR P204 SINGLE PLAYERS SPECIAL OFFERS
Two speed 33/45 r.p.m. hi-fi decks with stereo cartridges, cueing device and snake arm.
Ceramic – 240V AC **£15** or 9V DC **£19**
Magnetic – 240V AC **£20** or 12V DC **£24** Post £2 ea

GARRARD 6-200 SINGLE PLAYER DECK £22 Post £2
Brushed Aluminium Arm with stereo ceramic cartridge and Diamond Stylus, 3-speeds. Manual and Auto Stop/Start. Large Metal Turntable. Cueing Device.
Ready cut mounting board £1 extra.
GARRARD SP25 Mk 4. Less cartridge. Balanced arm. Few only.
3-speed single player **£30** Post £2

BATTERY ELIMINATOR MAINS to 9 VOLT D.C.
Stabilised output, 9 volt 400 m.a. U.K. made in plastic case with screw terminals. Safety overload cut out. Size 5 x 3¼ x 2½in. Transformer Rectifier Unit. Suitable Radios, Cassettes, models, £4,50. Post 65p.

DE LUXE SWITCHED MODEL STABILISED. £7.50. Post £1. 3-6-7½-9 volt 400ma DC max. Universal output plug and lead. Pilot light, mains switch, polarity switch.

DRILL SPEED CONTROLLER/LIGHT DIMMER KIT. Easy to build kit. Controls up to 480 watts AC mains, £3. Post 65p.
DE LUXE MODEL READY-BUILT 800 watts. Front plate fits standard box, £5. Post 65p.

EMI 13½x8in. LOUDSPEAKERS

Model 450, 10 watts R.M.S. with moving coil tweeter and two-way crossover; 3 ohm or 8 ohm. **£9.50** Post £1.50
"Final Clearance".
SUITABLE BOOKSHELF CABINET £6.50. Size 18×11×6in. Post £1.50.

RELAYS. 6V DC 95p. 12V DC **£1.25. 18V £1.25.**
BLANK ALUMINIUM CHASSIS. 6×4–£1.45; 8×6–£1.80; 10×7–£2.30; 12×8–£2.60; 14×9–£3; 16×6–£2.90; 16×10–£3.20. All 2½in. deep. 18 swg.
ANGLE ALI. 6×¾×¾in. 18 swg. 30p.
ALUMINIUM PANELS, 18swg. 6×4–45p; 8×6–75p; 14×3–75p; 10×7–95p; 12×8–£1.10; 12×5–75p; 16×6–£1.10; 14×9–£1.45; 12×12–£1.50; 16×10–£1.75.
PLASTIC AND ALI BOXES IN STOCK. MANY SIZES
ALUMINIUM BOXES. 4×4×1½ £1. 4×2½×2 £1. 3×2×1 £1. 6×4×2 £1.60. 7×5×3 £2.40. 8×6×3 £2.50. 10×7×3 £3. 12×5×3 £2.75. 12×8×3 £3.60. All with lids.
BRIDGE RECTIFIER 200V PIV 2a £1. 4a £1.50. 8a £2.50.
TOGGLE SWITCHES SP 30p. DPST 40p. DPDT 50p.
MINIATURE TOGGLES SP 40p. DPDT 60p.
RESISTORS. 10Ω to 10M. ¼W, ½W, 1W, 2p: 2W 10p.
HIGH STABILITY. ½w 2% 10 ohms to 1 meg. 10p.
Ditto 5%. Preferred values, 10 ohms to 10 meg, 3p.
WIRE-WOUND RESISTORS 5 watt, 10 watt, 15 watt 20p.
PICK-UP CARTRIDGES SONOTONE 9TA £2.50.
BSR Stereo Ceramic SC7 Medium Output £2. SC12 £3.
PHILIPS PLUG-IN HEAD. Stereo Ceramic. AU1020 (G306 GP310 - GP233 -AG3306, £2. A.D.C., QLM 30/3 Magnetic £5.
LOCKTITE SEALING KIT DECCA 118 . Complete £1.
ANTEX SOLDERING IRON 240V 15W 3mm bit £5.25.
JACK PLUGS Mono Plastic 25p; Metal 30p.
JACK PLUGS Stereo Plastic 30p; Metal 35p.
JACK SOCKETS Mono Open 20p; Closed 25p.
JACK SOCKETS Stereo Open 25p; Closed 30p.
FREE SOCKETS – Cable end 30p. Metal 45p.
2.5mm and 3.5mm **JACK SOCKETS** 20p. Plugs 20p.
DIN TYPE CONNECTORS
Sockets 3-pin, 5-pin 10p. Free Sockets 3-pin, 5-pin 25p.
Plugs 3-pin 20p; 5-pin 25p; Speaker plugs 20p; Sockets 15p.
PHONO PLUGS and SOCKETS ea. 15p.
Free Socket for cable end 20p. Screened Phono Plugs 25p.
300 ohm TWIN RIBBON FEEDER 10p yd.
U.H.F. COAXIAL CABLE SUPER LOW LOSS, 25p yd.
COAX PLUGS 30p. **COAX SOCKETS** 20p.
NEON INDICATORS 250V, round 30p. Rectangular 45p.
SOLID DIELECTRIC 100pf, 500pf £1.50.

POTENTIOMETERS Carbon Track

5kΩ to 2MΩ. LOG or LIN. L/S 50p. DP 90p. Stereo L/S £1.10. DP £1.30. Edge Pot 5K. SP 45p.

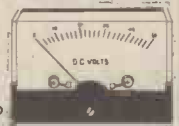
MINI-MULTI TESTER NEW

De luxe pocket size precision moving coil instrument. Impedance + Capacity – 4000 o.p.v. Battery included.
11 instant ranges measure:
DC volts 5.25, 250, 500.
AC volts 10, 50, 500, 1000.
DC amps 0-250μa, 0-250mA.
Continuity and resistance
0 to 600K ohms

£6.50 Post 65p

De Luxe Range Doubler Model, 50,000 o.p.v. £18.50. 7×5×2in. Post £1

NEW PANEL METERS £4.50



50μa, 100μa, 500μa, 1ma, 5ma, 50ma, 100ma, 500ma, 1 amp, 2 amp
25 volt, VU Meter.
2¼×2×1¼in. Post 65p

RCS SOUND TO LIGHT CONTROL KIT

Kit of parts to build a 3 channel sound to light unit. 1,000 watts per channel. Suitable for home or disco. Easy to build. Full instructions supplied. **£15** Post 95p

Cabinet £4.50 extra. Operates from 200MV to 100W.

200 Watt Rear Reflecting White Light Bulbs. Ideal for Disco Lights, Edison Screw. 6 for £4, or 12 for **£7.50.** Post 65p. Suitable panel mounting holders 85p.

RCS "MINOR" 10 watt AMPLIFIER KIT £14

This kit is suitable for record players, guitars, tape playback, electronic instruments or small PA systems. Two versions available: Mono, **£14**; Stereo, **£20**. Specification 10W per channel; size 9½×3×2in. SAE details. Full instructions supplied. 240V AC mains. Post £1.

RCS STEREO PRE-AMP KIT. All parts to build this pre-amp. Inputs for high, medium or low imp per channel, with volume control and PC Board Can be ganged to make multi-way stereo mixers **£2.95** Post 65p

MAINS TRANSFORMERS

	Price	Post
250-0-250V 70mA, 6.5V, 2A	£4.50	£2
250-0-250V 80mA, 6.3V 3.5A, 6.3V 1A	£5.00	£2
350-0-350V 250mA, 6.3V 6A CT	£12.00	£2
300-0-300V 120mA, 2×6.3V 2A C.T.; 5V 2A	£13.00	£2
220V 45mA, 6.3V 2A	£3.00	£1
250V 60mA, 6V 2A	£3.75	£1

AUTO 115V to 240V 150W **£9.** 250W **£10.** 400W **£11.** 500W **£12.00** £2

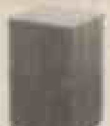
GENERAL PURPOSE LOW VOLTAGE

Tapped outputs available	Price	Post
2 amp. 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 25 and 30V	£8.00	£2
1 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£8.00	£2
2 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£10.50	£2
3 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£12.50	£2
5 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£16.00	£2

5-8-10-16V. ½ amp.	£2.50	80p	15-0-15V. 2 amps	£3.75	£1
6V. ½ amp.	£2.00	£1	20V 1 amp	£3.00	£1
6-0-6V. 1½ amp.	£3.50	£1	20-0-20V 1 amp	£3.50	£1
9V. 250ma.	£1.50	80p	20-40-60V 1 amp	£4.00	£2
9V. 3 amp	£3.50	£1	25-0-25V 2 amps	£4.50	£1
9-0-9V. 50ma	£1.50	80p	28V 1 amp Twice	£5.00	£2
10-0-10V. 2 amps	£3.00	£1	30V 1½ amp	£3.50	£1
10-30-40V. 2 amps	£3.50	£1	30V 5 amp and		
12V. 100ma	£1.50	80p	17-0-17 2a	£4.50	£2
12V. 750 ma	£2.00	80p	35V 2 amps	£4.00	£1
12V 3 amps	£3.50	£1	TOROIDAL30-0-30V 4a and		
12-0-12V. 2 amps	£3.50	£1	20-0-20V ½a	£10.00	£2

CHARGER TRANS	Post	RECTIFIERS	Post
6-12 volt 3a	£4.00+£2	6-12 volt 2a	£1.10+80p
6-12 volt 4a	£6.50+£2	6-12 volt 4a	£2.00+80p

OPUS COMPACT SPEAKERS £22 pair Post £2



TEAK VENEERED CABINET
11×8½×7in, 15 watts
50 to 14,000 cps. 4 ohm or 8 ohm

OPUS TWO 15×10½×7¾in 25 watt 2-way system **£39 pair.** Post £3.

LOW VOLTAGE ELECTROLYTICS Wire ends 10p
1 mf, 2 mf, 4 mf, 8 mf, 10 mf, 16 mf, 25 mf, 30 mf, 50 mf, 100 mf, 250 mf. All 15 volts. 22 mf/6v/10v; 25 mf/6v/10v; 47 mf/10v; 50 mf/6v; 68 mf/6v/10v/16v/25v; 100 mf/10v; 150 mf/6v/10v; 200 mf/10v/16v; 220 mf/4v/10v/16v; 330 mf/4v/10v; 500 mf/6v; 680 mf/6v/10v/16v; 1000 mf/2.5v/4v/10v; 1500 mf/6v/10v/16v; 2200 mf/6v/10v; 3300 mf/6v; 4700 mf/4v.
500mF 12V 15p; 25V 20p; 50V 30p. 1200mF 76V 86p.
1000mF 12V 20p; 25V 35p; 50V 50p; 100V 70p.
2000mF 6V 25p; 25V 42p; 40V 60p; 1200mF 76V 80p.
2200mF 63V 90p. 2500mF 50V 70p; 3000mF 50V 65p;
4500mF 64V £2. 4700mF 63V £1.20. 2700mF/76V £1.

HIGH VOLTAGE ELECTROLYTICS

2/500V	45p	8+8/450V	75p	32+32+16/350V	90p
8/450V	45p	8+8/500V	£1	100+100/275V	65p
16/350V	45p	8+16/450V	75p	150+200/275V	70p
32/500V	75p	32+32/350V	50p	220/450V	95p
32/350V	50p	32+32/500V	£1.80	32+32+32/325V	75p
50/450V	95p	50+50/300V	50p	50+50+50/350V	95p

CAPACITORS WIRE END High Voltage
.001, .002, .003, .005, .01, .02, .03, .05 mfd 400V 5p.
.1MF 200V 5p. 400V 10p. 600V 15p. 1000V 25p.
.22MF 350V 12p. 600V 20p. 1000V 30p. 1750V 50p.
.47MF 1500V 10p. 400V 20p. 630V 30p. 1000V 60p.
VALVE OUTPUT Transformers (small) 90p.
TRIMMERS 30pF, 50pF, 10p. 100pF, 150pF, 500pF 30p.
MICROSWITCH SINGLE POLE CHANGEOVER 40p.
SUB-MIN MICROSWITCH, 50p, Single pole changeover.
TWIN GANG, 120pF 50p. 500 plus 200pF £1.
GEARED TWIN GANGS 25pF 95p.
GEARED 365+365+25+25pF £1.
TRANSISTOR TWIN GANG. Japanese Replacement £1
SOLID DIELECTRIC 100pf £1.50, 500pf £1.50.

HEATING ELEMENTS, WAFER THIN
Size 11×9×⅛in. Operating voltage 240V, 250W approx. Suitable for Heating Pads, Food Warmers, Convector Heaters, Propagation, etc. Must be clamped between two sheets of metal or ceramic, etc.
ONLY 60p EACH (FOUR FOR £2) ALL POST PAID.

NEW baker Star sound

high power full range quality loudspeakers produced to give exceptional reproduction. Ideal for Hi-Fi, music P.A. or discotheques. These loudspeakers are recommended where high power handling is required with quality results. The high flux ceramic magnet ensures clear response.

MODEL	INCHES	OHMS	WATTS	TYPE	PRICE	POST
MAJOR	12	4-8-16	30	HI-FI	£14	£2
DELUXE MK II	12	8	15	HI-FI	£14	£2
SUPERB	12	8-16	30	HI-FI	£24	£2
AUDITORIUM	12	8-16	45	HI-FI	£22	£2
AUDITORIUM	15	8-16	60	HI-FI	£34	£2
GROUP 45	12	4-8-16	45	PA	£14	£2
GROUP 75	12	4-8-16	75	PA	£18	£2
GROUP 100	12	8-16	100	Guitar	£24	£2
DISCO 100	12	8-16	100	Disco	£24	£2
GROUP 100	15	8-16	100	Guitar	£32	£2
DISCO 100	15	8-16	100	Disco	£32	£2

BAKER 150 WATT MIXER/POWER AMPLIFIER £89 Post £2

For Discotheque, Vocal, Public Address. Three speaker outlets for 4, 8 or 16 ohms. Four high gain inputs, 20 mv, 50K ohm. Individual volume controls "Four channel" mixing. 150 watts 8 ohms R.M.S. Music Power. Slave output 500 M.V. 25K.ohm. Response 25 Hz – 20kHz ± 3dB. Integral Hi-Fi preamp separate Bass & Treble. Size – 16" x 8" x 5½". Wt – 14lb: Master volume control. British made. 12 months' guarantee. 240v A.C. mains or 120V to order. All transistor and solid state.
MONO SLAVE VERSION £75. 100 Volt Line Model £104.
New Stereo Slave Model 150 + 150 watt £125. Post £4.
BAKER'S NEW PA150 MICROPHONE PA AMPLIFIER £129. PP £3.
4 channel 8 inputs, dual impedance, 50K-600 ohm 4 channel mixing, volume, treble, bass. Presence controls, Master volume control, echo/send/return socket. Slave input/output sockets.

BAKER £69 Post £2 50 WATT AMPLIFIER

Ideal for PA systems, Discos and Groups. Two inputs, Mixer, Volume, Controls, Master Bass, Treble Gain.

RCS offers MOBILE PA AMPLIFIERS. Outputs 4-8-16 ohms
20-watt RMS 12v DC, AC 240v, 3 inputs. 50K **£46 PP £2.**
40-watt RMS 12v DC, AC 240v, 4 inputs. 50K 100v Line **£75 PP £2**
Mic 1; Mic 2; Phono; aux. outputs 4 or 8 or 16 and 100v line
60-watt RMS, Mobile 24 volt DC & 240-volt AC mains. inputs 50K. 3 mics + 1 music. Outputs 4-8-16 ohm + 100 volts line **£95 PP £2**

Battery only Shoulder PA Amplifier 10w max. Includes mike and speaker, OK for meetings, crowd control, stalls, fetes, traders, etc. Batteries included (6 of U2) £27.50 post £1.50.

FAMOUS LOUDSPEAKERS "SPECIAL PRICES"

MAKE	MODEL	SIZE	WATTS	OHMS	PRICE	POST
SEAS	TWEETER	4in	50	8	£9.50	£1
GOODMANS	TWEETER	3½in	25	8	£4.00	£1
AUDAX	TWEETER	4in	30	8	£6.50	£1
SEAS	MID-RANGE	4in	50	8	£7.50	£1
SEAS	MID-RANGE	5in	80	8	£12.00	£1
SEAS	MID-RANGE	4½in	100	8	£12.50	£1
GOODMANS	HIFAX	7½×4¼	100	4/8/16	£22	£2
GOODMANS	WOOFER	8in	25	4/8	£6.50	£1
GOODMANS	HB	8in	60	8	£12.50	£1
RIGONDA	GENERAL	10in	15	8	£5	£2
AUDAX	WOOFER	10in	50	8	£16.00	£2
GOODMANS	HPG	12in	120	8/15	£29.50	£2
GOODMANS	GR12	12in	90	8/15	£27.50	£2
GOODMANS	HPD	12in	120	8/15	£29.50	£2

SPEAKER COVERING MATERIALS. Samples Large S.A.E.
B.A.F. LOUDSPEAKER CABINET WADDING 18in wide 35p ft.

MOTOROLA PIEZO ELECTRIC HORN TWEETER, 3⅜in. square **£5**
100 watts. No crossover required. 4-8-16 ohm, 7⅜x3⅛in. **£10.50**

CROSSOVERS. TWO-WAY 3000 c/s 30 watt 8 or 15 ohm £3. 3-way 950 cps/3000 cps. 40 watt rating. £4. 3 way 60 watt £6.
LOUDSPEAKER BARGAINS
3 ohm, 5in, 7×4in, £2.50; 6½in, 8×5in, £3; 8in, £3.50. 10in, £5.
8 ohm, 2⅝in, 3in, £2; 5in, £2.50; 6½in, £3; 8in, £4.50; 12in, £6.
15 ohm, 3½in, 5×3in, 6×4in, £2.50.
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All parts and instructions with Zener diode printed circuit, mains transformer 240V a.c. Output 6 or 7½ or 9 or 12V d.c. up to 100mA or less. Please state voltage required.

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Approximately 100 tons of stock has to be cleared right away from our big store, hence these very low price offers. Prices quoted are for bulk orders, minimum order £100, minimum any item £25. VAT and carriage are extra, although large orders not too far away will be delivered free. Contact us on this point.

Should you want a small quantity of any of the items as samples, for instance, then send listed price x 2, which will cover the VAT and postage on letter post items. For heavy items, add the amount you think, bearing in mind that the smallest parcel now costs £1.35 and a 10 kilo parcel £3.25.

We have managed to list most of the items in the store we have to empty. All goods are offered subject to being unsold and the conditions of sale are as stated, but should you want more information, please contact Mr. Bull or Mr. Stepney at Haywards Heath between 12 and 4pm. On Haywards Heath (0444) 454563.

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ker switches: white push into hole 1" x 7/16". All rated
mp, AC 250 volt. on/off 12
changeover centre off 15
on/off with neon 30
push to make spring return . .20
push to break spring return . .20
ier two circuit one on one off with mounting plate . .20
mp rocker switch. Car Fastener (DoT) 15
bl Grip Switch: with lock-on as in electric drills . .30
rlocking Switch: blow heater, 3 rockers, 10 amp . .30
o switches. V3 types, 10 amp c/o contacts . . .20
is button operated: 15 amp c/o contacts . . .25
10 amp off/on 15
15 amp off/on 20
Lever operated add 10
Lever with roller operation add .15
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flat multi stackable 60 watt . .50
rating coils for reed switch multi voltage 3, 6, 9 or 12 .50
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" – 4" long 15p 5" long 20p 8" long 30p
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M coils for above, per set 20

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l plated: Collapsed 8½" extended 4' 50
Collapsed 4½" extended 2' 40

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h bulbs, 3.5v MES Box of 25 35
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Bulbs: 18 watt SBC 12
SBC Lamp holders 15

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ck record/playback heads .25
ck record 45
ck erase 20
ck erase 40
pe spool ¼" tape . .15

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o transistors. Mullards seconds 75% working, 100 for £5
wave rectifier, 440v 2 amp 20
0v Silicon diodes 02
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MPLIFIERS

tt, Japanese made with v.c. £1.50
t, Mullard module 1172 . . . . . £1.00
t, Mini-amp with v.c. £1.00
p, Mullard Ref. 9001 module 80

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Neon Mains indicators. Standard 15
Extra small 25
Bench isolation mains in 230/240v output. 250W . £4.50
Mains input. Porcelain removable fuse 20
Light operated switch 12 volt. Encapsulated . . £1.25
Insulating board. srbp etc. Approx 10 tons. Sheet size 4' x 4' or larger. Various thicknesses, price per lb. . . .50
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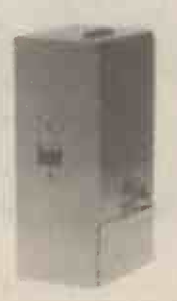
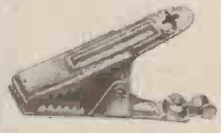
Aerosol can ICI Fluon lubricant 35
Varicap P.B. TV tuner 50
Battery Holder takes 6 U2 batteries, snap connector . .25
Car Battery clips, as for charger, + and – per pair .10



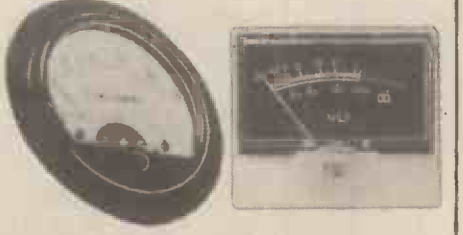


BUY TIME SLOT METER, 10p gives 1 hour, boxed with lock and coin tray £2.00
DIMMERS AND CONTROLLERS 1250W dimmer, Ultra ref SF20/5 . . . . . . £2.00

TOOLS:
8 ba button dies 15
Screw driver, miniature for grub screw 10
Small size, general purpose 08
Solenoid mains operated AIR VALVE
200/230 volt model £2.30
100 volt model £1.15
ULTRA SONIC Transmitters and receivers . . .25
VALVE HOLDERS: B9A with skirt ceramic . . .15
B7G PTFE . . .25
INSERT speaker/mike, balanced armature, 600 ohm .30
Rewireable fuse and carrier MEM 20 amp 250 volt . .28
Magnetic Clutch. Zerox 1215494 PN 866 – 10 . .90

PANEL METERS & INSTRUMENTS

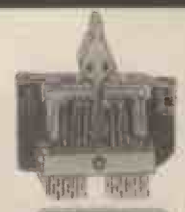
Volt meter 0 - 200 volts 2½" round £1.50
milli amp meter, 500 ma 2½" round £1.00
-- amp meter, not wire scaled 0 9 amps . . . £1.20
Ammeter, 2½" round, centre zero. 500 ma . . . £1.00



Charger panel meters, 1¾" dia. scaled 3 amp 35
Panel meter, 1 5/8" square, scaled Vu 60
Panel meter, Amstrad, 40mm sq. centre zero, scaled 1, 2, 3 .50
Edgeways panel, 3" 0 - 25 ma, ex GPO £1.00

SWITCHES

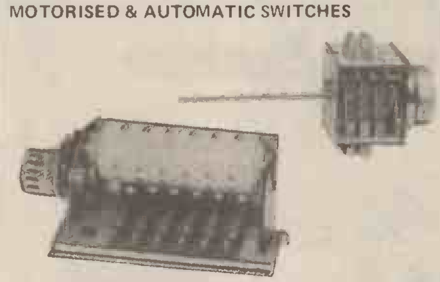
Miniature Make before break
Wafer Switch:
1 pole 12 way / 2 pole 6 way 20p
3 pole 4 way / 4 pole 3 way 20p
6 pole 2 way / 4 pole 2 way 20p
2 pole 2 way / 1 pole 2 way 20p
2 pole 12 way / 4 pole 6 way 45p
6 pole 4 way / 8 pole 3 way 45p
12 pole 2 way . . . 45p
6 pole 5 way / 6 pole 6 way 70p
9 pole 4 way / 12 pole 2 way 70p
18 pole 2 way 70p



Push/push table lamp type, better than average quality .15
10 digit switch pad for telephone £1.00
Computer key switches, bank of 6 with knobs . . £1.25
Lever type, as used by Post Office 60
Push button switch bank, 9 push (6 interlocking, 3 independent locking) 40
3 push switches, with integral knobs 40
PCB Mounting 2cm diameter 1 pole 4 watt . . .

Low pressure switch, sensitive could be mouth operated:
Single 10 amp changeover £1.15
Ditto, with spindle for adjustment £1.50
Ditto, 3 10 amp changeover £1.64

MOTORISED & AUTOMATIC SWITCHES



Uniselectors: 3 pole 25 watt 50 volt coil £4.75
4 pole 25 watt 50 volt coil £6.00
2 pole miniature 25 watt £2.30
Motorised c/o Micro switches. Adjustable sw cams mains capacitor run motor: 4 switch £2.00
6 switch £2.50
8 switch £3.00
12 switch £3.50
HUMIDITY SWITCH, spindle adjustable 50
DELAY SWITCH, A delay switch which can give delays of a few seconds to a few minutes, depending upon the voltage applied to its heater coil . . . . . .
WIRE WOUND POT, 25 watt 1K 50
and 8 ohm 50

100K Multi turn pots 15
Wire wound pot, with integral knob, available in values – 15 ohms, 33 ohms, 50 ohms, 100 ohms 15
Miniature PRE-SETS, ... each . .05

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240v fans 4½x4½x1⅛'' £5.75 inc. VAT + postage. 110v fans 4½x4½x1⅛'' £4.75 inc. VAT + postage. Radiospares price £14.50!!!

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12 or 24 VOLT

Ref.	12v	24v	£	£
111	0.5	0.25	2.42	1.00
213	1.0	0.5	2.90	1.00
71	2	1	3.86	1.00
18	4	2	4.46	1.20
85	5	2.5	6.16	1.20
70	6	3	6.99	1.20
108	8	4	8.16	1.30
72	10	5	8.93	1.50
116	12	6	9.89	1.50
17	16	8	11.79	1.50
115	20	10	15.38	1.60
187	30	15	19.72	1.70
226	60	30	40.41	2.00

30 VOLT RANGE

Ref.	Amps	£	£
112	0.5	2.90	1.00
79	1.0	3.93	1.00
3	2.0	6.35	1.20
20	3.0	6.82	1.30
21	4.0	8.79	1.40
51	5.0	10.86	1.40
117	6.0	12.29	1.50
88	8.0	16.45	1.80
89	10.0	18.98	1.90
90	12.0	21.09	4.00
91	15.0	24.16	4.00
92	20.0	32.40	4.00

50 VOLT RANGE

Ref.	Amps	£	£
102	0.5	3.75	1.10
103	1.0	4.57	1.10
104	2.0	7.88	1.30
105	3.0	9.42	1.50
106	4.0	12.82	1.60
107	6.0	16.57	1.70
118	8.0	22.29	2.00
119	10.0	27.48	4.00
109	12.0	31.79	4.00

60 VOLT RANGE

Ref.	Amps	£	£
124	0.5	4.27	1.20
126	1.0	6.50	1.20
127	2.0	8.36	1.40
125	3.0	12.10	1.50
123	4.0	13.77	1.70
40	5.0	17.42	1.70
120	6.0	19.87	2.00
121	8.0	27.92	3.00
122	10.0	32.51	4.00
189	12.0	37.47	4.00

VOLTAGES OBTAINABLE

30v range 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 30v, 12-0-12v or 15-0-15v. **50v range** 5, 7, 8, 10, 13. 15, 17, 20, 25, 30, 33, 40v, 20-0-20v or 25-0-25. **60v range** 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60v, 24-0-24 or 30-0-30.

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FOR AMERICAN EQUIPMENT

240/110 Volts. 80-2250 watts. Regular stock line. Types 80-1500 watts are fully shrouded. Fitted with American two or three pin socket outlets and 3-core 240v mains lead. Types 1750 and 2250 watts are steel cased with two American socket outlets. Neon indicator, three-core mains lead and carrying handle. Send SAE for price list and further details. American sockets, plugs, adaptors also available.

SPECIAL OFFER:
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Prim 240v. Sec 240v 250 watts. Open frame type. Tag connections. Fused input, £10, P&P £2, VAT £1.80. Parmeko pri tapped 115-220-240v. Sec 240v 6 amps. Fully shrouded top panel connections. Sec can be wired to give 120-0-120V, £25, carr. £5, VAT £4.50.

SPECIAL OFFER:
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Brand new, boxed, input 240V, output 0-265 volts 5 amps. Base or panel mounting with calibrated dial 0-265 volts and control knob. Price £26, inc. carr. and VAT.

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Pri tapped 120-240V sec tapped 34-29-0-29-34V 6 amps and 46V 1A. Open frame type. Tag connection. Size 5x4½x4ins. £9 inc. postage and VAT.

LATEST PURCHASE. COMPUTER GRADE TRANSFORMERS. Conservatively rated. All Primaries 220-240V. No. 1 secs. 27V 10A, 9V 3A, 15V ½A x 2. Separate windings. £5.50, P&P £1.50.
No. 2 sec. tapped 26-31-36V, 11.2A £12. P&P £2.
No. 3 sec. 36V 6A £6.50. P&P £1.50.
No. 4 sec. 43V 3A £4.75. P&P £1.50.
No. 5 sec. 24V 2A £2.75. P&P £1.25.
No. 6 sec. 27.5-0-27.5V 1.2A and 7-0-7V 0.75A £3.50. P&P £1.25.
No. 7 17V 1A £2 P&P 75p.
No. 8 13V 3A and 15V 1A £3.50. P&P £1.25.
No. 9 18V 2A £2.50. P&P £1.
No. 10 sec. 29-28-27-0-27-28-29V 350 M/A "C" Core £3. P&P £1.
No. 11 sec. 10-7-0-7-10V 0.6A and 29-21-0-21-29V 0.37A £3. P&P £1.
No. 12. 27V 1A 22V 1A 10V 1A 10V 1A, 4 separate windings "C" core type. £4.95. P&P £1.50.
No. 13. 65V 1A and 18-24V ½A £3.95. P&P £1.50.
No. 14. Tapped 12-15-27V 1A £2. P&P 75p.
No. 15. 6.3V 600M/A 6.3V 330M/A 6.3V 20 M/A 8V 500 M/A 50V 40 M/A £2. P&P £1.
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HEAVY DUTY ISOLATION TRANSFORMERS

240-240V ex-computer equipment. Large selection available 10-15 amps. Fraction of maker price. Telephone for further details.

INDUSTRIAL 12V/24V
20-AMP BATTERY CHARGERS

AC input 240V 50Hz. DC output 20A. Built-in steel case, size 15x12x9½ins. Complete with battery leads, £85 + VAT. Callers only.

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Cap start 240V AC RPM 44. Torque 4lb./ins., fitted with small cog on output shaft. Ideal for garage door opener or curtain puller. Our price £6.95 inc. carr. and VAT.

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Input 240v AC. Output 12v DC 2 Amps. With mains lead, red and black battery leads with attached clips. Completely fused. Housed in wall mounting, steel case size 6x4¾x4in. £4.50. P&P £1.50 plus VAT. Total £6.90.

BLOCK PAPER CAPACITORS

8 MFD 1000v DC WKG £3. P&P £1. 8 MFD 350v DC WKG. £1. P&P 50p, 6 MFD 350v DC WKG. £75. P&P 25p. 6 MFD 300v AC WKG. £1.50. P&P 50p. 4 MFD 350v DC WKG 50p. P&P 25p. 2 MFD 350v DC WKG 40p. P&P 20p. 1 MFD 1000v DC WKG. 50p. P&P 20p.

CRESSALL RHEOSTATS

Type S 150 4 ins. dia. 650 ohms 150 watts new and boxed £1.90, P&P 95p. VAT 29p. 1500 ohms 25 watts 1½ ins. dia. £1, P&P 50p VAT. 22p. 5000 ohms 25 watt 1½ ins. dia. £1, P&P 50p, 50 ohms 12½ watt ¾in. dia. £1, inc.post. VAT 15p.

SPECIAL OFFER HEAVY DUTY TRANSFORMERS

Pri 240V sec 50V 15 Amps. Twice will give 100V CT or 50V 30A. Open frame type. Terminal block primary. Sec heavy wire leads. Frame size 8½x7x5 inches. Screen winding between pri and sec. Brand new, fraction of list price. £32, carr. £5, VAT £5.55.

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Pri 110-220-240V. Secs 14V, 3V, 1½V, 1V. Separate windings. All at 40 Amps. 14-15-15½-17-18-18½-19-19½V can be obtained. £25, carr. £4, VAT £4.35.

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We would like to announce the opening of our new branch at **21-23 BELL STREET, NW1.** It will, of course, stock our fantastic range of products that have made us famous over the past 25 years. PLUS!! many new ranges, i.e. computer and electronic components, test equipment, panel meters, multimeters, semi-conductors, ICs and a large selection of plugs and sockets.

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Open frame clamped type, split bobbin. All primaries 240V No. 1 sec tapped 12-15-20-24-30V 750 M/A £4. No. 2 sec. 9-0-9V 1A and 6.3V 200 M/A £2.50. No. 3 15-0-15V 600 M/A and 6.3V 200 M/A. No. 4 sec. 12-0-12V 750 M/A and 6.3V 200 M/A £4. No. 5 sec 13V ½A £1.50. No. 6 sec. 8V ½A 6.3V 600 M/A, 6.3V 300 M/A 50V 40 M/A £2.50. No. 7 sec 17V ½A (DC) £1.75. No. 8 sec 16.5V ½A x 2 £1.75. No. 9 sec 18V 2A £4. No. 10 sec. 24V 2A £4.50, No. 11 sec 15V 2A £3.50. All prices include postage and VAT.

HEAVY DUTY ISOLATION TRANSFORMERS

240-240V ex-computer equipment. Large selection available 10-15 amps. Fraction of maker price. Telephone for further details.

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Computer grade Pri 115-230V sec 27V 10A, 9V 3A, 15V 0.5A, 15V 0.5A, 15V 0.5A, 175V 100 M/A. Separate windings, open frame type, top panel connections, £3.95, postage £2.40, VAT 94p.

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No. 2 sec. tapped 26-31-36V, 11.2A £12, P&P £2.
No. 3 sec. 36V 6A £6.50. P&P £1.50.
No. 4 sec. 43V 3A £4.75. P&P £1.50.
No. 5 sec. 24V 2A £2.75. P&P £1.25.
No. 6 sec. 27.5-0-27.5V 1.2A and 7-0-7V 0.75A £3.50. P&P £1.25.
No. 7 17V 1A £2 P&P 75p.
No. 8 13V 3A and 15V 1A £3.50. P&P £1.25.
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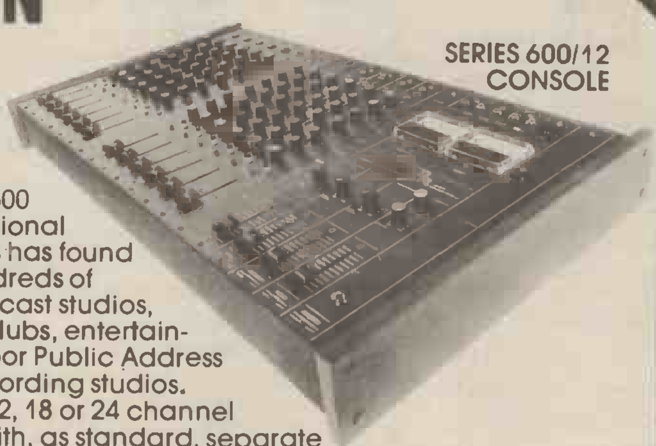
D S N MARKETING Ltd.



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The D&R SERIES 600 range of professional mixing consoles has found its way into hundreds of (hospital) broadcast studios, discotheques, clubs, entertainment and outdoor Public Address systems and recording studios.
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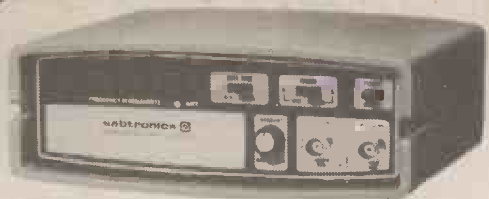

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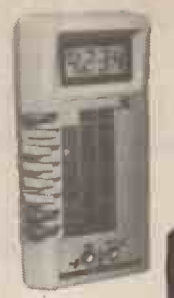

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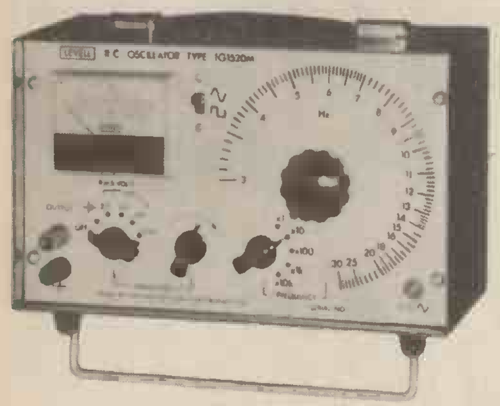

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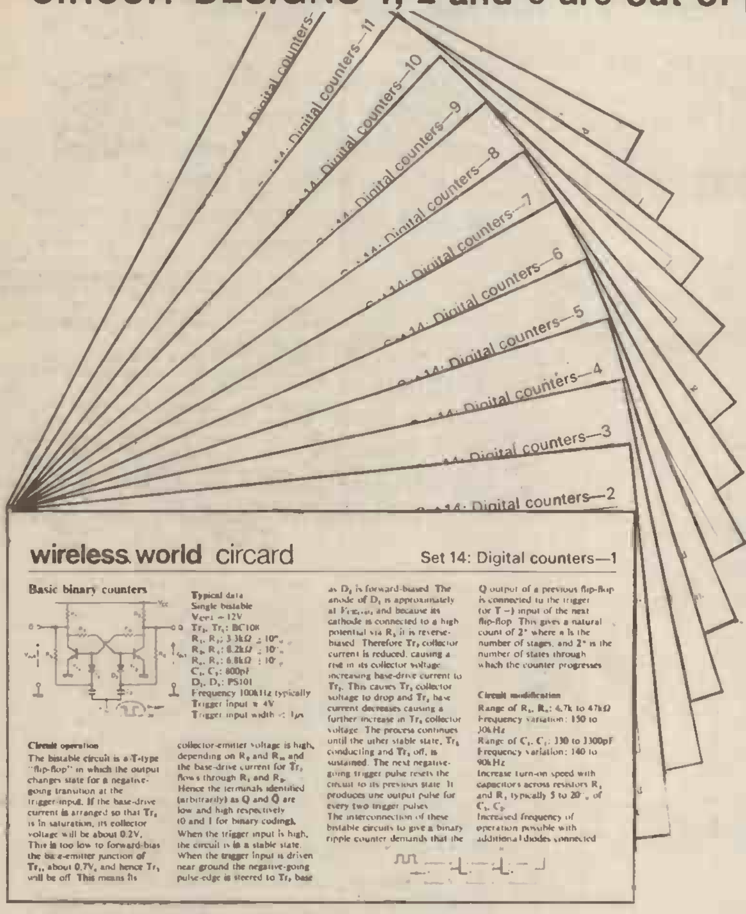

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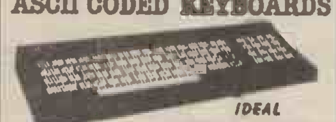

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Please write or phone for an application form from Maureen Brake, Reading (0734) 875200, Ampex Great Britain Limited, Acre Road, Reading, Berkshire.

(1729)

ST BARTHOLOMEW'S HOSPITAL, LONDON EC1A 7BE

Electronic Engineer

in Radiation Physics Department required

to assist in the servicing of a modern 20 MeV Linear Accelerator and a 6 MeV Linear Accelerator which is about to be installed and in the manufacture of dosimetry equipment and devices required for development and research.
Experience in Radar or Radiation Physics would be advantageous but not essential as appropriate training will be provided.
Support given to obtain relevant higher qualifications.
Applicants should possess ONC/HNC (Electronics) or other appropriate qualifications and at least three years' relevant experience.
Salary on Medical Physics Technician Grade III scale: £6,468 to £8,087 per annum inclusive.
For application form and job description please write to the Personnel Department or telephone 01-600 9000 Ext. 2271. Ref. no. TG/10.
Closing date, 4 August, 1982.

(1733)

14 Greek Street
London W1
01-434-2411

National Broadcasting School

The National Broadcasting School, an independent organisation under the auspices of the IBA, provides training for Independent Radio. As well as running full-time engineering courses, the Engineering Department also teaches the non-technical courses and maintains 6 broadcast-capable studios and ancillary areas.

PART-TIME LECTURERS IN ENGINEERING

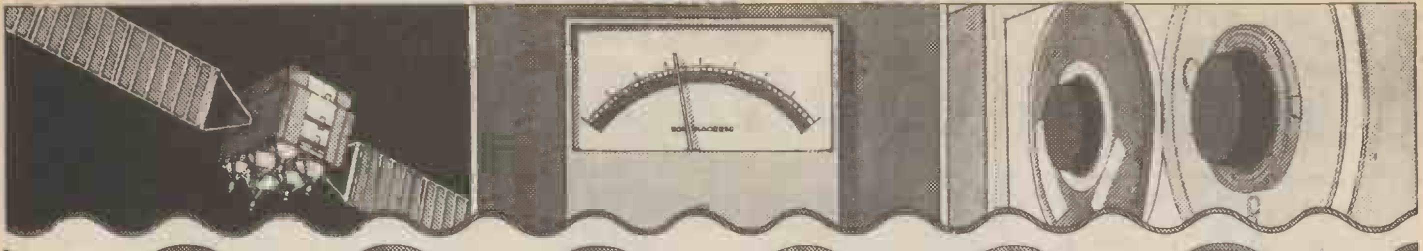
Two part-time lecturers are required to contribute to 3-month Engineering Course starting 21 September. They must have considerable experience in radio broadcasting and the ability to pass on that experience. Salary negotiable.

BROADCAST ENGINEER

A Broadcast Engineer with several years' experience in maintaining modern sound broadcasting equipment and a recognised technical qualification is required. In addition to the maintenance of the school's studios, the job includes teaching Broadcast Engineers. A desire to teach is therefore essential and previous experience in this and local radio would be an advantage. Salary negotiable.

Applications, which will be treated in confidence, should be made to the Chief Engineer, NBS, 14 Greek Street, London W1.

(1717)



ELECTRONICS TECHNICIANS

Total involvement across the spectrum of advanced communications

The Government Communications Headquarters at Cheltenham is one of the world's foremost centres for research, development and production in the fields of voice and data communications and communications security. Its comprehensive facilities, some of them unique, are geared towards producing creative solutions to complex communications problems using state-of-the-art techniques including computer/microprocessor applications.

There are currently opportunities for those with proven practical experience in electronics to become totally involved in complex systems spanning the whole spectrum of electronics technology. As a Telecommunications Technical Officer you will supervise a team of technicians involved in the management, construction, installation, testing, commissioning and maintenance of traditional and advanced technology communications and computer systems. Alternatively you will provide support for project engineers and scientists involved in the planning, research and engineering development of state-of-the-art systems.

You will work in one or other of the following fields:-

Telecommunications at HF, VHF and microwave frequencies, including satellite communications, computers and digital processing.

Data Transmission

Communications Security

Where necessary, in depth training will be provided and there are opportunities to attend familiarisation and management courses.

Posts are at two levels:-

At the lower level, the successful candidates will provide first line technical and supervisory control of a number of technicians involving work of a practical nature requiring 'hands on' participation. They may also undertake individual work of a highly technical nature with or without supervisory responsibilities.

The higher level posts involve the management of 2 or more teams as mentioned above. In many areas there is a close technical involvement requiring a high level of technical competence. Working as members of a multi-disciplinary team, the successful candidates will be expected to apply their knowledge and experience to the broader fields of work planning and management, including the implementation of medium to large scale projects.

Cheltenham

A significant advantage for people working at GCHQ in Cheltenham is its location in this elegant Regency town set in the heart of the Cotswolds. You can choose to live in the town itself, or in one of the delightful villages that surround it. Either way, you will have easy access to good shops, schools, sports facilities and cultural amenities in Cheltenham and nearby Gloucester, and also enjoy fast road/rail links to London, the Midlands and the West Country. RELOCATION ASSISTANCE MAY BE AVAILABLE.

Qualifications

Candidates must possess a TEC/SCOTEC Certificate in Electronics, Telecommunications or similar discipline; or a City and Guilds Part II Telecommunications Technicians Certificate, or Part I plus Mathematics B, Telecommunication Principles B, and either Radio Line Transmission B or Computers B; or equivalent. Preference may be given to candidates with higher qualifications. Senior ex-service personnel with formal approved Service technical training may also be considered.

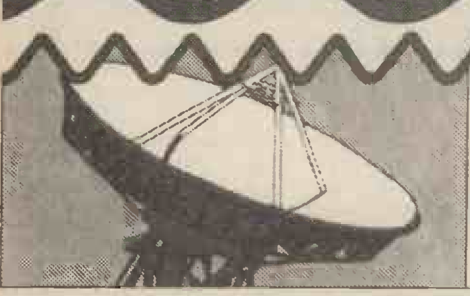
In addition, all candidates must have had appropriate training and will normally be expected to have about 4 years (lower level) or 7 years (higher level) experience in either radio communications transmitters or receivers, radar, data transmission, computers or similar electronic systems. High technical competence and/or proven managerial experience is also required.

Salaries up to £9085

Higher level posts: £8065 — £9085; lower level posts: £5980 — £8180. Level of appointment and starting salary according to qualifications and experience. There are good prospects of promotion to posts with salaries of up to £12,650.

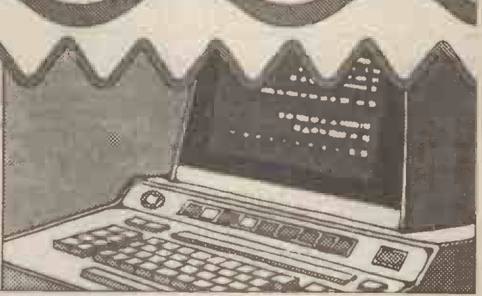
For further information and an application form (to be returned by 12 August 1982) write to Civil Service Commission, Alencon Link, Basingstoke, Hants RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours).

Please quote ref: T/5792/2.



GCHQ

in the heart of the Cotswolds



CCTV SERVICE ENGINEER

required to carry out repair and maintenance on all types of surveillance equipment. Salary commensurate with age and experience.

Please write, with full C.V., to: **BOX No. 1711**

(1711)

2-WAY RADIO SERVICE TECHNICIAN

Experienced in servicing V.H.F. and U.H.F. Land Mobile Equipment, required for expanding COMMUNICATIONS COMPANY in STAINES.

SALARY: Commensurate with experience.

CONTACT: Chris Turner,

FRANK CODY ELECTRONICS LTD
STAR HOUSE, GRESHAM ROAD,
STAINES, MIDDLESEX

Or telephone Staines 62682 for an appointment.

(1701)

LECTURERS AND TECHNICAL AUTHORS

The Engineering Training Centre situated near Evesham in Hereford and Worcestershire, trains the Corporation's technical staff, both on first appointment and thereafter in the technology of broadcasting. The site is residential for students and some 400 BBC staff normally work or are in training there.

LECTURERS

Duties will involve contributing towards the operational training of Technical Staff in Television and/or Radio Broadcasting. This includes instructing Technical Operators who are responsible for sound coverage, audio mixing, camera work and lighting in Television or operating Network Continuity Suites in Radio. The Training Centre has Radio and Colour Television Studios using the latest broadcasting equipment.

Candidates, male or female, should have recent experience in some aspect of Technical Operations or Engineering in the Broadcast or Closed Circuit field and a good technical knowledge of audio or video equipment. They should preferably have a qualification of HNC, C & G Full Technological Certificate in Telecommunications, a pass in the examination of the Council of Engineering Institutions or equivalent. Consideration will be given to providing appropriate training to otherwise suitable applicants who do not hold these qualifications.

TECHNICAL AUTHORS

Engineering Training Department includes a Unit, consisting of one Senior Author and four Authors, which provides overall systems descriptions for major installations throughout the Corporation and publishes technical standards and procedures. The unit is supported in-house by a drawing office and printing facilities, together with computer based phototypesetting, word processing and graphics.

The technologies covered by Technical Publications Unit are Radio, Television, Transmission and, increasingly within these fields, computers. Authors have substantial personal responsibility to assemble and present their material accurately and in a form acceptable to users.

The successful applicant will hold a degree in electronics or a reasonable equivalent such as a Higher National Certificate, have good experience of technical documentation and a good grasp of a significant area of broadcasting technology or of a closely related field of electronics. Increasing versatility across the whole field will be expected as experience grows. Appropriate training, including areas of broadcasting technology, will be provided if necessary.

Salary on appointment, for both positions will be between £9,435 and £10,293 rising to £12,254.

Excellent welfare and club facilities. Pensionable posts. Relocation expenses considered.

For an application form and further information about the Technical Author vacancy please contact **Head of Training Section (Engineering), Mr J H Brooks;** those interested in the Lecturer vacancy, please contact **Head of Training Section (Operations), Mr D G Enoch. BBC Engineering Training Centre, Wood Norton, Evesham, Worcs WR11 4TF. Telephone Evesham 45123.**

Closing date for return of application forms is 14 days after publication.

BBC

(1723)

£25,000?

1. DESIGN ENGINEER
RF test equipment including VSWR test sets, frequency standards and RF measuring instruments for a small successful company. £ Negotiable – West Country.

2. TEST ENGINEERS
To test and service VHF and UHF transmitters and receivers – several clients. To £8,000 – Hants/Berks.

3. RF DESIGN ENGINEERS
To join a small team designing microprocesspr-based signal sources. To £11,000 – Herts.

4. PROJECT LEADER
To head team engaged on microwave development, UHF/VHF techniques, microstrips and mixers. To £14,000 – Herts.

5. ELECTRONIC ENGINEERS
Development of digital-based intruder detection equipment. To £8,000 – Surrey.

6. DESIGN ENGINEER
To design all stages of microwave and satellite communication systems from base band to 6GHz. To £10,000 – Essex.

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87 St. Leonard's Road
Windsor, Berks.
Windsor (07535) 57818/58022
24-hour service (1640)

CLIVEDEN

UNIVERSITY OF EAST ANGLIA
Norwich

ELECTRONICS TECHNICIAN

Required to be responsible for the Electronics Workshop in the School of Mathematics and Physics. The workshop offers technical support to research and teaching in physics and electronics systems engineering. The successful applicant's responsibilities will include:

(i) the organisation and general supervision of the workshop;

(ii) the design and construction of digital and analogue circuits;

(iii) the repair and modification of electronic equipment including microcomputer systems.

Applicants must hold a suitable qualification in electronics, be able to work with minimum supervision and have substantial experience of modern electronic engineering techniques.

Salary on the Grade 7 scale £7,605-£8,542 per annum.

Application forms and further particulars can be obtained from the Senior Administrative Assistant, School of Mathematics and Physics, University of East Anglia, Norwich NR4 7TJ, to whom applications should be returned by 5 July, 1982.

1692

ecm

ALWAYS AHEAD WITH THE BEST!

£5,000-£15,000

★ **Experienced in:**
Mini/Microprocessor Hardware and Software Digital and Analogue circuitry; RF and Microwave techniques?

★ **Where does your interest lie:**
Image processing; Automation; Datacomms; Radar Nav aids; Mobile Radio; Medical; Telemetry; Simulation; Satcom; Lans?

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★ **Make your first call count – Contact MIKE GERNAT on 076 384 676/7 (usually until 8 p.m.)**

ELECTRONIC COMPUTER AND MANAGEMENT APPOINTMENTS LIMITED
148-150 High St., Barkway, Royston, Herts SG8 8EG.

(1734)

APPOINTMENTS IN ELECTRONICS

to £15,000

MICROPROCESSORS COMPUTERS – MEDICAL DATA COMMS – RADIO

Design, test, field and support engineers – for immediate action on salary and career advancement, please contact

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UNIVERSITY COLLEGE, CARDIFF
DEPARTMENT OF PHYSIOLOGY

ASSISTANT EXPERIMENTAL OFFICER

(ELECTRONIC INSTRUMENTATION)

CORRECTED ADVERTISEMENT

Applications are invited for the above post – design experience essential, degree in electronics an advantage. Salary range: OR Gr. IB £5,286-£8,925 p.a. – duties to commence as soon as possible. Applications (two copies), together with the names and addresses of two referees, should be forwarded to the Vice-Principal (Administration) and Registrar, University College, P.O. Box 78, Cardiff CF1 1XL, from whom further particulars may be obtained. Closing date 11th August. Ref. 2428. (1728)

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R & D AND SALES
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Electronic Engineers salaries up to £13k

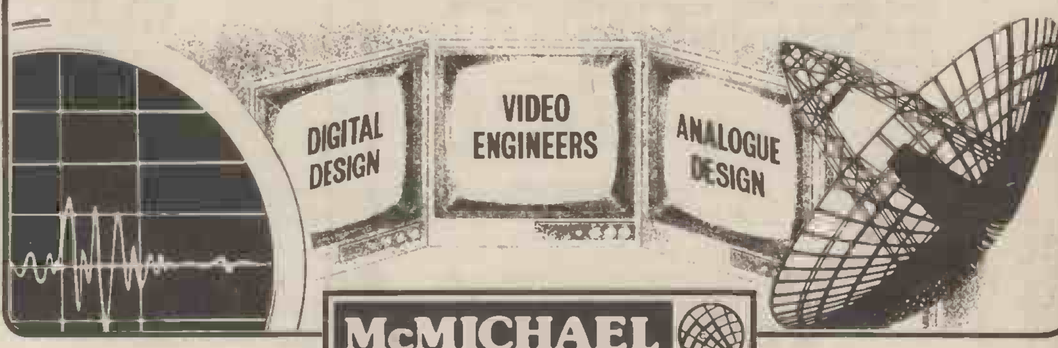
VIDEO is one of the World's fastest growing industries, and McMichael Ltd. is in the forefront of advanced video technology. We need young dynamic electronic engineers at all levels to join prestige high technology project teams.

As an analogue or digital video engineer, you would be involved in such projects as, video conferencing, broadcast effects, laser video transmission, precision displays, and other projects.

Our project teams are based at our new research and development Laboratories in Stoke Poges, Bucks., set in 37 acres of ground, with extensive sports and social facilities.

If you are experienced in high speed digital processing or analogue video, write or phone for an application form today.

McMICHAEL LIMITED
Sefton Park, Bells Hill, Stoke Poges, Slough SL2 4DY
Telephone Fulmer (02816) 2777 Telex 849212



McMICHAEL

TELECOMMUNICATION ENGINEERS

SAUDI ARABIA
C.£22,500 P.A. TAX FREE

SWITCHING SYSTEM ENGINEER
Exp. SPC switching system, analyse and evaluate tenders relating to electronic switching.
MOBILE TELEPHONE SYSTEM ENGINEER
Study requirement for new automatic mobile telephone system.
MARITIME TELECOMMUNICATIONS ENGINEER
Draw up tender specifications, coastal MF, HF, VHF stations.
COAXIAL CABLE SYSTEMS ENGINEER
Draw up tender specifications.
FREQUENCY MONITORING SPECIALIST
Study requirements for frequency spectrum management.
OUTSIDE PLANT NETWORK ENGINEER
Analyse and evaluate tenders and inspect contractors' work.
MICROWAVE SYSTEM ENGINEER
Study VHF, UHF and microwave link requirements and recommend appropriate system required.

Positions are offered on bachelor status. Candidates must be qualified to BSc. Age 35+. Leave is approx. 2 months per annum plus 3 economy excursion flights to UK. Telephone Montin (UK) Ltd on 0532-567141 for application form only or mail detailed résumé to Montin (UK) Ltd, Protection House, 83 Bradford Road, Pudsey, West Yorkshire LS28 6AT.

1700

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Ask for Paul Wallis

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(291)

FIELD SERVICE ENGINEER

LKB Instruments Limited, the U.K. subsidiary of a major international medical/scientific instrument company require a Field Service Engineer for their Customer Service Department.

Applicants should have a sound knowledge of digital and analogue electronics, with preferably some field experience in the scientific instruments world.

The work entails the repair and maintenance of instruments situated mainly in Hospitals and University Laboratories. Preference will be given to applicants living in the Gloucester to South Birmingham area.

Conditions of employment are excellent and in addition to a good basic salary and company car, the company have a profit sharing scheme, BUPA participation and 4 weeks annual holiday.

LKB

Contact Mrs S. Francis for application forms:-
LKB Instruments Limited,
232 Addington Road,
Selsdon,
South Croydon,
Surrey, CR2 8YD.
Tel: 01-651 5313

(1716)

UNIVERSITY OF OXFORD
DEPARTMENT OF ENGINEERING SCIENCE

GRADUATE ENGINEER

IN CHARGE OF THE ELECTRONIC SERVICES DIVISION

A graduate engineer is required to direct the Electronic Services Division, which provides the supporting services for the Department's research and undergraduate teaching. The person filling the post should have a proven knowledge and experience of advanced electronic technology, the ability to anticipate future developments in this field, to supervise the design of both analogue and digital electronics, including the hardware and software associated with the development of microprocessor-based instruments, and to advise research staff on how best to use this technology to advance their research.

The position also involves the management and administration of the electronic services staff, comprising at present three research assistants (Electronic Design Engineers) and five technicians, who are responsible for:

(i) design and construction of electronic circuitry;
(ii) servicing and modification of existing equipment;
(iii) operation of the departmental electronic stores.

The person appointed will also be required to supervise any laboratory stewards working in this field, the safety checking of electrical equipment and the control of the electronic section of the inventory. He/she will be expected to contribute to the teaching and future development of the microprocessor laboratory.

The position is on the University Research Support Staff Grade II Scale with a salary range from £9,750-£12,860 with superannuation on the USS Scheme.

Application should be made to the Administrator, Department of Engineering Science, Parks Road, Oxford OX1 3PJ, enclosing a detailed curriculum vitae and the names and addresses of three persons to whom reference may be made.

(1699)

MANY FIRMS ARE THROUGH THE RECESSION AND RECRUITING AGAIN

PROJECT MANAGER
VLF and LF equipment for helicopter systems control. Integration of program and cost data. Liaison with clients, etc. Experience in radio communications environment essential. Berks. To £12,500.

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For new high technology computer peripheral equipment with a resident basic interpreter. Many advanced design concepts. Experience Z80/8080 SW essential. Berks. To £10,000.

YOUNG ENGINEERS
For designs associated with processing low-noise signals, displays and control circuitry for a new thermal imaging system. Essex. £6,000-£8,000.

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To design non-broadcast TX up to 5 MHZ 20 KW for very advanced medical diagnostic instrumentation. Greater London. To £11,000.

ASSISTANT COMMUNICATIONS MANAGER
For large international L Comms. network, including FDM, TDM, Facsimile and voice staff supervision and hardware development client liaison – European travel. London. To £12,000.
Whatever your experience send your CV or ring:

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Tempo House, 15 Falcon Road, Battersea
London SW11 2PJ
Tel. 01-223 7662 or 228 6294

(1357)

UNIVERSITY OF YORK

Department of Electronics

1 post of Technician Grade 6
2 posts of Technician Grade 3

Applications are invited for the above posts in the new Department of Electronics.
The Chief Technician (Grade 6) will be required to set up and run the Research Laboratories and will be responsible for the development, provision and maintenance of equipment and services needed by staff and students working in communications, control engineering and microelectronics. A degree, HNC or equivalent qualification is required, together with extensive experience of electronic engineering, including computers.
Salary for Grade 6 on Scale £6,532-£7,802 p.a. (under review).
One Grade 3 Technician will be required to assist the Chief Technician in the research laboratories and the other Grade 3 Technician will assist the Senior Technician running the teaching laboratories. For appointments at this grade a degree or a minimum of 2 "A" levels plus some experience is required, but applicants with "A" levels without experience may be appointed at a lower grade and given training.
Salary for Grade 3 on scale £4672-£5473 p.a. (under review).
Applications in writing, giving full details of age, education and experience, together with the names and addresses of two referees, should be sent to Mrs. E. D. Heavans, Senior Administrative Assistant, University of York, York YO1 5DD, by Friday, 13th August, 1982.

(1725)

A Professional Audio Company situated in central London require a

TECHNICAL ENGINEER

interested in working with a wide range of studio equipment from video to 24-track digital recorders. Previous experience is not necessary but a good practical knowledge of electronics including digital techniques is essential. Please write giving information about yourself and for further details.

BOX NO. 1727

(1727)

R & D OPPORTUNITIES. Senior level vacancies for Communications Hardware and Software Engineers, based in West Sussex. Competitive salaries offered. Please ring David Bird at Rediffusion Radio Systems on 01-874 7281. (1162

SOUNDTRACS audio mixers require a test engineer for final product test. At least three years' experience of testing audio products in a production environment. The position entails final test, some sub-assembly approval, writing test specifications in conjunction with the design team and some post development work. Much of our sub-assembly is on semi-auto jigs. Up to £8,000 p.a. depending on experience, 26 days' holiday, BUPA and other normal benefits. Todd Wells, 01-399 3392 or write Soundout Laboratories Ltd., 91 Ewell Road, Surbiton, Surrey. (1710)

PART-TIME LECTURERS

Reqd. by private college to teach **ELECTRONICS and/or PHYSICS** up to A-level standard for between 7 and 15 hours per week (daytime only).

Contact City Tutorial College, 67/83 Seven Sisters Rd., London, N.7. Tel: 01-263 5937/8.

(1718)

SITUATIONS VACANT

Lecture Theatre Manager

The Institution wishes to recruit a Theatre Manager to replace the present manager who will retire shortly. The Institution of Electrical Engineers arranges approximately 200 meetings, seminars, colloquia and conferences a year in its lecture theatres at Savoy Place, London.

These lecture theatres are equipped with modern lighting and audio visual aids. The latter includes large screen projection facilities for video tapes and projection facilities for films, slides and transparencies; sound reinforcement and recording facilities; radio microphones and audio loop transmission for the hard of hearing. The facilities are subject to periodic updating and improvement.

The Lecture Theatre Manager is responsible for managing all the lecture theatres in the broadest sense by satisfying both the needs of the audience and the speakers. Will be expected to assist and advise the speakers through the correct choice and use of audio and visual aid equipment and to ensure that the audience obtain the maximum information from the lecture. Will be expected to maintain the equipment in first-class order and to make recommendations for changes and improvements, and will operate the equipment during lectures.

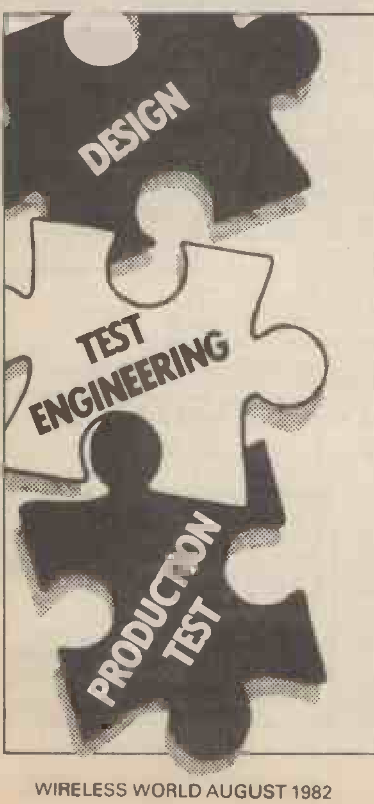
The Lecture Theatre Manager, in addition to being professionally and technically competent, should have a personality which inspires confidence in the lecturers.

We offer a competitive starting salary and other conditions of employment include: 35 hour flexible working week, generous leave entitlement, subsidised staff restaurant, and pension and life assurance scheme.

Candidates (male or female) should apply in confidence, detailing career and salary progression to the Director of Administration, Institution of Electrical Engineers, Savoy Place, London, WC2R 0BL.

THE INSTITUTION OF ELECTRICAL ENGINEERS

IEE



ELECTRONIC TEST ENGINEERING

Having introduced an extended new product range many of which are micro-processor based, Marconi Instruments has once again confirmed itself as Europe's leading manufacturer of measurement systems and automatic test equipment. Our products are selling throughout the world to all leading users in the electronics and aerospace industries and we are naturally developing further innovated designs.

A key role in our organisation is that of test engineering, where a group of professional engineers are responsible for the development of sophisticated methods and software for the manufacture of our products. We are now looking for experienced Engineers and are particularly interested if you have experience in the following disciplines:

IEEE Bus Control Systems ● ATE Programming Test Techniques

Whatever your level of experience we would like to hear from you. We can offer an excellent salary plus a wide range of company benefits, including relocation expenses where appropriate.

For further details contact Mr. J. Prodger, Recruitment Manager, Marconi Instruments Limited, Longacres, St. Albans, Herts. Telephone: St. Albans (0727) 59292 ext. 369.

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500 Kc/s – 30Mc/s 1Mhz wide. **RA17L** – £175. **RA117E** – £225. A few sets available as new at £75 extra. All receivers are air tested and calibrated in our workshop, supplied with full manual, dust cover, in fair used condition. New black metal louvred cases for above sets £25 each. **RA98D** – **ISB** – **SSB** – £75. **RA218** – **SSB** – ISB and fine tune for RA117 – £50. **TRANSMITTER DRIVE UNIT RA79**. 1.5mc/s – 30mc/s – SSB – **ISB** – **DSB** – **FSM** – **CW** – £150. **AERIAL TUNING UNIT** and protection unit **MA197B** – £25 to £50. **DECADE FREQUENCY GENERATOR MA350B** Solid state synthesiser for **MA79** or **RA117** – **RA217** – **RA1217** – £150 to £200. **MA250** – 1.6mc/s to 31.6mc/s – £150 (New). **MA259G** – precision frequency standard – 5mc/s lmc/s 100khz – £100 to £250. **RACAL MA152** – Standing wave ratio indicator. FX2mc/s – 25mc/s Power up to 1000watts – 50 ohms – Auto trip switch – Transistor mains 100 – 250AC, new and boxed – £40. **RACAL COUNTER** 836 (9036) 32mc/s **TTL** circuit design – tested with manual – £50 to £75. **OSCILLOSCOPES COSSOR CDU150** – 35mc/s – Twin Beam – Solid State – £175 with manual. **TEXTRONIC OSCILLOSCOPE** 647 and 647A Solid State – 50mc/s and 100mc/s bandwidth – £250 and £350. Tested, circuit and instructions. **AERIAL MASTS** – we have three masts approx. 130ft high, complete with all fittings. Base – insulators, etc., Mast steel tube 8" all parts galvanised, supplied brand new, all items boxed – £1000 – or each complete mast – £400.

All items are bought direct from H.M. Government, being surplus equipment. Price is ex-works. SAE for all enquiries. Phone for appointment for demonstration of any item. John's Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel. (0274) 684007. V.A.T. and Carriage extra.

MARTIN ASSOCIATES (ELECTRONICS) LTD.

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ADVANCE OS.2000 Oscilloscope Dual Beam 20MHz £185
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TELEQUIPMENT D.43 Dual Beam Oscilloscope DC–15MHz £125
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MARCONI TF.868B Universal Bridge 1% £100
MARCONI TF.2600 Sensitive Voltmeter 1mV-300V £100
PHILIPS PM.6456 Stereo Generator £195
KEITHLEY 130 Handheld Digital Multimeter... £75
GALLENKAMP ASOV 150 No. 2 OVEN £95
TAYLOR SG.62A AM/FM Signal Generator.... £95
NARDA 3020A Bi-Directional Coupler 50-1000MHz £95

The above prices do not incl. carriage and VAT

URGENTLY REQUIRED: OSCILLOSCOPES
ENVIRONMENTAL OVENS

(1384)

ENCAPSULATING EQUIPMENT FOR coils, transformers, components, degassing silicone rubber, resin, epoxy. Lost wax casting for brass, bronze, silver, etc. Impregnating coils, transformers, components. Vacuum equipment, low cost, used and new. Also for CRT regunning metallising. Research & Development. Barratts, Mayo Road, Croydon CR0 2QP. 01-684 9917. (9678)

OSCILLOSCOPES. 50 MHz, D. beam, D. timebase, N.P. Tek, etc. From £150. Marconi Siggen 200ZB AM/FM £900. Marconi DFM 2331 £230. RH Schwartz capacitance bridge £100. Advance 5-volt 40-amp switched P.S.U. £80. Oscilloscope probes, Tek/HP, etc. Wayne Kerr "Midge" –55 to 150C meter/probe £80. Please include VAT and postage. "Q" Services, 29 Lawford Crescent, Yateley, Camberley, Surrey, 0252 871048. (1695)

SCOOP PURCHASE new unused Cossor transistor testers, Model 1325, £37.50, including VAT, and postage/limited quantity/orders dealt with in strict rotation. Anchor Electronica, The Anchor, Eastwood, Notts (07737) 67281. (1694)

SAVE 33% on PCB 2H holders, in boxes of 15. Limited offer 30. Hurry and phone 0353 778756, 9 a.m. to 9 p.m. Save time. We represent over 30 leading manufacturers. Free index of hand tools and production aids. Batvale Mkt. Ltd., 50 High Street, Sutton, Ely, Cambs. Tel: (0353) 778756. (1667)

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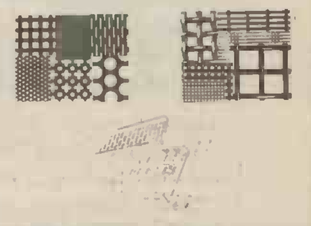

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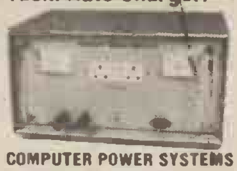

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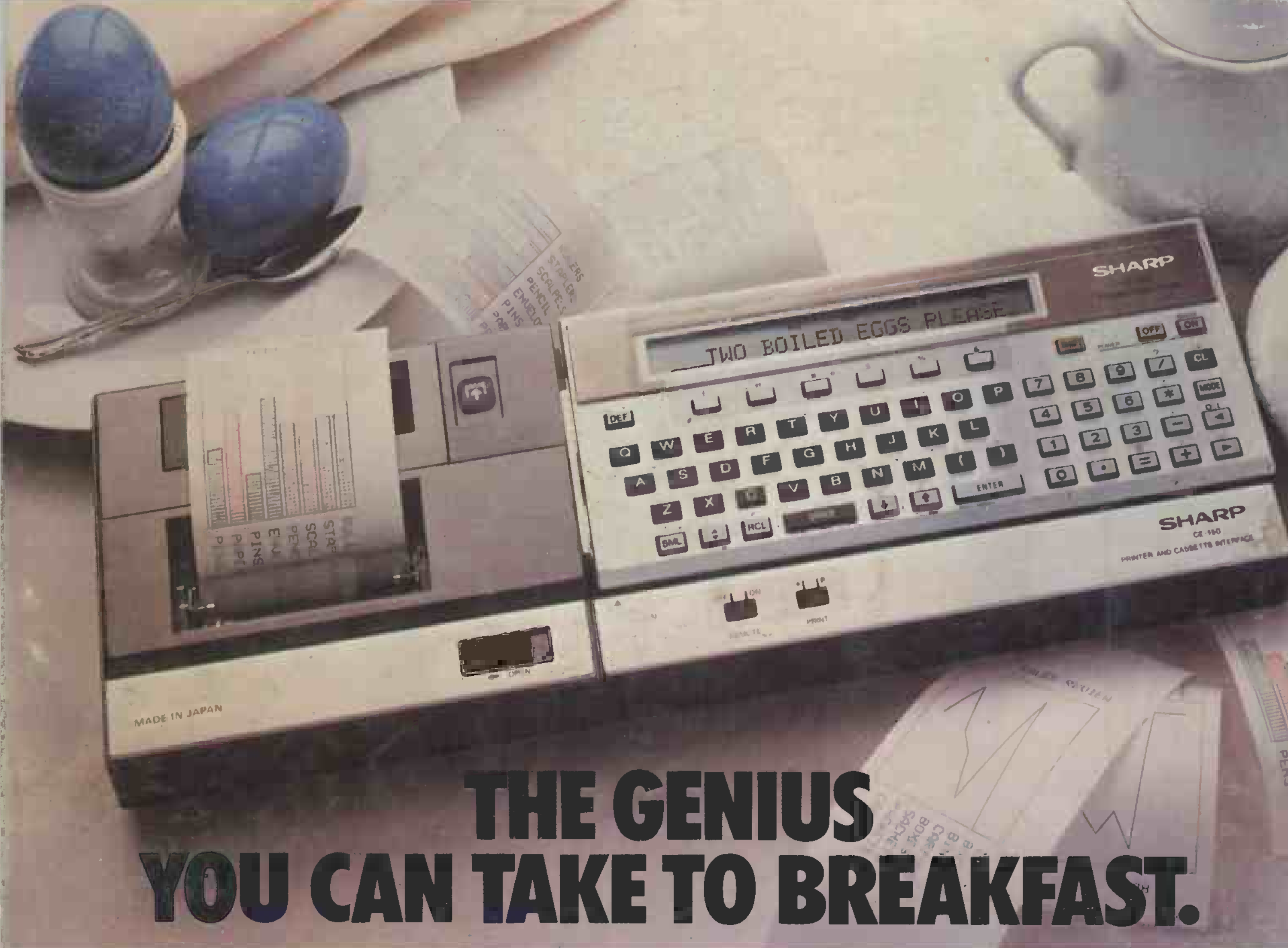

THE GENIUS YOU CAN TAKE TO BREAKFAST.

Now, at last, real portable computer power. The new Sharp PC1500 pocket computer. A pocket-sized genius that will travel with you to conferences, seminars and business breakfasts.

The PC1500 has the capacity and BASIC language usage that is very nearly that of the desk-size Personal Computer. When fitted with the optional 4-colour graphic printer, it is one of the most powerful pocket computers on earth.

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Large memory capacity, up to 11.5K bytes. 4-colour print-out. Six user-programmable keys. The incredible new PC1500. A revolution in pocket computers.

From Sharp. Where great ideas come to life.

SPECIFICATIONS

PC1500 Pocket Computer

CPU	C-MOS 8-bit CPU
Capacity	ROM: 16K bytes RAM: 3.5K bytes to 11.5K bytes

CE150 Colour Graphic Printer/Cassette Interface (Optional)

Printing Digits	Standard 18 digits (36,18,12,9,7,6,5,4 digits selectable)
Printing System	X-Y axis plotter system
Printing colours	Red, blue, green, black
Printing directions	Right, left, up, down
Cassette Interface	Up to two cassette tape recorders can be connected.

Please send details of the Sharp PC1500

Type of application: ____________________

Name: ____________________

Address: ____________________

WW I

The world of SHARP where great ideas come to life.

Sharp Electronics (UK) Ltd, Computer Division, Sharp House, Thorp Road, Newton Heath, Manchester M10 9BE. Telephone: 061-205 2333

Design and specifications subject to change without notice.

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