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Innovation for irrigation

Technology has by-passed the poorer nations of the world – the Third World – and, since the growth of technology is self-fuelling, the relative densities of technological ground cover in northern/western and southern/eastern areas cannot, without some serious commitment, even begin to approach each other.

Differences in attitudes and scale are well known, but remain to beggar the imagination. On a small canvas, there is the contrast between a difficulty in choosing one's new video recorder and a decision on whether to eat today or tomorrow. Larger in scale but possibly no more resistant to the western imagination are the agonies of decision between the types of power station to build for the next century and the hope that some day it might be possible to contrive a supply of water for irrigation and drinking.

All this has been in the western consciousness for many years but, in the main, that is where it stays. There is a great amount of talk about the provision of technological help for the backward nations, but precious little emergent hardware. It may be that the talk is about the wrong kind of help anyway. When a nation's need are so very basic, discussion on the frequencies to adopt for its very own satellite television broadcasting system can appear sensationally irrelevant to the churlish, who have their eyes and feet on the undernourished ground.

Yet, technology encompasses everything from the manufacture of toothpicks to interplanetary travel: it ought not to be totally impossible to channel some of the effort that goes into the production of equipment that offers only slight modification of the western way of life, such as the enormous output of domestic electronic entertainment, into small and relatively simple projects that would make a huge difference to someone trying to scrape a living from the parched earth.

Without a doubt, funds raised by the wholely praiseworthy efforts we have seen in the last few years have been desperately and instantly needed for "first-aid" relief of famine and disease and it is galling to learn that the difficulties of distribution and political manoeuvrings sometimes frustrate the efforts of relief organizers to put the aid where it is needed.

Since it seems inevitable that some small fraction of such funds will always be lost in this way, it may be that a little could be "officially" deducted and used to finance some kind of longer-term assistance in the form of the development of low-tech equipment to answer the call for better agriculture, power generation, communication, medical care, water purification and much more.

It is possible that our own branch of engineering could offer solutions to some of the problems – communication and power generation, for example. One wonders what would be the effect if one hundredth of the effort that goes into the launching of one television broadcasting satellite were used to reduce the incidence of future famine and pestilence by the development of a little practical, simple, reliable and affordable technology.

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Programming p.l.ds

Design and implementation of a low-cost microprocessor-controllable programmer for fuse-link logic.

V. LAKSHMINARAYANAN

Many logic tasks are too complicated for s.s.i./m.s.i. devices and too simple for a microprocessor. Custom chips reduce the number of components in the logic system but designing them can be a long and expensive process, which deters many would-be users.

Programmable logic devices, p.l.ds, provide an optimum solution for most medium-complexity logic and control-sequence applications. They combine programming flexibility with high speed and an extensive selection of interfacing options and they cut costs by reducing inventory, package count and p.c.b. size. Compared with custom i.cs, p.l.ds have a very much shorter design time.

Programming a p.l.d. involves selectively fusing NiCr links by applying specific voltage levels to the device inputs and outputs. This article describes the design and implementation of a programmable logic device (p.l.d.) programmer for Signetics PLS100/101 field-programmable logic arrays.

The programmer has bus-structured i/o for connection to a microprocessor. Being microprocessor controlled, the design can easily be modified to suit many other types of fusible-link p.l.d.

A CLOSER LOOK AT PLDS

The PSL100, with three-state outputs, and the PLS101, with open-collector outputs, are bipolar programmable logic arrays with 48 And product terms and 8 Or sum terms. Each Or term controls an output function which can be programmed to be either true or false. True represents active high (F_p) and false represents active low (F_p*).

For each output function, the true state is activated by any logical combination of 16 input variables, or their complements, for up to 48 terms. To implement the desired logic, the And and Or matrices and the output polarity have to be programmed.

Figure 1, the logic-equivalent path of the p.l.a., shows that each input variable is present in both true and complement forms. In the And matrix, there are 48 And gates, each with 32 inputs designated I_{0-15} and $\bar{I}_{0-15}$. The And matrix produces 48 outputs, P_{0-47}, each of which is a logical product of the input variables.

Symbolically, $P_i = I_j I_k$, where i is 0 to 47, j is 0 to 47 and k is 0 to 15. For example, output from the seventh And gate could be,

$$P_7 = I_0.\bar{I}_2.I_7.\bar{I}_8.\bar{I}_9.I_{15}. \qquad (1)$$

Outputs of the And gates connect to Or gates to obtain the sum terms. Each Or gate has 48 inputs, P_{0-47}, from the And matrix. Eight sum terms, S_{0-7}, each of which may be a logical combination of up to 48 P terms, are produced by the Or matrix so,

$$S_i = \sum_{j=0}^{47} P_j$$

where i is 0 to 7. Output of the second Or gate for example could be,

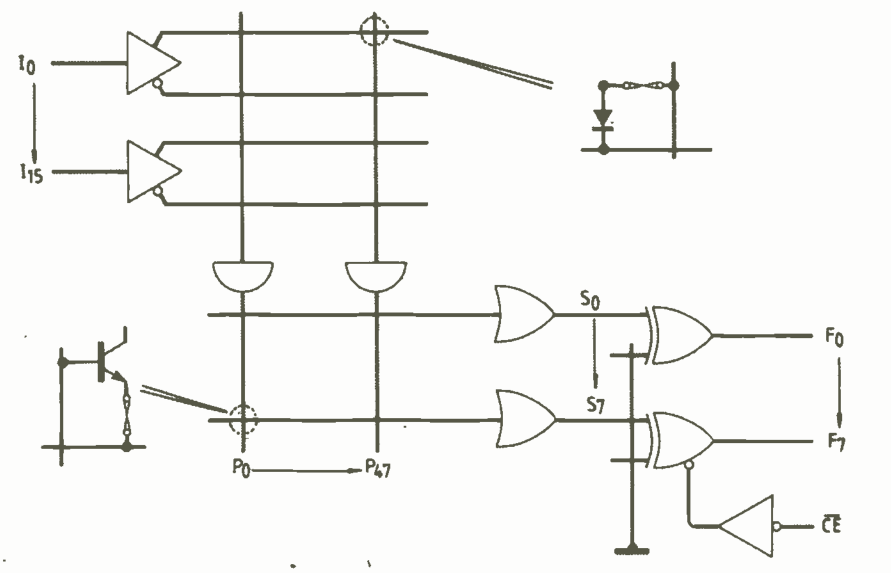
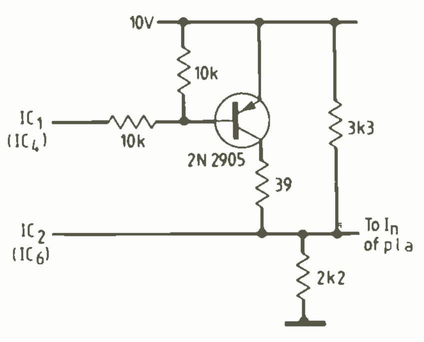


Fig. 1. Logic-equivalent path of the fuse-programmable logic array.



TRUTH TABLE

$IC_{1,4}$	$IC_{2,6}$	I_n
0	1	10V
1	0	0
1	1	4V
0	0	Not Allowed

TRUTH TABLE

D_0	D_1	D_2	D_3	FE
1	1	1	0	0
1	1	0	1	1.5V
1	0	1	1	4.V
0	1	1	1	17V

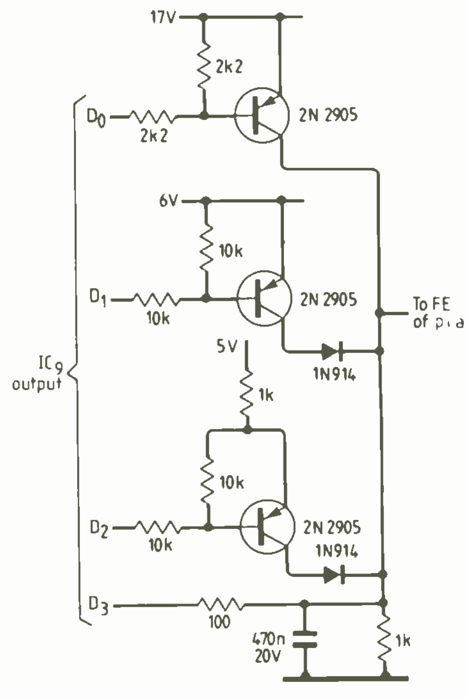


Fig. 2. Programming-voltage switching circuits. (a) is for lines I_{0-7} and (b) is for V_{FE}.

$$S_2=P_1+P_3+P_7+P_8+P_{33} \qquad (2)$$

Each output from the Or matrix can be programmed either active low or active high:

$$F_i=\overline{CE}+S_i$$

represents active-high programming and,

$$F_i{}^*=\overline{CE}+\overline{S}_i$$

represents active-low programming. For example output function F_7 may be programmed active low, in which case,

$$F_7{}^*=\overline{CE}+\overline{S}_7$$

PLD PROGRAMMING

All the inputs and their complements connect through fusible NiCr links to the And gate inputs. Similarly, the And gate outputs connect through fuse links the Or gate inputs. Outputs of the Or gates connect to one set of exclusive-Or gate inputs whose inputs are also fusible links.

Programming involves fusing the NiCr links. Inputs of the And gates can be programmed in one of the following ways.

- In and $\bar{I}_n$ both absent – both links to be fused (don't care).
- I_n present and $\bar{I}_n$ absent – $\bar{I}_n$ link to be fused.
- $\bar{I}_n$ present and I_n absent – I_n link to be fused.
- I_n and $\bar{I}_n$ both present – not permitted.

Thus, in our earlier example, equation (1), the links to be fused out are, $\bar{I}_0$, I_1, $\bar{I}_1$, I_2, I_3, $\bar{I}_3$, I_4, $\bar{I}_4$, I_5, $\bar{I}_5$, I_6, $\bar{I}_6$, $\bar{I}_7$, I_8, I_9, I_{10}, $\bar{I}_{10}$, I_{11}, $\bar{I}_{11}$, I_{12}, $\bar{I}_{12}$, I_{13}, $\bar{I}_{13}$, I_{14}, $\bar{I}_{14}$, $\bar{I}_{15}$. This leaves out the essential I terms.

Similarly, other P terms can be programmed as required. Each Or term can be programmed in one of two ways,

- P_n is present–don't fuse the P_n link.
- P_n is absent–fuse the P_n link.

In equation (2) the links associated with the P terms which do not appear in the function S_n should be fused. Similarly, the other Or terms are programmed.

To summarize, all input variable links of unused P terms are not required to be fused. However, unused variables must be programmed as don't-care for all programmed P terms. Similarly, all P_n links in the Or matrix corresponding to unused outputs and unused P terms are not required to be fused.

Input data to the p.l.d. programmer consists of the logic functions that are required to be generated by the p.l.a. These functions have to be encoded in a particular manner.

PROGRAMMABLE LOGIC DEVICES

Programmable logic devices, or p.l.ds. describes a group of i.cs including programmable read-only memories (proms), programmable logic arrays (p.l.as), and programmable array logic (pals). Essentially, these devices consists of And and Or-gate arrays in a two-level architecture and are used for implementing logic functions.

A number of input variables, in both true and complement form, connect to an array of And gates whose outputs in turn connect to the inputs of Or gates. Programmable logic devices, i.e. proms, p.l.as and pals, differ in the way that their built-in logic can be used, Table 2.

Each type of p.l.d. can be used to implement Boolean equations in sum-of-product form. Programmable logic arrays are the most flexible since both their And and Or arrays can be programmed, but they are also the slowest of the three types. Programmable roms have a fixed number of inputs and outputs and do not permit any flexibility in the use of their built-in logic, but they are faster than p.l.as.

Flexibility of programmable array logic – the fastest of the three structures – is in between that of proms and p.l.as. Features such as programmable i/o pins, buried state registers and alterable clock functions make pals ideal for implementing logic functions.

There are two principal types of p.l.d., namely fuse-based p.l.ds and erasable p.l.ds. Fuse-based p.l.ds have fusible links made from materials such as nickel-chromium or platinum silicide and can be programmed only once. Like eeproms and eproms, electrically and ultra-violet-erasable p.l.ds have cell arrays that can be programmed more than once.

A virgin fuse-based p.l.d. has all its fusible links intact and is programmed by blowing open selected fuses with a p.l.d. programmer. Erasable p.l.ds have no connections at all; logic functions are programmed by selectively making connections.

For both types of programming, the fuse pattern, or map, can be produced by an assembler which translates Boolean equations in a high-level language into a low-level programming pattern.

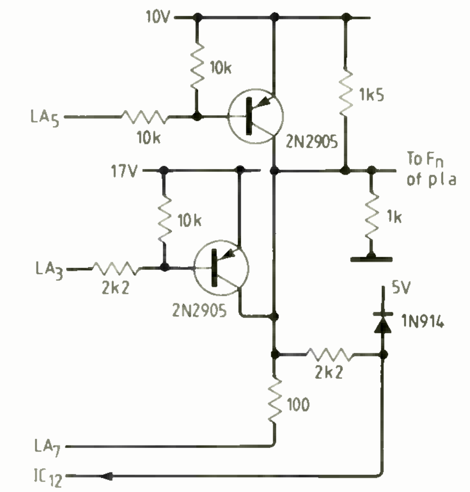
Table 2. Differences between various types of programmable-logic device.

Function	Prom	P.l.a.	Pal
And	Fixed	Programmable	Programmable
Or	Programmable	Programmable	Fixed

Fig. 3. Voltage switching. In (a) above, four voltages – 0V, 4V, 10V and 17V – are switched for output pins of the p.l.d. Three voltage levels for V_{cc} are provided by the circuit in (b) below.

TRUTH TABLE

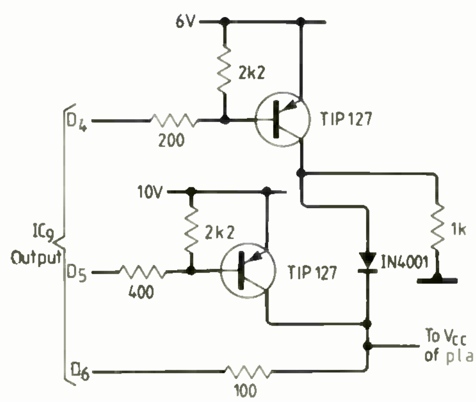
LA_5	LA_3	LA_7	OUTPUT F_n
1	1	0	0
1	1	1	4V
0	1	1	10V
1	0	1	17V



The output of the programmer is a specific sequence of waveforms which are impressed upon the various pins of the fusible-link p.l.a. These waveforms carry out the programming and the verification of the desired logic.

SYSTEM ARCHITECTURE

The complete p.l.d. programmer consists of a microcomputer, a programming module and power supplies. In my prototype a Z80-based processor with 64Kbytes of ram, a 3MHz clock and i/o ports formed the microcomputer. It communicates with the programming module through the address bus,



TRUTH TABLE

D_4	D_5	D_6	V_{cc}
1	1	0	0
0	1	1	5V
1	0	1	8.75V

ADVANTAGES OF PLDS

Programmable logic devices have the same flexible architecture as custom i.cs but they are more readily available, cheaper and easier to design.

To obtain a committed gate array or custom i.c may take several months of effort, involving the production of test vectors. An equivalent logic design implemented using p.l.ds can be completed in a fraction of the time, which in turn can drastically reduce the overall evaluation time of the product that the logic is part of.

Being standard off-the-shelf i.cs, p.l.ds retain their cost advantage when used in high-volume production. Since each p.l.d. replaces several s.s.i./m.s.i. devices, p.c.b. size is reduced. This high functional density also reduces production, inventory and testing costs.

Some p.l.ds include a security fuse which can be blown after programming to prevent access to the programming structure and hence copying of the design.

data bus and control signals i/o read, i/o write and i/o valid ($\overline{IOR}$, $\overline{IOW}$ and $\overline{IOV}$). All programming and verification of logic functions for the p.l.d. are under the control of this processor.

Software for carrying out these tasks was written in Intel 8085 assembly language. The HEX file was loaded into the microcomputer memory through a serial link from a PDP 11/40 computer. A terminal and keyboard which can communicate with the c.p.u. through CP/M kernel form the programming station.

PROGRAMMING MODULE

The programming module contains the logic and circuits necessary to produce the various voltages required for programming and verifying the p.l.d. It consists of the following sub-assemblies.

- Address-selection logic consisting of an LS85 4bit comparator and an LS138 3-of-8 decoder.
- Data latching and voltage generation circuits consisting of '07 buffers, LS374 latches and voltage-switching circuits.
- Power supplies consisting of voltage regulators for 6V and 17V, with current regulators.

Address-selection logic consists of two levels. One level selects the Programming module from the various cards connected to the microcomputer system and the other selects individual latches within the programming module. To achieve card selection, the higher nibble of the address on A_{4-7} is compared with a four-bit dip switch value in a digital comparator (LS85). If these two four-bit values are equal, and simultaneously $\overline{IOW}$ is low signifying an i/o operation, the programming module is enabled. When the programming module is selected, the comparator enables two 3-of-8 decoders which also connect to the lower nibble of the address byte, A_{0-3}. These decoders generate clock signals for the nine LS374 data latches.

In the data-latching and voltage-switching circuits, two LS245 buffers provide communication between the programming module and microcomputer. Dataflow direction is determined by these buffers, depending on whether a read or a write operation is being carried out.

Data required for voltage-switching circuits is present on the data bus only during certain times: at other times the data bus carries instructions and various kinds of data. For this reason, the data bus cannot be directly connected to the control points of the voltage-switching circuits. Nine latches connected to the data bus, $IC_{1-7,9,11}$ in Fig. 5, allow data required for voltage switching circuits to be latched from the data bus when required.

Various voltages required at the various pins during programming and verification of the programmable-logic array are shown in Table 1.

Figure 2(a) switches three voltage levels, 0, 4V and 10V, for the eight input lines I0-7. A similar-voltage switching circuit is used for the eight input lines I8-15. Fig.6. Transistors for all the voltage-switching circuits are chosen depending on the currents and voltages required.

Figure 2(b) switches four voltage levels i.e. 0, 1.5V, 4V and 17V, for V_{FE} and the circuit in Fig.3(b) switches three levels, 0, 5V and 8.75V, for V_{CC}. There are two units, one for V_{FE} and the other for V_{CC}. Data nibble, D_{0-3} controls the V_{FE} switching stage and the upper three bits, D_{4-6}, control V_{CC}. Truth tables for switching these various voltages are given in Figs.2, 3.

Latch $IC_{10,11}$ in Fig.5 has two functions: firstly it switches voltages for CE and secondly it produces control signals for the latches controlling the other switching circuits. These two functions are carried out by two four-bit latches (74LS175).

Voltage switching for CE of the p.l.a. provides three voltage levels 0, 4V or 10V. The latch enable signal generating part of this circuit produces the enable signals for the other latches. These control signals named ENC, ENF and ENI in Fig.5.

Four voltage levels, 0, 4V, 10V and 17V, required for the output pins of the p.l.a. are switched by the circuit of Fig.3(a). The truth-table for switching these voltages is also given.

Each of the p.l.d. programming-module supplies, of 5V, 10V and 25V, is rated at more than 1A. Other voltages are derived using voltage regulators as shown in Fig.4. Current output of the 17V supply is limited to 350mA using a 7805 regulator configured as a current regulator.

Figure 5 shows the complete circuit diagram of the p.l.a. programming module.

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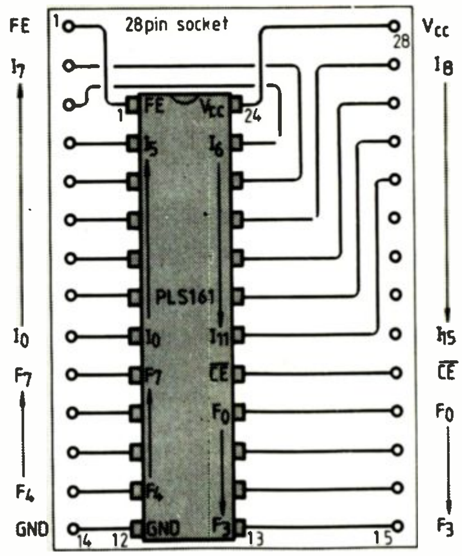
Software will be discussed in the next article.

PROGRAMMING OTHER PLDS



Device types other than the PLS100/101 can be programmed by making modifications. With minor software modifications, using a piggy-back socket like the one shown here allows 24-pin PLS161 p.l.as and PLS162/3 address decoders to be programmed.

Similar modifications facilitate the programming of common proms like the 82S23/123, which are widely used for microprocessor address decoding. Adding further latch i.cs and software to provide signals such as clocks, the PLS105 logic sequencer can be programmed.

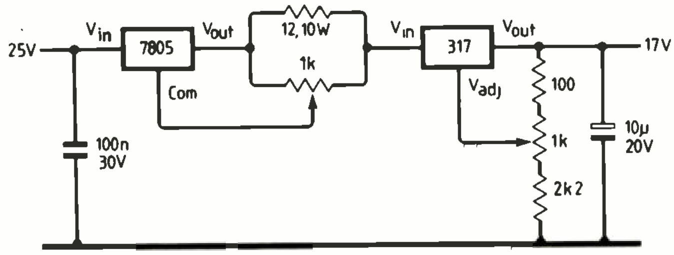


Table 1. Voltage levels required at various p.l.d. pins.

Pin name	0V	1.5V	4V	5V	8.75V	10V	17V
I_{0-15}	x		x			x	
F_{0-7}	x		x			x	x
V_{cc}	x			x	x		
V_{FE}	x	x	x				x
CE	x	x				x	

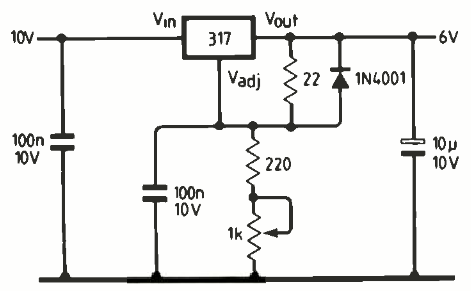
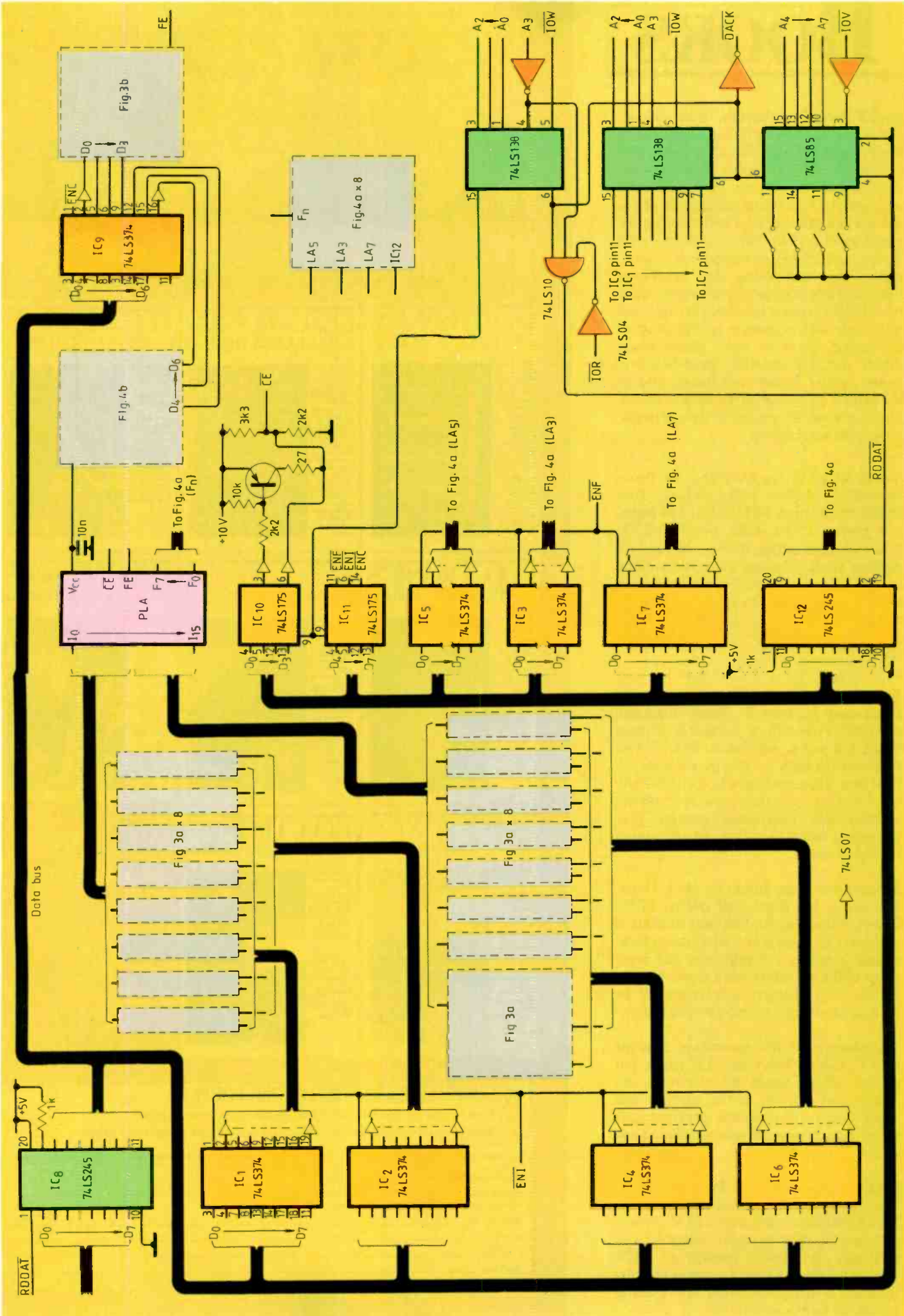


Fig. 4. Regulator i.cs provide some of the voltages needed to program the p.l.d.

Fig.6. Circuit of the p.l.d. programmer.



BOOKS

Sound Recording Practice, third edition, edited by John Borwick for the Association of Professional Recording Studios. Oxford University Press, 557 pages, hard covers, £39.50. Definitive survey for studio users and operators, covering all aspects of the subject and drawing on a variety of experienced practitioners. Topics include studio design, equipment, operation and maintenance, tape duplicating, disc processing (vinyl and CD), post-production work, radio, tv and film. Contents have been brought well up to date with references to digital signal processing, pressure zone microphones, direct metal mastering, Reed-Solomon codes, Sypher, Necam and Nicam; and on the artistic side, to matters such as microphone placing for authentic-style performances of baroque music.

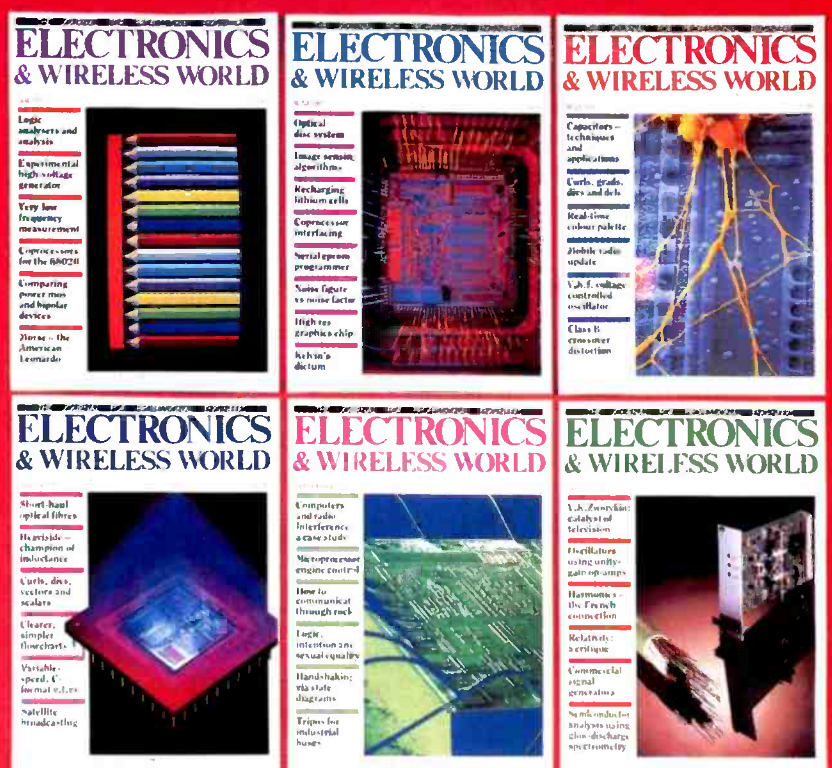
Sound Advice by Les Woodland. Jay Books (Woodside, Hadlow Park, Hadlow, Tunbridge Wells, Kent TN11 0HZ), 120 pages, soft covers, £5.50; ISBN 0-951008-65-X. Informal introduction to the radio and recording studio, dealing with interviewing and programme-making techniques as well as technical matters. The author, who is now a senior producer with the BBC, describes this as the book he wishes he'd had when he started.

An Introduction to Distributed and Parallel Processing by John A. Sharp. Blackwell Scientific Publications Computer Science Texts, 174 pages, soft covers, £14.95. Text based on the author's one-term course for final-year undergraduates at the University of Swansea. Sections cover parallel architectures, distributed systems, programming (occam etc.) and future computer architectures.

Sensors and Transducers by M. J. Usher. Macmillan, 163 pages, soft covers, £7.95. Undergraduate text for first-year students of engineering, physics and information technology, covering the principles and properties of the most important types of transducer. Each chapter is accompanied by exercises and there is a select bibliography.

Transducers for Microprocessor Systems by J. C. Cluley. Macmillan, 107 pages, soft covers, £6.95. Guide for electronic engineers and students to the selection and application of transducers, covering data acquisition, microprocessor interfacing and output devices.

Radar Systems by Paul A. Lynn. Macmillan New Electronics, Introductions to Advanced Topics, 145 pages, soft covers, £8.95. Principles and practice of radar systems, with particular attention to modern air traffic control radars. The closing chapter includes technical details of existing and planned systems in Europe and the US.



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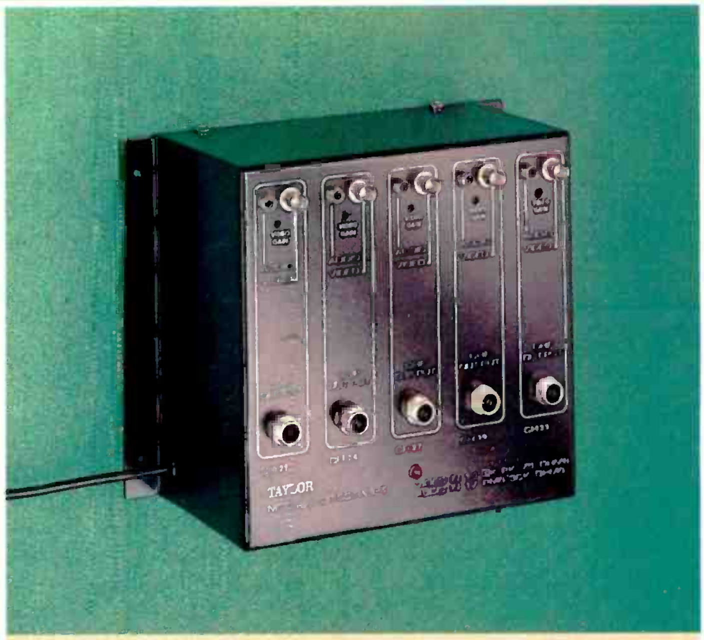

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Output	– 6dBm V (2m V) 470-860MHz
Modulation	– Negative
Audio Sub-Carrier	– 6MHz or 5.5MHz
Frequency Stability	– 15 Deg temperature change 150KHz
Intermodulation	– less than 60dB
Sound Pre-Emphasis	– 50us
Double Sideband Modulator (unwanted sideband can be suppressed using TCFL4 Combiner/Leveller)	

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Radio frequency link budgets

An understanding of the principles provides a powerful, accurate and quick method of analysing the type of system needed to achieve a specific link.

M.L. CHRISTIESON

For any radio communication link, the basic requirement is that the received carrier is strong enough for us to recover the information modulated on it. The exact signal to noise ratio needed of course depends on the type of modulation and the design of the demodulator.

It is very useful to be able to calculate the carrier, or pre-detection, signal-to-noise ratio from parameters such as transmitter power and receiver antenna gain. This technique is called a link budget calculation – a budget, because the various parameters represent gains and losses. Increasing antenna size and transmitter power are 'gains' or 'profit', while increased distance and receiver noise are losses. The aim of the calculation is to find out if a system is good enough without going to the expense of building it.

First of all, we can calculate the amount of power arriving at the receiving site. Obviously this depends on the transmitter's effective isotropic radiated power (e.i.r.p.) which is simply the r.f. power multiplied by the transmitting antenna gain. All antenna gains are referred to a theoretical isotropic radiator. Often it is the e.i.r.p. which is specified for the transmitter.

Confusion can arise from the use of decibels, but this is the simplest method because it results in manageable numbers. The convention here will be powers in dBW, i.e. decibels above or below one watt. Some parameters are expressed both as a numerical ratio and in decibels. If the ratio in decibels is R then the numerical ratio will be written as R'.

It is first necessary to calculate the path loss, i.e. the loss due to the distance between the transmitter and receiver. This can be very difficult to assess, as in an h.f. link for example; but for line of sight paths, such as satellites, it is very easy. The line of sight case will be used here but of course if a path loss model is available the method may be used more generally.

Figure 1 shows a transmitting antenna and a receiver located at a point d metres from it. Clearly all the radiated power must pass through the surface of the sphere of radius d. The power density at the receiver is simply

$$\frac{\text{radiated power}}{\text{sphere surface area}}\ \text{Wm}^{-2}$$

At point d in terms of dBW,

$$\text{power density} = P_{eirp} - 10\log(4\pi d^2)\ \text{dBWm}^{-2}$$

where P_{eirp} = transmitter effective isotropic radiated power.

The parameter needed is therefore the distance between the transmitter and receiver. This may be known directly but in the case of a satellite it may be calculated from the orbit height and the elevation. This distance is sometimes called the slant range. The application of the sine rule to the orbit geometry yields

$$d = \text{slant range} = \frac{\cos(E+H)\,(R_e+h)}{\cos E}$$

$$\text{where } H = \sin^{-1}\frac{R_e \cos E}{R_e + h}$$

R_e = earth radius
h = height of orbit
E = elevation from horizon of satellite from station

Note that the equation for path loss requires d in metres.

The amount of power collected by the receiving antenna depends on its effective aperture. For a dish the concept of aperture is easy; but it is not so obvious in the case of, for example, a dipole. However antenna gain and aperture are related thus –

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

where G' is the numerical gain, A the effective aperture in square metres and λ the wavelength in metres.

With this relationship any antenna, the gain of which is known, may be used. If the aperture size is to be used directly a correction must be made for efficiency which for a reasonable reflector varies between 50 and 80 per cent.

At this point the signal power, P_S, available at the output of the antenna terminals can be calculated.

$$P_S = P_{eirp} - 10\log(4\pi d^2) + 10\log A\ \text{dBW}$$

Since signal-to-noise ratio is the ratio of signal power to noise power all that is now needed is the noise power. However this is not as easy as it sounds.

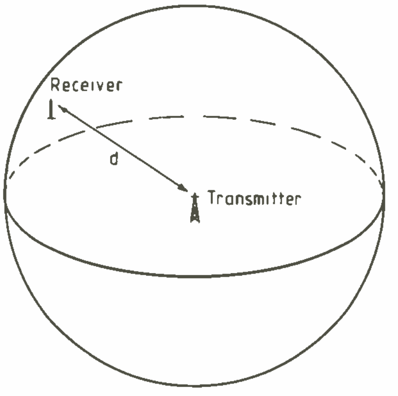


Fig.1. A receiver is located d metres from a transmitter. All the power radiated by the transmitter passes through a sphere of radius d. Power density at the receiver is therefore equal to the radiated power divided by the sphere's surface area.

BANDWIDTH CONSIDERATIONS

It was not necessary to consider bandwidth while calculating the signal power, except that we assumed it to be sufficient to allow most of the signal through. However as noise is considered to have a constant power per unit bandwidth, noise power is proportional to bandwidth. Rather than state the bandwidth at the start of the calculation it is easier to calculate the noise power in a 1Hz band and correct at the end. The noise powers involved are rather small but by using the concept of noise temperature we can make the calculations simpler and independent of bandwidth.

It can be shown that any resistor at above absolute zero temperature produces noise power proportional to its absolute temperature.

$$P_N' = KTB \text{ watts}$$

where P_N' = noise power; K is Boltzmann's constant, 1.38×10^{-23}J/K; B is the bandwidth in hertz; and T is the temperature in kelvins.

From this it can be seen that noise temperature is a measure of noise power per unit bandwidth.

SOURCES OF NOISE

There are two main noise sources: *internal*, i.e. that produced by the receiver itself, and *external*, that received through the antenna.

External noise can be from the ground, caused by electron movement at ambient temperature, or from sources in the sky and atmosphere. At low frequencies external or antenna noise dominates that produced by the receiver.

Figure 2 shows how antenna noise decreases with frequency, reaching a minimum between 4 and 6GHz. Above 6GHz it starts to rise again because of attenuation caused by water vapour and oxygen in the atmosphere. It may not be immediately obvious why it appears virtually independent of antenna gain. This is true only if noise is assumed to arrive equally from all directions. A high gain antenna receives noise strongly from one direction while a low gain one receives weakly from all directions; the result is almost the same. If a strong point source of noise, such as the sun, is in the antenna beamwidth, massive errors will result. Low gain antennas have difficulty differentiating between ground and sky noise and allowance should be made for this.

Using data such as that in Fig. 2, an assessment of antenna noise temperature (T_A) may be made although it will not be particularly accurate. Every engineer seems to use a different curve.

RECEIVER NOISE TEMPERATURE

Most readers will be familiar with the concept of noise factor or figure for amplifiers and mixers. Using the noise figures for each item in the receiving chain it is possible to calculate overall system noise performance, which can also be expressed as a noise temperature.

Individual noise figures are converted to noise temperature, thus –

$$T = 290(N' - 1) \text{ kelvins}$$

where T is the input noise temperature and N′ the numerical noise figure (i.e. not in decibels).

The whole concept of system noise performance relies on referring all individual noise temperatures to the antenna terminals. If another reference point is used it is possible to be fooled.

Figure 3 shows an example receiving system. The individual noise temperatures must be referred to the reference point and are then simply added together. A lossy element such as a cable has a noise contribution to the system and therefore a noise temperature. It is given by

$$T_C = \frac{290(1-\alpha)}{\alpha} \text{ kelvins}$$

where T_C is the cable input noise temperature and α is the numerical loss (i.e. 3dB means $\alpha = 0.5$). Since antenna and cable temperatures are already at the reference point they are ready for use.

The temperature of the first amplifier must be reduced by the 'gain' of the cable. The temperature of the second amplifier is reduced by all the preceding gains, i.e. the cable and amplifier one. The mixer temperature is reduced by the gains of the cable and amplifiers one and two. This is why, providing that the first amplifier has significant gain, the noise performance of subsequent stages is not so important.

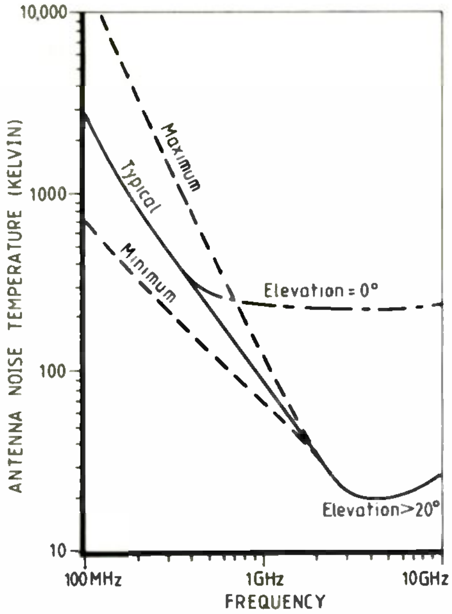


Fig. 2. Antenna noise decreases with frequency, falling to a minimum at about 5GHz.

Thus the system noise temperature T_s is

$$T_A + T_C + \frac{T_1}{\alpha} + \frac{T_2}{(\alpha)(G'_1)} + \frac{T}{(\alpha)(G'_1)(G'_2)} \text{kelvins}$$

Note that gains are numerical ratios, not expressed in decibels.

T_s may now be converted to noise power using $P_N = KT_s B_N$ watts where K is Boltzmann's constant and B_N is the noise bandwidth.

Noise bandwidth will depend on the modulation and signal bandwidth: in the simplest case it equals the signal bandwidth. It may be less, for example, in the case of frequency demodulation using a p.l.l.

Since both signal and noise power are now known, the signal to noise ratio, SNR, may be calculated:

$$SNR' = \frac{\text{signal power}}{\text{noise power}}$$

where SNR′ is the numerical signal to noise ratio.

As the signal power was calculated in dBW the noise power should be converted,

$$P_N = 10 \log P_N'$$

therefore $SNR = P_S - P_N$.

REARRANGING EQUATIONS

The equations stated so far can now be collected together to produce a single relationship for predetection signal to noise ratio

Since $SNR = P_S - P_N$, SNR=

$$P_{eirp} - 10 \log (4\pi d^2) + 10 \log A - 10 \log (KT_S B_N)$$

Using the relationship between gain and aperture for an antenna,

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

then

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

Expressing the gain in dB, i.e. 10 log G′, then

$$10 \log A = G + 10 \log \left(\frac{\lambda^2}{4\pi}\right)$$

and so the signal-to-noise ratio is given by

$$P_{eirp} - 10 \log (4\pi d^2) + G + 10 \log\left(\frac{\lambda^2}{4\pi}\right) - 10 \log (KT_s B_N)$$

Collecting terms, SNR can be expressed as

$$P_{eirp} + G - 10 \log T_s - 10 \log K - 10 \log B_N - 10 \log \left(\frac{16\pi^2 d^2}{\lambda^2}\right)$$

The last term is often referred to as the path loss as it is the loss between two isotropic antennas. Note that it is frequency dependent because the relationship between gain and aperture is frequency dependent.

The second and third terms are often combined, called 'G over T', and used as a measure of receiver performance, i.e. $G/T = G - 10 \log T_s$. Note that the value has no physical meaning.

A specific G/T may be produced by a high gain antenna and a poor receiver or by a low gain antenna and a good receiver. Note that the lower limit for T_s is T_A.

Another term often encountered in the literature is C/N_0 or C/KT. This is the predetection signal to noise ratio in a theoretical 1Hz bandwidth and is a useful measure of link performance independent of signal bandwidth, i.e. C/N_0 or $C/KT = SNR + 10 \log B_N$.

This means that

$$C/N_0 = P_{eirp} + [G/T] - 10 \log K - 10 \log L_P$$

where G/T is expressed in dB/K.

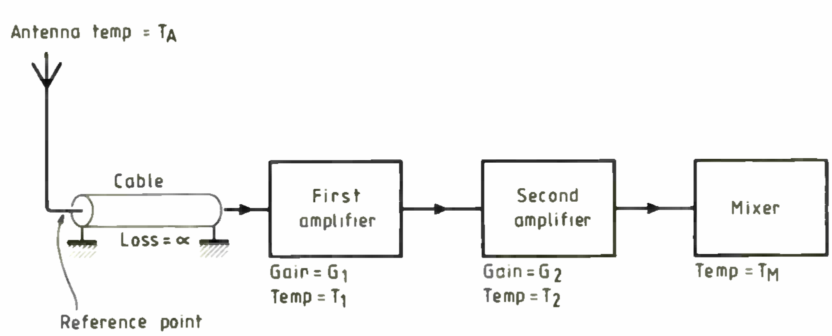


Fig.3. Example receiver system. Individual noise temperatures must be referred to a reference point then they can simply be added together.

```
10 'Link budget estimating program system
25 'Earth radius
30 RE=6378
40 PI=3.14159
45 'radian/degree conversion constants
50 CDR=PI/180
60 CRD=180/PI
70 PRINT: PRINT: PRINT: PRINT
80 PRINT"LINK BUDGET CALCULATION SYSTEM"
90 PRINT: PRINT: PRINT: PRINT
100 INPUT"Enter orbit height, 35798km for
   geostationary satellites";H
110 INPUT"Enter elevation of satellite,
   degrees";EL
120 EL=EL*CDR
125 'calculate slant range
130 SINAN=(RE*COS(EL))/(RE+H)
140 GOSUB 510
150 SLR=COS(EL+ANGLE)*(RE+H)/COS(EL)
160 PRINT: PRINT: PRINT
170 PRINT"Slant range in km is "SLR
180 PRINT: PRINT
190 INPUT"Frequency in MHz";F
200 PRINT: PRINT
205 'calculate path loss
210 L=20*.4343*(LOG(SLR*F))+32.44
220 PRINT"Path loss is ";L;"dB"
230 PRINT: PRINT
240 INPUT"Enter satellite e.i.r.p. in dBW"
   ;P
250 INPUT"Enter antenna aperture diameter
   in metres";D
260 INPUT"Enter efficiency, per cent";ETA
270 ETA=ETA/100
280 LAM=300/F
285 'calculate antenna usable gain
290 UG=(4*PI*PI*(D/2)^2*ETA)/LAM^2
300 UG=10*.4343*LOG(UG)
310 PRINT: PRINT
320 PRINT"Usable antenna gain is ";UG;"dB"
330 PRINT: PRINT
340 INPUT"Enter receiver noise figure in
   dB";NF
350 INPUT"Enter antenna noise temperature
   in kelvins";TA
355 'calculate receiver temp
360 TR=290*(EXP(NF/4.343)-1)
365 'calculate system temp
370 TS=TR+TA
375 'convert to dB
380 TS=10*.4343*LOG(TS)
385 'calculate G/T
390 GOT=UG-TS
400 PRINT: PRINT
410 PRINT"System G/T is ";GOT;"dB/K"
415 'calculate C/N0
420 CNO=P+GOT-L+228.6
430 PRINT"C/N0 is ";CNO;"dB.Hz"
440 PRINT: PRINT
450 INPUT"Enter noise bandwidth in kHz";B
460 B=B*1000
465 'calculate C/N
470 CN=CNO-10*.4343*LOG(B)
480 PRINT: PRINT
490 PRINT"Carrier to noise ratio at
   detector is ";CN;"dB"
500 GOTO 70
505 'arcsine subroutine
510 ANGLE=ATN(SINAN/SQR(-SINAN*SINAN+1))
520 RETURN
```

$$L = \frac{16\pi^2 d^2}{\lambda^2} \text{ or path loss.}$$

Signal to noise ratio may be calculated once the bandwidth has been stated –

$$SNR = C/N_o - 10 \log B_N$$

A minor confusion can arise when measurements are made from a receiver. The quantity most often measured is (S+N)/N, i.e. the numerical ratio of i.f. power with the signal on and off. It may easily be converted thus,

$$SNR = 10 \log \left(\frac{S+N}{N} - 1\right)$$

At low ratios there is a significant difference between the two, but over about 10dB they are approximately the same.

USING THE EQUATIONS

One of the best ways to use these relationships is on a computer or programmable calculator. This enables many permutations to be tried in the time it would take to do one by hand. The listing shows a simple Basic program which has been most useful. It uses only the simplest Print statements so it could be viewed as crude; but, in its defence, it should work on most machines.

As can be seen from the equations, the level of mathematical skill required to work on link budgets is not great. But an understanding of the principles provides a powerful, accurate and quick method of analysing the type of system required to achieve a specific link. It has been used many times on satellites like Meteosat, Tiros-N, ECS and Intelsats at v.h.f., S band, C band and Ku band. The results have always been accurate to within a dB or so.

Mike Christieson is with Feedback Instruments at Crowborough in Sussex. His previous articles for Electronics & Wireless World *have dealt with the theory and practice of parabolic dish antennas and the reception of images from weather satellites.*

BOOKS

Major Advances in Parallel Processing edited by Chris Jesshope (of the University of Southampton). Technical Press – Unicom Applied Information Technology Reports series, Gower Publishing (tel. 0252-331551), 388 pages A4, soft covers, £50 (ISBN 0-291-39728-X). Major sections cover new technology; system architectures; parallel languages; methods and applications; and the marketplace for parallel computers. Appendices summarize products from Amdahl, Apollo, BBN, Concurrent Computer, Control Data, Convex, Encore, Flexible, Goodyear, Intel, Logica, Marconi, NCUBE, Norsk Data, Numerix, Sension, Sequent, Stonefield and Topexpress. The 27 articles are by various hands (mostly British) drawn from industry and higher education. Other volumes in this series deal with fourth generation languages, computer-controlled interactive video, expert systems and computer graphics.

Television & Radio 1988; Yearbook of Independent Broadcasting, edited by Mike Melaniphy. Independent Broadcasting Authority, 190 A4 pages, £5.90. Review of the year's activities on Britain's commercial radio and television networks, extensively illustrated. Engineering matters are confined now to just 10 pages (the useful transmitter coverage maps having been squeezed out entirely), but these include brief descriptions of innovations such as d.b.s. and ITCA's experimental digital studio, plus a slightly confused account of the new 'radio teletext' services which bring Stock Market information to City financiers as they relax on their golf courses. The Yearbook's 1988 edition is to be the last: in future, Independent Broadcasting plans to promote itself in other ways.

Standards for Open Systems Interconnection by T. Knowles, J. Larmouth and K.G. Knightson. BSP Professional Books, 388 pages, hard covers, £30. Comprehensive, and comprehensible, guidebook to the International Standards Organization's ambitious OSI standards for data communication.

Detection and Classification of Ice by Edward O. Lewis, Brian W. Currie and Simon Haykin. Research Studies Press, John Wiley & Sons, 325 pages reproduced from camera-ready typescript, hard covers, £36.45. Research study into surface-based radar surveillance of ice at sea, also describing a six-year radar evaluation programme and ship trials of a new ice radar design devised by the authors. This volume, edited by John Clarke of RSRE, Malvern, is the first of a series on radar and sonar.

Quick reference guide to dBASE III Plus by Robert A. Byers. Microsoft Press, Penguin Books, 69 pages 108×280mm, soft covers, £4.95. Alphabetical guide to this database management language, with a brief description of each keyword.

dBASE III Plus by Douglas Hergert. Microsoft Press Command Performance Series, Penguin Books, 646 pages 188×234mm, £21.95. Heavyweight reference guide with over 300 alphabetical entries covering all dBASE III Plus commands and functions. Aimed at all classes of users, from casual to advanced.

Managing your business with Multiplan by Ruth K. Witkin. Microsoft Press, Penguin books, 528 pages 188×234mm, £17.95. Hands-on guide to Microsoft's spreadsheet for the IBM p.c., updated to cover release 3.0. Contents include a chapter on estimating project costs.

Puzzled Programmers by Michael Wiesenberg. Microsoft Press, Penguin Books, 254 pages, soft covers, £10.95. At first glance, this looks like the ideal Christmas stocking filler for the computer user. But the 15 stories are rather slight, and their accompanying puzzles are connected to them only loosely. (Sample puzzle: "Find all the nine-digit numbers that are perfect squares and that use the digits 1 through 9 once each".) Brief hints are given on solving each problem and full solutions are supplied in Basic, Pascal and C.

The **Loudspeaker Design Cookbook** mentioned in the October 1987 issue (page 994) is available in the UK from Falcon Acoustics Ltd, Tabor House, Norwich Road, Mulbarton, Norwich NR14 8JT. The cost is £15 including inland postage, or £15.50 to Europe; in the US, the price for the second printing of this book has been increased to $19.95. Falcon also distribute **The Audio Amateur** and **Speaker Builder** magazines plus other literature on loudspeaker design.

Electromagnetically induced atomic fission

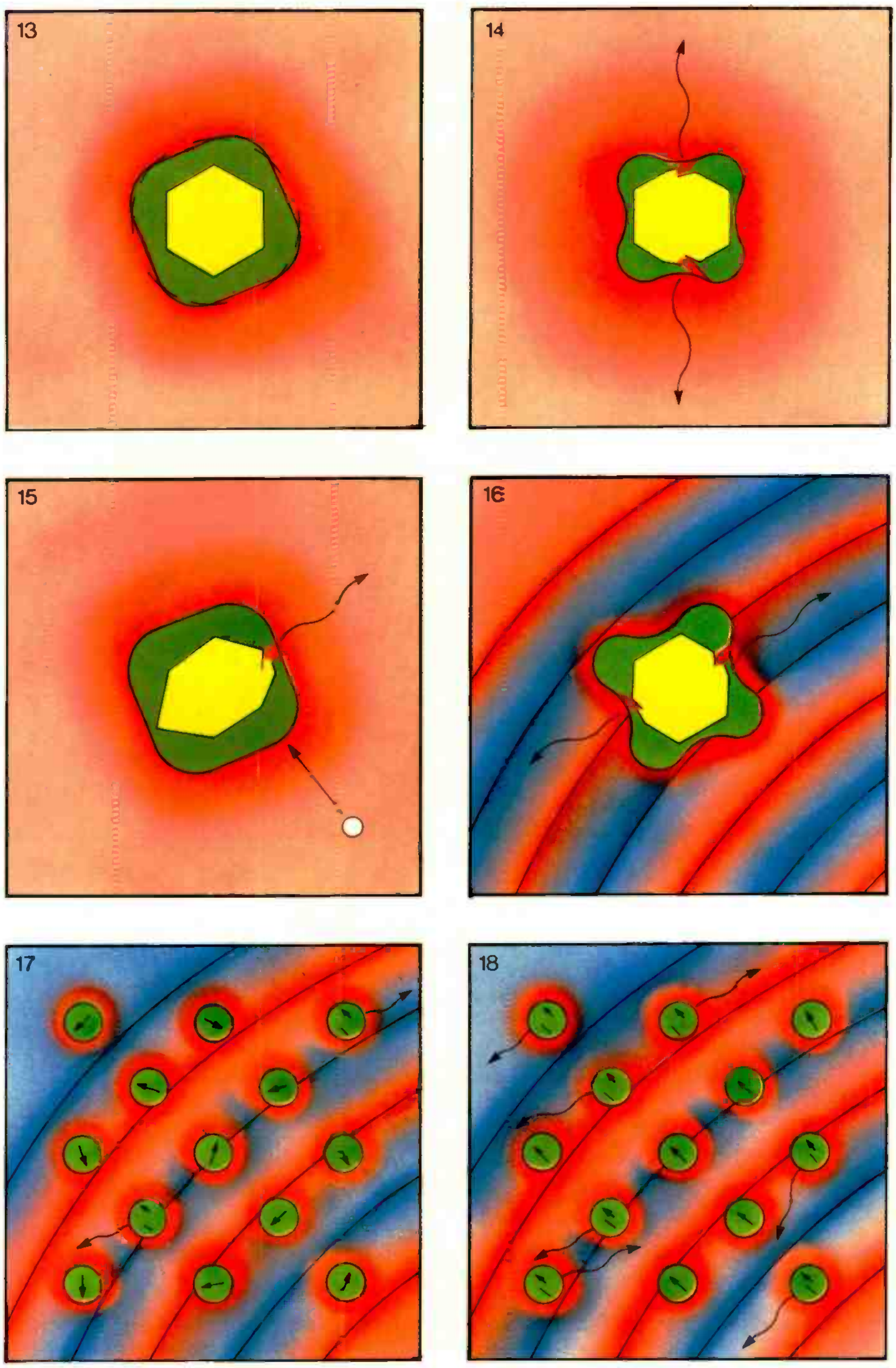
Recent developments in physical theory suggest that fission could be induced an oscillatory field rather than by the establishment of a critical mass.

CARL D. ADAMS

Scientific research can broadly be divided into three categories – theoretical, experimental, and applied. These correspond to the creation of new ideas and concepts, the testing of those concepts for validity, and the application of them, once verified, to practical uses. Of the three, theoretical research is the most abstract, and the least comprehensive, especially as regards utility, to those not directly involved. It is also the most thankless and unrewarding, at least until experimental proof is forthcoming. When the ideas being explored lie outside the accepted doctrine, neither the mathematical symbology nor a common terminology are available with which to communicate them; and, even after some degree of understanding has been developed, the reaction from others is all too often, "So what?"

For this reason, suggestions as to practical applications are essential in attracting a wider interest, without which the necessary resources for experimental investigation are difficult to find. The theoretical basis of electromagnetism has been undergoing widespread examination during the past few decades, and, despite the success of Maxwell's equations in describing the propagation of electromagnetic radiation without resource to the properties of a transmitting medium, the existence of that medium, which is denied by current thinking, can no longer be doubted. This is particularly true in biology, where the theory of formative causation proposed by Dr Rupert Sheldrake[1] has enabled biologists to frame their ideas in an acceptable manner. The many physicists who desire to see more research into theories of the ether are hampered, not only by the lack of common terminology previously referred to, but also by the aforementioned "so what?" syndrome.

Terran Research has been exploring such theories for well over a decade, but the papers which have been prepared can be of interest only to specialists; and, without some promise of practical utility, it is unlikely that a wider audience can be attracted. It is therefore the purpose of this short article to provide a simple discussion of an exceedingly practical application of ether theory, albeit one which few will have contemplated – the disintegration of atomic nuclei by electro-



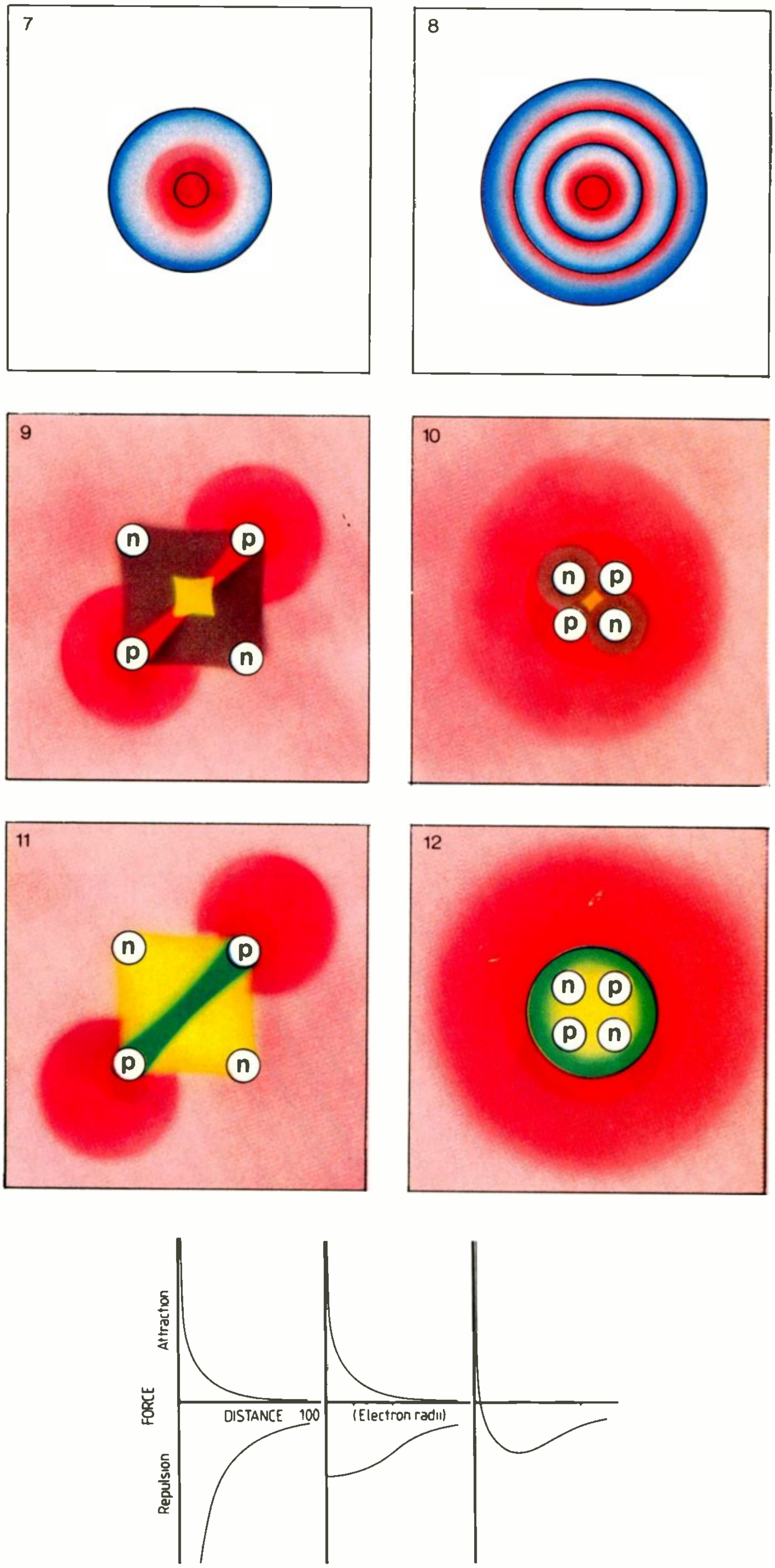


Fig.1. Conventional and modern views of forces in the atom. The graph at (a) shows the traditional "square-law" repulsive force and the attractive interaction above the axis. In the second graph, the repulsive force departs from the square law and is limited, with the result shown in the third graph that the attractive force predominates at nuclear distances to give a stable structure.

magnetic means. This process has been named "electromagnetically induced fission", and promises solutions to the most difficult problems facing the atomic energy industries – those of reactor instability and radioactive waste products.

All present-day reactors rely on the creation of a critical mass of fuel to maintain a sustained reaction, and little or no control over the by-products of reaction is possible. By stimulating fission using tuned electromagnetic fields, not only can a very small mass of fuel be utilized, but the by-products can, to some extent, be selected to produce the least toxic and shortest-lived isotopes. With the promise of such solutions available, it is hoped that far more interest and effort can be attracted to the development of ether theory.

The accompanying series of diagrams uses colour to represent the various forces under discussion, and some brief preliminary explanation is required. It is now understood that the ether is not a simple structure; it is more accurate to conceive of there being several different "aethers", or transmission media. Moreover, each of these has finite parameters; for instance, the medium which transmits electromagnetic radiation has accurately determined values of inductance and capacitance – u_0 and e_0 – resulting in a finite velocity of propagation through it. Of particular relevance to our discussion is the little-realised fact that it can only sustain a finite intensity of electric field. If a spherical body possesses a fixed electric charge, and its diameter be progressively reduced, the electric field intensity at its surface increases proportionately, not to infinity, as classical theory would have, but until a limiting value is reached. This limiting value is that which obtains at the surface of the electron and the proton, which is why they both appear to have the same physical diameter. Any internal structure possessed by these particles exists within this electric boundary, and is at present inaccessible to our experimental techniques. As will become evident, the same is true of the structure of the nucleus.

Diagram 1 shows the electric field surrounding a negatively charged sphere, the colour blue indicating negative polarity, and the intensity (or saturation) of the colour indicating the intensity of the field; the colour white therefore represents "normal" space, what may be termed unpolarized ether. Red represents opposite, or positive, polarity, as in diagram 2, and the conjunction of two opposing fields is shown in diagram 3, where the expected zone of neutrality between the fields appears in white. Diagram 4 shows how the conjunction of two fields of the same polarity results in a localized region of high field intensity. The effect of a conducting body on the field of diagram 3 is shown in diagram 5, and the increasing field intensity with decreasing diameter previously referred to appears in diagram 6.

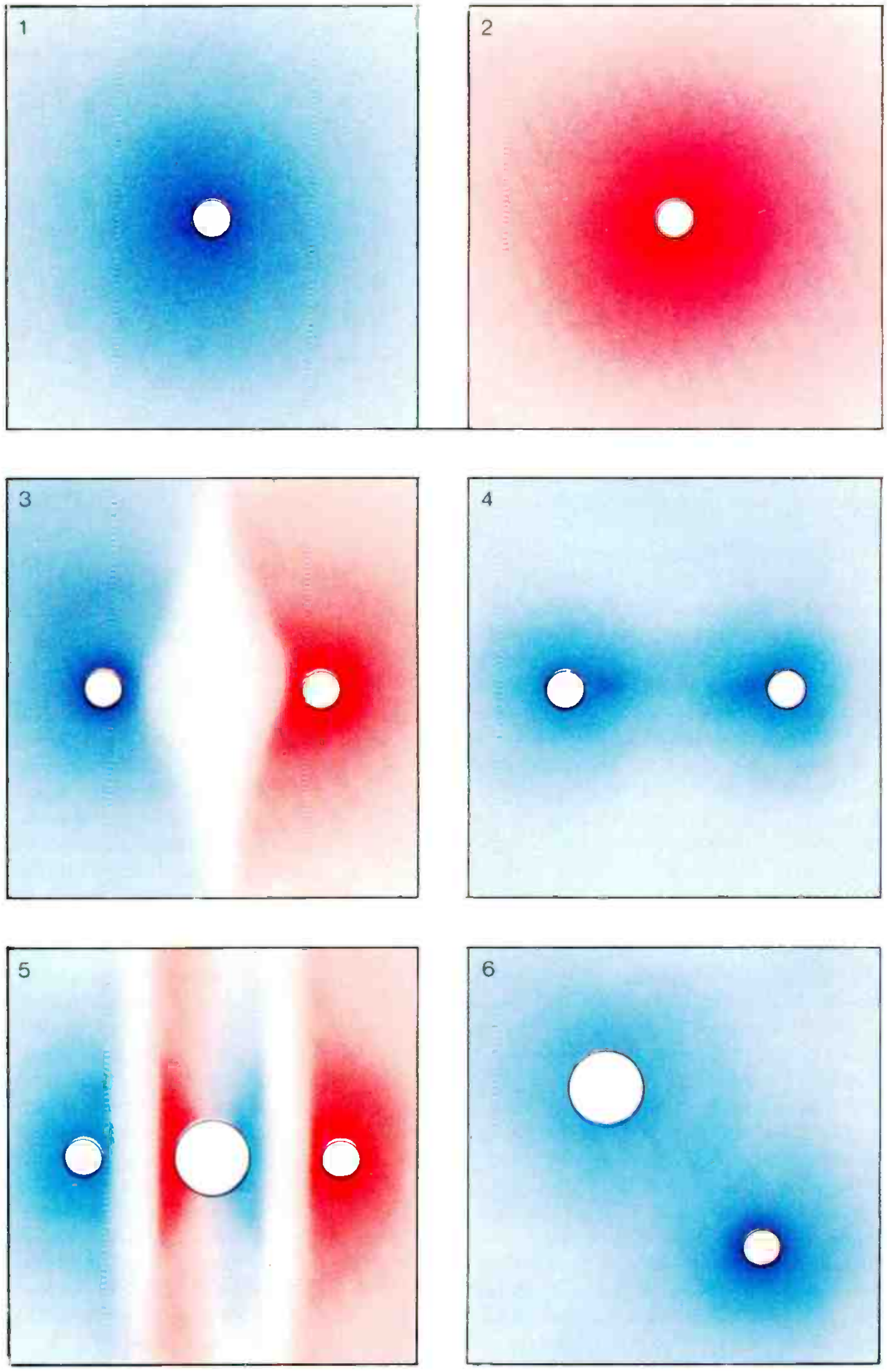
Turning to an analysis of atomic structure using these diagrammatic techniques, the electrical structure of hydrogen and helium appears as in diagram 7, and it should be remarked at this stage that the remaining diagrams have at least one major limitation

– they are static, and cannot show the continuous activity present in the real world. For this, computer-generated animation is required, and such animated sequences will soon be available from Terran Research. Diagram 8 shows the electrical structure of more complex atoms, and this too is somewhat approximate: there exists a complex series of electrical standing waves with harmonically related frequencies within the atomic field caused by the motion of the electrons, and the analysis and representation of this dynamic pattern presents a fascinating challenge.

The main point of our discussion, the analysis of nuclear structure, can now be approached, and the application of ether theory requires a consideration of the differences between the conventional model and the new one. With reference to the three graphs it can be seen that there are forces of attraction and repulsion both operating; the electrical force is that of repulsion, and the first graph shows that, according to traditional thinking, this force increases with the square of decreasing distance, so that at nuclear distances it attains an enormous magnitude, far surpassing that of the attractive force.

To explain how a stable nucleus could be formed under these conditions, a new force was invented, called *binding energy*, and later, the *strong interaction*. This force was never observed or measured – being required by theory, it was simply accepted, and has been so without question ever since. A weaker force was later found to be operating as well, the so-called *weak interaction*, and this is the force shown on the upper, attraction, part of the graph. Either theory allows us to dispense with this fictitious strong interaction, since we know that the electrical force of repulsion does not increase indefinitely, but departs from the square law curve at sub-atomic distances and approaches a finite and limiting value, as the second graph shows. The result, as is apparent from the third graph, is that, at a distance of some tens of electron radii, the weak interaction, which in reality is a force operating in another sub-stratum of ether, begins to overpower the electrical force until it dominates, giving rise to a stable nuclear structure. The weak interaction is everywhere present, not just within the nucleus, but is normally so weak as to be practically unmeasurable: those with an interest in gravitational theories will see an interesting suggestion here.

Returning to our sequence at diagram 9, we see the process of nuclear fusion as proposed by the conventional model. Four nucleons, two protons and two neutrons, are drawing together to form the nucleus of the helium atom – an alpha particle, as it is called. Although the neutrons are electrically neutral, the protons possess similar charges, and a force of repulsion of considerable magnitude exists between them. At the same time, however, the strong interaction comes into play, gradually overpowering the electrical force permitting the formation of a stable assembly as in diagram 10. The weak interaction plays a relatively insignificant role. Our new model differs in several



aspects. Diagrams 11 and 12 show the same sequence of events, but instead of the strong interaction, we find a region of space forming in which the electric field intensity has reached its maximum, and the weak interaction begins to dominate. This new region of space is called the *nuclear zone*, and is coloured green, where the strong interaction was coloured brown. The weak interaction is in each case indicated by yellow. When the nucleons enter the nuclear zone, they are no longer subject to a repulsive force, since the weak interaction dominates, and is renamed the *nuclear force*. Thus, the new model is both simpler, and more in accord with observation: from the outside, the nucleus appears somewhat fluid, since the boundary of the nuclear zone can oscillate, as required by the "liquid drop" model of nuclear structure, but contains a rigid, geometric core, as required by other models. It is the relationship between this boundary (which does not exist in the older model) and the inner structure which permits an understanding of nuclear phenomena.

The remaining diagrams use simplified representations of the nucleus. In diagram 13, the yellow hexagon stands for the rigid nuclear core, in which the nucleons form a regular crystalline structure. Surrounding this, and shaded green, is the nuclear zone, and this is bounded in turn by the positive electric field which surrounds all nuclei. The boundary of the nuclear zone is not static – it possesses a pattern of standing waves which is unique for each element. Diagram 13 shows four peaks and their associated troughs, and these should be visualized as oscillating – anyone who has seen slow-motion replays of liquid drops in space will have little difficulty in correctly picturing what is represented. The nucleus of diagram 13 is a stable one; in diagram 14 the distance between the nuclear core and the boundary, and the amplitude of the surface wave, are both such that the boundary occasionally intersects the core, and the nucleons are then subject to electrical forces. This can result in the core being fragmented, and such a nucleus is unstable, or radio-active. The frequency with which this happens is determined by a number of factors which need not be enumerated here, but is an exact statistical function, and gives rise to the measurable half-lives of all unstable isotopes.

The artificial stimulation of radioactive decay is usually accomplished by particle bombardment: in diagram 15 an energetic particle entering the nucleus so distorts the structure of the core that it intersects the surface wave, resulting in fission. The technique under investigation by Terran Research uses a different approach; by irradiating the nucleus with a precisely tuned and oriented electromagnetic wave, the boundary oscillations are excited to the point where it intersects the core, again resulting in fission, as in diagram 16. A larger mass of fuel is considered in diagram 17, where it is shown that the target nuclei are oriented in different directions, so that very few of them fragment: but if, as in diagram 18, a strong external magnetic field is applied to align them to a common orientation, a far greater proportion are so affected.

The above descriptions are necessarily simplistic, but show that a sound theoretical framework can now be developed for investigating alternative techniques of atomic fission, and although several years research and a great deal of effort will be required to refine them for commercial application, the severe environmental and social problems caused by the world's energy demands justify both. Those who oppose atomic energy on the grounds that reactor techniques and technology can be applied to weapons manufacture can take heart in the fact that the new methods will be safer, will produce fewer poisonous by-products, and will be far less amenable to the furtherance of weapons technologies. The promise of an abundant and inexpensive energy source that atomic energy held in its prime may soon be attainable. The question remaining is in regard to our own will and wisdom in its use.

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Improving stereophonic image sharpness

Using two loudspeaker systems, it is possible to arrange that the low and high frequencies in a sound field appear spatially coincident

F. O. EDEKO

The ultimate aim in the design of any sound reproduction system is to be able to convey to a listener an auditory event that has identical spatial and spectral characteristics to the original sound. To accomplish this, the reproduction system must be capable of reconstituting the wavefront from a particular sound scene in an exact form over a region of space occupied by a listener. The recording and replay processes involved must be holosonic in nature so that they are capable of adequately sampling and regenerating the wide temporal and spatial bandwidths encountered in practice.

Though the two-loudspeaker system, as it exists today, approximates to these requirements and provides what is generally considered as an acceptable and economical form of reproduction system, it has been shown that the system has very serious problems. The use of only two spatially separated speakers imposes restrictions on the ability of a system to reconstruct the original acoustic wavefront. During recent decades, much thought has been given to the spatial and spectral aspects of sound reproduction and considerable progress has been made in improving stereophonic image quality[1-8].

However, it takes only a comparison of a musical sound scene reproduced via two loudspeakers with the live performance to appreciate that quite a lot still needs to be achieved. Over the years, the spectral problem of stereophonic sound reproduction has largely been solved with the development and manufacture of amplifier and loudspeaker systems with constant frequency response over the entire audio range and with reduced distortion[9]. But there is room for significant improvement in the spatial characteristics of the system. The kind of spatial improvement needed might, for example, be produced by an enormous radiating surface which would cover the front wall of a room.

This is, however, inpracticable, so the improvements in spatial performance which are to be expected must come not from improvements in the design of each loudspeaker but rather from the use of additional ones. From the wavefront-reconstruction approach, an obvious and rather well known method of improving the spatial aspects of sound reproduction is the loudspeaker array system.

LOUDSPEAKER ARRAY SYSTEM

This is generally believed to be the ideal method of music reproduction[10,11]. From the wavefront-reconstruction standpoint, this is essentially correct. Wavefront reconstruction requires the reconstruction of good-quality plane waves if sound images are to be well resolved[12]. The ability of two speakers to do this is limited to low frequencies. If however, loudspeakers are arranged in an array in front of the listening area, then the reconstruction of good-quality plane waves over the listening area by all the speakers will extend into the high frequencies: the more the number of speakers, the better the quality of the plane wave and the higher the frequency range.

Though these qualities are well known, the inconvenience and cost of having many amplifying channels and subsequently many speakers have made the array system very uninviting.

PROPOSED METHOD OF IMAGE IMPROVEMENT

The quality of stereophonic images is greatly improved if the images are well defined or sharp: this is possible in a two-loudspeaker system. The problem of image sharpness in stereophony is centred on the fact that images due to the low-frequency components of an auditory event are located in one region, and those due to the high-frequency components are elsewhere. Figure 1 shows the curve of image-position variations with frequency: for frequencies up to 1000 Hz, the image positions are virtually in one position, while the high-frequency ones are located in different places. This will be perceived as spreading of the image.

To increase the frequency range over which the two-loudspeaker arrangement can reproduce sharp images, the system shown in Fig. 2 still retains the two-speaker set-up, but each speaker cabinet houses three separate cones: L—low-frequency cone, M—mid-frequency cone, and H—

high-frequency cone. The cones are displaced from one another along the horizontal axis within each cabinet, such that the low-frequency cone forms the biggest azimuth angle with respect to the listener in the median plane and the high-frequency cone has the smallest azimuth angle.

If the distance between the cones, DX, is correctly calculated, then for a given geometric layout, it is possible for such a system to reproduce low- and high-frequency images of a sound source in one place, by feeding the low-frequency signals into L, the mid-frequencies into M and the high frequencies into the H-cone. Signal separations are accomplished by using a low-pass filter for the L-cone, a band-pass filter for the M-cone and high-pass filter for the H-cone. Technical specifications of the filters will be examined later. With the cones correctly fed with the corresponding signals, the identical L-cones in the left and right loudspeaker cabinets will reproduce an image in a given position within the stage width defined by the intensity ratio used. An image will correspondingly be reproduced by the M-cones, but because the stage width of the M-cones is less than that of L-cones, the increased image displacement as frequency increases will be related to a smaller stage width and consequently the images due to the L-cones and M-cones will coincide. In a similar manner the image due to the H-cones will be located in the same position as the images from the L- and M-cones. By so doing, the low-range and high-frequency components of an auditory event can be reproduced in one place, greatly enhancing the reproduction of sharp images. An important aspect of this process is the correct determination of the cone separation, DX (Fig. 2).

DETERMINATION OF CONE SEPARATION

Chances of the images from L, M and H-cones being located in one place are highly dependent on DX, which should be such that it reflects the spatial separation of images of low, mid-range and high frequency signals in the ordinary two speaker system.

Cone separation DX is determined from the image displacement curves at low and high frequencies. Consider Fig. 3, which shows the average, practical image-displacement curves with interchannel intensity ratio for a low- and high-frequency signal. The difference between the curves is the spatial separation of low- and high-frequency images and should be related to the separation DX of the L-cone and H-cone.

In Fig. 3, let the low-frequency image displacement in terms of stage width be defined as a α_L and high-frequency image as α_H. Image position, in terms of stage width, is defined as:

$$\alpha_i = \frac{\text{image displacement}}{\text{stage width}} \qquad (1)$$

Therefore, at low frequency,

$$\text{image displacement} = \alpha_L . 2D_L \qquad (2)$$

where $2D_L$ is the stage width formed by the two L-cones. For the high-frequency cones, with a stage width of $2D_H$,

$$\text{image displacement} = \alpha_H . 2D_H \qquad (3)$$

From Fig. 2 it follows that

$$D_H = D_L - DX \qquad (4)$$

For the images of low- and high-frequency signals to be located in one place, equations (2) and (3) must be equal. That is

$$\alpha_H D_H = \alpha_L D_L \qquad (5)$$

Substituting equation (4) into equation (5),

$$\alpha_H (D_L - DX) = \alpha_L D_L \qquad (6)$$

Therefore

$$DX = [D_L(\alpha_H - \alpha_L)]/\alpha_H \qquad (7)$$

For a given ratio of R/L, α_L and α_H can be deduced from the curves in Fig. 3, which we obtained from the system geometry having a stage width of 230 cm[12]. For example, if R/L = 10dB,

$$\alpha_H = 82/230 = 0.352$$
$$\alpha_L = 60/230 = 0.261$$
$$DX = 29.73\ \text{cm} \simeq 30\ \text{cm}$$

The M-cone is placed equidistant from the L-cone and H-cone. For the given layout in Fig.2, a cone separation of 15 cm was found to be the optimum value.

TECHNICAL SPECIFICATION OF FILTERS

In the proposed system in Fig. 2, the different cones are fed with signals that have passed through the appropriate filters. The curve of image-position variations with frequency shown in Fig. 1 shows that, for frequencies up to 1000 Hz, the image position is virtually constant. Therefore the L-cones should be fed with signals passing through a low-pass filter with a cut-off frequency of 1000 Hz. The M-cones are for mid-range signal frequencies and should be connected to a bandpass filter. The cut-off frequency (1000 Hz) of the low-pass filter forms the lower cut-off frequency of the band-pass filter, while 2000 Hz is chosen as the upper cut-off frequency. The value of 2000 Hz marks the beginning of a new and sudden rise in the curve of image-position variation with frequency shown in Fig. 1. The H-cones are designed for high-frequency signals and should be connected to a high-pass filter with cut-off frequency of 2000 Hz.

Theoretically, only the signal frequencies within the ranges specified by the different filters should be fed to the appropriate cones. However, this is not possible in practice and the problem of cross-over frequencies always exists in any practical filter. To minimize the influence of cross-over frequencies in the reproduction of well defined images in the proposed system, the filters should have a large attenuation factor. From analysis, an attenuation of 60 dB/decade is adequate for the generation of sharp images in the proposed system for all frequencies up to 3000 Hz. Above this frequency, the phenomenon of central-image disappearance is likely to appear.

The question naturally arises here as to whether signal phase delay due to the presence of the filter will affect the working of the system. Any signal passing through a filter network undergoes a phase change. In the proposed system, this would not have any effect. All the filters have an equal roll-off value of −60dB/decade and therefore equal phase angles for each component

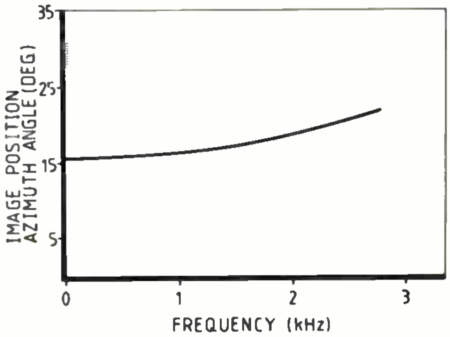

Fig. 1. Image position variations with frequency (R/L=0.3, D=14 cm). Ref. 12.

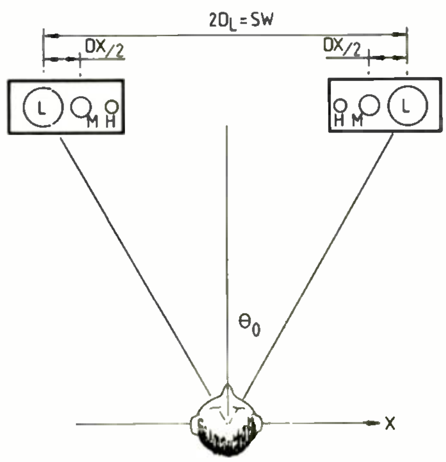

Fig. 2. Geometric arrangement of proposed method of improving image sharpness. θ_0=30 degrees, SW=230 cm.

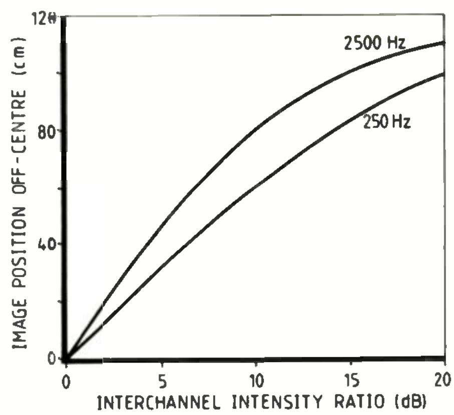

Fig. 3. Image displacement with interchannel intensity ratio (10 subjects, 1/3 octave pink noise, Ref.12).

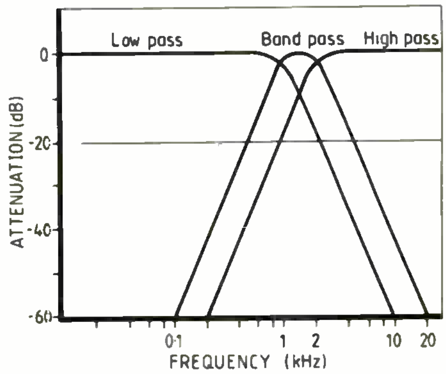

Fig. 4. Filter response characteristics.

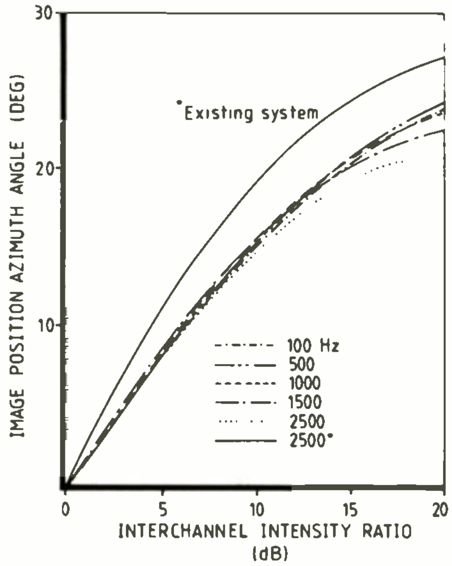

Fig. 5. Image displacements with interchannel intensity ratio in proposed system (60dB/decade filter).

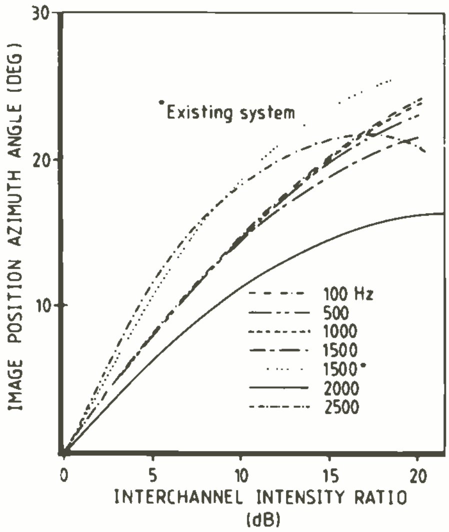

Fig. 6. Image displacement with interchannel intensity ratio in proposed system (−20dB/decade filter).

frequency in the corresponding left and right cones.

The response characteristics of low, high and band-pass filters with a roll-off of −60dB/decade are shown in Fig. 4 and such a response curve will be used in computational analysis of the proposed system. The cone input signals at each frequency are determined from Fig. 4 taking into account the cross-over effect. In doing this, analysis has shown that any signal value less than −20 dB can be neglected, since the presence of such small signals in one cone or the other has no significant effect on image localization[12].

It is recognised that practical realization of a 60dB/decade filter could be difficult and expensive. To investigate what effects a cheaper filter will have on the performance of the system, analysis was also carried out using filters with −20dB/decade attenuation.

IMAGE LOCALIZATION IN PROPOSED SYSTEM

Computer simulations have been carried out to determine image position variations with interchannel intensity ratio in the proposed system using Fig. 2 and a value of DX = 30 cm. The cone input signals determined using the response curves of the −60 dB/decade filters in Fig. 4 are shown in Table 1 for the different frequencies.

The computer simulations involve generating the wavefront due to the L, M and H cones along the X axis over a range of $-X_m \leq x \leq X_m$ where $2X_m$ = 14 cm (head width). For the layout in Fig. 2, the wavefront generated by the left and right speaker system along the X-axis in the region $-X_m \leq x \leq X_m$ can be expressed as

$$H(x) = L_L \exp jkr_{L_1} + R_L \exp jk r_{L_2} + L_M \exp jkr_{M_1} + R_M \exp jk r_{M_2} + L_H \exp jkr_{H_1} + R_H \exp jk r_{H_2} \ldots$$

where L_L, L_M, L_H are signal amplitude to the low, medium and high frequency cone respectively in the left speaker cabinet.

R_L, R_M, R_H – signal amplitude to the low, medium and high frequency cones respectively in the right speaker cabinet.

$r_{L_1}, r_{M_1}, r_{H_1}$ – distance from respective low, medium and high frequency cones in the left channel to each sampled point along the X-axis.

$r_{L_2}, r_{M_2}, r_{H_2}$ – distance from respective low, medium and high frequency cones in the right channel to each sampled point along the X-axis.

$k = \frac{2\pi}{\lambda}$ is the wave constant.

In generating the wavefront H(x), it is assumed that the radial amplitude reduction in the divergent wavefront and variations in loudspeaker polar patterns are small over the region occupied by the head.

The linear variation of the phase component of H(x) allows the use of the least-squares approach to obtain the best-fit phase slope for a particular wavefront. The direction of virtual source can then be deduced from the gradient of line of best fit phase as in ref. 12.

$$\alpha = \sin^{-1}\frac{M\lambda}{2\pi}$$

where M is gradient of line of best fit phase
α – image displacement in degrees
λ – wavelength.

Results of computer simulations of image positions are shown in Table 2 and curves of image displacements with inter-channel intensity ratio are shown in Fig. 5 for different frequencies. It is evident from the graphs that the image positions at low and high frequencies are almost coincident. The curves demonstrate significant improvement in performance when compared with the curve for the existing stereophonic system at 2500 Hz: Differences between the curves in the proposed system only occur at the extreme image positions. This is extremely encouraging as, at this stage, the image is likely to be already perceived as coming from the loudspeaker. The curves demonstrate that sharp images can be reproduced in the proposed stereophonic system.

Curves of image displacement using filters with attenuation of −20 dB/decade are shown in Fig. 6. In this case, a sharp image can also be reproduced for frequencies up to 1500 Hz. Above this frequency, the curves for low and high frequencies become increasingly diverse and lack of image resolution will occur.

Table 1. Simulation: values of input signal in cones (filter attenuation=−60dB/decade).

Frequency	Image position azimuth angle, α° degrees)				
Hz	R/L=1.0	R/L=0.8	R/L=0.5	R/L=0.3	R/L=0.1
100	0	3.18	9.6	16.5	24.1
500	0	3.25	9.6	15.86	24.28
1000	0	3.31	9.87	15.86	23.43
1500	0	3.45	10.1	15.78	22.5
2000	0	3.59	10.4	15.99	21.68
2500	0	3.11	9	15.15	18.5

Table 2. Simulation: image localization in the proposed system (−60dB/decade).

Frequency	Signal levels, V (maximum = 1)		
Hz	(L) low-pass filter	(M) band pass filter	(H) high pass filter
100	1.0	0.0	0.0
500	1.0	0.0	0.0
1000	0.707	0.707	0.1
1500	0.3	1.0	0.3
2000	0.1	0.707	0.707
2500	0.0	0.5	0.88

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Intelsat's future satellites

International communications to the year 2000 and beyond will depend on Intelsat's forthcoming generation of spacecraft.

P.T. THOMPSON

Intelsat, the International Telecommunications Satellite Organisation, is a co-operative which at present comprises 114 member countries. To date, 40 satellites have been procured and launched by Intelsat, though because of eight launch failures not all of these have become operational.

Currently, the operational system consists of two Intelsat IVA satellites, four Intelsat V, four Intelsat VM (the same as V but with a maritime communications subsystem which is leased to Inmarsat) and three Intelsat VA.

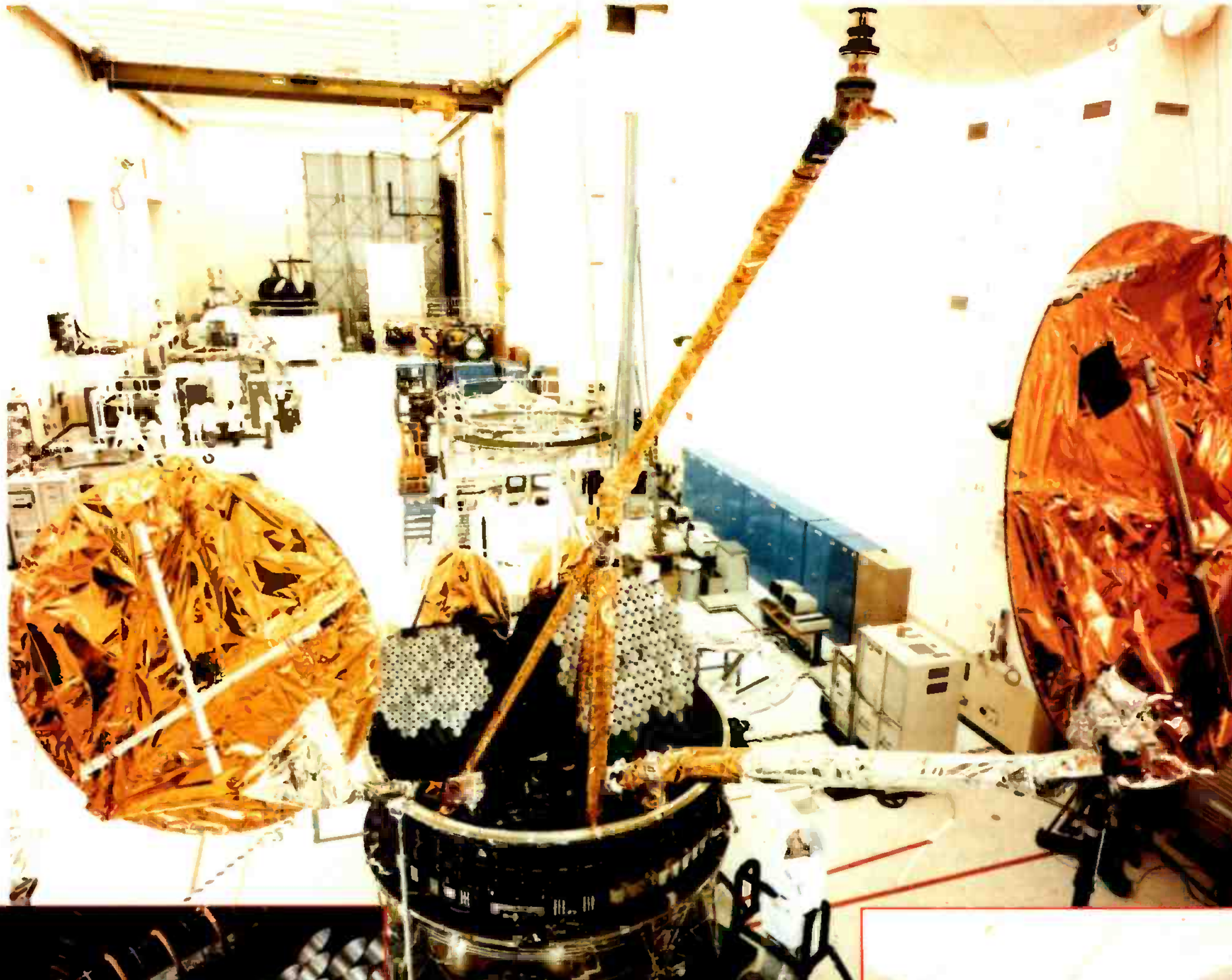
Three Intelsat VA(IBS) were built, but unfortunately the first fell victim to a launch failure. The remaining two are in storage awaiting launch by Ariane in 1988. These satellites differ from Intelsat VA in that they are capable of operating in the 14/12GHz bands which are exclusively allocated to the fixed satellite service and are ideally suited to the Intelsat Business Service (IBS), a small Earth-station service.

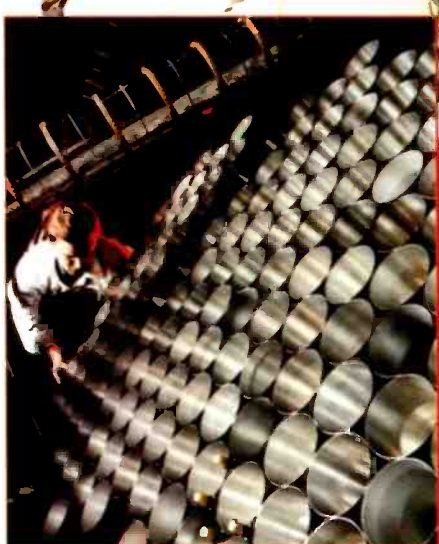
So, with 15 Intelsat V class satellites constructed and 11 in orbit, what next?

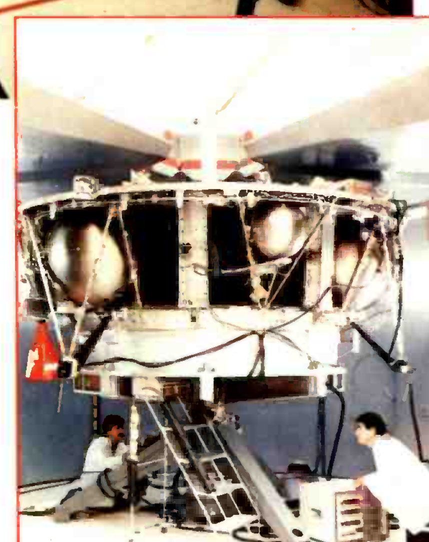
In 1981, Intelsat completed the specification for new generation of spacecraft to be known as Intelsat VI. After competitive bidding, five spacecraft were ordered from Hughes Aircraft Company (HAC) in 1982 and are now under construction.

After assessing the remaining lifetime of the operational satellites (which is limited by the amount of station-keeping propellant which can be carried) and the predicted growth in international traffic, Intelsat developed a specification for a further generation, Intelsat VII. These satellites are designed for initial use in the Pacific Ocean Region (POR) to provide adequate space segment for this region of expanding traffic. In the past, satellites were primarily designed for the more demanding Atlantic Ocean Region (AOR) role. Consequently, in terms of complexity Intelsat VII emerges between Intelsat V (which it will replace) and Intelsat VI. However, care has been taken to ensure that the new Intelsat VII spacecraft can be used in the AOR for less demanding roles, as well as in the POR.

Right: an engineer examines part of a beam forming network (with its cover removed) of the Intelsat VI satellite, believed to be the most complex yet developed for commercial satellite communications.







Above: Intelsat VI prototype with its large antenna reflectors supported by helium-filled balloons for testing. The feed array can be seen at the lower part of the spacecraft.

Left: one section of the antenna feeds that will be used to create the complex coverage areas of the Intelsat VI footprint.

Right: lower module of Intelsat VI, containing the propulsion system for station-keeping and attitude control.

Intelsat issued a request for proposals (RFP) for Intelsat VII on October 1, 1987, and several teams of potential vendors are preparing bids for evaluation. A contract should be placed around September 1 next for delivery and launch of the first spacecraft in 1993.

Technical details of Intelsat VII, as developed for the RFP, are given below. But specific implementation details will be left to bidders, and until the successful bidder is known such information will not be available.

INTELSAT VI

This highly complex satellite is by far the most elaborate civilian satellite yet developed, and it is impossible in the space of this article to describe it fully.

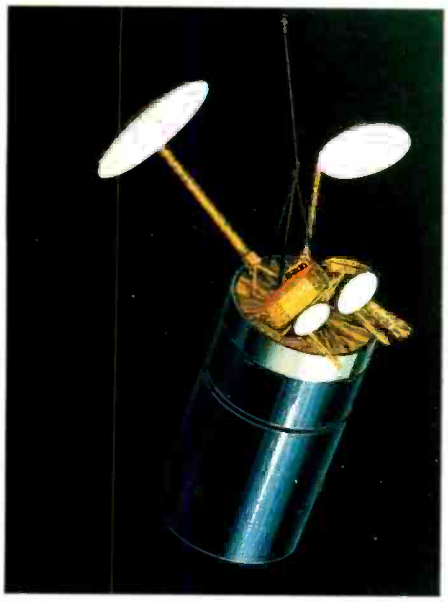
The five satellites (plus various development models) are being constructed by an international team led by Hughes Aircraft Company as the prime contractor. Approximately 17% of the work was placed with non-US companies; the UK has about 7%. All told, these satellites will cost Intelsat about $600M – not a trivial sum, especially in view of the possibility of a launch failure (launch costs being extra!).

Major testing of the current Y1 or development model of the spacecraft has been completed and the flight units are well in hand. However, the original delivery dates have not been met for a variety of reasons. Among these have been the need for redesigns, unexpected development delays, requests for modifications by Intelsat to meet changing communications requirements, and last but by no means least the current delays in launch vehicle availability.

However, the overall scene is very healthy, with all major problems resolved and everyone getting anxious to fly the bird. The first launch is now scheduled for 1989 (instead of the end of 1986 as originally anticipated) and the others are scheduled for 1990 and 1991.

LAUNCH VEHICLE

Intelsat VI was designed for launch by Ariane 4 and the Space Shuttle. However, because of the tragic Challenger disaster and the change in US policy relating to future Shut-



Above: artist's impression of the completed Intelsat VI, which is 11.8m high on-orbit. The satellite's complex channelization plan (right) employs six-fold frequency re-use.

tle launches, the opportunity for Intelsat VI to be launched by Shuttle was withdrawn.

As a replacement vehicle the Titan III was selected from a number of alternatives. This is a two-stage launch vehicle (Ariane 4 has three stages) and therefore needs a perigee stage to achieve an adequate transfer orbit. This perigee stage is a modification of that being developed for the Space Shuttle launch arrangement.

The satellite will weigh approximately 2300kg in orbit at the beginning of its life, and would have taken half the payload capability of the Shuttle.

MECHANICAL DETAILS

Intelsat VI is a spin-stabilized satellite standing some 5m high at launch and 11.8m when the solar cell drum is lowered and the antennas deployed.

Two large antenna reflectors (manufactured in the UK) are deployed on booms. These highly-accurate reflectors are 2m and 3.2m in diameter.

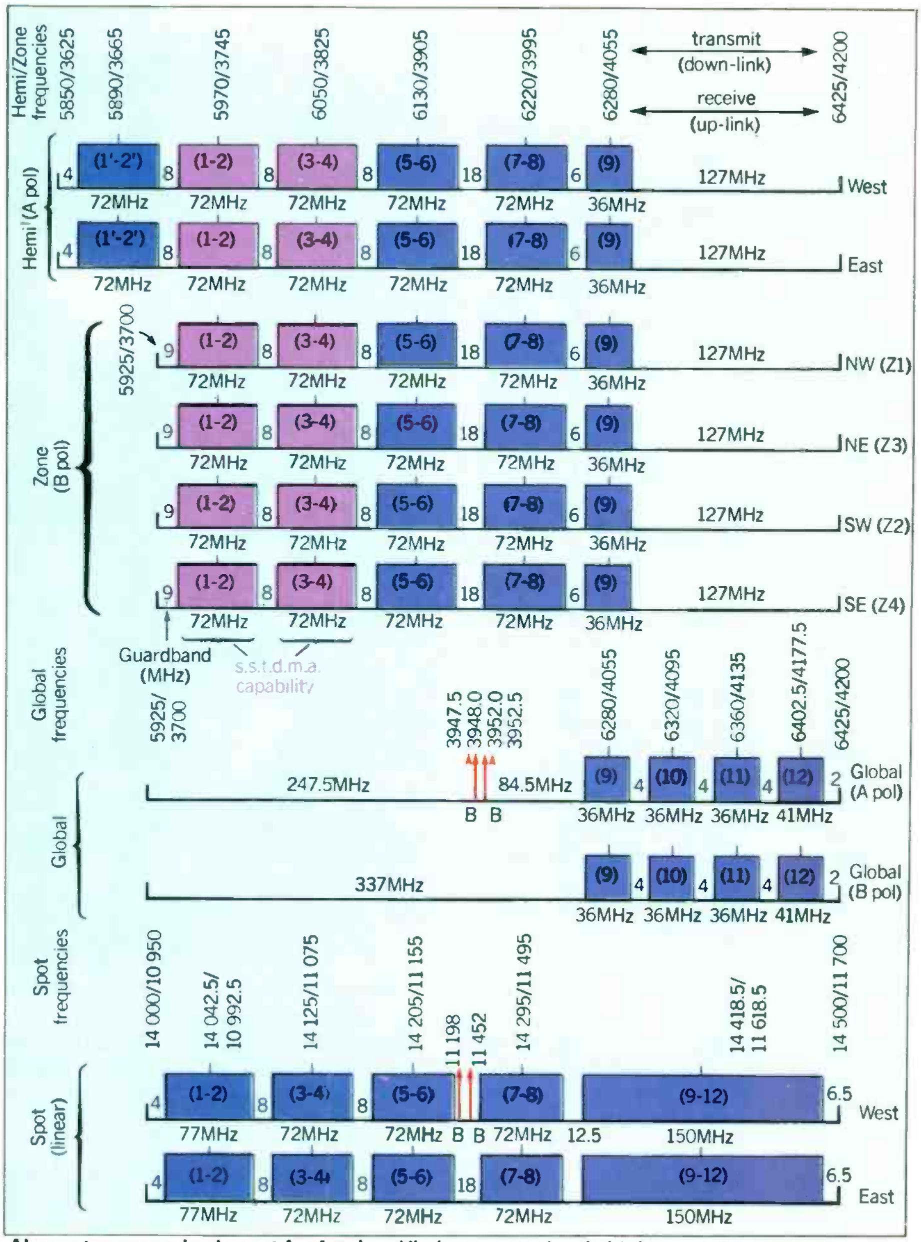
Electrical power is supplied by one fixed and one telescoping solar array panel. The fixed panel is approximately 2.2m high; the deployable panel is 3.8m high.

COMMUNICATIONS PAYLOAD

Intelsat VI provides a number of significant enhancements over the Intelsat V series of satellites whilst maintaining a high degree of compatibility for transitioning and for spares. Key features of the improvements are

- increased capacity
- improved coverage areas
- increased frequency re-use
- 10-14 years operational life
- increased e.i.r.p. (particularly global and spot beams)
- implementation of satellite-switched time division multiple access.

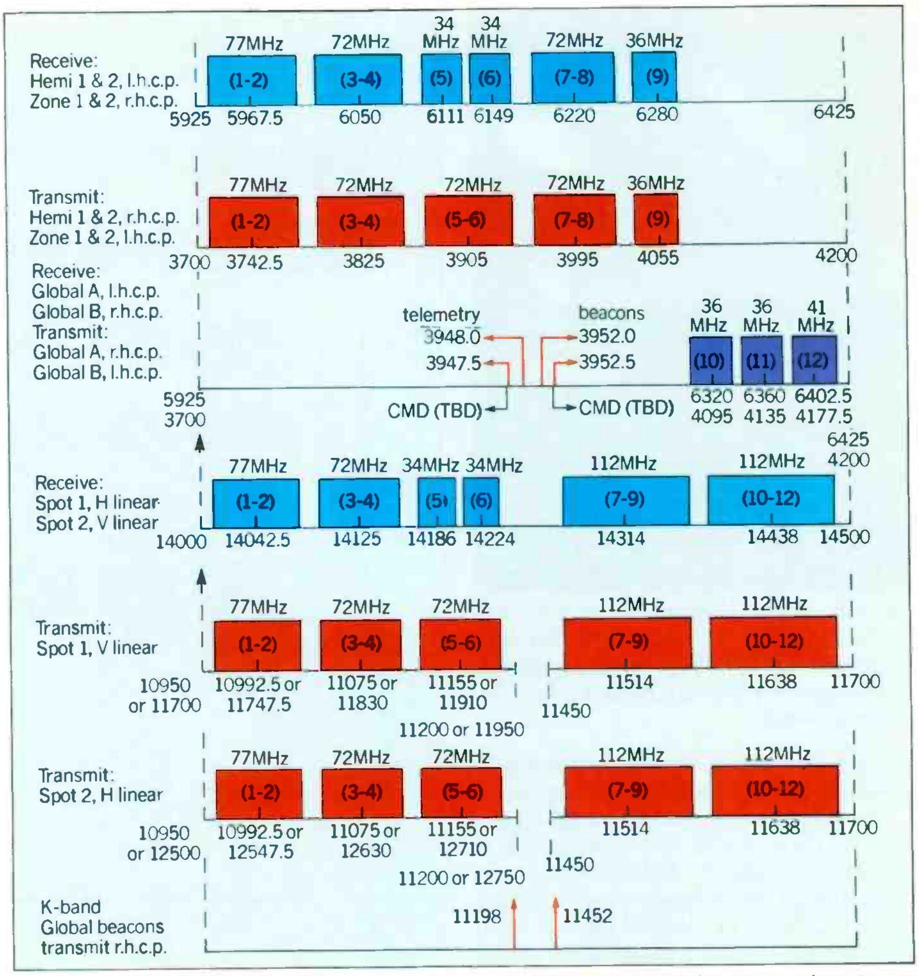
The satellite will operate in the 6/4GHz and 14/11GHz bands. Coverage areas for the latter are two spot beams (East and West)



Above: transponder layout for Intelsat VI, the consortium's high-capacity satellite.

Sections of the C band feed array for Intelsat VI.

Right: Intelsat VII communications subsystem channelization plan.



which can be steered over the whole visible Earth by ground command.

For 6/4GHz operation there are several beams. Global coverage, i.e. coverage over the whole of the visible Earth from the satellite, is provided for some channels. Others operate with 'hemi' beams, equivalent to half a global. The hemi beams are configured identically for all orbital locations of the satellite.

Four 'zone' beams operating with the opposite polarization to the hemi beams provide independent coverage areas, the shape of which can be configured by ground command for whichever ocean region the satellite is operating in.

Thus the satellite uses the same frequency band in two hemi beams (spatially isolated from each other) and again in the four zones. These are spatially isolated from each other and isolated in polarization from the hemi beams (circular polarization is used). Hence the satellite has six-fold frequency re-use, compared to Intelsat V's four-fold.

The complex hemi and zone coverage areas are created by the use of multiple feed reflector antennas. Some 144 feeds can be excited in prescribed amplitude and phase patterns to create a number of elemental beams which merge to give the required coverage. The conical feed horns are connected to the appropriate satellite channel by means of a beam-forming network (b.f.n.).

Couplers, phase-shifters, switches and terminating loads are all used to make up the elements of the b.f.n. By switching in different planes of the b.f.n. the various coverage zones can be reconfigured.

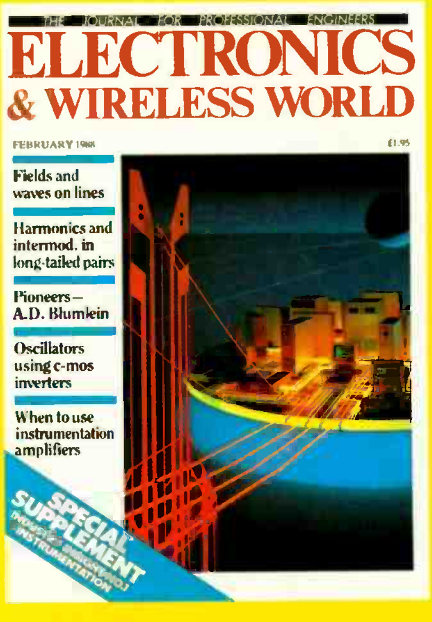
Frequency translation, amplification and connection between the beams are provided by 48 transponders or channels. By means of an interconnect switch matrix, almost any beam can be connected to any other. Cross-strapping is possible between the different frequency bands (6GHz to 11GHz and 14GHz to 4GHz). For two sets of these

NEXT MONTH

Industry Insight. The first of our special features on the electronics industry focusses on instrumentation, taking a close look at oscilloscopes, frequency measurement and digital meters. It runs to over thirty pages.

Alan Dower Blumlein. The Pioneers piece this month features this most prolific and original of engineers, perhaps best known for his work on scanning circuitry, the long-tailed pair, stereophony and the Miller integrator.

Poynting the way is the title of Joules Watt's piece on transmission lines, in which he discusses the propagation of energy and expresses the hope that the article might, just possibly, help to dispel the *canard* that r.f. technology is unfashionable.



The seven-per-cent rule. Ivor Catt offers a piece on text compression, which may well have important consequences in data storage and processing. It could also mean that there is an uncrossed bridge between linguistics and computing which ought to be investigated.

Convolution. A description of how convolution allows the processing of analogue and sampled data to be carried out in the time domain rather than in the complex frequency domain.

Instrumentation amplifiers. The standard, three-op-amp instrumentation amplifier is not always better than a simple, single-op-amp, differential amplifier. F.J.Lidgey's analysis provides the reasons.

channels the interconnection matrix is able to switch rapidly such that time-division multiple access (t.d.m.a.) can direct bursts to different coverage areas. This rapid switching is carried out on board the satellite to a prescribed pattern, which can be reconfigured by ground command. The satellite does not process or demodulate the transmitted signals: in fact, the t.d.m.a. network synchronizes itself to the satellite.

Full redundancy and reconfigurable switching give a high level of protection from failure of this satellite-switched t.d.m.a. (s.s.t.d.m.a). The s.s.t.d.m.a. switching network can be bypassed by static switches if the satellite is used in a role where t.d.m.a. is not operational.

DEPLOYMENT

Intelsat maintains a very flexible approach to the deployment of satellites, such that the best possible configuration of space segment can be adopted to meet traffic requirements. Thus it is impossible to be definite as to where Intelsat VI satellites will be stationed. Currently it is expected that three will be located in the Atlantic Ocean Region and two in the Indian Ocean Region.

INTELSAT VII

This new satellite is primarily designed for the Pacific Ocean Region. Bidders have been asked for varying lifetime estimates, from a minimum of 10 years. The spacecraft is to be compatible with the Ariane 4 and Titan III launch vehicles.

A special feature of it is the possibility of electric propulsion for its North-South station-keeping, which could potentially lead to 20-year lifetimes. This option is specified around a xenon ion thruster technology which has shown considerable potential in the last decade.

Another feature of the specification is promotion of the use of off-the-shelf hardware, especially in the spacecraft bus area. However, it is recognised that some modifications to existing designs are inevitable.

COMMUNICATIONS PAYLOAD

Intelsat VII will have four-fold frequency re-use, like Intelsat V at C-band. This reduction from Intelsat VI is quite deliberate, to reduce costs and to match the satellite to its operational role. In addition, the beams are not planned to be reconfigurable; but they have some flexibility by means of extended coverage areas for certain beams. However, operation in the 14/12GHz exclusive frequency bands will provide for IBS and other such services in these bands through ground selection of alternative frequencies. On a channel-by-channel basis the 14/11GHz transponders can be switched to 14/12 GHz.

The frequency plan of the Intelsat VII satellite is shown on page 26. There are four transponders (or channels) at Ku-band which are 112MHz wide. These have been especially designed to permit 140Mbit/s q.p.s.k. operation in the future.

To meet the required C-band antenna performance, it is envisaged, but not specified, that about 95 feeds will be required along with reflectors of the order of 2.5m in diameter.

Two hemi beam coverages will be provided, together with the activation of two out of four zone beams. The latter will be conducted by ground command as required.

For some locations, it is envisaged that the North-South orientation of the satellite will be reversed, effectively turning the beams upside down.

A special feature of Intelsat VII is an enhanced zone coverage for the C band frequencies. This is associated with Zone 2 and is known as Zone 2A. The satellite will receive signals from both Zone 2 and Zone 2A simultaneously but will transmit only to one of them, the choice being made by ground command.

In Ku band, coverage will be provided by elliptical beams which will be steerable over the whole Earth.

BEYOND INTELSAT VI AND VII

Satellite communications has evolved so unpredictably that to crystal ball gaze is a punishingly inaccurate act! However, in considering its longer-term requirements, Intelsat research and development has focused on elements such as on-board processing, inter-satellite radio links, fully-reconfigurable spacecraft antennas and advanced spacecraft propulsion and bus development. In addition, a drive toward small Earth station operation and interference-tolerant network operation is present.

For a network employing more than 800 antennas in over 150 countries, it is essential to take account of the impact of such infrastructure on the space segment. Thus new technologies will have to be phased into operation when the maturity of the network and technology permit it and when such developments are cost-effective. It is therefore likely that the current 'transparent transponder' concept will be gradually and carefully supplanted in certain applications by advanced processing transponders. Whether this will be initiated with Intelsat VIII is a matter of pure speculation; it will be dominated by the evolution of traffic requirements.

One feature of satellite communications of the past that will remain is its ability to be very flexible in adapting to changes in communication requirements. This flexibility must continue to be exploited if satellite systems in the future are to remain competitive in the communication arena.

Paul Thompson is Fixed Satellite Systems Manager with British Telecom International. He has been closely involved with the Intelsat consortium, of which BTI is a member.

The author wishes to acknowledge the help of colleagues in Intelsat and Hughes Aircraft Company in preparing this article.

● *Ariane's resumed launch programme continued on November 21 with the successful placing in orbit of the West German TV-Sat 1, Europe's first direct broadcasting satellite. Although the Ariane-2 vehicle worked perfectly, one of TV-Sat's two solar panels failed to open, giving rise to fears that the satellite's life might be shortened.*

Launch history of Intelsat satellites

Satellite Series	Flight	Launch vehicle	Month	Year	Comments
I	1	TD	Apr	1965	Early Bird
I	2	–	–	–	Assembled but never launched
II	1	TD	Oct	1966	LEO (motor failure)
II	2	TD	Jan	1967	
II	3	TD	Mar	1967	
II	4	TD	Sep	1967	
II	5	–	–	–	Assembled but never launched
III	1	TD	Sep	1968	Launch failure
III	2	TD	Dec	1968	
III	3	TD	Feb	1969	
III	4	TD	May	1969	
III	5	TD	Jul	1969	Launch failure
III	6	TD	Jan	1970	
III	7	TD	Apr	1970	
III	8	TD	Jul	1970	Launch failure
IV	2	AC	Jan	1971	
IV	3	AC	Dec	1971	
IV	4	AC	Jan	1972	
IV	5	AC	Jun	1972	
IV	7	AC	Aug	1973	
IV	8	AC	Nov	1974	
IV	6	AC	Feb	1975	Launch failure
IV	1	AC	May	1975	
IVA	1	AC	Sep	1975	
IVA	2	AC	Jan	1976	
IVA	4	AC	Mar	1977	
IVA	5	AC	Sep	1977	Launch failure
IVA	3	AC	Jan	1978	
IVA	6	AC	Mar	1978	
V	2	AC	Dec	1980	
V	1	AC	May	1981	
V	3	AC	Dec	1981	
V	4	AC	Mar	1982	
VM	5	AC	Sep	1982	
VM	6	AC	May	1983	
VM	7	AR1	Oct	1983	
VM	8	AR1	Mar	1984	
VM	9	AC(e)	June	1984	LEO, Centaur launch failure
VA	10	AC(e)	Mar	1985	
VA	11	AC(e)	June	1985	
VA	12	AC(e)	Sep	1985	
VA(IBS)	14	AR2	May	1986	Launch failure
VA(IBS)	13	AR2			Not yet launched
VA(IBS)	15	AR2			Not yet launched

TD: Thor Delta   AC: Atlas Centaur
AC(e): Atlas Centaur extended   AR: Ariane
LEO: low Earth orbit

Table 1: Intelsat VI communications characteristics

6/4 GHz (C band)

Beam	West (gain setting)	East (gain setting)	Saturation flux density dBW/m² high	low	G/T dB/K	e.i.r.p. dBW	Comments
Hemi	W	E	–77.6	–67.1	–9.4	31.0	
Hemi	W	E	–77.6		–9.2	28.0	Channel 9
Hemi	W	E		–70.1	–9.5	28.0	Channel 9
Zone	W		–77.6	–67.1	–7.0	31.0	SE & SW, Note 1
Zone		E	–77.6	–67.1	–2.0	31.0	NE & NW, Note 1
Zone	W	E	–77.6		–2.0	28.0	NW/E, Channel 9
Zone	W	E	–77.6		–7.0	28.0	SW/E, Channel 9
Zone	W	E		–70.1	–3.0	28.0	NW/E, Channel 9
Zone	W	E		–70.1	–7.5	28.0	SW/E, Channel 9
Global			–77.6	–70.1	–14.0	26.5	

Notes
1. Low gain G/T = –7.5dB/K
2. Low gain G/T = –3.0dB/K

14/11 GHz (Ku band)

Beam	Saturation flux density dBW/m²	G/T dB/K	e.i.r.p. dBW	Comments
Spot W	–77.3	–1.3	41.7	Outer coverage 72 MHz
Spot W	–78.0	1.7	44.7	Inner coverage 72 MHz
Spot W	–77.3	–1.3	44.7	Outer coverage 150 MHz
Spot W	–78.0	1.7	47.7	Inner coverage 150 MHz
Spot E	–78.0	1.0	44.7	

Table 2: Intelsat VII communications characteristics

Beam	G/T (dB/K)	e.i.r.p. (dBW)	Saturation flux density (dBW/m²) Low	High
Hemi 1	–8.5	33.0	–87	–73
Hemi 2	–7.5	33.0	–87	–73
Zone 1	–5.0	33.0	–87	–73
Zone 2	–3.0	33.0	–87	–73
Zone 2 A	–6.0	33.0	–87	–73
Global A,B poln. ch. 10, 11	–12.0	26.5	–87	–73
Global A,B poln. ch. 12	–12.0	29.0	–87	–73
Spot 1 inner	+4.8	45.0	–90	–76
Spot 1 outer	+1.8	42.0	–87	–73
Spot 2 inner	+2.3	45.0	–90	–76
Spot 2 outer	–0.7	42.0	–87	–73
Spot 2 A inner	0.0	45.0	–90	–76
Spot 2 A outer	–3.0	42.0	–87	–73

FEEDBACK

Sibilant distortion

Peter Hirschmann commented (*Electronics & Wireless World*, July 1987) that voices on the BBC World Service sound natural and without undue emphasis on sibilants.

The BBC, like most other short-wave broadcasters, uses compression and limiting on the audio signal to keep the modulation level of the transmitters at a relatively high level. This is necessary to maintain the audibility of the signal – especially important considering the high levels of interference that exist in the short-wave bands.

Audio compressors and limiters can, however, exacerbate problems with sibilance. The BBC has taken some care to ensure that the processing used on its World Service transmission does not significantly contribute to this effect. A sophisticated multiband audio processor is used which maximizes audibility while at the same time keeping distortion and sibilance low.

Sibilance can also be reduced by careful microphone technique in the studio. The BBC uses high-quality microphones, positioned to give a natural sound which does not over-emphasize sibilance. This combination of microphone technique in the studio and careful choice of audio processor has, we believe, allowed World Service transmissions to have good audibility, while keeping sibilance effects to a minimum.

Henry Price
Head of Engineering Information Department
BBC

Design in solation

I agree wholeheartedly with Messrs Kyle (*EWW* August) and Wilson (*EWW* November) in their various comments concerning electronic call switches. I am amazed that these devices are not designed with e.m.c. in mind. I design electronic weighing-machine controllers and the DTI (National Weights and Measures Laboratory) insist on tough r.f. immunity testing of equipment, initiated by the CB-emission/petrol-pump conflicts in the early 1980s. Once understood, the design principles are easy to incorporate; how come the infinitely larger telephone-equipment manufacturers' R&D departments can't or won't implement them?

Indeed, how come the BABT doesn't apply the same criteria as the DTI? Could it be that BT is involved? Surely, in the long run BT would be the beneficiary of e.m.c. kit. I believe that design without electromagnetic compatability is sloppy and negligent – whatever the product.

D.J. Smith
Burton Joyce
Nottingham

Chillerton Down v Emley Moor

I read with interest the claim by my colleagues at Chillerton Down IBA, that they have the highest microwave link dish in the United Kingdom. Emley Moor has had, and still has, a microwave link at 910 feet.

We now claim the record, unless someone else, of course, can prove to the contrary.

D.J. Long
Transmitter Maintenance Engineer
IBA Emley Moor

E.H. Armstrong

Mr Atherton's recent article on the life of E.H. Armstrong and his references to early work on the triode feedback oscillator and the superheterodyne receiver, called to my mind a story on the origins of the term 'squegging'.

As a student in the early 1930s I was told by a well known Scientific Officer of the Department of Scientific and Industrial Research, that the phenomenon of grid blocking in r.f. oscillators had been noted in the Admiralty Research Laboratories in 1916.

It was also noted that the audio note it produced in the receiver varied with the value of the grid resistor and that the device could be used to compare high-value resistors. Here was a new type of megger, a low voltage megger, and because of its peculiar squeak it was given the name of "Squeaking Megger" or "Squegger".

I have not heard the story since and wonder if any of your readers may have more information on the origin of this word.

O.H. Davie
Reading

Coupling as a way of life

I was happy to see that Tom Ivall is still in electronic journalism, but not so happy with his treatment of P.E.K. Donaldson's work in the interesting article on coupling coefficients in the June issue.

In *Electronic Engineering circa* 1945 I gave the design details for a number of types of tuned transformer, together with equivalent circuits and the conditions for the onset of double humping. Shortly afterwards I up-dated it to include designs based on insertion-loss characteristics. In dealing with inductively coupled circuits, it is useful to consider "k" as having a value between +1 and −1, depending on the direction of connection and the degree of coupling.

Referring to the implantable receiver, presumably power is important and this implies that the inductor L_2 has a high Q. Figure 2 shows a test circuit that presents an inductance in series with a parallel combination of a 13 ohm resistance and an inductance, which can hardly be recommended as an elegant method of measurement. Would it not be better to use a direct measurement of the magnetic field or, since there are lots of volts and amps around, the voltage across a low resistance of 0.5 ohms?

It is well known that, for any network using purely reactive components and operating between resistive loads, at the frequency at which zero insertion loss obtains the impedances presented to the driving source and to the output load must be purely resistive and of such values as to provide matched conditions. Thus, an oscillator using the input impedance of such a network for frequency discrimination will oscillate at this frequency when the maintaining amplifier in the oscillator has zero phase shift.

When the resistance R_2 is zero, the network presents zero impedance at frequencies corresponding with $\omega^2LC(1\pm k)=1$, as stated. An inspection of the equivalent T networks given in my article makes this obvious. This is not a desirable state of affairs, since Sod's Law says that the system will operate at the unwanted frequency or, possibly, both frequencies. The current flowing in the secondary circuit is independent of the coupling coefficient at either of these frequencies for a loss-less transformer. In practice, the dissipation in the components will make this current somewhat dependent on coupling.

In ultra-reliable equipment, is it good practice to use an op-amp to drive a pulse waveform into the large input capacitance of the Vmos transistors? Perhaps the op-amp used is exceptional.

F.G. Clifford
Wynberg
Cape Town
South Africa

Early naval radar

An effort is being made to compile a comprehensive record of naval radar during World War II – before it is too late. Such records as currently exist are somewhat scant and unrepresentative.

This was proposed at a reunion, at Churchill College Cambridge in December 1985, of former engineers and scientists of the Admiralty Signals Establishment, Witley, Surrey, by Professor J.R. Coales and J.D. Rawlinson.

FEEDBACK

For my part, I am writing some notes on the ship-fitting, commissioning and maintenance-at-sea aspects and would greatly welcome contacts with any of the earlier RNVR Radar Officers with good recall of their technical experiences over this period.
N.P. Abbott
2 Hawkshaw Close
Liphook
Hampshire
GU30 7DF

Catt's anomaly

I note that it is Ivor Catt himself who dubs his puzzle the Catt Anomaly, and that his references are to his own work (*E&WW*, September 1987, p.903).

As one who is to some extent 'disciplined in the art', I do indeed fail to grasp his point.

At the bottom of my mountain lives an old man who acts as my servant. Having compassion for his arthritic joints, I permitted the installation of a mechanical signalling system consisting of a thin steel cable, sliding in the forks of trees, and having a small bell attached to each end, one in his mean hovel and one in my cave. Should I require provisions, I give this wire a pull, and if Thrimble (for such is his name) is awake (an unusual state with a short time-constant, I might add), he confirms with a return tug. Likewise if visitors are present he gives me a bell, and if I am not deep in meditation I will return confirmation that they may begin the climb.

Measurements have shown that Thrimble, arthritic as he is, cannot move his hand with a velocity greater than about 10cm/s, and even the straightish path of the cable is some 300m. The steepness of the mountain (whose precise location I must keep secret, for obvious reasons) requires visitors to make a climb of some 2km on foot, which usually takes them the best part of an hour. A little calculation will show that if the speed with which movement of the cable *propagates* were limited to the speed with which the cable itself moves, visitors would have to wait two hours for a reply. Determined ones who set off on the climb without waiting might be disappointed to find me in profound absorption, from which I might not arise for hours or even days. Since I gave him an abacus last Christmas, Thrimble has been fond of demonstrating this to visitors. This now gives me time, after replying to the bell, to scrape some lichen off the back wall, and with flint to make a fire and brew some strong tea with which to welcome the climbers.

In a similar way when Thrimble opens the tap outside his mean hovel (there being no drainage within) the displacement of water propagates back up to the pool some 50m away at a speed about that of the speed of sound in water, though only a trickle – and a brackish one at that – actually comes out, indicating a low water velocity. Personally I believe the pipe to be infested with a variety of fauna, and refuse to drink from it.

So it is also that the propagation of a charge pulse along conductors, at a speed approaching that of light, does not require the electrons to drift at anything like that speed – the rearrangement is what travels, not the electrons themselves.
Alex Wilding
Crabbs Cross
Redditch

Ivor Catt replies:
I do not think this letter is as amusing as Mr Wilding thinks it is. He has the equivalent of a rigid rod (the cable) buried in his story. The rigid rod is used to warn electrons ahead of the TEM wave that they must start to drift forward. This is a forward E field which contradicts the concept of a TEM wave.

Pure resistance is presented to its terminals by any capacitor at one or more spot frequencies. However, the value of this resistance and the frequency at which it occurs are dependent on the construction. Therefore, it might well be helpful to shunt a large capacitance with a much smaller one to obtain the least possible impedance at high frequencies.

The traditional explanations are quite adequate for "Catt's anomaly", although they need constant revision for other purposes, and that is why Catt's criticisms are so valuable. He stirs things up and forces us to think, and not all his ogres are windmills. (I would like him to turn his powerful lance against those who decide what is taught in schools, as they have produced a level of understanding of magnetic fields even lower than in the bad old days of threefold irrational units and "point-poles".)

Consider a pair of parallel copper wires, 5mm apart and each 1mm in diameter, carrying a logic transition of +5V from left to right. The step is followed by 18mA to the right in the positive wire and 18mA to the left in the negative wire, the characteristic impedance being 275 ohms. Also behind the step comes surface charge of ± 60 picocoulombs per metre. (If this were the only moving charge it would, indeed, have to move at the speed of light.) On the assumption that each copper atom provides one mobile electron, each wire actually has 10,000 coulombs of moving charge per metre and its drift velocity is only about 2 microns per second.

In answer to Catt's question, the surface charge on the negative wire does come from the left. When a wave of rightward movement progresses rightward through the mobile electrons at 3×10^8 ms^{-1}, the effect is to concentrate them, rather like shouting "fire!" at the end of a crowded corridor remote from the exit. In the positive wire, it is like shouting at the exit end and the leftward moving electrons become slightly more spaced out. It can be shown (!) that these effects are just sufficient to produce the ± 60pCm^{-1} of unbalanced charge, which moves to the surface and terminates the electric flux.
R.J. Sharp
St Austell
Cornwall

Vladimir Kosma Zworykin

I have read the interesting account by W.A. Atherton in *EWW* for October, in which is mentioned in passing Dr Zworykin's great interest in medical electronics.

May I draw your attention to p.357 of *Wireless World*, August, 1957 under 'World of Wireless' to the report of Dr Zworykin's proposal for the formation of an international organization for electronics applied to medicine.

Out of the 2nd conference in Paris 1959, national societies were formed, in particular the Biological Engineering Society.

For information I enclose a photocopy of *MBEC News*, No 6, November 1982, "Founder of the IFMBE dies aged 93".*
R.E. George
Ilford
Essex
**Enclosed – Ed*

Glasses improve your hearing

I have been severely deaf since birth and I wear two hearing aids; my comments below are based on experience and *not* on experimentation (See Research Notes, September, 1987).

I have 20/20 vision but when an optician asks me to read the bottom line of his chart my hearing aids do not enable me honestly to reply, "Made In Hong Kong". On the other hand, I would appear to be more observant than T.C. Mits (The Celebrated Man in the Street).

Rare is the person who has a hearing loss which is flat across the frequency spectrum; equally rare is the hearing aid which has a flat response and no such device has a high-fidelity or omndirectional microphone. Consequently, the choice of hearing aid is a compromise between the requirements of the individual and the selection of models currently available. There can be no perfect matching of man to machine and it is a

FEEDBACK

fallacy to say that a hearing aid corrects the hearing loss. The user finds, as a rule, that most frequencies have been amplified to some degree and thus he is left with the task of discriminating between those which he actually required amplifying and the increased amplitude of the frequencies which are redundant to him. The result is that the brain, far from being able to relax a little from the strain of hearing, instead has to work at least as hard; things are louder, but *everything* is louder. It is hard to see how my brain can have more time to spare to process any interaction between sight and sound.

My lipreading is considerably better than that of T.C. Mits. This skill was derived instinctively – I have never had a lesson. It is a necessity to supplement the product of the hearing aids. However, if I remove my hearing aids my lipreading ability deteriorates compared with what it is when I simply turn them off but leave them in place! My conclusion from this is that the presence of the hearing aids gives me confidence in some way, i.e., a psychological phenomenon. Within the general context of observation ability, however, I would tend to subscribe to the empirical view that Nature makes up in one area for a deficiency in another, wherever possible, because I appear to register more than T.C. Mits whether or not I am wearing my hearing aids.

Research Notes comments on our ability to put up with poor sound quality on television sets and appears to suggest that we use our sight to rectify the quality. On this point I would disagree: I have a better reason than most to use my sight as such, yet I find it near impossible to watch the box because the picture is small and fuzzy, and because often the speaker is not in any case shown on the screen in full-face. Could it not simply be that T.C. Mits uses what he does hear to extrapolate for that which he does not hear, given that he will have a relatively high 'hit rate' compared to a deaf person? After all, such extrapolation is the way in which good lipreaders operate, focusing *(sic)* their attention on key aspects and filling in bits which they miss by putting in context.

I would just like to add that most of the imperfections in hearing aids are a direct result of the need for compression. Despite their defects, these devices do have one or two extremely positive benefits aside from their original purpose, e.g: I am the one who does not have to get out of my chair to adjust the hi-fi balance setting – I simply adjust the volume control on one of my cylinders! More, what better way to avoid the nagging mother/wife than to switch off, in full view of course!

Simon Tushingham
Whitefield
Manchester

Catching the pirates

In his Radio Broadcast article in the September 1987 issue – page 959, Pat Hawker makes a small but very understandable mistake in quoting the House of Lords' decision on the case of Department of Trade and Industry v Rudd given on 4 June 1987.

Since the sentence could encourage unlicensed broadcasters mistakenly to attempt to resist lawful seizure of records and tapes, I should be grateful if you could publish a sentence of correction.

Their Lordships ruled that records and tapes are not apparatus for wireless telegraphy and are therefore not liable to *forfeiture* by the Courts under section 14(3) of the Wireless Telegraphy Act 1949. However, an RIS officer has power under section 79 of the Telecommunications Act 1984 to "seize and detain, for the purposes of any relevant proceedings, *any apparatus or other thing* which appears to him to have been used in connection with or to be evidence of the commission of any such offence". This seizure power is not affected by the judgement. Records and tapes are "things" which may be part of the evidence which the RIS needs to put before the Court during the prosecution of an unlicensed broadcaster.

I should underline that this is a detail which in no way undermines the general accuracy of Pat Hawker's reporting.

D. Gane
Director
Radio Investigation Service

Underground radio

I was pleased to read Dr B.A. Austin's review article on through-the-rock radio propagation (September 1987 issue). He rightly points out the comparative neglect of this aspect of underground communications in the published literature. At the same time he himself has now redressed the balance substantially and authentically, and his well-chosen references will allow the serious student to follow the subject up.

Dr Austin himself meticulously avoids making any extravagant claims for this form of communication, or suggesting that through-the-rock propagation could take over the general role of leaky feeders in day-to-day mine radio communication; indeed he deliberately and properly uses the epithet 'mine-wide' in respect of leaky-feeder systems, while speaking of typical ranges of 300m or so for through-the-rock propagation in normal conditions.

And yet, the article does seem to be giving the impression in some quarters that here is a recently rediscovered form of underground communication that can eliminate the need for costly leaky feeders. This misunderstanding is probably a result of too perfunctory a reading of what is essentially a serious scientific paper with no axe to grind. It is therefore perhaps worth pointing out briefly the different roles that the two forms of radio propagation can play.

Leaky feeders can be guaranteed to provide reliable underground communciation over any required range, with the ability to employ conventional v.h.f. radio sets of one's choosing (which nowadays can be truly pocket-sized). If the particular channels used are so approved, the system can be extended above-ground to cover the surface precincts of a mine (or even, in one case I know, to the manager's house in the next county) by means of a conventional surface aerial. The price of all this is the installation underground of a special type of cable – the leaky feeder – throughout the mine: but contrary to what is sometimes alleged, such feeders can be simply bunched with other cables in the normal cable hangers; nor need they be nearly as expensive as is sometimes quoted.

However, it could be inconvenient or uneconomic to lay leaky feeders throughout the extracting areas of some types of mine worked on room-and-pillar or stoping principles, even though very cheap and expendable 'ribbon feeder' will usually serve in such situations, and here may be the appeal of the through-the-rock possibilities. But in this respect one statement of Brian Austin's perhaps needs qualifying. He speaks of communication being possible 'within some metres' of a leaky cable. This would be a fair statement in respect of the earlier leaky-feeder systems where the utmost longitudinal range was being squeezed out of each base station, but modern systems using in-line repeaters in the v.h.f. High Band (150 – 174 MHz) maintain a very high and consistent signal level, typically with a margin of some 20dB over the earlier standards. Such surplus would normally be good for a lateral range of 25 and perhaps 50 metres into a side tunnel or workings not equipped with feeder, making use of tunnel-guided propagation. In fact, by installing a local repeater feeding directly into a conventional aerial such range may often be pushed up to 200m or more, depending on the size and straightness of the side tunnel. These possibilities should perhaps be considered before looking to specially designed and quite expensive through-the-rock equipment, even though that equipment by being purpose-designed might better withstand mining conditions and use.

The really awkward situation, fortunately rare, is where a long winding tunnel has to be served and any form of laid conductor is expressly ruled out. It is here that through-the-rock propagation offers the best hope. In such cases some form of composite system seems to be called for – leaky feeders at v.h.f. in the long trunk routes and on the surface, through-the-rock using lower frequencies for the working areas. I have sometimes wondered whether a specially designed dual-band personal radio set would meet a need here.

There is, of course, a third type of underground radio system using inductive techniques. Brian Austin touches upon this subject in his mention of guidance by existing conductors. Generally, it is considered worthwhile to lay special conductor wires for the purpose, held clear of the tunnel walls and metal structures. This principle is still used as the basis of some proprietary systems, for which somewhat extravagant claims are sometimes made. Perhaps a specialist in this type of communication could redress the balance there with a similar authoritative treatment?

D.J.R. Martin
Great Bookham
Surrey

Readers' letters for publication are always very welcome, and it is helpful if they can be kept as short as possible to enable us to print a varied selection. Please do not feel inhibited about starting new hares for correspondents to chase – there is no need to confine your letter to matters already mentioned in the journal – *Ed.*

Self-repairing computer for space

A demonstration computer system has been designed for the European Space Agency by a British company, Smith Associates of Guildford. It is based on the transputer and can offer, for the first time in space, supercomputer power in a small enough package for use in satellites and other spacecraft. The principle involved is fault-tolerance and self-repair which makes the computer overcome the soft errors caused by radiation in outer space. This also allows the use of components that are not radiation hard.

Cosmic rays cause, on average, one soft error in a day. This will not affect the hardware but may corrupt the computer memory or program. The Smith system uses four transputers operating through 'voting' logic so that control or communications commands need to be confirmed by any two of them. In the event of an error, the faulty transputer can be reset by the others. All four have copies of the software for all functions and so can re-program each other. A further check involves having four different versions of the software; one for each processor.

All this can be accomplished with three processors but the fourth is provided in case of a hardware fault caused by radiation which could occur after about ten years. The demonstration model uses a standard Inmos four-processor development board with voting logic added.

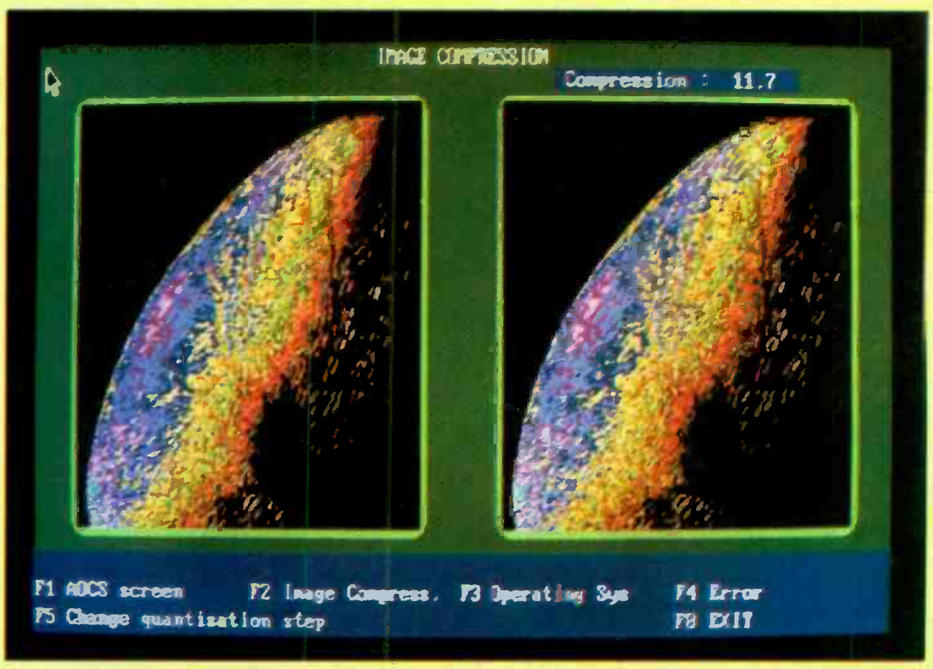
The advantages of such a system are considerable. Up to now 'radiation hard' components have been used in on-board computers of comparatively low standards. The Giotto craft, for example, which met Halley's Comet, had an eight-bit computer less powerful than the average desktop device.

Such systems have depended principally on ground control, but deep-space missions offer considerable delay in signalling; message and response takes about a 20 minutes round trip at the distance of Mars. So there is a great advantage if much of the control can be carried out autonomously. Similarly, the computer can undertake image compression and relay an image back to base every 10 to 20 seconds, instead of taking up to 100 seconds as is the case with some recent deep-space probes. Such images could be received by a number of users directly instead of their having to wait three months or more to get processed remote-sensing images from a space agency.

Other uses include control of on-board experiments; and control of robotic vehicles in unmanned missions to, for example, Mars. In the year 2003, there is another comet approaching Earth and there is a proposal to land a craft and attempt to sample the nucleus for analysis.

Smith Associates is an independent consultancy of systems engineers. They developed the transputer-based fingerprint recognition system for the Home Office, which is now manufactured commercially and used in many countries.

Traditionally, it has been necessary to send relatively old technology into space to ensure reliability. Fault-tolerant design makes it possible to take advantage of the latest devices. Fast processors provide efficient image compression, reducing the bandwidth required to transmit pictures back to earth.



New teletext for BBC-tv

Level 2 teletext pages are among the features Ceefax will soon be able to offer with its new computer from Softel.

Improvements in BBC television's teletext service Ceefax are coming, though few viewers at first are likely to notice them. In a few months' time the DEC minicomputer system which has been in operation at the Television Centre in West London since 1979 is to be replaced by more powerful hardware. Besides having support for extensive modem links to outside information sources, the new computer will process pages faster and will be able to handle enhancements to the basic teletext format. The hardware will still be based on DEC equipment, but support for it will come from Softel, the company behind ITV's rival Oracle system. Peripheral items such as monitoring decoders and editing terminals for the new system will be manufactured by Softel's hardware offshoot, Softel Electronics.

Softel is a relatively new company: it was started in 1983 by George Berry and Steve Gould, both of whom were previously with the special projects group of Digital which until then maintained Oracle's system. The BBC's present system was supplied by Logica.

Right: preparing a Level 2 teletext page on a Softel SE3030 terminal. By pressing a key, the operator can quickly switch to Level 1, revealing any features of his design which will show up badly on older tv receivers equipped with Level 1 decoders.

Level 2 teletext (above) provides more foreground and background colours and can give double-width characters as well as double-height. Up to 193 control characters are allowed per page; the extra cost in transmission time is relatively slight. Pages can be assembled quickly by pouring Level 1 text on to Level 2 backgrounds prepared in advance.

Broadcasters in the Netherlands, Belgium, Sweden, Ireland, Dubai, Malaysia and Australia are among the overseas users who now have teletext systems installed or maintained by Softel. But to have gained contracts for both UK systems will provide Softel with a valuable showcase to promote further sales abroad.

Accents and special characters for foreign languages are no longer the obstacle they were in the anglocentric early days of teletext. Dubai's system is bilingual in Arabic and English, with hybrid decoders developed by Mullard and special editing terminals from VG Electronics. Even Japanese characters are now included in the expanded World System teletext specification.

New freedoms offered by advanced decoder i.cs such as those from Mullard now make it possible for newcomers to teletext to adopt the higher-level specifications from the outset. Teletext is a hierarchical family of system, with the Level 1 standard now familiar in British homes at its base and Level 5, which is equivalent to photo-videotext, at the top. Spain is likely to be the next major European broadcaster to begin a teletext service; and the need for the tilde and special punctuation marks may encourage her to begin with Level 2.

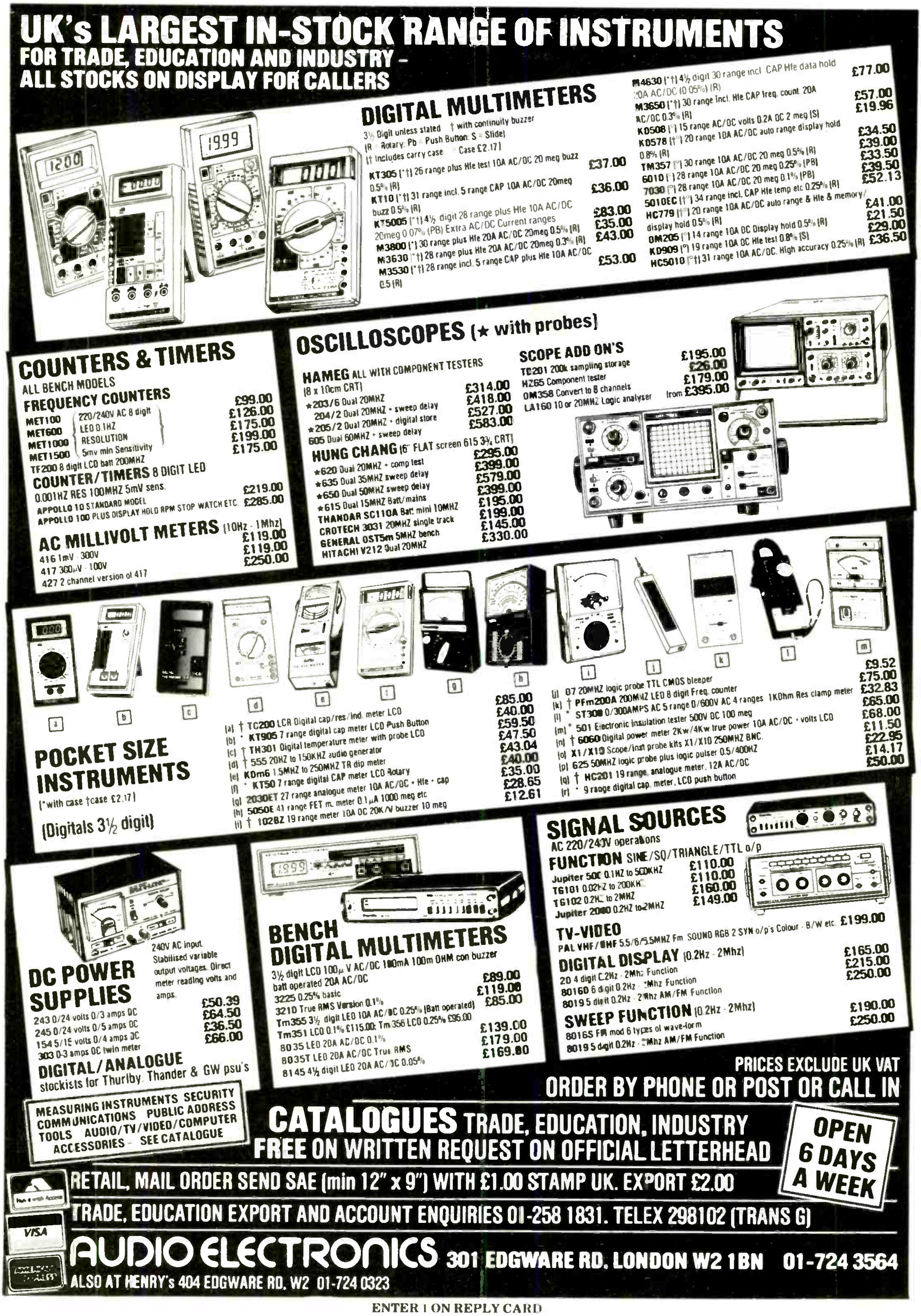
Level 2 teletext also offers a marked improvement in appearance at a fairly small cost in transmission time. Pages can include smooth mosaics and can be made up of 16 standard colours plus a further 16 redefinable colours out of a choice of 4096. Level 3 brings in addition the further benefit of dynamically-redefinable character sets, and here the characters can be graphic elements as well as text characters.

Softel is also active in the field of non-broadcast teletext systems. Among these is a pair of installations for the Manpower Services Commission, which make up pages of job advertisements for transmission on the Central and Yorkshire independent tv networks during the night. The advertisements are composed as Level 2 teletext pages and transmitted in vision.

Another rather unusual closed-circuit system was commissioned by Softel at the Yeovilton naval air base in conjunction with another company, System Skill. This feeds air traffic control information to some 50 screens around the base, using full-field teletext distributed by cable. Teletext pages, which can include block graphics, are sent in groups of four, then re-formatted into 80-column screens for display. Individual pages can be accessed in less than a second, which is very much faster than would have been possible with a system based on RS232 serial links.

Softel says its software-based approach enables it to adapt systems easily to satisfy individual customers' needs. And improvements devised for one can be made available to all. Software for Softel's broadcast teletext systems is written in PDP-11 assembly language and in the Pascal-like RTL-2.

Softel is at Pangbourne on 07357-2151. System Skill is at Woking on 04862-24766.



ENTER 1 ON REPLY CARD

Institution of Electrical Engineers.

Pioneers

13. Heinrich Rudolf Hertz (1857-1894) and the discovery of radio waves.

W.A. ATHERTON

Because he died young we think of Hertz as a 19th century scientist, a man from long ago. It is a salutary thought that, had he lived into his eighties, he could have ended his days in a Nazi concentration camp.

Heinrich Hertz needs no introduction. A hundred years ago today he was deep at work on what was to become the experimental verification of Maxwell's theory of electromagnetism. His work proved the existence of electromagnetic or radio waves, shattered the concept of action at a distance, posed problems for electrical science and paved the way for radio communications.

Hertz found himself in the foremost rank of world physicists, lauded in science publications and the popular press. He was just 31 years old and the new scientific megastar. Six years later he was dead. Blood poisoning had robbed the world of his genius.

ELECTRIC WAVES

Early in his investigations Hertz found that electric waves move with finite velocity along a wire. Oliver Lodge performed similar work at about the same time in London and both men had been anticipated by Wilhelm von Bezold in 1870.

But Hertz made another discovery which set him apart. He observed that if a piece of wire was formed into a circle, with only a tiny gap between the ends, a spark could be made to cross the gap whenever a spark discharge was produced at a nearby inducation coil. This happened even when there was no physical connection between the two, provided the resonant frequencies were similar. He had transmitted and received electromagnetic radiation through the air.

Others had in fact made similar observations but they had not realised what it was they had seen, nor had they linked it with Maxwell's ideas. Uniquely, Hertz now had a thorough understanding of Maxwell's theory and a rudimentary transmitter and receiver with which to investigate its physical assumptions and predictions. It was a task he now set himself.

Early in a series of experiments performed in 1887 and 1888, he studied the effects of placing different dielectrics between the transmitter and receiver. Wood, sulphur, paraffin and asphalt were used and his results confirmed one of the basic principles of Maxwell's theory: the polarization of a dielectric by electromagnetic forces.

Next, by measuring the length of the electric waves and calculating the frequency of his oscillator, Hertz was able to calculate the velocity of transmission of the waves through air. It was close to the known value for the speed of light and the two were later shown to be equal. This was a momentous discovery.

Two schools of thought had arisen as to how magnetic and electric forces acted on objects with which they were not in contact. The action-at-a-distance school assumed instantaneous action. Maxwell and others assumed the forces were transmitted by action between neighbouring particles, rather like a train shunting. This takes time. Hertz had shown that, incredibly fast though electromagnetic radiation is, its velocity is finite. This fact killed the widely-held concept of action at a distance.

Also in 1887 he discovered the photoelectric effect (the increase in current caused in some materials by incident light). He left its further examination to others, even though he recognized its importance. His goal was to test Maxwell's electromagnetic theory of light.

Demonstrations of standing waves, polarization, interference and diffraction followed. By the end of 1888 Hertz had proof that, like light, electromagnetic radiation is propagated as waves.

Walls covered with zinc sheeting reflected the radiation and enabled standing waves to be produced by interference between the incident and reflected waves. A 100kg prism of hard pitch was used to obtain refraction. Parallel wires arranged as a grating polarized the waves, a phenomenon which could also be achieved by reflection from the wall. The waves cast a shadow when directed at tin foil or gold paper and this demonstrated their ray-like properties. A screen with a hole in it produced diffraction.

Hertz had even found that the electric and magnetic fields oscillated at right-angles to one another.

EQUIPMENT

His equipment was modified several times and it is impossible to know exactly all the frequencies at which he worked, although estimates have ranged from 50 to 500MHz, in what are now the v.h.f. and u.h.f. bands.

For the final set of a long series of experiments the transmitter (or primary conductor as Hertz called it) consisted of an adjustable spark gap, set at 3mm, in the middle of a 26cm long brass dipole. The poles of the spark gap were formed by two spheres and fed by a small induction coil. A parabolic reflector was made from a zinc sheet two metres square. This simple and elegant device was held together with paper, wood, sealing wax and rubber bands. It could be dismantled quickly for the frequently-needed repolishing of the pole surfaces.

The receiver, or secondary conductor, had a dipole aerial. Each arm was 50cm long. Two wires connected the arms to a tiny spark gap formed between a brass sphere and a fine copper point. A wafer spring and micrometer screw gave exceptionally fine adjustment to the spark gap.

With this simple equipment, for which he measured the wavelength at about 66cm (455MHz), Heinrich Hertz conducted experiments which led to a revolution in physics and a revolution in electrical communications.

HERTZ'S EDUCATION

Hertz was born on February 22, 1857 in Hamburg, the son of a prosperous barrister who later became a senator. He had three brothers and a sister, all younger than himself. His father's family was Jewish, a fact which drew the attention of the Nazis some fifty years after Hertz's death. Hertz himself was a Lutheran.

At the age of six he started school. Though he did not demonstrate much artistic or musical aptitude, by twelve his practical skills were such that he had his own workbench and wookworking tools. Later he acquired a lathe. These practical skills were to prove important in his career.

He also had a great aptitude for languages, coming first in his class at Greek and taking private lessons in Arabic.

When he was 18 he moved to Frankfurt to prepare for a career in engineering. It was the first of a series of moves.

Engineering was a career he never followed but a year was spent gaining practical experience and reading for the state examination. As a side interest he also studied natural science and mathematics, a hint of an internal conflict between the rival attractions of science and engineering.

There followed a short spell at Dresden Polytechnic and a year of military service with the railway regiment in Berlin. Then in 1877 he moved to Munich, planning to enter the Technische Hochschule. Instead, with his father's financial backing, he entered the University to begin an academic and scientific career. The mental tug of war between engineering and science had been settled.

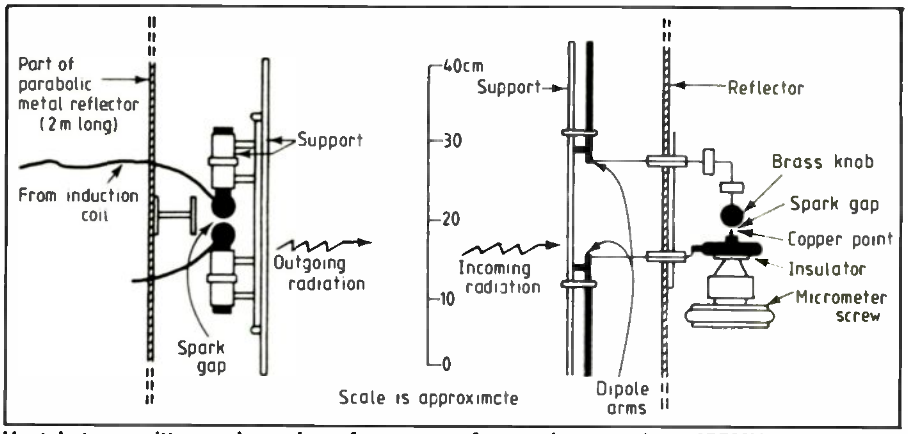
At Munich he alternated between theoretical and practical studies, a pattern which continued in his professional life. After a year he moved to Berlin to continue his studies, having also considered Leipzig and Bonn. Berlin was the right decision. It brought him directly into contact with Hermann von Helmholtz, a major figure in German physics and the man who was to become his mentor.

Immediately on his arrival in Berlin, Hertz was drawn by a prize offered to solve a problem concerning possible electrical inertia. Though a university student for only a year he decided to go for it. He won it by showing that electrical inertia, if any, is either zero or very close to it.

Helmholtz, who had suggested the problem, provided facilities and his own growing respect.

Helmholtz had by now suggested that Hertz try for another greater prize. This one was offered by the Berlin Academy for an experimental decision about the crucial assumptions of Maxwell's theory. Helmholtz was pointing his star student at a problem which would eventually make the student greater than the master. But Hertz turned away.

After writing his doctoral dissertation, which took him a mere three months, he became a salaried assistant to Helmholtz at the Berlin Physical Institute. It was a position he held for three years from 1880. He performed his duties, conducted research, published papers and attended scientific meetings which brought him into contact with the Germany's greatest physicists.



Hertz's transmitter and receiver: frequency of operation was about 455MHz.

The next career step for a budding university researcher was as an unpaid lecturer at the bottom of the hierarchy. This he undertook at the University of Kiel.

As Kiel had no physics laboratory, Hertz concentrated on theoretical work: meteorology, electric and magnetic units – and Maxwell's theory. This was his first deep study of Maxwell. Slowly everything was fitting into place.

KARLSRUHE

The lack of a laboratory at Kiel caused Hertz to turn down the eventual offer of a salaried position. So he moved again, his seventh move in eleven years, this time to the Karlsruhe Technische Hochschule as a professor of physics. He went there in 1885. The next year changed his life in two ways.

In the first half of the year he met Elisabeth Doll, the daughter of a colleague, courted her, and in July they were married. In November he began the experimental work which earned him his place in history.

Throughout he kept in touch with Helmholtz. Whilst at Karlsruhe Hertz published nine papers about his work on electromagnetic radiation. The ramifications of the discovery of the photoelectric effect he left for others to work through. In fact it was the future quantum theory which solved that particular puzzle and that was begun by Max Planck, the man who had succeeded him at Kiel.

In 1888 Hertz's fame was such that the university headhunters were after him. He refused an offer from the University of Giessen. Berlin wanted him as Kirchhoff's successor but in December it was the University of Bonn that succeeded in acquiring his services. Later Clark University in America approached him and the University of Graz tried to tempt him to become Boltzmann's successor. The tale is reminiscent of the transfer market for a modern-day football star.

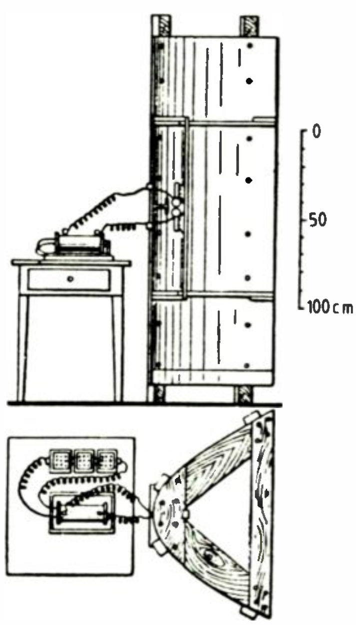
In Bonn he lived with his family in the house where Rudolph Claussius had lived. He took on one research assistant – Philipp Lenard, who later won a Nobel Prize. More scientific papers and books followed.

By now Hertz had received many awards and medals by way of international recognition. One was the Rumford Medal of the Royal Society of London for which he came to England and was welcomed by the leading British physicists and electrical engineers.

Whilst at Karlsruhe Hertz had complained of toothaches. They were so bad that in the middle of his epic work one hundred years ago he underwent an operation on his teeth. The next year all his teeth were removed. Later he stopped work for a time because of nose and throat pains. Head operations followed and, understandably in an age of limited anaesthetics, he was often depressed. It would seem probable that he had a developing brain tumour but, whatever the cause, it was beyond his doctors' full understanding.

In the autumn of 1893 he worked on the last stages of his book on mechanics. This went to the publisher early in December. On December 7 he gave his last lecture.

At the age of 36 he still had much to offer, but he died on New Year's Day 1894. He was survived by his wife and two daughters, all of whom fled to England from Nazi Germany in 1937.



The parabolic reflector arranged on a wooden frame. (After W.F. Magie: A Source Book of Physics, McGraw-Hill, 1935.)

Next in this series of pioneers of electrical communication will be Alan Blumlein, the British electronics genius.

Lossy ells for pie tea

Matching networks for r.f. power transfer come in several forms. In spite of J.W.'s weird title, this is his subject this month

JOULES WATT

Most electronics people on the communications side know that, to get r.f. power from the p.a., up the transmission line and into the aerial, equal impedances on each side of the interface between system and aerial, or between stages, in some way become involved.

Strictly speaking, there is an error in my last comment. A closer look shows that you require not just equal impedances, but complex conjugate impedances for maximum power transfer matching: I discussed this in an earlier article[1]. But there is more to it than that in r.f. circuit design, because other frequencies, such as harmonics, tend to arise that require the coupling circuits to filter them out.

As you know, there are strict rules about harmonic suppression and the elimination of spurious emissions. This means that the networks used must not only match the stages one to another or the aerial to the final stage, but in addition they must tune to the appropriate frequency. Even this does not end discussion about the question, because the Q of the tuning sections has to be correct for efficient power transfer between stages and to give sufficient off-channel attenuation to carry out the said harmonic suppression and so on. And which Q are we talking about in any case? A recent article in this journal discussed how more than one Q value can appear in the description of the same circuit[2].

L – NETWORKS

If you consider Fig.1(a), the coil and capacitor form the common or garden series-tuned circuit, or *acceptor circuit* we all know about. The reactance of the capacitor equals that of the inductor at a certain frequency and we talk about the circuit being resonant at that point. But you can redraw the series LC circuit as in Fig.1(b), which emphasizes its potential-divider aspects. In a kind of intuitive way, you can see that the L circuit will offer a large reactance in the inductive arm and a low one in the shunt capacitance branch to all frequencies above resonance. The circuit forms a simple low-pass filter.

In a way not so obviously seen as the tuning action I have just described, this L network also acts as a resistance-matching transformer.

The plot thickens, because the L section hardly ever gets described via the series resonant circuit approach I tried above. The more detailed parallel resonant circuit, or rejector circuit stands in for this service.

From your basic studies, you might remember that a parallel LC circuit offers a very large impedance at its resonant frequency. This impedance is real, and we call it by the old radio engineer's term *dynamic resistance*, R_D. The following quick review shows how we derive the value of R_D. From Fig.2(a), the admittance from A to B is,

$$Y = j\omega C + \frac{1}{R_1 + j\omega L}.$$

By adding up and rationalizing the denominator, this is,

$$Y = \frac{R_1}{R_1^2+\omega^2L^2} + j\frac{\omega C R_1^2 - \omega L(1-\omega^2 LC)}{R_1^2+\omega^2L^2} = \frac{1}{R_p} + \frac{1}{jX_p}$$

so that R_p and X_p correspond to the shunt equivalent circuit of Fig.2(b).

For the reactive part to disappear, the numerator in the 'j' term of the expression for Y has to be zero. This yields the resonant frequency f_o.

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R_1^2}{L^2}}$$

Putting this back into the term for R_p (or rather using it in the form of the angular frequency ω_o) simplifies R_p down to $R_p = L/R_1C$, which is what we have also called R_D. You can see that with a very small R_1, R_D is huge. In addition, with R_1 small, f_o approaches a value given by the simpler expression for resonant frequency,

$$f_0 = \frac{1}{2\pi\sqrt{LC}},$$

which is given in all the elementary text books for high-Q tuned circuits.

If we use this expression in the form $\omega_0^2 = 1/LC$ in the R_D equation above, then we obtain all the alternative descriptions.

$$R_D = \frac{L}{R_1 C} = \frac{\omega_0^2 L^2}{R_1} = Q\omega_0 L = \frac{1}{\omega_0^2 C^2 R_1} = \frac{Q}{\omega_0 C}$$

from which you can take your choice in applications.

These show that R_D increases with Q – as you would expect from knowing that Q describes the 'goodness factor' of the coil.

TRANSFORMING IMPEDANCES

You might ask at this stage, "What has this elementary theory of tuned circuits got to do with impedance matching – such as coupling my high-Z transmitter p.a. output circuit into the low-Z aerial?"

We have actually found the answer already. The low-impedance aerial corresponds to the low R_1 position and would be

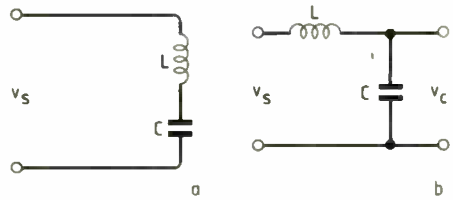


Fig.1. A series L-C circuit can be thought of a reactive potential divider, as well as a resonant circuit.

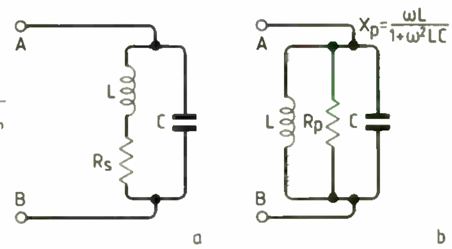


Fig.2. The parallel resonant circuit has some interesting properties, not least the fact that smaller and smaller R_s gives rise to a larger and larger R_p.

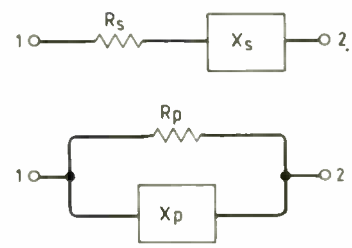


Fig.3. The impedance seen between 1 and 2 in both these circuits is the same, so that transformations can be made between them as desired.

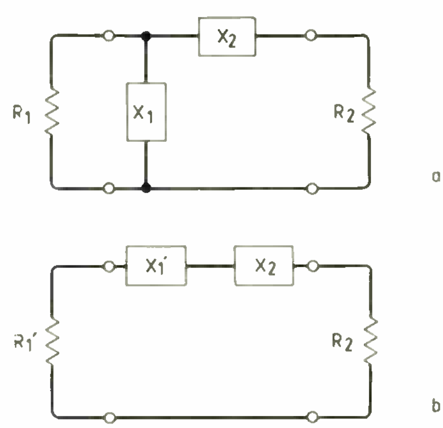


Fig.4. The transformation of the L circuit shown here employs the series-to-parallel conversion, which simplifies calculations considerably.

placed there in practice. The value of R_p corresponds in value and circuit position to the high-impedance output-stage load requirements. The factor that connects the two is Q. (Have another glance at the equations above).

A few points arise immediately from the discussion in the way I have given it. Firstly, the reactive parts of any source and load impedances to be matched combine with the L network components and end up tuned out. This means that we only have to consider resistive values. Another point shows that the *series* arm has to contain the lowest resistance – while the high value must go across the shunt arm. Lastly, because there are three quantities varying but only two components which you can adjust (the L and C), the value of one quantity (the Q) cannot be independently chosen, and this has implications for those harmonics that we said need suppressing.

The way you can design L – networks usually proceeds slightly differently from my discussion, which I intended as a familiar path to assist understanding. Before going on to summarize the procedure, there is a transformation that most people soon get rusty about and some students fail to see as at all relevant to anything. You will find the transformation of shunt values to series equivalents and vice-versa valuable in circuits containing, say, transistors at high frequencies. Figure 3 shows the two circuits and the transformations arise from,

$$Z=R_s+jX_s$$

and
$$\frac{1}{Z}=\frac{1}{R_p}+\frac{1}{jX_p}$$

where Z is the same in both networks. Adding and rationalizing the second expression, then equating real and imaginary parts gives us,

$$R_s=\frac{R_pX_p^2}{R_p^2+X_p^2}$$

and
$$X_s=\frac{R_p^2X_p}{R_p^2+X_p^2}=\frac{R_p}{X_p}R_s.$$

Similarly you can derive
$$R_p=\frac{R_s^2+X_s^2}{R_s}$$

and
$$X_p=\frac{R_s^2+X_s^2}{X_s}=\frac{R_p}{X_s}R_p.$$

L NETWORK MATCHING SECTION

Discussion has reached the stage where you can see how to match any source impedance to a load differing in value. Consider Fig.4(a), where source resistance R_1 is to be matched to load resistor R_2 by means of the reactive L network X_1, X_2. A direct use of the parallel-to-series transformation allows us to write series equivalent values R_1' and X_1', so that the L network now looks like the circuit in Fig.4(b) with

$$R_1'=\frac{R^1X_1^2}{R_1^2+X_1^2}=R_2 \text{ and } X_1'=\frac{R_1}{X_1}R_1'=-X_2$$

because for matching, X_2 must tune out X_1 and the transformed value, R_1', must equal

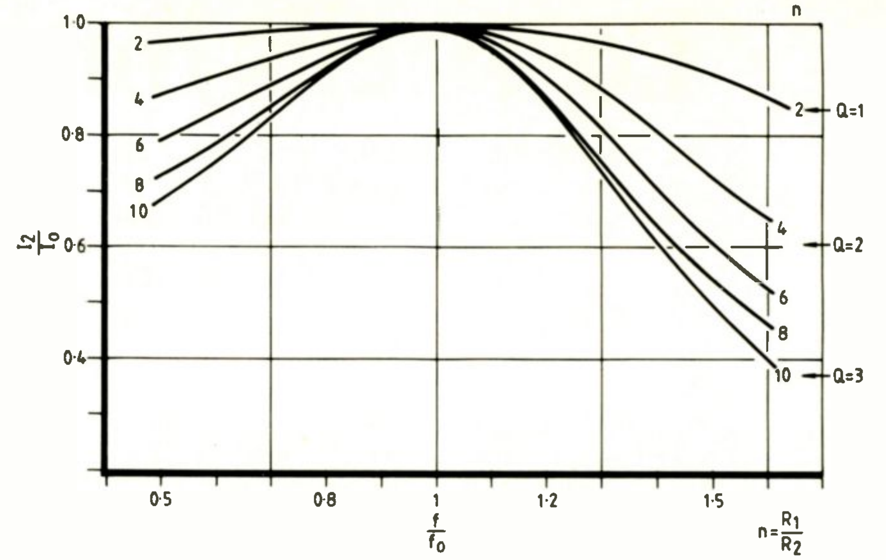


Fig.5. With a shunt capacitor in the L network, the high frequencies become more attenuated than the low. This is a low-pass filter property.

R_2. Solving for the reactances gives the design values for this piece of work,

$$X_1=\pm R_1\sqrt{\frac{R_2}{R_1+R_2}}$$

and
$$X_2=\mp\sqrt{R_2(R_1-R_2)}.$$

A few more points of interest arise again. You might notice that the reactances must be of the opposite kind. If X_1 is an inductance, then X_2 must be a capacitor, or vice versa. The quantities under the square root signs will only be positive if $R_1>R_2$, agreeing with my earlier statement. In passing, you could note that if the capacitor is in shunt, then we have the low-pass solution. If you swap over the inductor and capacitor, then you get the *high-pass* version, of course. This has ramifications for the harmonic suppression.

Q

The resistors determine the reactances, so for the shunt capacitor version the Q automatically follows,

$$Q=\frac{R_1}{\omega_0C}=\frac{\omega_0L}{R_2}.$$

Therefore from the relation,

$$R_2=\frac{R_1X_1^2}{R_1^2+X_1^2}$$

we obtain,

$$R_1=R_2(1+Q^2)$$

which shows the relation between R_1, R_2 and Q. Larger transformation ratios give increasing Q. Figure 5 illustrates the filter-like characteristics as well as the increasing Q with larger transformation ratios.

FROM L TO T (AND π)

The awkwardness we find in having to put up with a Q we cannot choose disappears if we introduce a third variable to add its effect. You can always use two L networks, one transforming R_1 to some intermediate resistance R_m, then the other network going from R_m to the final resistance, R_2. Of course, as Fig.6(a) shows, R_m comprises a virtual resistor, but drawing it in as a stepping stone through the network, as it were, helps us visualize what is going on.

You might think that two L networks

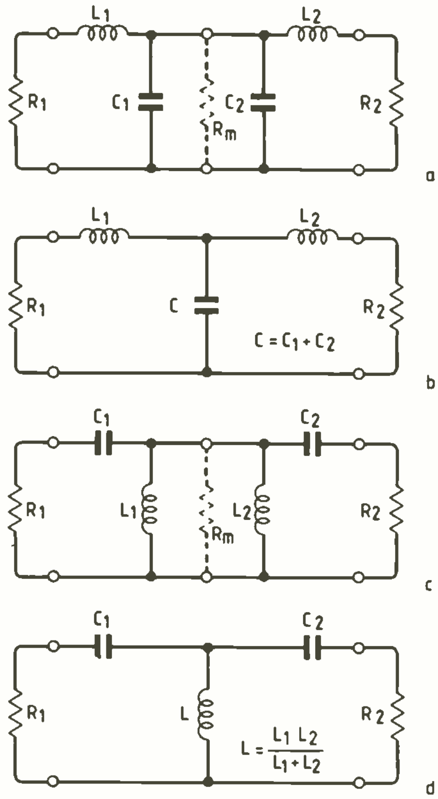


Fig.6. When two L-sections combine in various ways, all the interesting T and π circuits can be derived. In (a) the two Ls form a T network, as shown in (b). (c) and (d) show the high-pass version of the same T-network.

would add *four* variables. But the two inner ones add or subtract to leave a single resultant, which means only three really there. The discussion so far shows that L networks and the combinations have many forms. If the pair suggested for the transformation have their shunt arms inside, then a T-network results, as shown in Fig.6(b). Series arms facing inward give the π – networks.

The story does not end there. As we saw above, the L networks matching two resistors can have their inductive arm swopped with the capacitive. In other words, if you are in the low-pass configuration, you can change to the high-pass version without altering the matching. The result gives, at resonance, an electrically equivalent, but physically different T-network, as Fig.6(c) and (d) show.

ANALYSIS AND DESIGN OF T AND π NETWORKS

Glance back at Fig.6(a). L_1 and C_1 transform R_1 into R_m across the capacitive arm. This means $Q_1 = X_{L1}/R_1 = R_m/X_{C1}$. Similarly, you can see that C_2 and L_2 transform R_m to the final value R_2. The Q this time is $Q_2 = R_m/X_{C2} = X_{L2}/R_2$. In general, you will find these Qs not necessarily equal. The largest Q value sets the overall circuit, or operating Q.

Combining the two capacitors into the single equivalent yields the shunt C in the T network in Fig.6(b). The design procedure is:

select a Q

$$\therefore \quad X_{L1} = QR_1$$

The Q of the second half of the circuit follows,

$$Q'=\frac{X_{L2}}{R_2}.$$

R_m is given by,

$$R_m=R_1(1+Q^2)$$

or

$$R_m=R^2(1+Q'^2).$$

From these equations you can see that, for the T network, R_m must be larger than R_1 and R_2.

Now

$$\frac{1}{X_C}=\frac{1}{X_{C1}}+\frac{1}{X_{C2}}=\frac{1}{R_m}\left(\frac{R_m}{X_{C1}}+\frac{R_m}{X_{C2}}\right)=\frac{1}{R_m}(Q+Q')$$

therefore

$$X_C=\frac{R_m}{Q+Q'}.$$

Our job now is to get Q', X_{L2} and X_C in terms of R_1, R_2 and Q. After being presented with R_1 to be matched to R_2 and then choosing the Q, if we can derive these quantities we can design the network.

The results accrue from manipulating the equations written above. For example, eliminating R_m from the two equations containing it gives,

$$R_1(1+Q^2)=R^2(1+Q'^2)$$

or

$$Q'=\sqrt{\frac{R_1}{R_2}(1+Q^2)-1}$$

and we can check this against Q to see which is the largest. Using this expression for Q' in the equation for X_{L2}, gives,

$$X_{L2}=R_2\sqrt{\frac{R_1}{R_2}(1+Q^2)-1}$$

Similar, substituting for Q' and R_m in the expression for X_C

$$X_C=\frac{R_1(1+Q^2)}{Q+\sqrt{\frac{R_1}{R_2}(1+Q^2)-1}}$$

These design equations give us the reactances of all arms of the T-network to match a given source resistance R_1 to a load R_2 with a circuit Q chosen independently.

LOSSY L's

You may ask, "What about the 'lossy L' of the title?" I have always wondered about that question also. Apparently this term arises in the literature to describe an L,C,C, T-type network that we obtain by exchanging the second C and L, as in Fig.7. When $R_1 < R_2$, the result of C_1 and L_2 is a single capacitor C whose reactance is given by,

$$\frac{1}{X_C}=\frac{1}{X_{C1}}-\frac{1}{X_{L2}}$$

By procedures very similar to the T-network derivations, you can show that the three reactances and the chosen Q, relate to the second Q (=Q'), R_1 and R_2 by,

$$Q' = \sqrt{\frac{R_1}{R_2}(1+Q^2)-1}$$

$$X_{L1}=QR_1$$

$$X_{C2}=R_2\sqrt{\frac{R_1}{R_2}(1+Q^2)-1}$$

and

$$X_C=\frac{R_1(1+Q^2)}{Q-\sqrt{\frac{R_1}{R_2}(1+Q^2)-1}}$$

The last equation shows that R_1 has to be *less* than R_2, or else no real capacitor fits the model. (The sign of the reactance changes, so that you would have to use an inductance.) When R_1 equals R_2, the limiting case occurs – X_C goes to infinity. In other words, the capacitor C goes to zero and you are left with a series tuned circuit coupling the two equal resistors.

FINALLY THE π CIRCUIT

The two L sections form a π network when their series arms face inward, as you can see from Fig.8. Now R_m must be less than either R_1 or R_2 as you can see from the Q relationships,

$$Q=\frac{R_1}{X_{C1}}=\frac{X_{L1}}{R_m}$$

and

$$Q'=\frac{R_2}{X_{C2}}=\frac{X_{L2}}{R_2}$$

By doing a shunt to series transformation at each end, we obtain,

$$R_m=\frac{R_1}{1+Q^2}$$

$$\text{and } R_m=\frac{R_2}{1+Q'^2}$$

which justifies the statement that R_m must be smaller than either of the other two.

Exactly the same as before you can show that,

$$Q'=\sqrt{\frac{R_2}{R_1}(1+Q^2)-1}$$

with

$$X_{C1}=\frac{R_1}{Q}$$

$$X_{C2}=\frac{R_2}{\sqrt{\frac{R_2}{R_1}(1+Q^2)-1}}$$

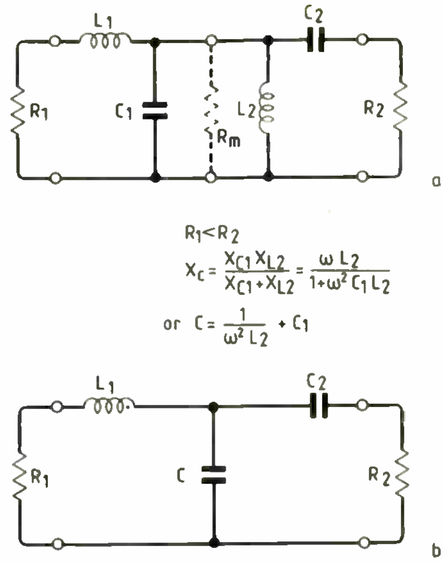


Fig.7. By making a kind of 'hybrid' with the Ls, as in (a), assymetrical T-networks, such as the lossy L shown in (b) can be obtained.

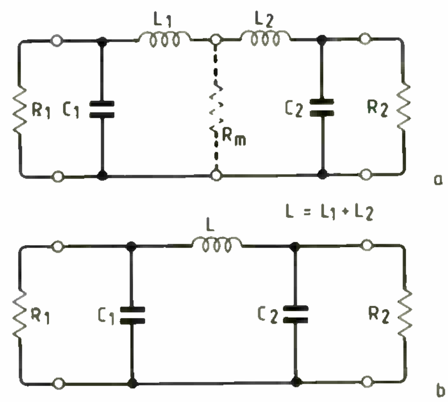


Fig.8. By turning round the L-networks, the π circuits result, as seen here in (a) which forms the low-pass π type matching network.

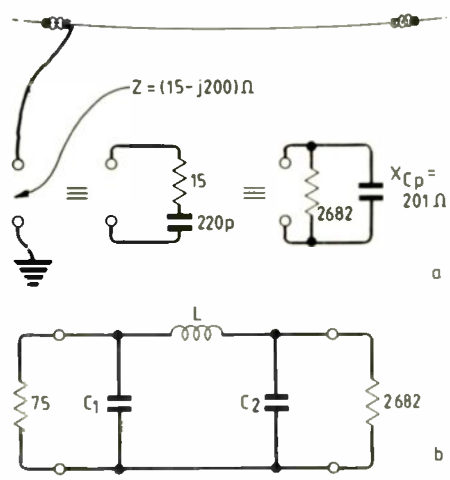


Fig.9. This shows a typical application. In (a) a non-resonant aerial and its terminal equivalent circuit is converted to the parallel form by the transformation. A π network then matches it to 75Ω.

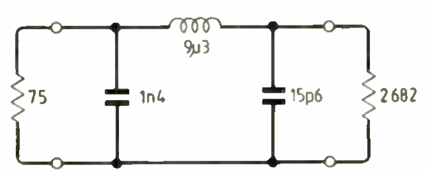


Fig.10 The final network for the aerial with values.

and

$$X_L=\frac{R_1Q+R_1R_2(1+Q_2)-R_1^2}{1+Q^2}=\frac{R_1Q+\dfrac{R_1R_2}{X_{C2}}}{1+Q^2}$$

These appear slightly more complex than the other network design equations, but you will not find that significant. More important, if your R_1 turns out to be less than R_2 in the π-network, inconveniently small inductances become involved, while the capacitors become very large. In that case, the T network might be the best choice, or you can notionally invert the π network, making R_1 the R_2 value, letting X_{c1} become X_{c2}, and so forth, as the example below illustrates. The final outcome rests on your decisions from experience as a designer.

EXAMPLES

This is the kind of discussion that rounds off well if you try an example or two.

Take a typical h.f. radio transmitter operating, say, in the 3.5MHz band, which has an output impedance of 75 + j0. The problem is to feed an electrically short aerial. Aerials shorter than the first resonance will have large capacitive reactances, which require tuning out and will offer rather low radiation resistances. Suppose measurements show[3] that the aerial looks like a resistance of 15Ω in series with a reactance of −j200Ω, as Fig.9(a) illustrates. At 3.5MHz, the capacitance of the wire aerial turns out to be 220pF. We convert this series circuit into its shunt equivalent, which gives R_p = 2682Ω and X_{Cp} = 201Ω. Fig.9(b) shows the final circuit ready for the analysis. The design might require good harmonic suppression, calling for a Q of say, 15. If you try this value in $X_{C1} = R_1/Q$, a very large capacitor (to give a reactance of 5Ω) turns up in the C_1 position. Also, you will find that Q' is larger (in fact its predicted value from the equation is a ridiculous 8000 or so...).

Invert the network, so that you can start with R_2 as the 'new' R_1. This gives for a Q of 15,

$$X_{C2}=\frac{2682}{15}=178\Omega$$

Now calculate X_{c1}

$$X_{C1}=\frac{75}{\sqrt{\frac{75}{2682}(1+15^2)-1}}=32.5\Omega$$

Similarly for X_L

$$X_L=\frac{15\times2682+\dfrac{75\times2682}{32.5}}{15^2+1}=205.4\Omega$$

and a quick check to see that Q' comes out reasonably.

$$Q'=\sqrt{\frac{75}{2682}(1+15^2)-1}=2.3$$

which is lower than Q.

The only tiny little pitfall to watch is that X_{C2} contains the existing aerial capacitance, so that the lumped component we have to add will be considerably smaller than expected by the reactance value. In fact it is a capacitor C_2', such that its reactance at 3.5MHz is,

$$X_{C2}'=\frac{X_{Cant}\times X_{C2}}{X_{Cant}-X_{C2}}=\frac{200\times178}{200-278}=1618\Omega$$

We know all the reactances of the π-network and, as the frequency is 3.5MHz, the actual component values from the usual formulae follow immediately,

$$C_1=1400\text{pF}, L=9.3\mu\text{H}, C_2'=15.6\text{pF}$$

As a final example, suppose you want to match the 2N4072 driver stage in a 145MHz exciter to a 2N3866 p.a. which you intend to deliver 1 watt into a 50Ω load. If the details of the circuit are as shown in Fig.11(a), with the equivalent in (b), try designing a lossy L network, say, to accomplish the match with a Q of 8. Answers next time.

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1. Joules Watt, "The Maximum power theorem", *Electronics and Wireless World*, Vol. 92, No. 1611, January 1987

2. K.L. Smith, "Q", *Electronics and Wireless World*, July, 1986

3. L.A. Moxon, "H.f. antennas for all locations" RSGB, 1982.

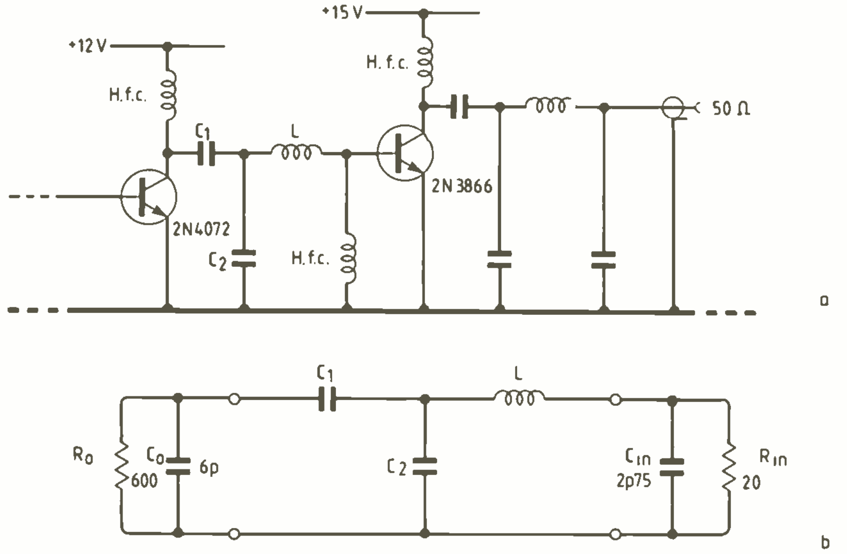


Fig.11. The circuit in (a) shows a driver stage and p.a. with the equivalent output and input impedances of the devices running at the power level assumed, shown in (b). The problem is to calculate suitable values for C_1, C_2 and L for maximum drive to the p.a.

New r.f.i. test centre

With r.f.i. emission regulations expected to be harmonized throughout Europe in 1992 (and the likelihood that any new requirements will conform to the stringent West German standards), the need for compatibility testing of new electronic equipment is likely to increase dramatically. In particular, it is probable that for the first time all new data processing equipment will have to be tested for radio emissions.

To cope with the expected demand for test facilities, a new company, Radio Frequency Investigations, has been set up by two former staff of the test equipment manufacturer Rohde & Schwarz. Stephen Kirk and Brian Watson believe their service will prove especially popular with small manufacturers because of the confidentiality they can offer. At present, almost all r.f.i. test centres are offshoots of large electronics companies who use them to evaluate their in-house products; and outside users of their facilities are often uneasy about exposing their prototypes to a potential rival.

Besides testing new products and giving advice and technical solutions, RFI can provide consultancy services and radiomonitoring facilities on customers' own premises. Details from Radio Frequency Investigations Ltd on 0256-851193.

Using fully-automatic test equipment dramatically reduces the time taken to produce results, says the company; operator error in recording measurements is eliminated and the systems are self-documenting.

Multiprocessor systems

When designing a multiprocessor system, one of the first steps is to consider the various bus-structure options.

G.A.M. LABIB

Microprocessors are used for their low cost, small size and wide range of processing and control capabilities. Compared with logic i.cs, software-controlled microprocessors are much more flexible.

Nevertheless, some microprocessors are not fast or powerful enough to keep up with demanding real-time applications. In such situations, an alternative to choosing a faster and much more expensive device is to use many cheap microprocessors working in parallel. Having each processor executing a different task compensates for the speed drawback, increasing system throughput the flexibility.

In order to work together harmoniously in a multiprocessor system, the microprocessors need an efficient means of exchanging data with each other. If the communication paths are not efficient, bottlenecks occur.

Data is usually exchanged between microprocessors in one of two ways – either through i/o ports or using shared memory. Even with specially designed microprocessors, communication through i/o ports is not particularly fast and each additional connection within the system requires special hardware.

Figure 1(a) shows a widely known multiprocessor architecture in which all processors connect to a shared global memory through one bus. Such a configuration has limitations; increasing the number of processors to more than about three causes bottlenecks in the system[1].

Allocating a private memory to each processor, as in Fig. 1(b), reduces the number of accesses to global memory and hence the problem of bottlenecks. Each processor is a complete microcomputer with its own read-only and random-access memory, peripherals and direct-memory-access devices.

Removing global memory in the previous configuration and allowing each processor to access the private memory of the other processors as in Fig. 1(c) reduces bottlenecks and memory requirements, but requires more complex control hardware.

SYNCHRONOUS vs ASYNCHRONOUS

Buses for connecting several microprocessors to common memory and i/o devices can operate either synchronously or asynchronously. There are two ways of implementing an asynchronous bus, differing in control-bus structure: one relies on centralized bus control and the other decentralized bus control.

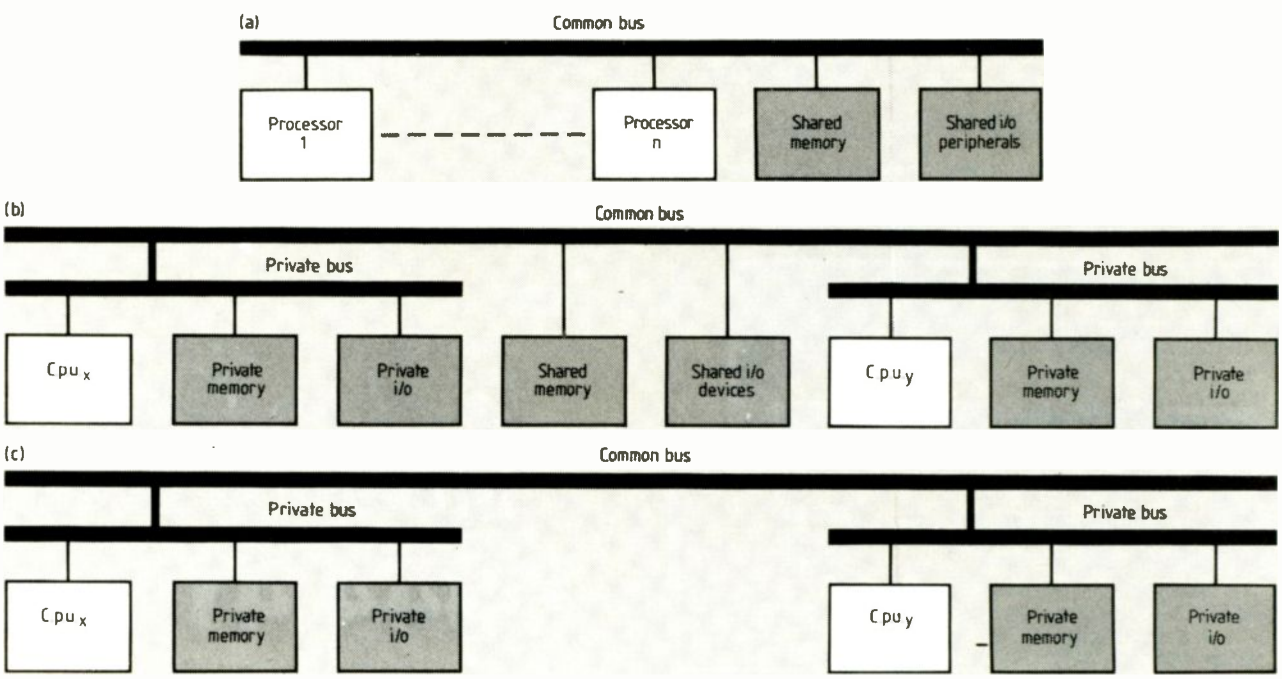
With centralized asynchronous bus control, one processor is master of the common bus and is responsible for giving control of the bus to a requesting slave processor. It is the duty of the master processor to resolve request contention by applying a priority-control policy when simultaneous requests for access to the bus occur.

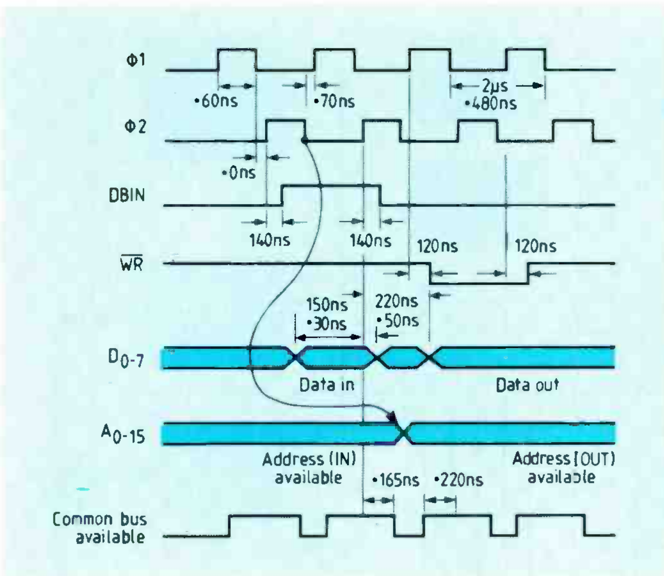
Decentralized asynchronous bus control involves control of the common bus being distributed among the processors and requires extra hardware for each processor. Contention between processor requests for bus control is resolved by hardware which coordinates the distributed bus-control sections.

In a synchronous-bus system, each processor takes control of the common bus whenever it requires it, independently of the other processors. Synchronous bus control is achieved by dividing the bus-control cycle into equal time slots, each of which is permanently assigned to one processor.

Each bus-control cycle must contain a number of time slots equal to or greater than the number of processors connected to the common bus. A central control circuit maintains synchronization so that each processor can only access the common bus during its allocated time slot.

Fig. 1. Three multiprocessor structures. In (a), the simplest structure, each processor connects to shared memory and i/o through a common bus. Bottlenecks caused by the processors making heavy demands on memory are reduced when each processor also has its own memory (b). A further enhancement is to give each processor its own memory and allow this memory to be accessed by other processors in the system (c).





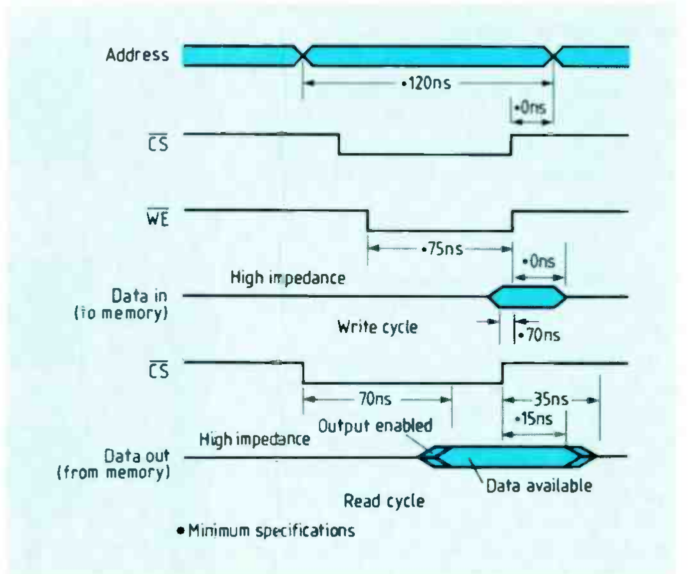
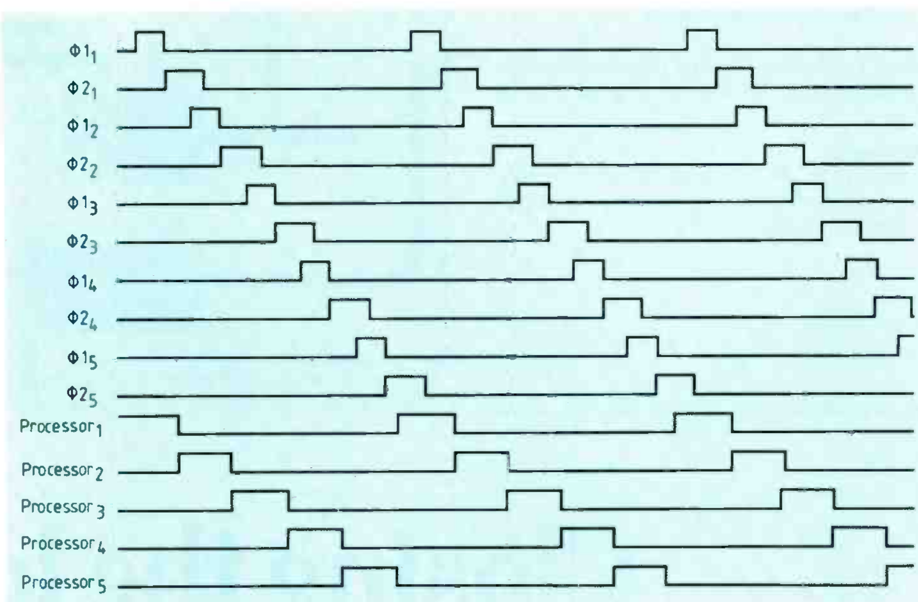


Fig.2. Timing characteristics relevant to connection of an 8080A microprocessor to a common synchronous bus.

Fig.3. Memory timing specifications for 2114 static rams, top right.

Fig.4. Microprocessors such as the 8080 can operate together synchronously over a common bus when their clock signals are phased shifted.



Asynchronous buses readily accommodate different types of processor running at different speeds whereas with a synchronous bus all of the processors must run at the speed of the slowest processor, reducing overall performance.

Increasing the number of processors connected to an asynchronous bus is done by adding control circuits. The number of processors on a synchronous bus is limited to the number of time slots in the bus-control cycle; in turn, size of the common bus cycle and the number of time slots within it are limited by memory and i/o device access times.

But synchronous buses also have advantages. Their control circuits are simple compared to an asynchronous bus with decentralized control. Adding a processor to a centrally-controlled asynchronous bus involves altering the master c.p.u. software; synchronous bus operation does not have this drawback. Finally, processors attempting to access an asynchronous bus while it is in use will be forced to wait, which wastes time. This does not occur with a synchronous bus.

The remainder of this article deals specifically with processors linked via a synchronous bus of the type shown in Fig.1(a).

MICROPROCESSOR BUS REQUIREMENTS

Consider an 8080A microprocessor with a typical cycle time of 480-2000ns and a global memory built from 120ns 2114 static rams. Timing requirements relevant to connection of an 8080A microprocessor to a common bus are shown in Fig.2 and timing characteristics of the rams forming the global memory are shown in Fig.3.

In order to transfer data from global memory to either one of two processors connected to a common bus, the bus should be available to each processor at least 220ns before the rising edge of the processor's $\phi 2$ clock signal. This period comprises 70ns for chip-select signal $\overline{\text{CS}}$ to activate the memory and provide stable data, and 150ns during which the data on the processor's data bus must be stable before its $\phi 2$ clock-pulse rising edge.

Transferring data from either of the processors to the global memory involves having the bus available to each processor for at least 225ns after the processor's $\phi 1$ rising edge. This requirement can also be interpreted as being at least 165ns after the $\phi 2$ clock rising edge.

Of the 225ns period, 120ns is delay between the write signal $\overline{\text{WR}}$ becoming active and the $\phi 1$ clock rising edge ($\overline{\text{WR}}$ produces write-enable signal $\overline{\text{WE}}$ for the global memory). A further 35ns is taken for the memory devices to change their data-line states from output to input, and the remaining 70ns is the period during which data is stable on the bus. Taking the $\phi 1$ 60ns pulse width from the 225ns gives the timing value relative to the $\phi 2$ clock rising edge.

Thus each processor should gain control of the common bus for at least 385ns during each machine-state period.

PROCESSOR SYNCHRONIZATION

In a multiprocessor system, having all the processors running at the same speed, i.e. with equal machine-state periods, gives each processor an equal share of the bus and reduces hardware complexity.

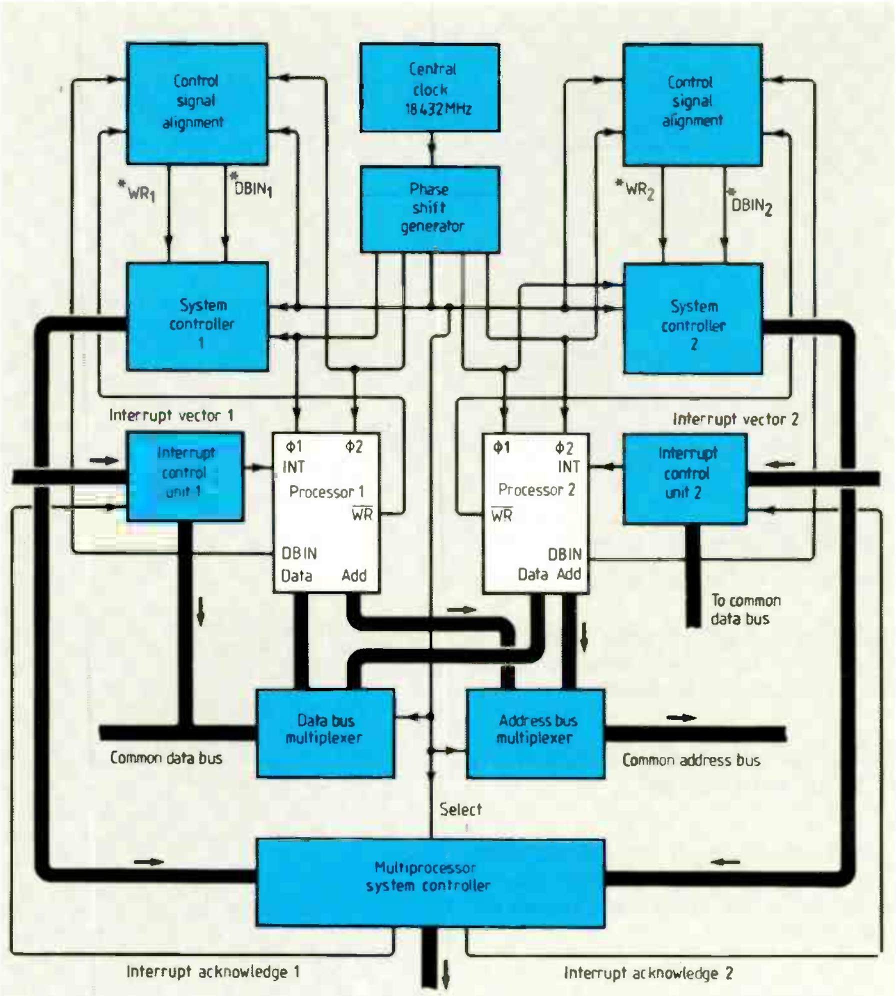
Phase shifting between the clocks of each c.p.u. provides a time slot for each processor. Applying clock shifting as shown in Fig.4 to the 8080 example gives each microprocessor machine state its own time slot of at least 385ns, assuming a 60ns $\phi 1$ pulse width and no delay between the falling $\phi 1$ edge and $\phi 2$ rising edge.

With this method, each bus-control cycle is equal to a c.p.u. machine-state duration and is divided into equal slots, one for each processor in the system. How many processor can be connected to the system in this way is estimated using,

$$385_{max} = 2000 \rightarrow N_{max} = 5$$

where the figure of 2000 represents the

Fig.5. Main functional blocks of an 8080 dual-processor system.



8080's maximum cycle time of 2000ns and N is the number of processors. Faster memory devices allow faster clock speeds and/or more processors to be connected to the system but,

$$385_{min}=480 \rightarrow N_{min}=1$$

shows that it is not possible to run two processors at their minimum cycle time of 480ns.

Multiplexing between the common bus and the address and data buses of each microprocessor ensures that only one procesor is linked to the common bus at a time and that it is only linked during its allocated time slot. Each c.p.u. has its own system controller whose output lines are multiplexed over the common bus in the same way. Figure 5 shows the main elements of an 8080A dual-processor system.

Design details for a dual-processor system based on Fig.5 will be given in a subsequent article.

Reference

Rothlisberger, H., A standard bus for multiprocessor architecture. Euromicro conference proceedings, 1977.

Closing the loop

This discussion of t, s and z-domain representation of delayed signals supplements last month's article illustrating a practical approach to closed loop microcomputer control.

In my last article[1] I described using a microcomputer to control the speed of a d.c. motor. Although the article was primarily concerned with the practical details of interfacing and system configuration, some mathematics were necessary to describe the signal-processing operations.

This month I would like to establish a more comprehensive understanding of the mathematical techniques associated with sampled-data systems.

Laplace transformation decomposes a differential equation into an algebraic equation, allowing much of the manipulation to be done in a simpler domain. For example, differentiation in the time domain is equivalent to multiplication by s in the complex frequency domain. This is illustrated in Fig.1, where double-headed arrows symbolize the integral relationship between domains.

Stated formally, the transformation from the time domain to the complex frequency domain is given by,

$$F(s)=\int_{0}^{\infty} f(t)e^{-st}dt$$

The reverse process of inverse transformation,

$$f(t)=\frac{1}{2\pi j}\int_{\sigma-j\omega}^{\sigma+j\omega} F(s)e^{st}ds$$

is not so straightforward. The complex limits make this integral tricky; fortunately in practice it is seldom necessary to employ this heavy artillery.

I make use of the method of partial fractions together with tables of Laplace transform pairs. If you have time, confirm the solidarity of the mathematical scaffolding – it increases confidence in the results. You will find these topics covered comprehensively in Jaeger[2], Lynn[3], Hutchings[4] and other literature.

A CLOSER LOOK AT A-TO-D CONVERSION

When computers are used to control engineering systems the best they can do is to take occasional snapshots, or samples, of events. Providing that the events are changing slowly and the computer is sampling rapidly, Shannon's sampling rule should be satisfied and it should be possible to recover the processed signal without aliasing[5]. However, to produce a valid mathematical model, asynchronous conversion must be avoided; instead, the a-to-d converter must be synchronized with the program to ensure that the time between samples is constant. This validates the use of the z transform to model time delays.

THE Z-OPERATOR

In the following development, some important z-domain properties and relationships with the Laplace transform are established. The s-domain model of delayed signals includes the exponential term e^{-skT} which makes it difficult to use.

$$f(t-kT) \longleftrightarrow e^{-skT}f(kT)$$

Fortunately there is another transform specially for this application – the z transform – which models time delays and advances with ease. Simply substitute $z=e^{sT}$ (a time advance) or $z^{-1}=e^{-sT}$ (a time delay).

As an aid to understanding, recall that the operation of multiplication by s in the complex frequency domain was equivalent to time domain differentation. Similarly multiplication by z^{-1} in the z domain is equivalent to a single time delay in the time domain.

Referring to Fig.3, the output of the a-to-d converter is the set of sampled data, f(0), f(T), f(2T), etc. As a first attempt at describing the behaviour of the sampled-data system, consider the a-to-d converter modelled as an impulse modulator, Fig.5.

The output pulse train of the impulse modulator assumes the pulse width of each sample to be infinitesimal, while the height is a precise replica of the sampled signal at that instant only.

$$f^*(t)=f(0)\delta(t)+f(T)\delta(t-T)+f(2T)\delta(t-2T)+\ldots$$

↕ transforming (Laplace)

$$F(s)=f(0)+e^{-sT}f(T)+e^{-2sT}f(2T)+\ldots$$

↕ transforming (z)

$$F(z)=z^0f(0)+z^{-1}f(T)+z^{-2}f(2T)+\ldots$$

Now the way is prepared for a more practical a-to-d converter – the zero-order sample-and-hold. Its effect is to take a sample in zero time and to hold this snapshot constant until the next sampling instant occurs one period later.

Notice that sampled signal f*(t) has been decomposed into a train of rectangle pulses each of width T.

$$\begin{aligned}f^*(t)=&f(0)[u(t)-u(t-T)]\\&+f(T)[u(t-T)-u(t-2T)\\&+f(2T)[u(t-2T)-u(t-3T)\\&+\ldots\end{aligned}$$

transforming

$$\begin{aligned}F^*(s)=&f(0)[1/s-e^{-Ts}/s)\\&+f(T)[e^{-2Ts}/s-e^{-2Ts}/s]\\&+f(2T)[e^{-2Ts}/s-e^{-3Ts}/s]\\&+\ldots\end{aligned}$$

taking out the common factor,

$$\frac{1-e^{-Ts}}{s}$$

$$F^*(s)=\frac{(1-e^{-Ts})}{s}[f(0)+f(T)e^{-sT}+f(2T)e^{-2sT}+\ldots]$$

$$F^*(s)=\frac{(1-e^{-Ts})}{s}F(s)$$

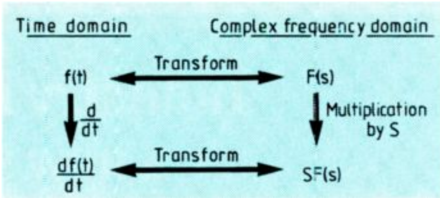


Fig.1. To evaluate the Laplace transform of df(t)/dt, trace the top right-hand path giving F(s) followed by the operation of multiplication by s. Alternatively follow the left hand path to obtain df(t)/dt and then perform the transformation – both routes are equivalent.

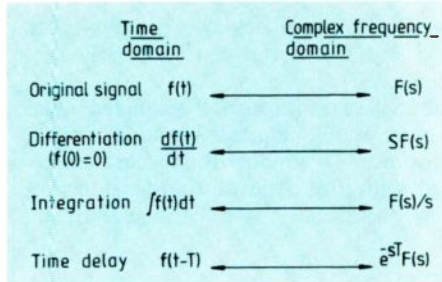


Fig.2. A few important results demonstrating the equivalence of time-domain and frequency-domain signal processing.

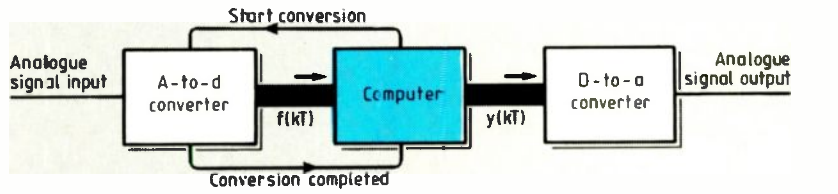


Fig.3. How the a-to-d converter receives signals from an analogue source. To ensure that the conversion time is independent of input amplitude, conversion by successive approximation is employed. The a-to-d converter is synchronized with the program by control signals, to enable the complete signal-processing time (T) to be fixed. A constant conversion rate and fixed processing time are essential to good design, because they allow the behaviour of the system to be predicted by a suitable choice of pole-zero configuration. Processed output is converted back to analogue form via the d-to-a converter.

Table 1. Some Laplace and z-transform pairs

Signal f(t)	Transform F(s)	Transform F(z) of sampled signal
u(t)[step]	$\frac{1}{s}$	$\frac{z}{z-1}$
t[ramp]	$\frac{1}{s^2}$	$\frac{Tz}{(z-1)^2}$
exp(−at)	$\frac{1}{s+a}$	$\frac{z}{z-e^{aT}}$
1−exp(−at)	$\frac{a}{s(s+a)}$	$\frac{z(1-e^{-aT})}{(z-1)(z-e^{aT})}$

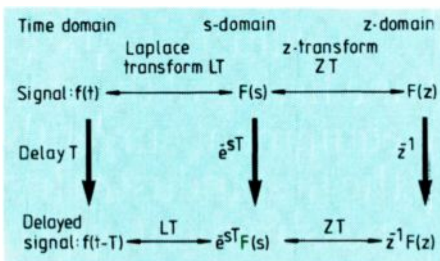


Fig.4. The t, s and z domain representation of delayed signals.

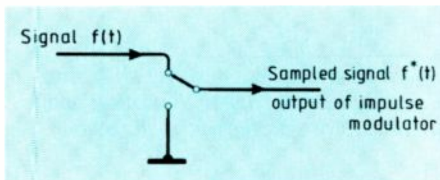


Fig.5. Periodic processing of a continuous time signal can be represented by this simple switching circuit. Asterisk notation denotes a periodic sampled signal occurring every T seconds.

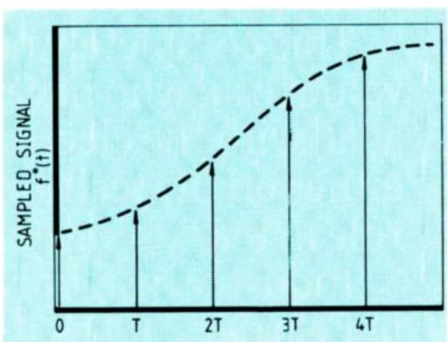


Fig.6. Modelling the sampled signals as a train of weighted impulses. Suppose the signal to be sampled is represented by the dotted lines. Provided that the samples are of infinitely short duration, the sampled signal can be modelled as a train of weighted impulse functions depicted by the vertical arrows.

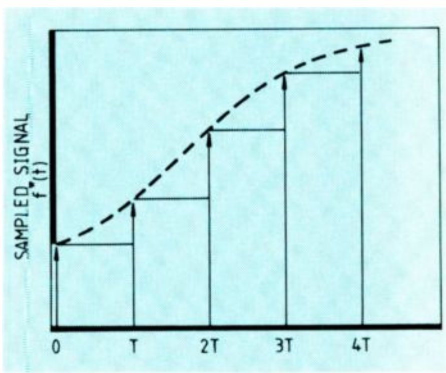


Fig.7. Modelling the sampled signal as a train of weighted pulses. The effect of the a-to-d converter is to take a sample in zero time and to hold this snapshot constant until the next sampling instant occurs one period later.

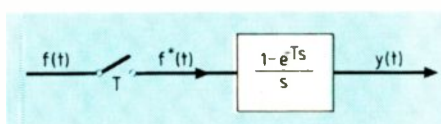


Fig.8 Transfer function model of a-to-d converter.

Thus the linear behaviour of the zero-order hold a-to-d converter can be modelled by equation (1).

The Laplace transform of the sampled signal is more usefully expressed in terms of its z transform. To simplify the algebra associated with this type of transfer function simply substitute $z^{-1}=e^{-sT}$ in equation (1).

$$F(z)=(1-z^{-1})\frac{F(s)}{s}$$
$$=\frac{(z-1)}{z}\mathcal{Z}\left|\frac{F(s)}{s}\right.$$

The symbol $\mathcal{Z}$ means look up the z transform of the Laplace transform within the brackets.

Hence to conclude, F(s) is the transfer function of the continuous system and F(s)/s is the unit step response. F(z) is the model of the pulse response of the sampled data system.

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3. Lynn, P.A., Introduction to the analysis and processing of signals, Macmillan 1982.
4. Hutchings, H.J., A simplified method of Laplace transformation, *SERT*, January 1976.
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Industry Insight – a new series

The February issue sees the start of the new series. Every two months, a complete section of the journal is to be devoted to a detailed examination of one area of the electronics industry, starting with a look at **instrumentation**.

In each Industry Insight, we outline the evolving design techniques applied to the type of equipment under discussion and consider the research being carried out by companies and universities. In addition, production techniques are investigated and some of the latest dedicated chips.

On the commercial side, we analyse market trends and indicate the specialities and long-term aims of some of the leading companies, presenting interviews with their decision makers.

To illustrate the state of the art, there is a listing of the characteristics of equipment currently on the market. In the first Industry Insight, on test and measurement, we cover oscilloscopes, digital meters and frequency-measuring instruments.

This completely new series will be of value to all who have any involvement at all with the electronics industry – either on the technical side or with a role in marketing or management.

Industry Insight Number 1 appears in February. It has its own cover and is separate from the rest of the journal. It even has its own Editor – Geoff Shorter, who until recently was Deputy Editor of *Electronics and Wireless World.*

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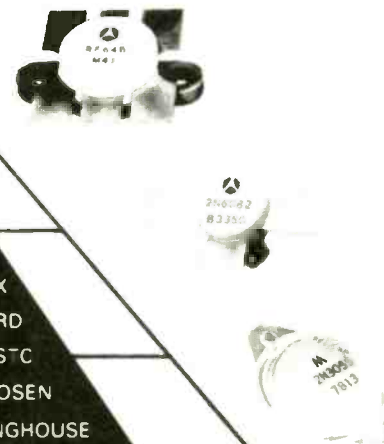

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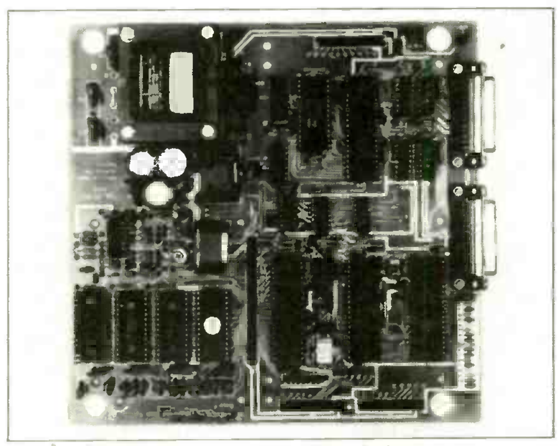

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The conquest of truth

Catt presents his views on why apparently liberal scientists combine in seeming to suppress the facts

IVOR CATT

> **"Any physical law which contains a derivative (d/dt or d/dx) is wrong because it implies instantaneous knowledge of two things which are separated by distance or by time. This transgresses the principle 'No instantaneous action at a distance'.**
>
> $$\oint E ds = \frac{dq}{dt}$$
>
> **is one such faulty equation.**
>
> **Michael S. Gibson**
>
> Please note, in amelioration of Gibson's assertion, that he is writing about physical laws – *prescriptive* statements. Also, he is writing about fundamental laws in physics. In contrast, should a mountain get steeper higher up in a certain way, it is perfectly valid to make the *descriptive* statement
>
> $$dh/dx = kh$$
>
> should that happen to be true for that particular mountain. Also, this could even be a *prescriptive* statement should it be a necessary result of the wind or ice shaping the mountain. However, in such a situation, we are not dealing with a relativistic universe; in the case of erosion, we are within a universe of discourse where we can conceive of "instantaneous" action at a distance. Gibson refers to the deeper level of physics, with fundamentals, where there is no instantaneous action at a distance.

Einstein rejected the legacy of the early twentieth century, which I call "Modern Physics", with which his name tends to be associated. In the 1940s, he wrote*

> ". . . I am quite convinced that someone will eventually come up with a theory whose objects, connected by laws, are not probabilities but considered facts, as used to be taken for granted until quite recently."
>
> ". . . We all of us have some idea of what the basic axioms in physics will turn out to be. The quantum or the particle will surely not be amongst them; the field, in Faraday's and Maxwell's sense, could possibly be, but it is not certain."
>
> "Quantum Mechanics and Reality. In what follows I shall explain briefly and in an elementary way why I consider the methods of quantum mechanics fundamentally unsatisfactory."

While this rejection by Einstein is occasionally admitted,** the main thrust of today's scientific propaganda makes out that Einstein was a card-carrying member of the Modern Physics party.

In the July issue of *EWW*, page 683, I listed some of the characteristics of 'Modern Physics', describing it as a soft subject, lacking the brittleness of true science, which it has usurped. In his book The Structure of Scientific Revolutions, T. S. Kuhn opposes the softness of Modern Physics. On page 97, he writes,

> ". . . The successful new theory must somewhere permit predictions that are different from those derived from its predecessor . . . It is hard to see how new theories could arise without these destructive changes in beliefs about nature."

In stark contrast, 'Joules Watt' had this to say in *EWW*, July 1987, page 697, paraphrasing the same book,

> "Yet the developed theory of electromagnetism still holds sway. If there are some phenomena such a theory does not explain, then any new model must explain all that has gone before – plus the new aspects. At least that is the way Thomas Kuhn outlined the situation."

A clue to the attitude which could have led to these two extracts is given in the assertion by Professor Ziman on television, quoted in the July 1981 editorial, "the aim of science is to achieve consensus." His assertion that science is monolithic is supported by the fact that the medieval method of achieving consensus, or suppressing heresy, in religion, using anonymous censors, has been copied in today's science.

Let us investigate the consensus view of science. I feel that Kuhn is describing it in what follows.

> "If science is the constellation of facts, theories, and methods collected in current texts, then scientists are the men who, successfully or not, have striven to contribute one or another element to that particular constellation. Scientific development becomes the piecemeal process by which these items have been added, singly and in combination, to the ever growing stockpile that constitutes scientific technique and knowledge." – T. S. Kuhn, *op.cit.*, p.l.

A Great Scientist has successfully contributed one or more elements to the body of knowledge. Any aberrant, heretical offering merely indicates that he is not as great as he might have been. Something like 80% of his work takes its place within the consensus, and the remaining 20% we must forget in order to help the Forward March of Science. From the consensus point of view, this is not suppression. Also, it is encouraging to find that the central circle, the least common denominator, is so large. The consensus is obviously the centre of gravity of so many mildly divergent views. It then becomes a short step to rewrite the aberrant views of some of the more troublesome great scientists. In fact, if Kuhn is regarded as one of the 'greats', then any reading of his works which might indicate that he falls significantly outside the main consensus circle must be a misreading. If he were so different, then he would not be known.

Having dealt with the conquest of truth about scientists, we now turn to the conquest of truth about scientific experiments.

It seems that any book called Relativity for Tiny Tots, or The Ascent of Man, or such like, contains clear assertions about a number of pivotal experiments in the history of science, nearly all of those assertions falsifying the experimental results. This falsification of most of the key experiments extends all the way up to about first-degree physics-level textbooks. It is galling rather than pleasing to find that post-graduate books generally admit to such errors, but on page 500, not page 5. My position is that if there is any uncertainty as to the conclusion indicated by the results of one of the key experiments, then that should be reported in quite elementary texts, for instance those used by 17-year olds.

There are four so-called† "acid tests" of Relativity. All are disputed.

Hawking/Israel admit that light bending round the sun *contradicts* Einstein's prediction*. Brillouin says that the Mercury perihelion results, properly studied, contradict Einstein's prediction**. Polanyi and

continued on page 54

* The Born-Einstein Letters by Max Born, pub. Macmillan 1971, further discussed in Electromagnetic Theory Vol 2, by I. Catt, C.A.M. Publishing 1980, p307. Also see I. Catt, *EWW*, July 1987, page 683.

**P. E. Hodgson, Fontana Dictionary of Modern Thinkers, ed. A. Bullock and R. B. Woodings, Fontana, 1983, p208. However, if we read Hodgson on page 604 we see the ambivalence and confusion in the admission.

†I myself find Relativity flawed at other levels anyway.

600W uninterruptible power supply

In the presence of mains-supply drop-outs and mains-borne interference, a u.p.s. will prevent the destruction of computer data and corruption of readings from measuring instruments.

CHARLES FRIZELL

Using a personal computer on anything like a regular basis, one becomes aware of the severe problems caused if the mains supply fails for even a few hundred milliseconds. Mains-borne transients can cause even more of a problem, leading to corruption and loss of data. Although the mains supply is normally reliable in western Europe, transients and noise, particularly in industrial areas, can wreak havoc with sensitive equipment. And it is not only computers which need a reliable and noise-free supply.

This design is based on very well proven technology. The emphasis is on reliability: it is not helpful to have a supply which is less reliable than either the normal mains, or the equipment it feeds.

PRINCIPLE OF OPERATION

The load is fed at all times from the inverter section, rather than switching over on mains failure. The battery is kept fully charged by the charger, which is of the c.v.c type (controlled voltage and current): when the mains supply fails, the inverter carries on running.

The output waveform from the inverter is a nominal square wave, arranged for 120 degrees electrical conduction at normal battery volts, which produces a wave functionally similar to a sine wave. Since the power supply in much equipment is of the switching type, the waveshape and frequency are of no great consequence – even the fans in most equipment operate from d.c. However, some peripherals (many printers) still use linear power supplies, in which it is important that the input is equivalent to the normal sinewave supply in r.m.s. terms. In particular, the peak value must be adequate. A straight square wave of adequate peak value, however, will usually saturate the transformer, causing overheating and early failure. As an option, the design of output filter shown produces a sine wave of very low distortion, but at a considerable increase in size and mass.

A point to note is that, with this type of design, there is absolutely no connection between the supply and the load. With a well-grounded system, it is almost impossible for transients and noise to be passed to the load.

INVERTER POWER CIRCUIT

A 24V supply voltage is obtained from two "maintenance free" car batteries, which give about 40 minutes operation at full load. I would *not* recommend the smaller sealed type, since once they become heavily discharged, they will not take a charge without special treatment.

Operating voltage (float voltage) is 27.6 volts, equivalent to a cell voltage of 2.3 volts, with end-point voltage around 22 volts. To allow for the transistor forward voltage drop, the primary transformer winding in Fig.1 is designed for a 20V minimum battery voltage: its r.m.s. voltage is therefore 14-0-14 volts.

The secondary (output) winding is designed to give a nominal 225 volts. A special feature of this design is the driver supply winding, which provides a voltage to the driver transistors *in phase* with the main transistors which they drive. This provides the ideal drive conditions – a high supply voltage to turn on followed by a drop to only a few volts when the transistors are on. Drive current is limited by the winding resistance.

Since the primary current is high – in the order of 30A – it is necessary to use a parallel arrangement of transistors. Although 100A and 200A Darlington transistor modules are available, they are not really cost effective. However, contrary to popular belief, it is very easy to parallel bipolar power transistors: Emitter resistors ensure load sharing and maintain physical symmetry. The emitter resistors are not resistors as such, but equal lengths of relatively thin, stranded-copper wire, all brought back to a common point: Collector leads are also of equal length. The positive temperature coefficient of the copper also helps to equalize current.

Collector diodes are essential, as they carry the reactive current in the circuit, which would otherwise reverse bias the power transistors, with unpredictable results. Voltage spikes are generated by the switching of the primary current, and, if no precautions are taken will quickly destroy the power transistors through avalanche breakdown. If the primary transformer windings are bifilar, the snubber circuits are not strictly necessary, as the leakage inductance is low. Beware of any switching which do not take this into account. The designer has forgotten Lenz's law!

A 31.5A magnetic circuit breaker protects the inverter circuit against overloads, and is also an essential safety feature in any

Table 1

Inverter transformer

Core			
Core type	246	core mass (kg)	7.64
area product no	1030.4	stack depth (mm)	50.8
output power (watts)	849.49	tongue width (mm)	50.8
former thickness mm	2	window height (mm)	34.9
total winding height	32.82	free space (mm)	0.08
Primary			
primary r.m.s. voltage	230	primary current	3.88
primary resistance	0.48 ohm	primary copper loss	7.22
primary turns	405	bare wire diameter (mm)	1.9
turns per layer	54	number of layers	8
winding height (mm)	16		
Secondary 1			
secondary r.m.s. volts	14.1	secondary current	29.69
secondary resistance	8.520001 mohm	full load volt drop	0.25
secondary turns	25 + 25	bare wire diameter (mm)	5
turns per layer	20	number of layers	3
winding height (mm)	15.78		
Secondary 2			
secondary r.m.s. volts	12	secondary current	1
secondary resistance	0.1 ohm	full load volt drop	0.1
secondary turns	21	bare wire diameter (mm)	0.95
turns per layer	105	number of layers	1
winding height (mm)	1.04		

Table 2

Sine filter series choke. C=60 μF.

Output power (watts)	443.86	inductance (mH)	168
core type	149	core mass (kg)	2.35
stack depth (mm)	38.1	tongue width (mm)	38.1
maximum flux (1.2 Tesla)	1.11	free space (mm)	1
former thickness mm	2	bare wire diameter (mm)	1.32
number of turns	425	copper loss (watts)	6.61
wire resistance	0.78	gap loss (watts)	9.01
iron loss (watt)	6.1	each airgap (mm)	1.22
total airgap (mm)	2.44	current (rms) in choke	2.9
primary r.m.s. voltage	153.05	wire length (metres)	56.71
impedance (ohm)	52.77	calculated area cm²	547.9
loss watt/cm²	0.039		
turns per layer	36	number of layers	11.8

Table 3

Sine filter parallel choke. C=20 μF.

Output power (watts)	334.22	inductance (mH)	506
core type	149	core mass (kg)	2.35
stack depth (mm)	38.1	tongue width (mm)	38.1
maximum flux (1.2 Tesla)	1.09	free space (mm)	1
former thickness mm	2	bare wire diameter (mm)	1.06
number of turns	653	copper loss (watts)	3.93
wire resistance	1.87	Gap loss (watts)	6.53
iron loss (watt)	5.87	each airgap (mm)	0.92
total airgap (mm)	1.84	current (rms) in choke	1.45
primary r.m.s. voltage	230.49	wire length (metres)	87.07
impedance (ohm)	158.96	calculated area cm²	465.42
loss watt/cm²	0.035		
turns per layer	45	number of layers	14.5

Table 5

15 A battery-charger choke

core type	158	area product no	50.7
core mass (kg)	.98	energy (watt/second)	.4
tongue width (mm)	28.58	stack depth (mm)	28.58
inductance (mH)	3.58	frequency (50Hz)	100
stack depth (mm)	28.58	tongue width (mm)	28.58
number of turns	68	d.c. current (A)	15
bare wire diameter (mm)	2.36	current (r.m.s.) in choke	6.26
copper loss	7.79	fringing factor	1.22
total losses	7.84	loss watt/cm²	0.025
turns per layer	15	number of layers	4.5
total airgap (mm)	1.65	each airgap (mm)	0.825
loss watt/cm²	.025	wire length (metres)	6.8
mean turn (metres)	.1	impedance (ohm)	2.24
a.c. volts r.m.s.	14.08	designed temp. rise	50°C
maximum flux (1.2 Tesla)	1.09		

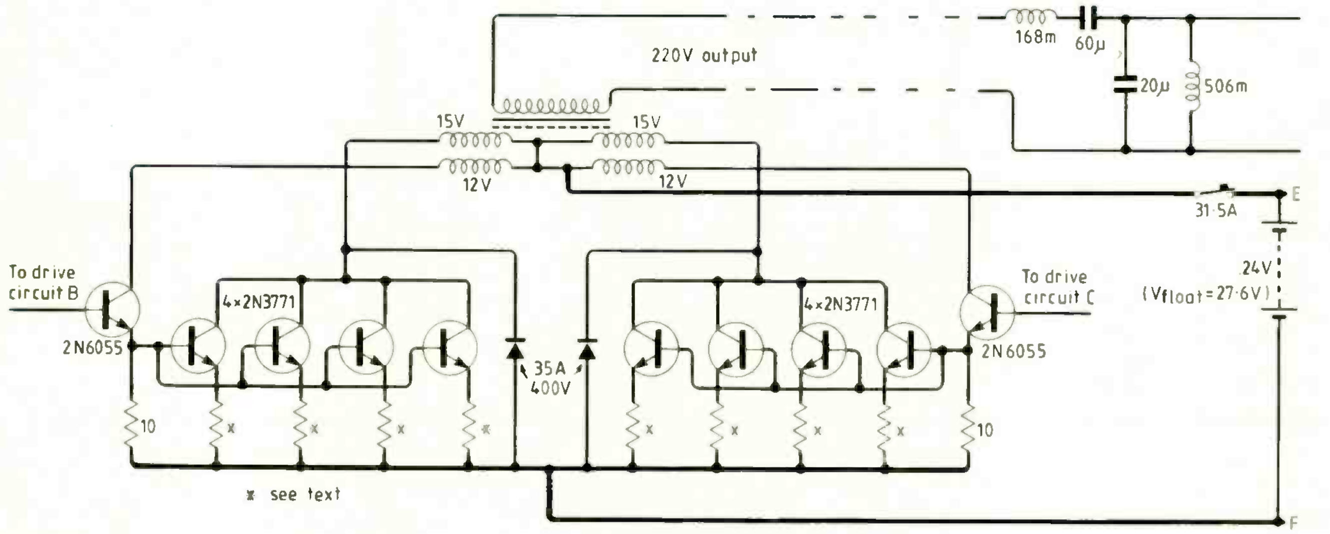


Fig.1. The inverter circuit. Winding information is given in Table 1, with filter choke details in Tables 2 and 3.

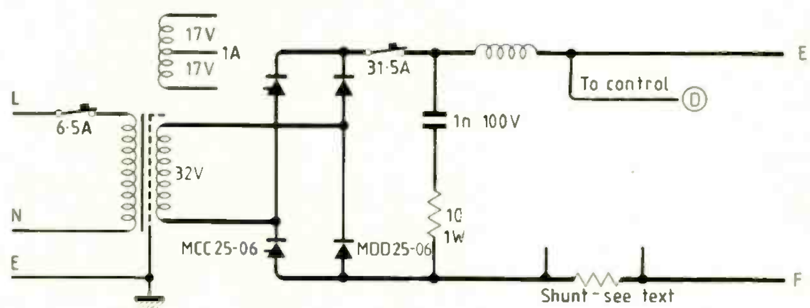


Fig.2. Charger power supply. The current-sensing shunt is 50mm of 1.6mm brazing rod. Choke details are in Table 5.

battery-powered equipment. As the voltage is so low, normal a.c.-mains type are suitable, and a special d.c. type is not necessary.

CHARGER POWER CIRCUIT

The circuit of Fig.2 is quite conventional. The mains feeds the stepdown transformer (see Table 4) via a 6.5 amp circuit breaker, which doubles as the on/off switch, its secondary being applied to a thyristor bridge, the firing angle of which is controlled to vary the output. Two series diodes make the circuit self-flywheeling. A choke shown in Table 5 is essential to limit the ripple current and to control the transformer form factor, which means that the transformer can be dimensioned to supply the d.c. load power only. As full power is not drawn continually, it is sufficient to rate the charger for around 400 watts.

The capacitor-resistor combination across the input side of the choke is to ensure there is sufficient holding current to latch even worst-case thyristors.

Current in the negative-line shunt is used by the control circuit to vary the thyristor firing angle and keep the battery terminal voltage at 27.6V. This signal is used to

Table 4

Battery charger transformer 15A

Core			
core type	233	core mass (kg)	5.01
area product no	395.2	stack depth (mm)	60
output power (watts)	457.21	tongue width (mm)	44.45
former thickness mm	2	window height (mm)	22.2
total winding height	19.7	free space (mm)	0.5
Primary			
primary r.m.s. voltage	230	primary current	2.09
primary resistance	0.88 ohm	primary copper loss	3.84
primary turns	327	bare wire diameter (mm)	1.18
turns per layer	48	number of layers	7
winding height (mm)	8.89		
Secondary 1 single winding			
secondary r.m.s volts	30	secondary current	15
secondary resistance	0.01 ohm	full load volt drop	0.21
secondary turns	43	bare wire diameter (mm)	3.35
turns per layer	17	number of layers	3
winding height (mm)	10.34		
Secondary 2 centre tap winding			
secondary r.m.s. volts	17	secondary current	0.21
secondary resistance	1.13 ohm	full load volt drop	0.24
secondary turns	24 + 24	bare wire diameter (mm)	0.4
turns per layer	135	number of layers	1
winding height (mm)	0.46		

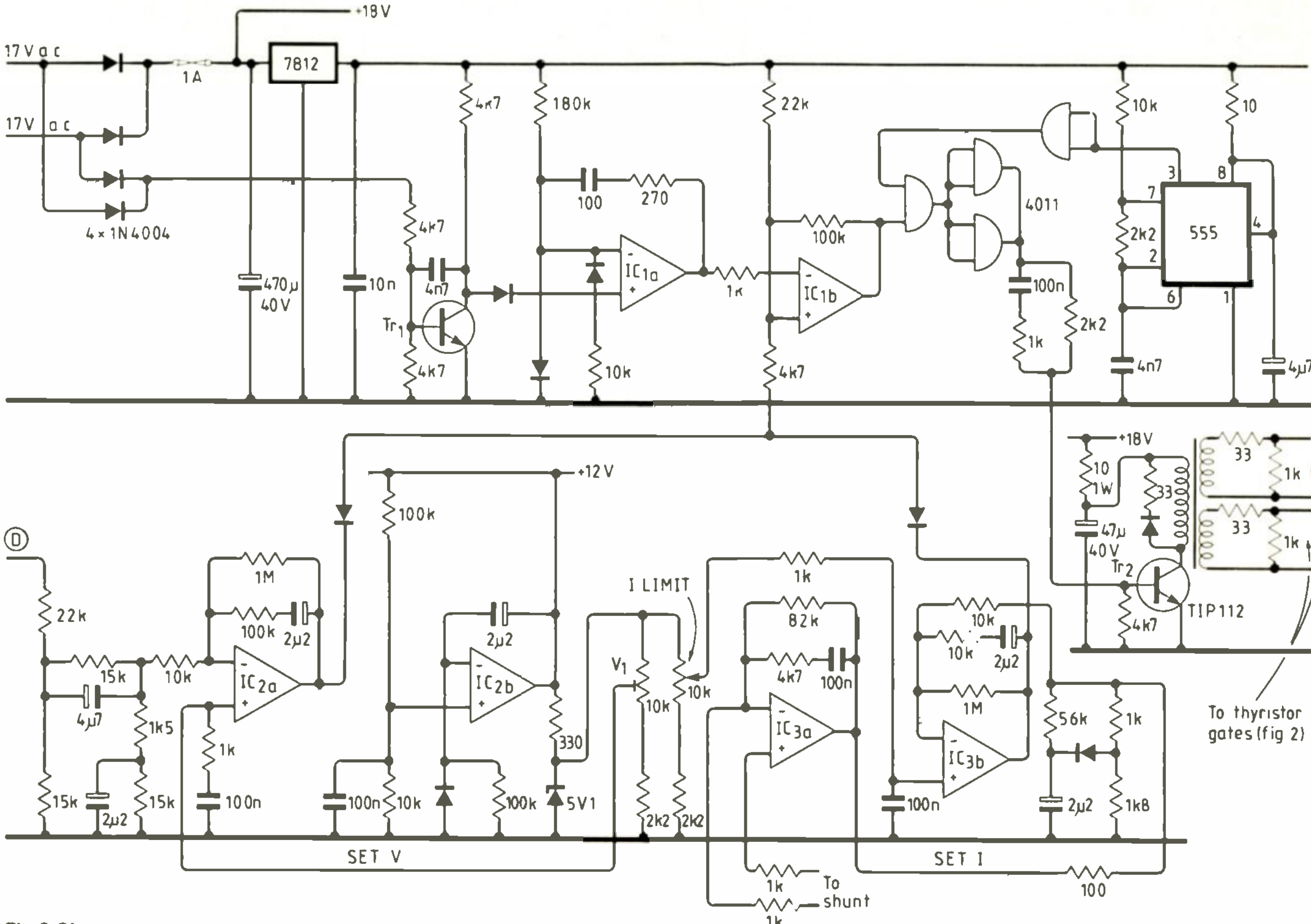


Fig.3 Charger control circuit.

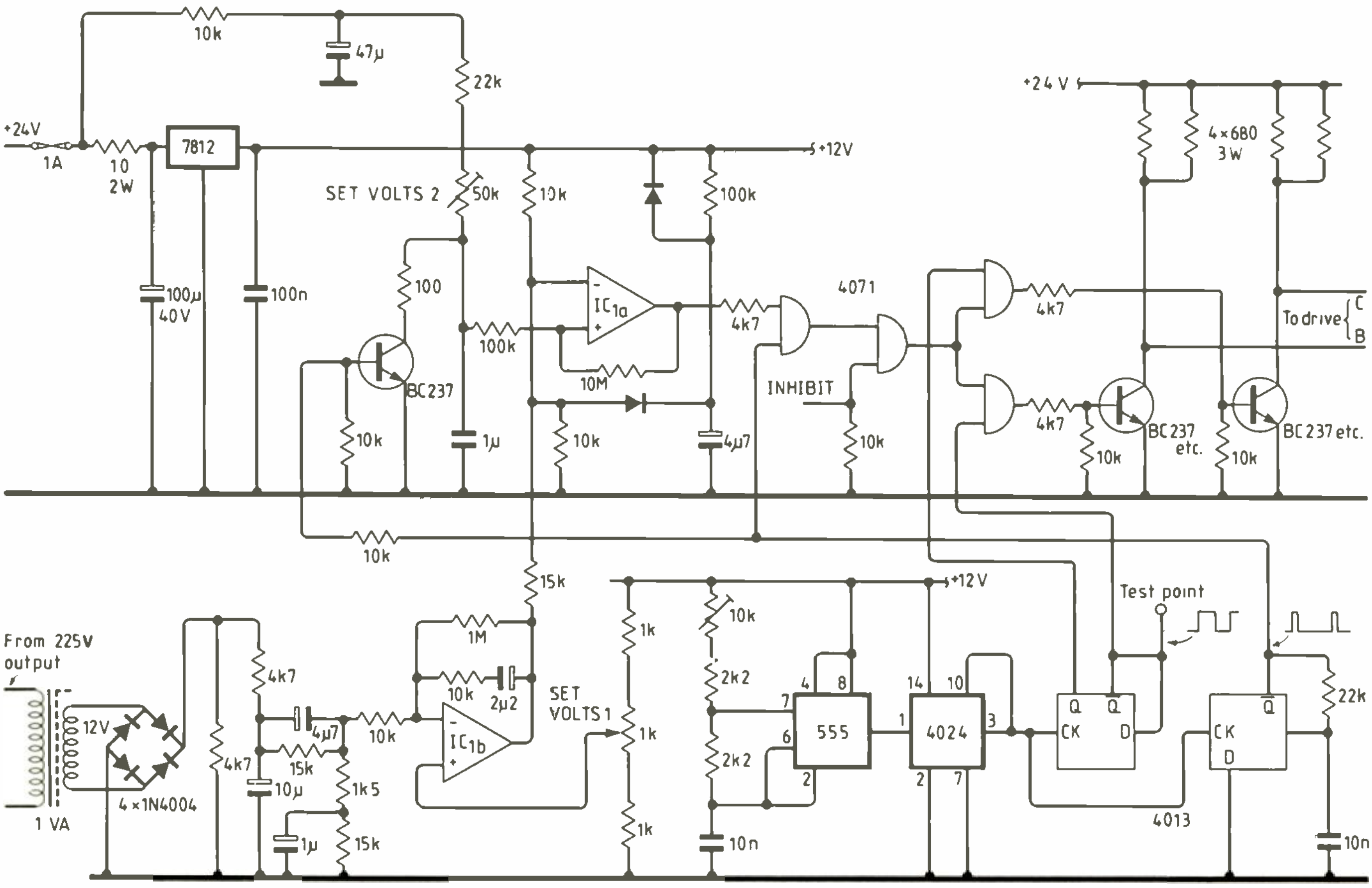


Fig.4 The inverter is controlled by varying the power transistor conduction periods by means of the waveforms at B and C.

reduce the firing angle to maintain the current at the limit value. The shunt is nothing more elaborate than about 50 mm of 1.6 mm brazing rod, giving a voltage drop of around 50 mV at 15A.

An important point is that all the power wiring *must* be short and of adequate cross section. I have found the best material is 6mm^2 wire, known as "Autoflex" here. Do not use anything thinner.

MAGNETIC COMPONENTS

I have included designs for all the magnetic components, which should be sufficient for any transformer manufacturer. The design temperature is 50°C above ambient, which gives a running temperature of 75°C – just too hot to hold. There is absolutely no point in designing for a lower temperature rise, since this merely wastes material and money.

The pulse transformer for the charger is a commercial item with a ratio of 3:1+1. Do *not* try and make this yourself.

CHARGER CONTROL CIRCUIT

The supply to the circuit shown in Fig.3 is derived from a 17-0-17 volt tertiary winding on the main transformer, rectified and smoothed to give an unregulated supply of 18 to 20 volts.

This supplies the thyristor gate-drive circuit, and it is important that the supply lines to this are short and of adequate width. The driver transistor is not critical; a Darlington with about a 1 amp and 60 volt V_{ce} rating is sufficient. Pulse transformer ratio is 3 to 1+1: the two secondary windings drive the two thyristor gates in the charger with narrow, positive-going pulses: 33-ohm series resistors ensure proper current sharing, and the parallel 1k resistors improve the dv/dt characteristics. The primary is snubbed by means of a diode/resistor network.

Ramp circuit. A linear ramp is generated by $IC_{1(a)}$ starting at a high level and ramping down. It is reset to the high level at every mains zero crossing point by Tr_1 and this is compared with the d.c. control-voltage signal in $IC_{1(b)}$. The output of this comparator is used to gate the oscillator signal to the pulse amplifier Tr_2.

Linear control circuit. Comparator IC_{2a} compares the output voltage of the charger with the set voltage, its output varying the voltage at one of the inputs of IC_{1_h}, thus controlling the firing angle.

The current sensed in the shunt is amplified to about 5V by IC_{3a}, and is then compared with the current set value in IC_{3b}. This signal is also applied to IC_{1b}, via an analogue Or gate, such that the signal demanding the lowest output will always prevail. The demands on the current limit circuit are stringent, it should have a fast response, and yet also be stable in continuous current limit. To this end, the amplified actual current value is passed via a network with two time constants before going to the comparator amplifier.

Since there is a spare op-amp available, IC_{2b}, it is used to provide a slowly rising reference voltage at switch-on. A 5V1 Zener is chosen because of its near-zero temperature co-efficient.

Output voltage is set on light load of around 0.5A. The current limit is then set using a flat battery, while monitoring the output voltage to ensure that the circuit is not in the voltage-control mode. Light-emitting diodes can be connected to give an indication of whether the circuit is in the voltage or the current mode.

Connections between the pulse transformer and the thyristor gates should be made from a twisted pair of wires.

INVERTER CONTROL CIRCUIT

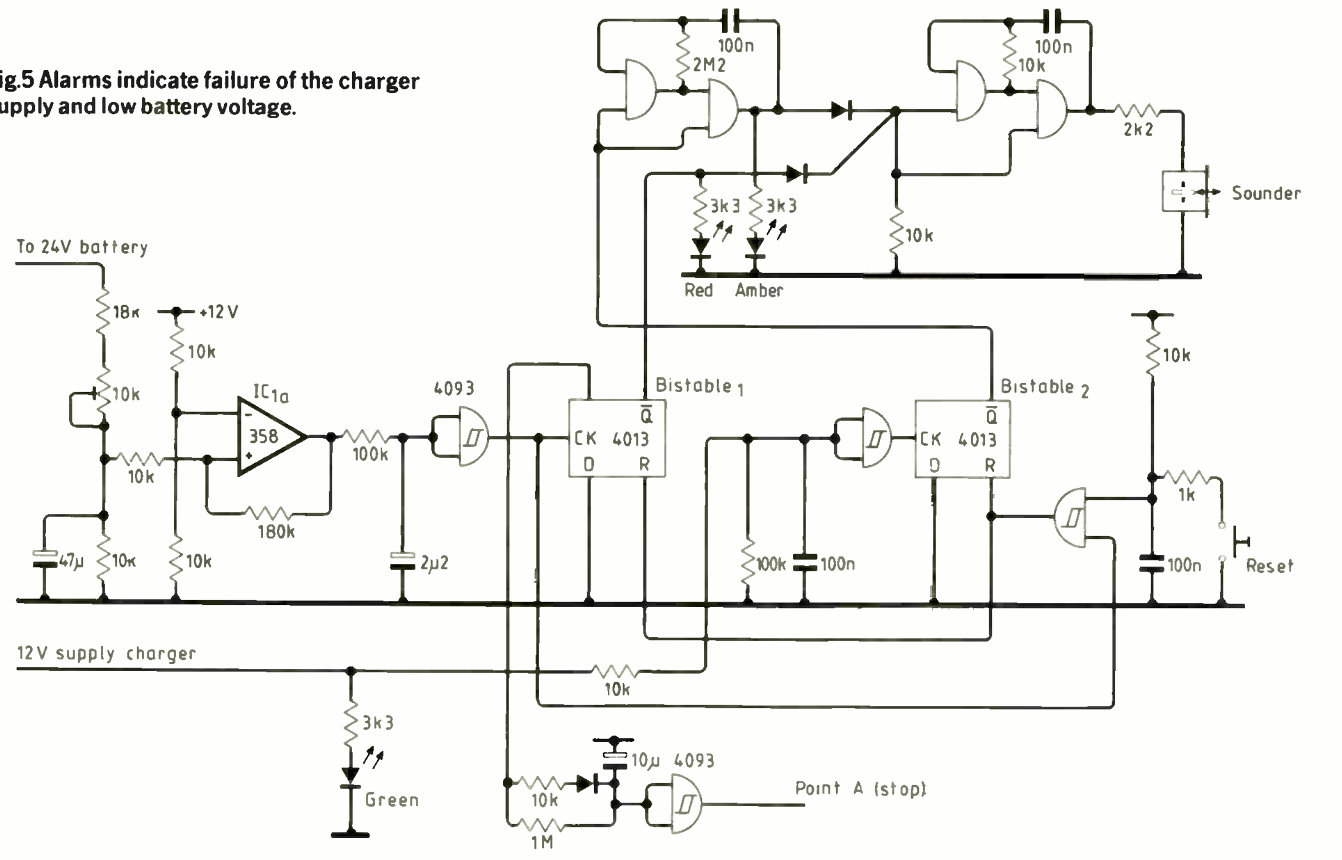
Output voltage of the inverter is controlled in the circuit of Fig.4 by varying the mark/space ratio of the current conduction time of the power transistors.

There are actually *two* control loops in operation. Firstly, it will be readily understood that the on time of the power transistors must be in inverse proportion to the battery supply voltage. Capacitor C_1 is charged from the unregulated battery voltage via a noise-removing network. Across it is a linear, positive-going ramp, which is compared with a fixed voltage by comparator IC_{1a}. The higher the battery voltage, the sooner the voltage across C_1 exceeds the reference, switching off the conducting output transistor.

Secondly, the output voltage of the inverter is transformed to 12 volts, rectified, and applied to control IC_{1b}. The action of this is to reduce the reference voltage slightly if the inverter output is high, and vice versa.

It is not strictly necessary to have both control loops, but the reasoning is as follows. The battery-voltage control gives a large measure of pre-compensation with excellent dynamic characteristics, whilst the feedback circuit enables the output voltage to be held to close values under varying conditions of load. If you decide to discard

Fig.5 Alarms indicate failure of the charger supply and low battery voltage.



one, discard the feedback circuit. This is because most equipment is *not* unduly fussy about the actual voltage, within fairly generous limits. However, if you use an output filter, the feedback circuit becomes necessary because of the far higher effective output impedance of the inverter.

The main clock is the ubiquitous 555, which is run at a frequency higher than the desired output frequency in order to achieve stability with economical components. A flip-flop provides two outputs which are used to gate the drive alternately to the two output power transistors. At the zero-crossing points a monostable is triggered which resets the input ramp circuit and ensures a dead period between the conduction cycles of the two power transistors. This is essential to prevent both sides being on at once due to the long storage times of high current transistors.

ALARM CIRCUIT

When the supply to the charger fails, its 12V rail fails to zero, triggering bistable 2 in Fig.5. This enables the two oscillators, which together give an interrupted tone to the piezo-electric sounder. This can be reset to silence the sounder.

When the battery voltage falls to 1.9V per cell, comparator IC_{1a} triggers bistable 1, to give a continuous tone, and you have about 10 seconds in which to close down. After this time, the inverter is automatically turned off. Reset is inhibited during the "battery low" condition.

This design is very rugged and relatively simple: the output power circuit is extremely reliable if well laid out. C-mos i.cs are used throughout because of their vastly superior properties in this type of circuit. That is to say, the power consumption is very low, supply voltage is uncritical, the noise margin is very good and they are not too fast (which helps greatly to reduce problems of interference to the electronics). The lack of any significant heat generation also helps reliability.

However, when powering up the circuit, check it out slowly and thoroughly before connecting the supply to the transformer. When you do this, start at a low voltage with a current limited supply and check that all is well before connecting the full 24 volts. The inverter can deliver 600 watts, and fault currents can be high. The cost of 10 power transistors destroyed with a single blow is not inconsiderable.

Charles Frizell was born and educated in Rhodesia. He came to the UK in 1965, where he worked at Racal on coils and transformers, subsequently returning to Rhodesia to work on radio telemetry for the Kariba hydro-electric project. Since then he has been chiefly concerned with high-power electronics in Zimbabwe and South Africa and is now with Brown-Boveri in Harare, Zimbabwe.

continued from page 48

others say that the Michelson-Morley experiment does not produce a null result***. In any case Einstein did not develop relativity as a result of the Michelson-Morley experiment****. The formula $e=mc^2$ pre-dates relativity. Relativity pre-dates Einstein. And so on.

We are helped in trying to understand why apparently liberal, progressive scientists should combine to create such a reactionary, unstable juggernaut if we read about the term "Whig History" in the dictionary of the History of Science, 1981, page 83.

> ". . . . Although favouring progressive movements in the past, the thought of Whig historians was essentially conservative. They saw their own beliefs, practices and institutions as the goals for all previous beliefs, practices and institutions. The historian's task was reconstructing the progressive march of history focusing on those past developments which anticipated the present."
>
> "The 'Whig' interpretation of history has had a powerful influence within the history of science. . . . . Some historians of science have, therefore, seen the present state of scientific knowledge as an absolute against which earlier (and we would say later) attempts to understand Nature could be evaluated.,"

Like the Whig historian, today's Establishment Scientist, although apparently progressive, is in fact conservative.

MAXWELL, EINSTEIN AND THE AETHER

The conventional story is as follows.

Maxwell followed in the wake of a physical, non-mathematical Faraday, who thought in terms of tubes of flux in space. Faraday had a space in which resided electric flux and magnetic flux. His space had physical reality and physical properties, these properties making it able to accommodate his fluxes.

Maxwell set out to make Faraday's ideas more rigorous and scientific (a) by firming up the physical model for space, or the aether, and (b) by placing a mathematical structure over them.

He constructed a mechanical model for the aether, with large rotating wheels and small idler wheels, on the lines of a gear box run riot in complexity. Using this model, he constructed his Equations of Electromagnetism.

However, the reported[1] failure of the Michelson-Morley experiment and the birth of Relativity led to the removal of the physical model upon which Maxwell constructed his equations

> ". . . . one is almost exactly the antithesis of the other: the primary function of the ether was to provide a fixed frame of reference – . . . . the theory of relativity merely implies the negation of this preliminary assumption, so that the two are exactly antithetical."[2]
>
> "Now although Maxwell's Equations have survived to the present day, the discovery of the electron and the development of relativity theory have removed the physical props upon whch they were built."[3]

All of this flows along swimmingly until we assemble the next disastrous pair of observations.

In 1949 Einstein wrote[4];

> "The special theory of relativity owes its origin to Maxwell's Equations of the electromagnetic field."

Here we reach the point where Einstein says that the foundation of relativity is Maxwell's equations excluding, of course, its now defunct physical origin, the aether; that is, space with physical properties.

Now add my own discovery that Maxwell's equations are devoid of any information *except* that on the physical properties of space.

> "The only purpose served by Maxwell's equations is as a package to deliver the constant Z_0 to the theorist and to the practitioner."[5]

Here we have closed the loop in the argument, and the whole crazy structure underlying 'modern physics' collapses.

To sum up. Einstein says that relativity, which he believes to have been based on the disappearance of a space with physical properties, is based on Maxwell's equations, which are now found to contain *only* information about the physical attributes of that disappearing space.[5]

By analogy, it would be possible to proclaim a new theory of mechanics which lacked the concept of mass, but which contained both velocity (v) and moment (mv) within it, and which preferably included lots of fancy maths involving momentum and velocity. Then, unknown to any one among the awed observers, the new theory could be made to function, produce results, and correlate with reality. The necessary parameter m, like the rabbit in the hat, could go about its business, staying all the time firmly hidden inside the hat, the hat being in our case the term momentum and a fog of mathematics.

Can we not chase this obscurantist 'modern physics' out of our universities, and start to prepare for a 21st century of real scientific progress?

*See I. Catt, Electromagnetic Theory republished C.A.M. Publishing 1986, p.III.
**See I. Catt, *op.cit.,p116*
***M. Polanyi, Personal Knowledge, pub. RKP 1958, p.12.
****M. Polanyi, *op. cit.*, P.10.

References

1. For the exact nuances here, read Polanyi M., Personal Knowledge, R.K.P., 1958, pp9-13. Catt, I., Electromagnetic Theory Vol. 1, C.A.M. Publishing, 1979, p108
2. Jeans, J., The Mysterious Universe, C.U.P., 1931 P.85
3. Cullwick, E.G., Electromagnetism and Relativity, Longmans, 1959, p.ix. See also Whittaker, E.T., A History of the Theories of Aether and Electricity, Nelson, 1951, p255.
4. Ed. Schilpp, P.A., Albert Einstein, Philosopher-Scientist, Library of Living Philosopher, 1949,p62.
5. Catt, I., The Hidden Message in Maxwell's Equations, *EWW*, Nov'85

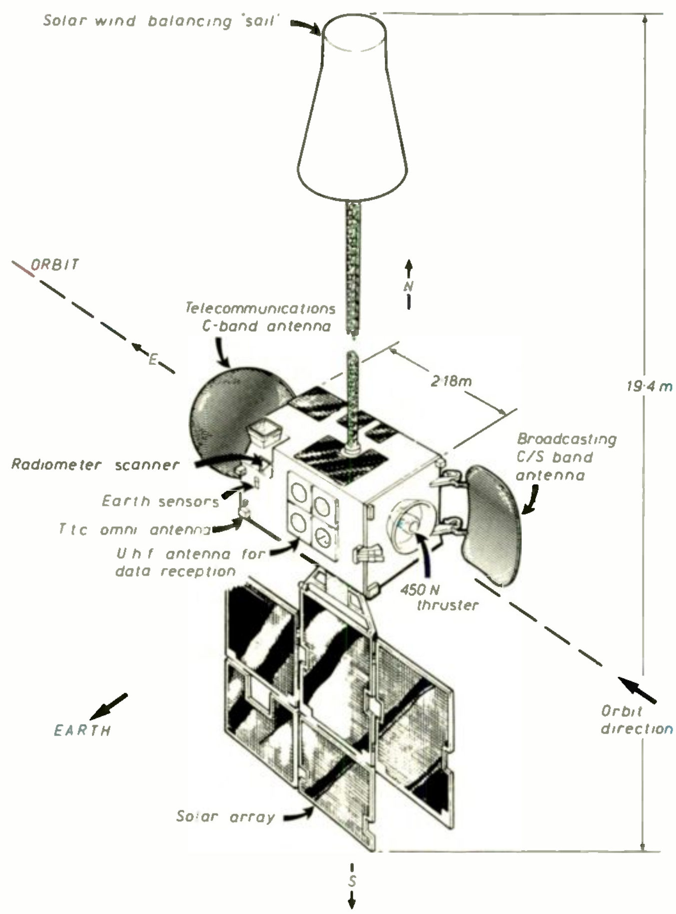
India's second multi-purpose satellite

Due to be launched by Arianespace in the next few months is the second spacecraft for India's national satellite system. Called Insat-IC, it will join the similar Insat-IB which has been operating in geosynchronous orbit at 74°E since October 1983. Among its first uses will be to provide additional regional television programme feeds to broadcasting stations in Karnataka, Orissa and the north-eastern regions of the country. This second satellite bears the code letter C because, although an Insat-IA was actually launched into orbit (in April 1982), it failed mechanically and was never put into service.

This new spacecraft, together with the present IB and a ID to follow later, constitutes a first generation of multi-purpose geosynchronous satellites, Insat-I. (A second generation, Insat-II, is planned for the 1990s.) The system is multi-purpose in that each satellite carries four distinct payloads for different purposes – telecommunications, meteorology, broadcasting, and the relaying of information from terrestrial data collection platforms. As such it is a joint operation run by the Indian government departments of space, telecommunications and meteorology, together with the broadcasting authorities. Overall management is by a co-ordinating committee in the Department of Space, which is directly responsible for the space segment of the whole system.

For India, with her huge land area of over 3 280 000 square kilometres, the wholesale adoption of satellite communications is both practical and cost-effective. The government realised the potentialities after conducting their Satellite Instructional Television Experiment in 1975 (*Wireless World*, Sept. 1975, p.441 and Sept.1976, p.59).

Monochrome tv pictures were transmitted on 860MHz from NASA's geosynchronous satellite ATS-6 to community viewing centres in villages all over the country. The present satellite coverage reaches over great distances and rugged terrain into very inaccessible regions. The cost of running the equivalent landlines to thousands of remote towns and villages would be prohibitive for the Indian economy.



India's second multi-purpose satellite has an asymmetrical structure with a solar array on one side and a balancing solar-wind 'sail' on the other. Diagram shows the orientation of the spacecraft in its geosynchronous orbit, with its antennas facing the Earth (somewhere off the picture to the bottom left). Overall height is 19.4m.

The telecomms part of the Insat system works in C band, with uplinks at 5.935-6.425GHz and downlinks at 3.71-4.2GHz. Each satellite carries twelve 36MHz bandwidth transponders for national coverage and these give a transmitter e.i.r.p. of 32dBW over the primary coverage area. So far there are 38 telecomms earth stations in service (large, medium, small and transportable). Altogether this part of the Insat system has provided 3961 two-way voice or equivalent circuits over 68 trunk routes. But already more than 300 additional earth stations have been approved for secondary telecomms services such as private business and public sector networks, rural telegraphy and computer communications.

Meteorological information is transmitted in the form of complete Earth images at 30 minute intervals from a high-resolution scanning radiometer carried in each spacecraft. This instrument has one channel for visible pictures (0.55-0.75μm wavelength) with a resolution of 2.75km, and a second channel for infra-red images (10.5-12.5μm) with 11km resolution. It uses a 20° scan in the North-South direction corresponding to 1137 scan lines and a sector scan measuring 5° N-S by 20° E-W corresponding to 285 scan lines.

Information is transmitted to the ground as digital data at 400kbit/s on a 4GHz downlink with an e.i.r.p. of 8dBW. It is processed at a meteorological data centre in Delhi and is also available at 22 secondary centres spread around the country. Among the users of this data is the World Weather Watch organization (see June 1987 issue, p.603).

Also providing meteorological measurements, and hydrological and oceanographic ones as well, are 100 land- and sea-based data collection platforms distributed around the country. These are automatic and unattended. They transmit their data at u.h.f. (402.75MHz) to a special antenna on the spacecraft (see diagram). A data relay transponder then sends the information on a 4GHz downlink to the processing centre at Delhi.

For broadcasting services, each satellite carries two high-power S-band transponders giving national coverage. Their uplinks are actually in C band (5.855-5.935GHz) and the S-band downlink are at 2.555-2.635GHz. The transmissions are in fact within the 2.5-2.69GHz frequency band allocated at WARC 1979 for community satellite broadcasting in national and regional systems. Each transponder has a bandwidth of 36MHz, a travelling wave tube amplifier r.f. output power of 50W per channel, a transmitter antenna gain of 27dB and a minimum e.i.r.p. of 42dBW. Altogether, each 36MHz transponder will handle one direct broadcast television channel for community reception and five low-level carriers for radio broadcasting signal distribution, disaster warnings and standard time and frequency signals.

As well as directly broadcasting television programmes to about 3200 community tv receivers installed around the country, the S-band downlinks also do the important job of providing signal feeds to 197 stations in the national terrestrial television service. In fact the rapid expansion of the Indian tv service over the past two or three years has been entirely due to the availability of this satellite signal distribution system. Educational programmes for schools and special programmes for selected rural areas are also distributed through the system. A further 1100 direct-reception tv sets are being installed in the north-east region of the country.

For sound radio broadcasting the Insat system transmits high quality five-channel signal feeds to national and regional stations run by All India Radio. So far 96 of these radio stations have been equipped with S-band earth terminals. A sixth radio networking channel is being prepared, not only to provide programme feeds but also for synchronization of m.f. transmitters in the national radio broadcasting service.

The mechanical structure of Insat-IC (also of IB and ID) is somewhat unusual. As seen in the diagram, the spacecraft, built by Ford Aerospace & Communications Corporation to Indian specifications, has a solar array on only one side of the main body. The purpose of this design is to ensure an unobstructed field of view into cold space for the radiation cooler of the Earth-imaging radiometer. But this asymmetrical arrangement on its own would disturb the attitude of the spacecraft because of the solar wind pressure on the 11.5m^2 solar array. So the mechanical system is balanced by a solar-wind 'sail' on a 12 metre boom projecting from the other side of the spacecraft.

Apart from the normal reaction-propulsion thrusters for attitude and orbit corrections, the 1089kg spacecraft also has an electromagnetic torque system for fine position control. This comprises a loop of wire running around the periphery of the satellite body. When a current is passed through this loop it interacts with the Earth's magnetic field rather like a coil on the rotating armature of a permanent-magnet electric motor. Thus a small force is applied to the wire loop and it becomes a torque on the body of the spacecraft.

I am greatly indebted to Professor Jai P. Singh, programme director of Insat, for much of the information in this report.

Europe's new weather satellites

The cloud patterns currently seen by viewers of UK television weather forecasts are derived from a European Space Agency geostationary weather satellite called Meteosat-F2. This was launched in 1981. From its position at 0° longitude, it carries on the work of Meteosat-F1 which started transmitting in November 1977 but became defunct in October 1985. A third ESA metsat called Meteosat P2 is due to be launched by Ariane rocket during 1988.

All three of these weather satellites are pre-operational designs, and Meteosat P2 will be the last of the group. Europe's future satellite-based meteorology will then be carried on by a second generation of permanent spacecraft called Meteosat Operational Satellites, MOP-1, -2 and -3. These are now being manufactured, with Aerospatiale of France as prime contractor, and the first launch, MOP-1 on an Ariane 4 rocket, is provisionally planned for late 1988 or early 1989.

Meanwhile an international organization has been set up specifically to run the whole Meteosat operational programme. Called Eumetsat (European Meteorological Satellite Organisation), it is made up of 19 participating countries from Europe and North Africa. A Eumetsat secretariat has been taking over various meteorological activities previously performed by ESA.

The new operational Meteosats, also geostationary, will be similar to the current pre-operational ones but will do more. The enhanced service they provide will have four main parts to it. The principal task will be to take pictures of the Earth and send them to a central control and processing station at Darmstadt, W. Germany (actually ESA's present Space Operations Centre, ESOC). For this the camera is a radiometer, producing images by scanning in the visible, infra-red and water-vapour spectral ranges.

This electro-optical instrument comprises a telescope with a focal length of 3650mm and a set of detectors, located in the focal plane, measuring the radiance of the Earth and its cloud cover. The spin of the satellite causes the radiometer to scan the Earth along the E-W axis, while a N-S scan is achieved by incrementally tilting the telescope a small amount at the end of each E-W scan. Raw image data from this scanning process will be sent to ground at either 333kbit/s or 2.66Mbit/s on the L-band frequency of 1.686GHz.

Secondly, the spacecraft will be used as comsats to disseminate weather facsimile pictures (Wefax) or high-resolution digital pictures from Darmstadt to weather forecasting services in Europe, Africa and the Middle East. For this there will be two S-band uplink channels at 2.1GHz and corresponding L-band downlinks at 1.69GHz. This part of the system also provides a service channel using similar uplink and downlink frequencies for data exchange purposes.

The third part of the satellites' job will be to collect weather data transmitted in 66 channels at 402MHz in the u.h.f. band from unmanned automatic buoys in the Atlantic Ocean. An L-band downlink will then relay this data to Darmstadt for near-Earth weather forecasting. Finally, there are the t.t.c. communications for operating the satellites themselves (see September 1987 issue, p.927). Telecommand data will be transmitted to the spacecraft on S-band uplinks from a ground control station at Michelstadt, near ESOC, while telemetry data will be sent back to the control station on L-band downlinks.

Each MOP spacecraft is formed from two concentric cylindrical structures. The main, larger-diameter cylinder, which is covered with solar cells to provide electrical power, carries the scanning radiometer and most of the satellite sub-systems. The second, smaller-diameter, cylindrical structure carries an electronically de-spun antenna, the bulk of the communications transponder equipment (made by ANT Nachrichtentechnik of West Germany) and some additional antennas. All three of the new metsats will be put into geostationary orbit at about 0° longitude.

Geostationary satnav trials

Inmarsat is planning a satellite radionavigation system similar in principle to the GPS/Navstar and Glonass schemes (see April 1987 issue, p.377) except that it will use geostationary satellites. The 50-member co-operative has just started to transmit L-band test signals for position finding through its Marecs B2 geostationary comsat at 26°W over the Atlantic Ocean.

The test transmissions are spread-spectrum signals generated by direct modulation with a pseudo-random noise (p.r.n.) sequence at 1.023Mbit/s. A comparison of such signals coming from several sources enables the exact position of a receiver to be found.

The similarity to GPS and Glonass offers two advantages. One is that participants in trials will be able to use modified existing satnav receivers to receive the signals. The other is that, if the trials are successful, manufacturers of satellite communications terminals will be able to design composite equipment that will allow reception of satnav signals from both the existing 12-hour period satellites and those in the new Inmarsat scheme. By transmitting p.r.n. signals on a regular basis, Inmarsat could improve the coverage of GPS/Glonass as well as provide a built-in navigation service, including integrity information and differential correction data, with its normal satcoms service.

The current test transmissions are at a variety of power levels in order to determine the minimum power needed for effective performance and to demonstrate that such signals can co-exist with communications signals in the same band. Organizations with L-band receiving equipment, especially for GPS reception, are being invited to take part in the trials. Later on another possible satnav scheme, based on coherent narrow-band carriers, will be tested over the Inmarsat system.

Satellite Systems is written by Tom Ivall

Microcoding and bit-slice techniques

Bit-slice technology and microcoding represent the point where hardware and software meet. Together they produce high performance processors with flexible instruction sets.

A.N. EDMONDS

State machines – the simplest and hence fastest digital processors – can be made from hard-wired logic and registers. Provided that the number of states required is small, the design of a state machine is quite easy, but when the number of states reaches double figures, working out the logic becomes a daunting task.

Microcoding simplifies the design work, allowing state machines with many thousands of states to be produced with relative ease. Read-only memory and a register make up the simplest form of microcoded machine, Fig.1.

Outputs from the prom are split into two fields, one controlling some external devices and one producing the next address for the rom. But such a configuration is of little use if the next address can not be determined externally.

Figure 2 shows a general-purpose sequencer. It is built around a multiplexer; a further microcode field from the rom selects the source of the next rom next address.

The source options are an instruction counter for stepping through a sequence of locations in ascending order, the next address field from the rom used to jump to a new sequence, a mapping input used to jump to a new address supplied externally, and a stack, where a number of previous addresses can be stored in a last-in-first-out manner to provide subroutine linkage. All or some of these choices can be made conditional upon the state of an external line to give conditional branching.

Frequently, a counter is provided for 'for-next' loop counting. Source selections for the next address form a primitive series of control instructions analogous to control functions found in high-level languages, like IF, FOR, WHILE, GOSUB, GOTO and RETURN. Microcode "meta assemblers" can make the writing of microcode much easier than it seems at first glance, and much more like writing a program in a high-level language.

Thus the primitive controller consists of a sequencer with a single line-condition input, some proms connected in parallel to give a microcode width as large as required, and a mapping input of a width commensurate with the number of address lines needed to control the proms. It is possible to buy an entire controller on a single chip: an example of this is the AM29PL141.

MICROCODE CONTROL STORE

Registered proms are normally used in microcoded designs since they reduce the number of chips needed. They ensure that all the parallel outputs of the microcode are at the same pipeline depth, which makes coding easier, and produce clean control signals that are valid throughout most of the cycle.

Most devices that would be controlled by bit slice have a flow-through architecture, making the microcode proms the source of synchronization in design, minimizing

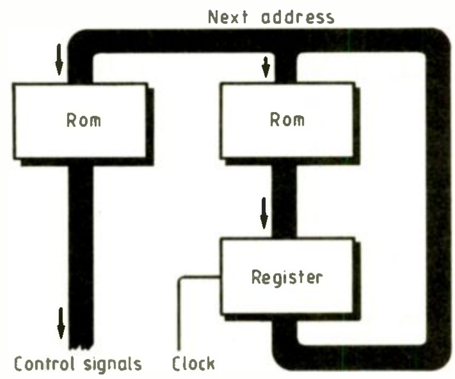
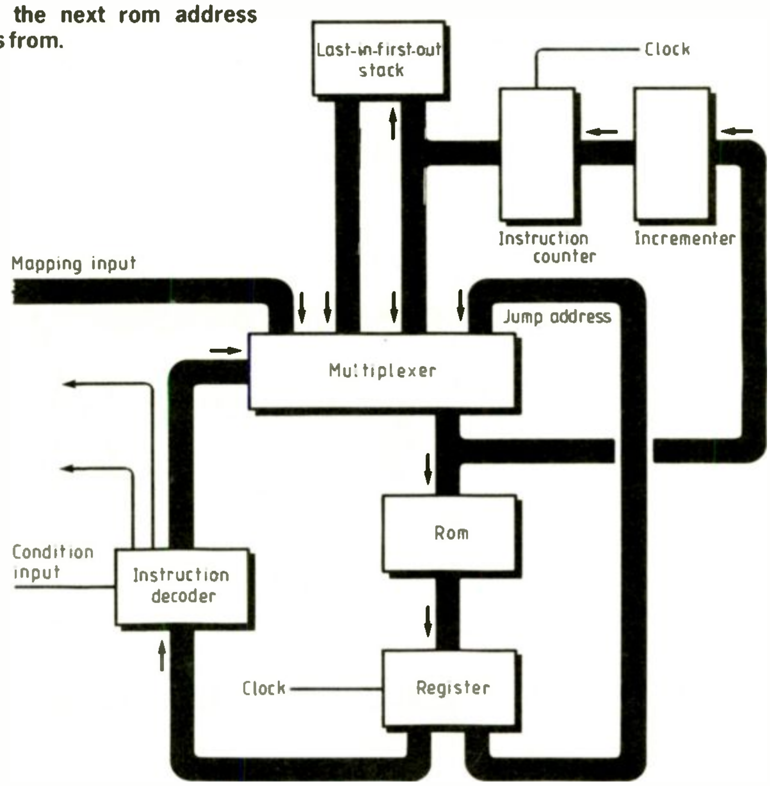


Fig 1. Read-only memory and a register make up the simplest form of microcoded machine.

Fig.2. In this general-purpose sequencer, a microcode field from the rom determines where the next rom address comes from.



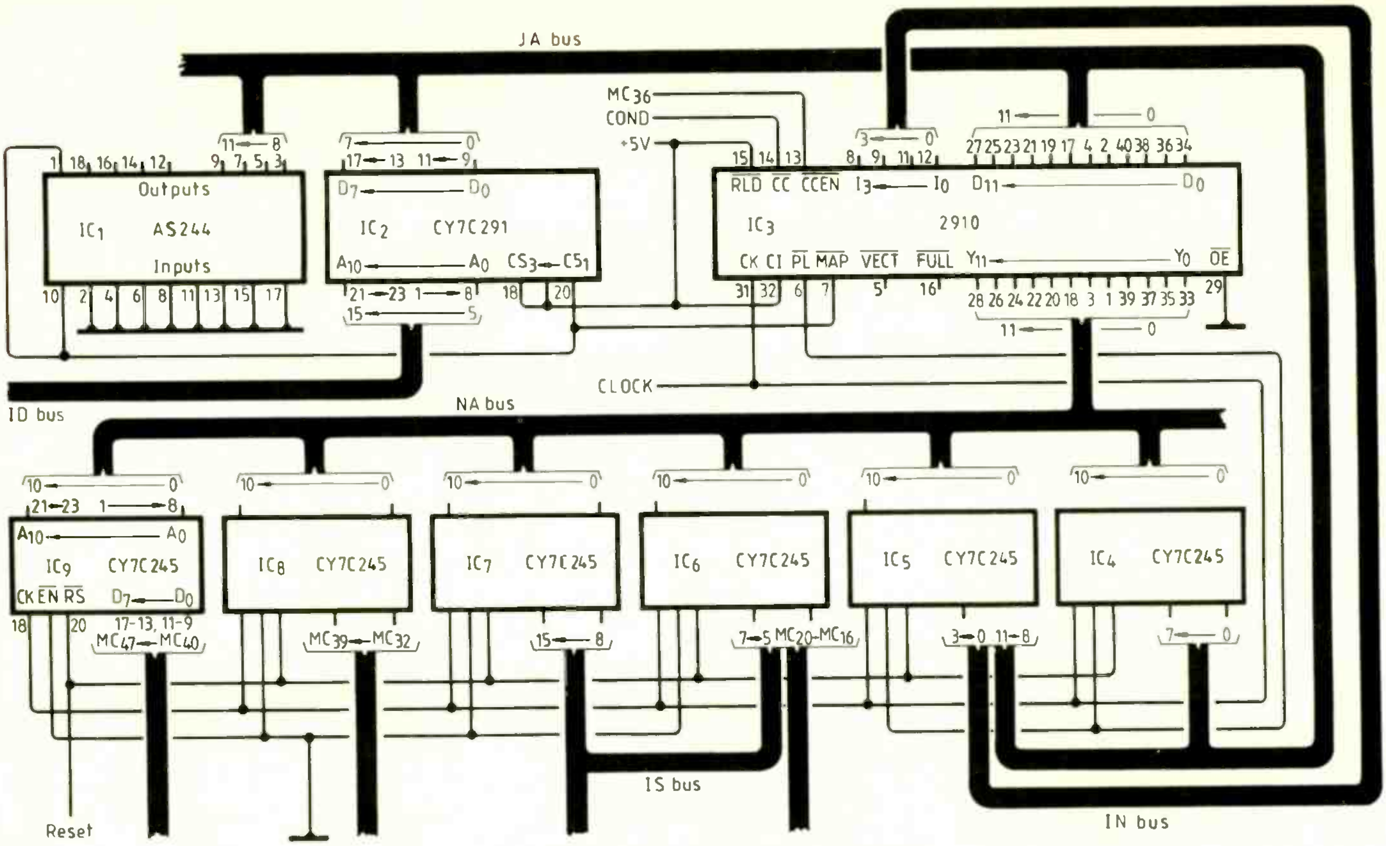


Fig.3. This controller, based on the 2910, is optimized to work with the a.l.u. of Fig.5 to produce a simple 16bit c.p.u.

clock skew problems and simplifying timing calculations. The exception to this is the Analog Devices range of 16bit digital signal processing chips. They have internal control-path registers, meaning that a designer must use a mixture of registered and unregistered parts to bring the pipelining back into line.

It is not a problem to have different parts of a circuit at different pipeline depths. But if the circuit you design must respond instantly to some external stimulus, for example an interrupt, it is important that elements controlled at different depths have no interaction.

Figure 3 shows a complete design for a controller using the well established 2910, originally from AMD but now also from many other manufacturers. Address/data width of the 2910 is twelve bits, giving a maximum microcode depth of 4K. This is frequently all that is needed. The diagram shows 2K registered proms, so most-significant bit Y_{11} of the NA bus is disregarded.

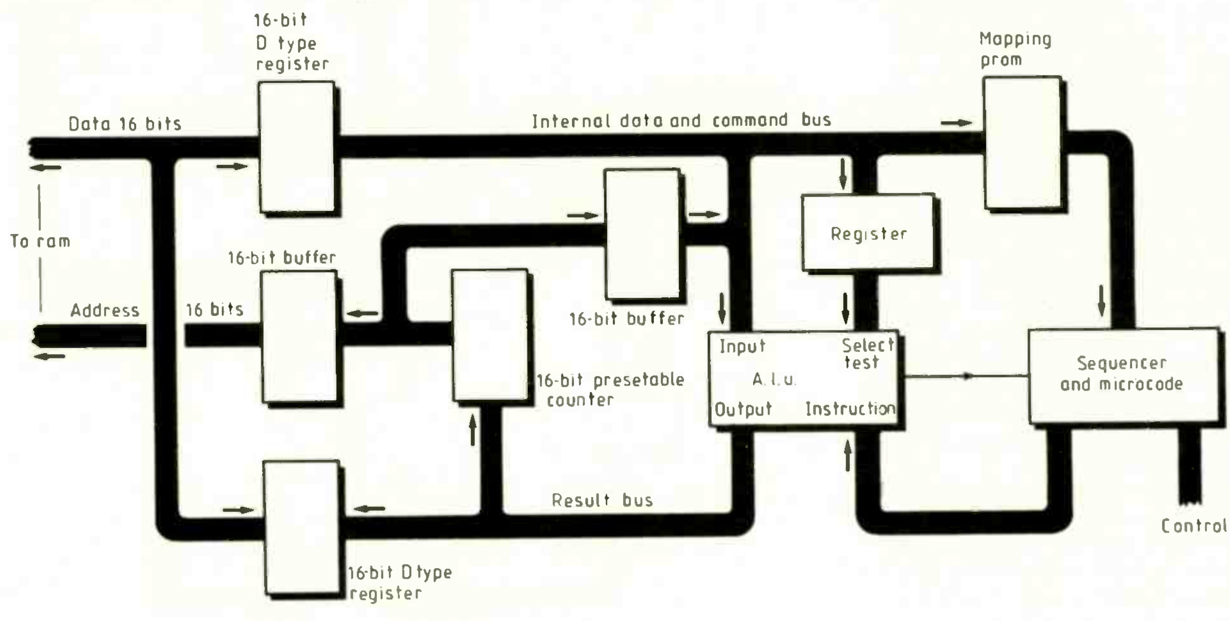
Four instruction-bus bits of the 2910 provide 16 instructions. These assume inputs from various sources, and outputs PL, MAP and VECT can be used to selectively switch several different drivers onto the 2910 D input.

Devices $IC_{1,2}$ perform the mapping function. Often, as in my later example, a controller is required to perform a series of discrete tasks, each requiring one or more microcode words. These sequences of words can be placed arbitrarily in the microcode depth, and each has a unique start address.

Assuming that the instruction to start one of these sequences is received as a coded word on the ID bus, the mapping prom IC_2 is used merely to convert the code to the appropriate start address. If the decoding were not too difficult, IC_2 could be replaced by a pal, or even discrete logic. If you were very lucky with the instruction format and start addresses used, you might even be able to do without a mapping prom.

Controller Fig. 3 is optimized to work with the a.l.u. in Figs 4,5 to produce a simple 16bit c.p.u.

Fig.4. Block diagram of the processor in Fig.5. This 16bit c.p.u. performs simple operations on data from 32 registers.



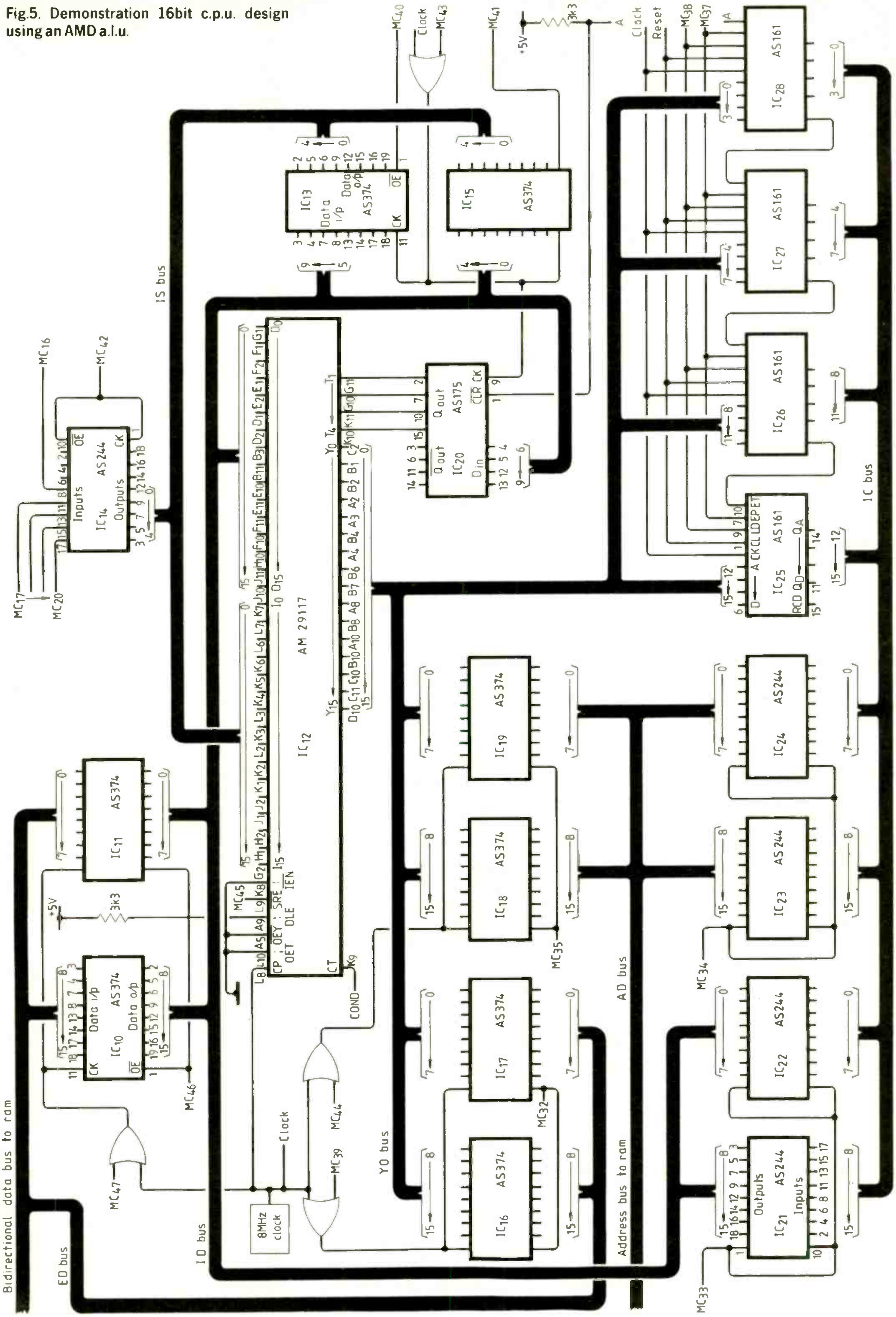


Fig.5. Demonstration 16bit c.p.u. design using an AMD a.l.u.

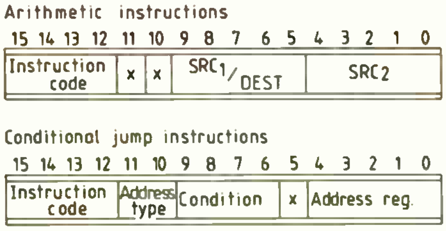


Fig.6. Examples of instruction words for the 16bit processor, Fig.5.

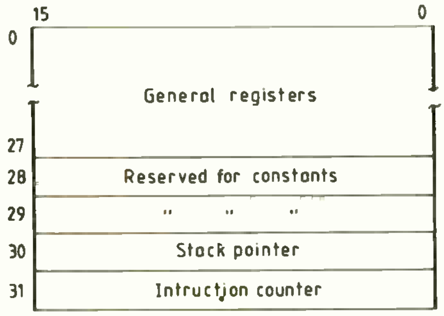


Fig.7. Allocation of the demonstration processor's 32 registers.

BIT-SLICE DEVICES

Originally, the name bit slice applied to a family of parts from which a general processor could be made, and which are now largely superseded. A 16bit a.l.u. for instance could be made from four of these parts, each of which would deal with four bits, a 32bit a.l.u. with eight and so on. Data into the a.l.u. is thus "sliced" horizontally.

Now the term bit slice is used rather inaccurately to cover any devices that perform processing tasks that are not capable of standing alone and require external control. Examples are sequencers, a.l.us, floating-point processors, interrupt controllers, multipliers, direct memory access controllers, etc.

Bit-slice devices are mainly used in computation and control. The same can be said of microprocessors, and bit-slice techniques can be applied over the same wide field. It is the speed and flexibility of these devices that make them preferable in many high speed applications like signal processing.

For high-volume production a custom i.c. design gives a much lower chip count and power consumption, although low-power bit-slice products are now available in c-mos. For smaller runs, however, these devices are often the optimum choice, and it is interesting to note that custom-chip cell libraries frequently contain bit-slice a.l.us and sequencers.

It is now common to breadboard and debug in bit-slice, and ultimately implement designs in application-specific i.c. technology. Complexity of microcode controllable devices has kept pace with microprocessors, and 32-bit slices are now available from several manufacturers.

When comparing microprocessors and bit slice for a design it is often difficult to compare like with like. A 12.5MHz 68010 takes 400ns to add two registers. A design using the AMD 29300 family clocked at 8MHz could do it in 125ns. When one considers floating-point performance, the ratios in performance can be even more impressive.

SUPPLIERS OF BIT-SLICE DEVICES

It is impracticable to list all the manufacturers of microcode controllable devices, but here are a few. AMD produces a range from the humble 2900 family, to the 29100 16bit family and 20300 32bit series. Most are now available in c-mos. Analog Devices makes a series of 16bit i.cs including a sequencer and address generator, but notably lacking a general purpose a.l.u.

Integrated Device Technology has a c-mos range from four bits to 32, some modelled on AMD parts. Cypress Semiconductor provides c-mos versions of AMD parts with various speed and performance improvements. Finally, Wietek produces a formidable range of floating-point processors for microcoded systems.

A SIMPLE 16-BIT BIT SLICE CPU

To help illustrate the writing of microcode I have included the design of a simple 16bit c.p.u. using the AMD AM29117 a.l.u., Fig.5. It performs a range of primitive operations on data from two internal registers or from its D input and deals with byte or 16bit word values.

Most operations are completed in two cycles. The design lacks several of the requirements of a complete c.p.u., for instance d.m.a. and interrupts, although these could easily be added. It is, however, exceedingly fast, and with a clock speed of 8MHz, three mega-instructions per second can be expected, depending on the instruction set.

I have already chosen an instruction set, which the configuration of $IC_{1,2}$ in Fig.3 suits. Similarly I have made choices in Fig.5, like a 16bit address and data bus and a Von Neumann architecture. My final circuit is still capable, merely by changing the contents of IC_2 and IC_{4-9}, of running a wide range of instruction sets. It is one of the strongest features of bit-slice technology and microcode that with them one can emulate other processors, and quite possibly improve on their speed.

Referring to block diagram Fig.4 and circuit Fig.5, incoming data from the ram is latched in IC_{10-11}. These values could be instructions, pure data, or addresses. For an instruction value, $IC_{1,2}$ of Fig.3 define the appropriate start address in the microcode for that instruction. The sequencer jumps to that start address as the previous instruction ends. If the value is data, then the a.l.u. is instructed to load it and operate on it. If the value is an address, the a.l.u. passes it or operates on it, and the result is latched in $IC_{18,19}$ for use in the next cycle on the address bus.

Components $IC_{13-15,20}$ are concerned with a.l.u. control. I have decided in my instruction set that all arithmetic and logical instructions, i.e. all data-related instructions, will act only on registers. The lower five instruction bits of the 29117 select the register for each operation and decode non-register instructions. Figure 6 shows examples of the standard instruction form I have chosen. You can see that IC_{13-15} form a multiplexer selecting either the source/destination operand, the second operand, or microcode onto these bottom five bits. Figure 7 shows the assignments for the 29117 registers that I have selected.

Which aspect of the internal status is selected for tests is controlled by T Inputs of the a.l.u., IC_{12}. Component IC_{20} latches the conditional field of the instruction for conditional jumps etc. The 29117 condition output connects to the 2910 test input.

INSTRUCTION FETCHING

In such a design it is common to use the a.l.u. for both address and data calculations. This means that for every instruction performed the a.l.u. has to modify the instruction counter. If you assume that for perhaps 80% of the time the processor is merely accessing the next sequential instruction, performance can be drastically enhanced by off-loading the incrementing of instruction counter IC to a separate counter.

This counting is done by IC_{25-28}, arranged as a 16bit presettable counter. When the value of IC is modified by a jump the counter is merely reloaded. During normal sequential accesses the counter is incremented while the a.l.u. process the instruction. A similar tactic could be tried with the stack pointer, but this would over-complicate an illustrative design. Devices $IC_{21,22}$ allow the IC value to be used in address calculations by passing it back to the a.l.u. D input.

Clock and enable lines of the registers and buffers all receive individual microcode bits where possible; my first rule of bit-slice design is, if in doubt assign a microcode bit to it. Once the micrcode is written you can look for duplication in the use of control lines, but at this stage it is better to assume that the lines need to be separate.

An active-low reset line is assumed for the design. The proms specified have an initialization function that forces the outputs to a programmable state at power up.

ADJUSTING THE CYCLE PERIOD

Life is easier if the clock-cycle period of the system is constant. This does however mean that the worst-case delays for all the data and control paths in the system must be calculated, and the clock cycle adjusted to accommodate the longest.

If the worst delay occurs in a subset of the possible cycle types, i.e. only while a condition is evaluated for a conditional jump, another tack can be taken. Length of the clock cycle itself can be microcode selected by using a much higher clock rate and a programmable divider. The AMD Am2925 or IDT IDT49C25 are examples of such devices and 15-30% speed improvements can be obtained by using them.

In his next article A.N. Edmonds looks at the writing of microcode and writing aids available.

Andrew Edmonds is consultant digital design engineer and Director of Guyvale Ltd. Hitchin.

CIRCUIT IDEAS

Three-way crossover network

This is a slightly different line of thinking on low-level crossover networks, the chief merit of which is that it leads to an unusually simple three-way design.

Transmission functions for maximally flat, two-pole high and low-pass networks are,

$$\left|T_H\right|^2=\frac{\frac{\omega^4}{A^4}}{1+\frac{\omega^4}{A^4}}$$

and,

$$\left|T_L\right|^2=\frac{1}{1+A^4\omega^4}$$

respectively where A is the cut-off frequency for the high-pass network and the reciprocal of the cut-off frequency for the low-pass network. In a two way system with cross-over $\omega=1.0$, $A=1.0$ and the sum of the expressions is 1.0; this means that, ignoring phase angle, the total power delivered to the two channels is constant.

In a three-way system based on $\omega=1.0$, the sum of the power contributions from the high-pass and-low pass channels is,

$$\left|T_H\right|^2+\left|T_L\right|^2=\frac{\frac{\omega^4}{A^4}(1+A^4\omega^4)+1+\frac{\omega^4}{A^4}}{\left(1+\frac{\omega^4}{A^4}\right)\left(1+A^4\omega^4\right)}$$

$$=\frac{1+2\frac{\omega^4}{A^4}+\omega^8}{1+\omega^4\left(A^4+\frac{1}{A^4}\right)+\omega^8}$$

If the constant total power criterion is accepted, the mid-range channel must have,

$$\left|T_M\right|^2=\frac{\omega^4\left(A^4+\frac{1}{A^4}\right)-2\frac{\omega^4}{A^4}}{1+\omega^4\left(A^4+\frac{1}{A^4}\right)+\omega^8}=$$

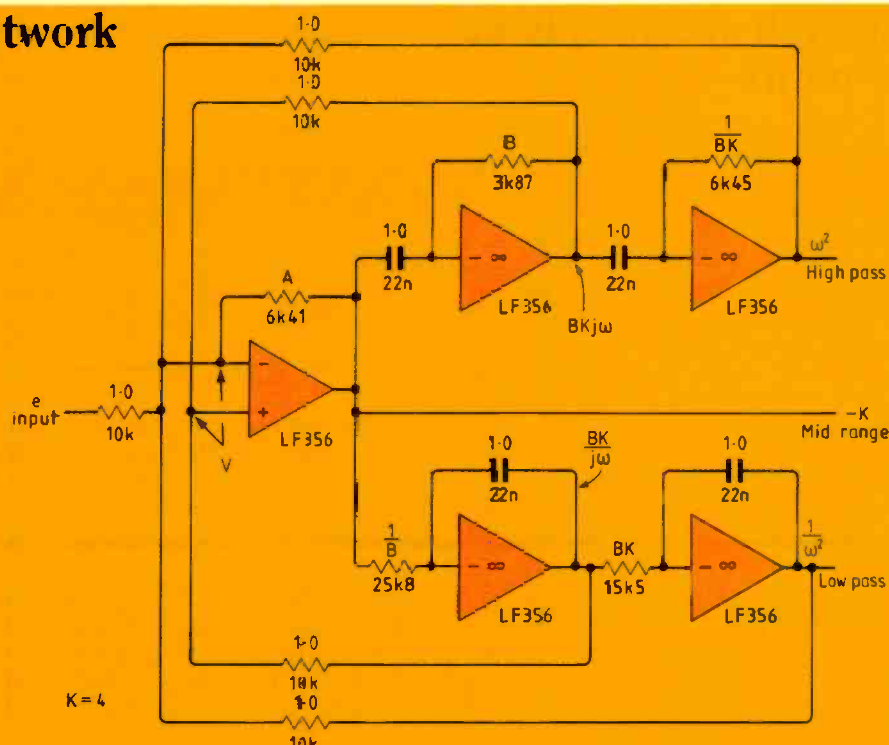
$$\frac{\omega^4\left(A^4-\frac{1}{A^4}\right)}{1+\omega^4\left(A^4+\frac{1}{A^4}\right)+\omega^8}$$

which is not maximally flat but approaches it as A grows larger. It is a common and satisfactory practice to use a maximally flat bandpass filter for the centre channel.

Observe, though, that for reasonable values of A, say 2 or greater, A^4-1/A^4 hardly differs from A_4+1/A^4. Substituting K^4 for both gives,

$$\left|T_M\right|^2=\frac{K^2}{\frac{1}{\omega^4}+K^2+\omega^4}$$

$$\left|T_H\right|^2=\frac{\omega^4}{\frac{1}{\omega^4}+K^2+\omega^4}$$



$$\left|T_L\right|^2=\frac{\frac{1}{\omega^4}}{\frac{1}{\omega^4}+K^2+\omega^4}$$

The general form of these functions suggests that all three can be produced in a single network, and further that the network will consist mainly of two cascaded differentiators and two cascaded integrators. These clues and some trial and error produce the circuit shown.

Crossover frequencies are $\sqrt{K}$ and $1/\sqrt{K}$ and coefficients A and B are most easily found as follows.

Assume output voltages of ω^2, $-K$ and $1/\omega^2$ as shown. Find voltage V for each of the two feedback paths and set the two values equal. Solve this equation for e and then set $|e|^2=\omega^4+K^2+1/\omega^4$. There will be a term in ω^2+1/ω^2 which must equal zero, equation (1), and a constant term which must equal K^2, equation (2). The two equations are solved for A and B in terms of K.

$$v=e\frac{A}{1+3A}-\frac{K}{1+3A}+\left(\omega^2+\frac{1}{\omega^2}\right)\frac{A}{1+3A}$$

$$=j\frac{BK}{2}\left(\omega-\frac{1}{\omega}\right)$$

$$e=\frac{K}{A}-\left(\omega^2+\frac{1}{\omega^2}\right)+j\frac{BK(1+3A)}{2A}\left(\omega-\frac{1}{\omega}\right)$$

$$\left|e\right|^2=\frac{K^2}{A_2}-2\frac{K}{A}\left(\omega^2+\frac{1}{\omega^2}\right)+\omega^4+\frac{1}{\omega^4}+2$$

$$+\left[\frac{BK(1+3A)}{2A}\right]^2\left[\left(\omega^2+\frac{1}{\omega^2}\right)-2\right]$$

$$2\frac{K}{A}-\left[\frac{BK(1+3A)}{2A}\right]^2=0 \qquad (1)$$

$$2+\frac{K^2}{A^2}-2\left[\frac{BK(1+3A)}{2A}\right]^2=K^2 \qquad (2)$$

Substituting (1) in (2) and completing the square,

$$\frac{K^2}{A^2}-4\frac{K}{A}+4=K^2+2$$

$$A=\frac{K}{2+\sqrt{K^2+2}}$$

Solving (1) for B

$$B=\frac{\sqrt{8\frac{K}{A}}}{1+3A}$$

I found it necessary to shunt resistor A with 200pF to suppress high-frequency oscillation, but otherwise performance was as expected.

McKenny W. Egerton jr.
Owings Mills
USA

Don't waste ideas

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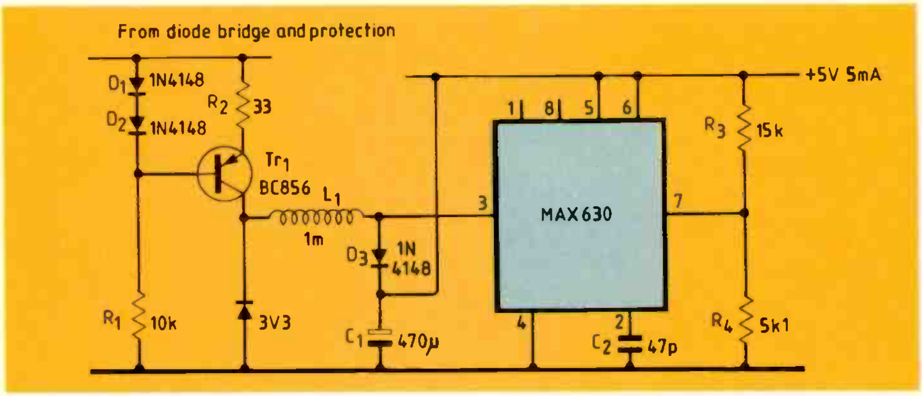
CIRCUIT IDEAS

5V rail for telephone circuits



Obtaining a 5V rail from a telephone line is difficult because a.c. speech and d.c. occupy the same pair of lines.

Direct voltage, which at a line current of 30mA must be less than 9V, is reduced by 2 or 3V by the polarity guard bridge and protection circuits. Of the remaining say 6.5V, one has to allow about 2V peak for the speech signal, which makes a 5V supply difficult to achieve. In addition, circuits across the line have to present a high impedance to a.c. signals.

This circuit provides 5V at 5mA. Supplying the 3.3V zener diode is a transistor constant-current source set to about 12mA. A Maxim MAX230 i.c. with its oscillator running at about 40kHz (set by C_2) provides d.c.-to-d.c. conversion. Supply voltage determines whether the oscillator is on or off.

Efficiency of the converter depends mainly on the inductor; 60/70% is easily achievable.

T. Segaran, York

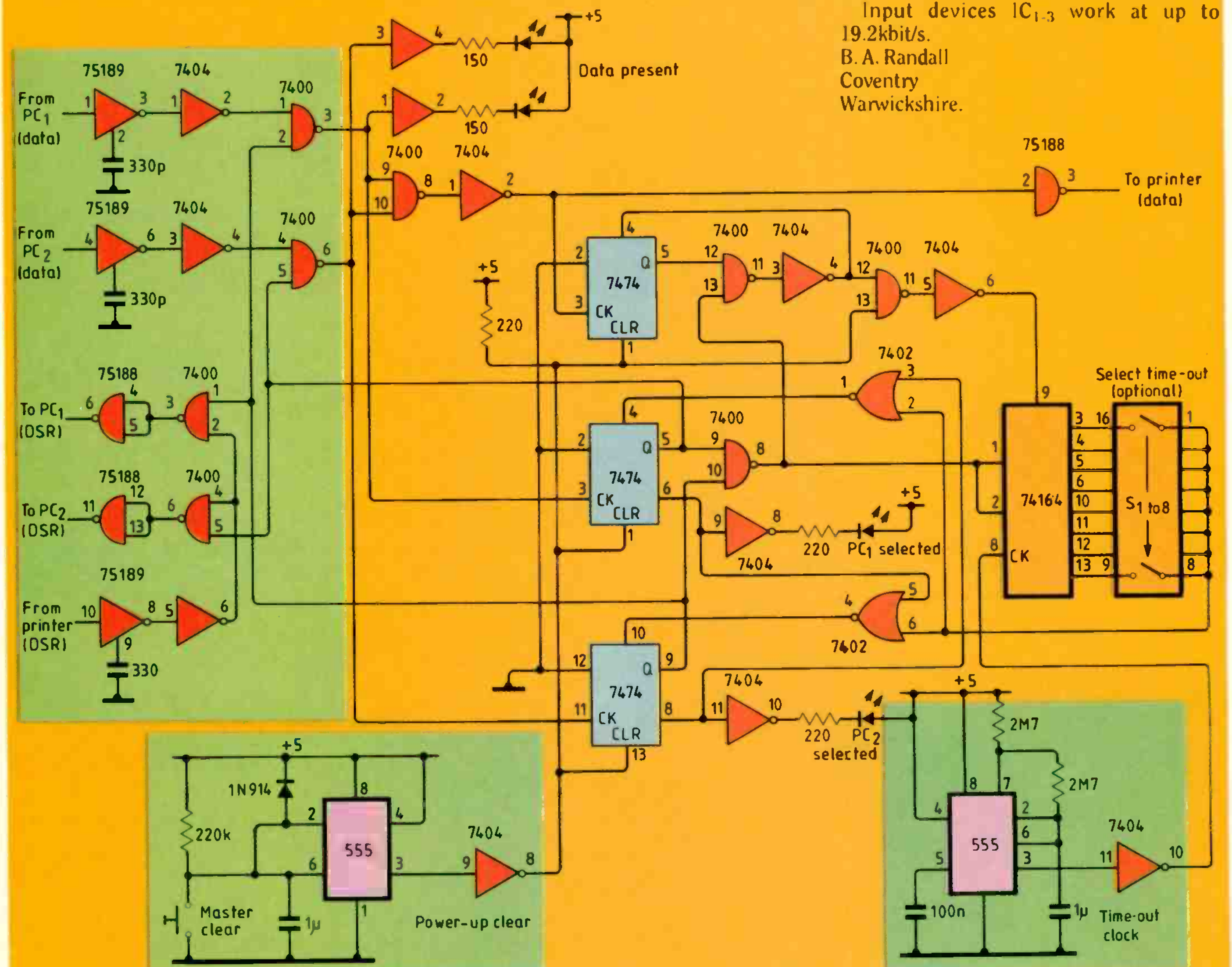
Peripheral sharing

It is often useful to share one serial peripheral such as a printer between two computers. This sharing circuit consists of readily available components, is easily adapted for more than two channels, and can be modified to suit either RS232 or RS422 periperals.

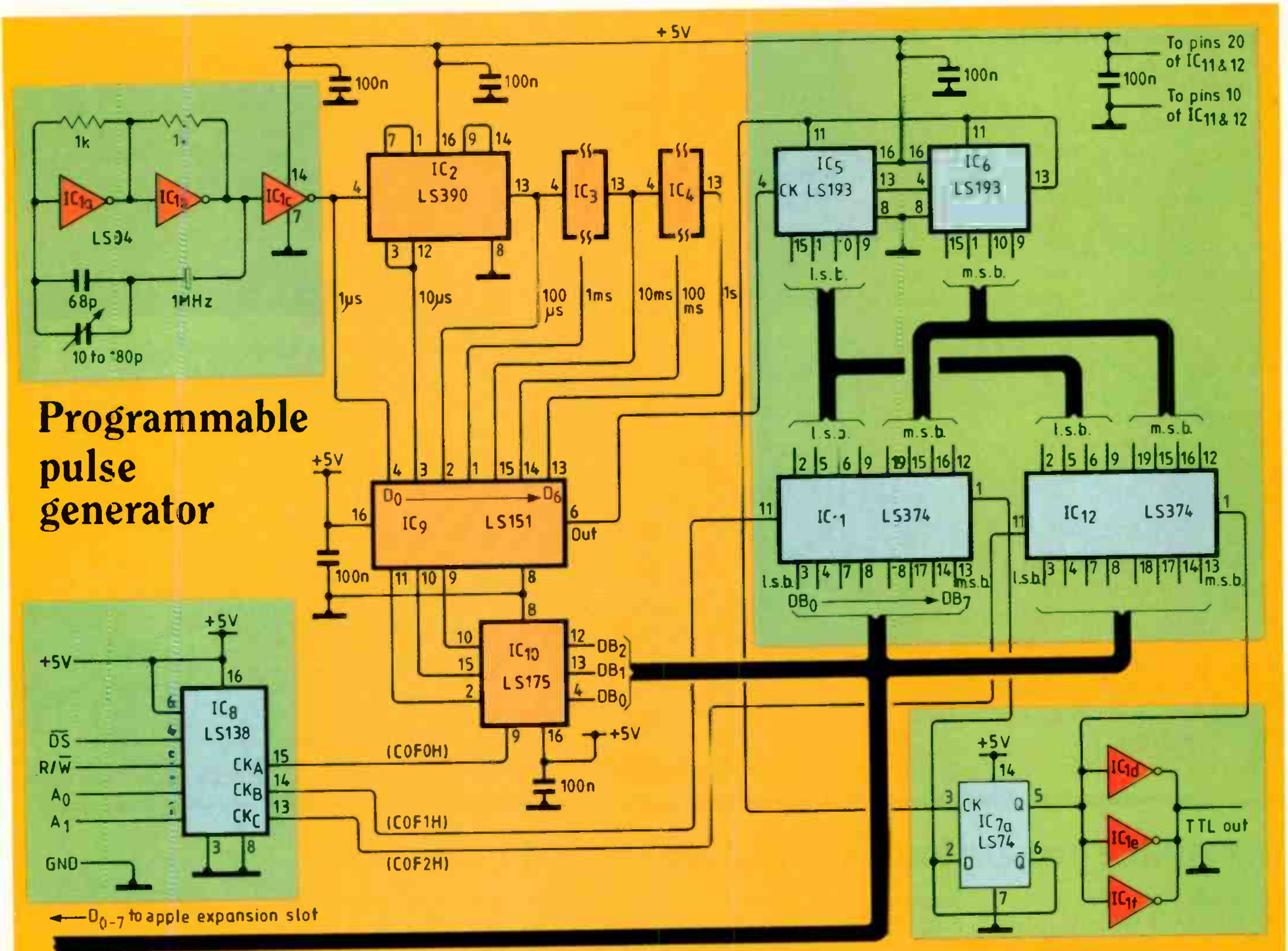
While the first channel is sending, the second-channel input is disabled. Input data acts as a clock for IC_{1a} to keep the DSR signal low. To prevent the second channel from breaking in during a brief transmission break, $IC_{2,3}$ hold off its access for a period depending on the settings of switches S_{1-8}.

Input devices IC_{1-3} work at up to 19.2kbit/s.

B. A. Randall
Coventry
Warwickshire.



CIRCUIT IDEAS



Programmable pulse generator

A few t.t.l. devices provide a software-programmable pulse generator for Apple IIe computers. Both the pulse's mark/space ratio and frequency are programmable.

Output from the 1MHz clock generator passes through six divide-by-ten stages to provide seven output frequencies. One of these outputs, selected by demultiplexer IC_9, passes to the next stage. Assuming that Apple slot seven is used, writing a zero value to address C0F0 selects 1MHz output and writing 6 selects 1Hz.

Two further programmable divide-by-n counters, $IC_{5,6}$, determine the pulse mark/space ratio. Latch IC_{11} holds the count value for logic one while latch IC_{12} hold the value for logic zero. Values for these latches range from 0 to 255 and are written to addresses C0F1 and C0F2.

Bistable device IC_7 connects IC_{11} and IC_{12} alternately to the counters. If slot 7 is not used, addresses required are,

Slot	Address	Slot	Address
6	C0E0-2	3	C0B0-2
5	C0D0-2	2	C0A0-2
4	C0C0-2	1	C090-2

Virgilio Lattanzi
Civitanova Marche, Italy.

Stop-band pilot filter

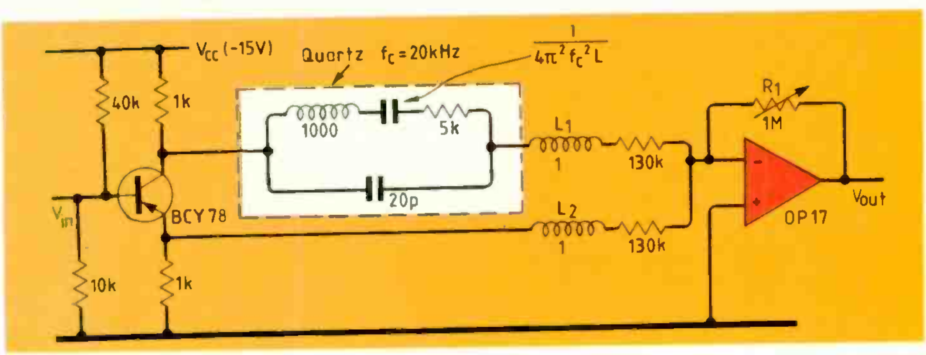
In frequency-division multiplexing, pass and stop-band filters are used to split pilot frequencies from telephone channels. This stop-band filter, and the pass-band filter shown earlier*, avoid using differential transformers.

Requirements for the filter were a pass band from 2 to 19.85kHz, attenuation ripple ≤0.3dB, stop bandwidth of 20kHz ±4Hz and attenuation of ≥15dB. Using the equations given for the pass-band filter gives this circuit. For narrower stop bandwidth and/or lower stop-band attenuation, inductors $L_{1,2}$ can be eliminated.

Laka Jovan, Beograd, Yugoslavia

These filters may be difficult to obtain. Webster Electronics can supply 20kHz filters in standard HC34/U 2in can with H-type element. Inductance of these filters is around 2000H and equivalent series resistance is 16kΩ.

*In the pass-band filter circuit in the September issue, $A_{1,2}$ should read $Z_{1,2}$ and 50kΩ should read 5kΩ. Supply voltage for that circuit was 15V.



CIRCUIT IDEAS

Sensor crystal oscillator

Quartz crystals may be used as very senstive temperature or mass sensors by monitoring changes in the resonant frequency. This circuit was developed for such applications.

To prevent fluctuations in resonant frequency caused by stray capacitance, the crystal is used as a series-resonant circuit. This is important in sensor applications since a few centimetres of screened twin lead must separate the crystal from the circuit. It is also important that the circuit presents a very low impedance at the two points where the crystal is connected.

Transistors in the circuit are part of a CA3046 high-frequency, low-voltage array. Their numbering corresponds to the data sheet; this choice allows compact p.c.b. layout.

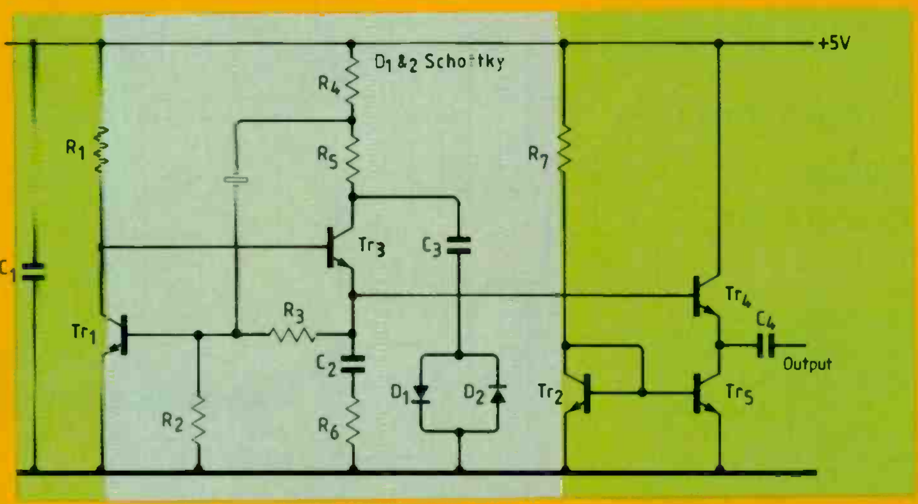
The oscillator is a Meacham bridge configuration. Transistors $Tr_{1,3}$ form a wide-band amplifier with an inverting output at the emitter of Tr_3 and a non-inverting output at junction $R_{4,5}$. Positive feedback is via the crystal while a smaller amount of negative feedback, which also fixes d.c. levels, is provided by R_3.

A simple calculation shows that the condition of oscillation is $R_x < R_3R_4/R_6$, where R_x is the crystal's equivalent series resistance. Limiting Schottky diodes set the final oscillation level. Crystal dissipation in this circuit is very low – another important point for sensor applications.

Output buffering is provided by the three remaining transistors; Tr_4 works as an emitter follower into current-sink Tr_5, which is biased by Tr_2.

With a 5MHz crystal, optimum circuit values are 2.2kΩ for R_1, 150Ω for R_2, 330Ω for R_3, 12Ω for R_4, 220Ω for R_5, 68Ω for R_6 and 820Ω for R_7. Resistor R_1 needs to be reduced for higher frequency crystals and increased for lower frequency crystals. All decoupling capacitors are 0.33μF ceramic types. Output is a good sinusoidal waveform of over 100mV r.m.s.

T.H.O'Dell
London



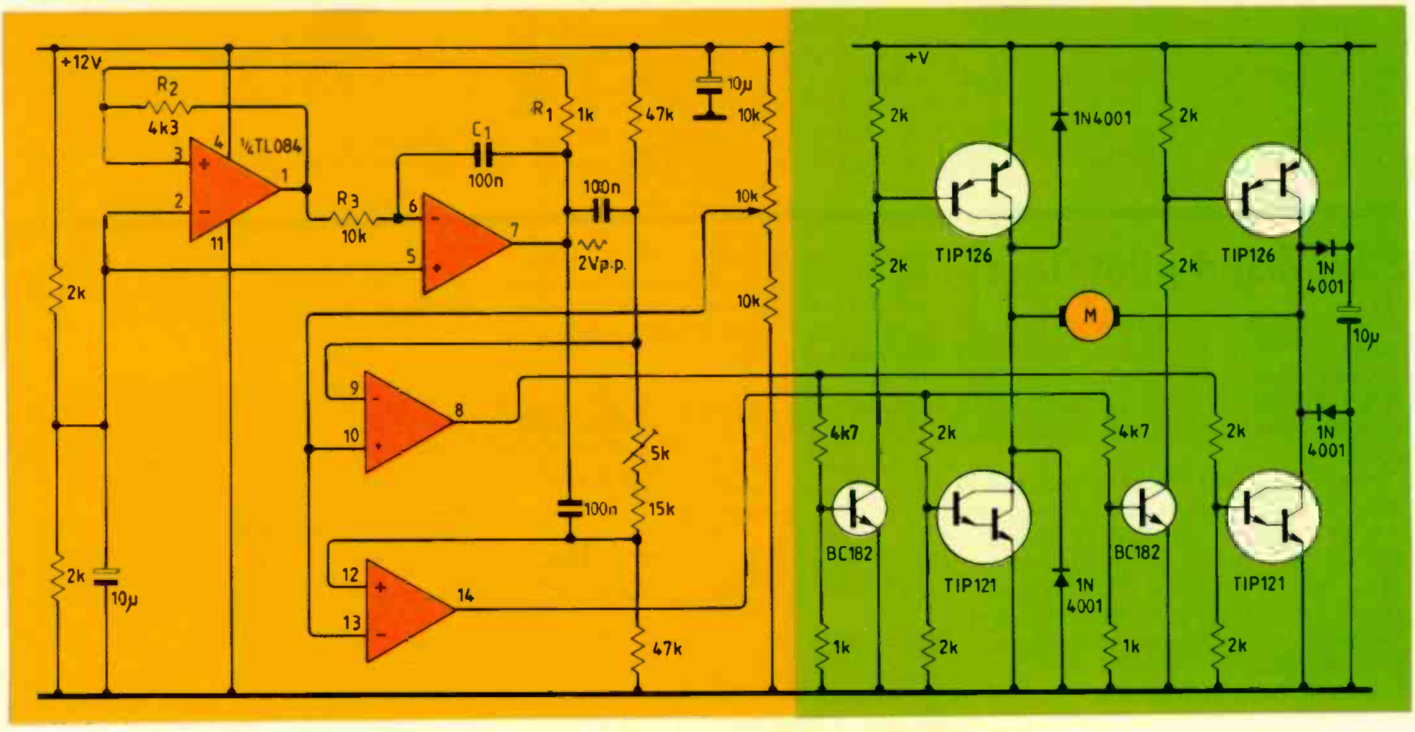
Reversible proportional control for small d.c. motors

One quad i.c. and a few driving components provide smooth bidirectional power control, with centre off, for a small d.c. motor.

Triangle-wave amplitude is set by $R_{1,2}$ and frequency is set by timing components R_3 and C_1. Power to the motor in both directions is controlled by the 10kΩ potentiometer and the preset potentiometer varies width of the dead band at the centre of the control-potentiometer travel.

Use of power mosfets would increase efficiency. Control circuitry needs a 12V supply but the motor-drive circuit supply voltage can be selected to suit the motor – within reasonable limits.

R.A. Beck
Hook
Hampshire



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The future of leaded components

The surface-mounted device business is forecast to grow ten-fold over the next five years, though the market for leaded components is still likely to rise. For many companies, if and when to move over to surface mounting will not be a simple choice.

GRAHAM FOSTER

Without leads, components offer higher-speed digital circuitry and less susceptibility to electromagnetic interference. But the irresistible attractions of surface-mounted devices to most producers of electronics are miniaturization and potentially lower automation and manufacturing costs. Board-area savings are typically between 40 and 60% when converting a traditional through-hole design to a surface mounted one. The cost per unit area for a multilayer board suitable for surface mounting may be about 20% higher, but the cost of the bare boards can still be significantly reduced. With cost parity between leaded and unleaded devices now commonplace, surface mount can offer lower overall board costs.

MATERIALS AND AUTOMATION

With a little lateral thinking, however, the production of smaller boards can be turned either into more compact products or alternatively into systems with many additional features but no bigger than their conventionally manufactured counterparts. These cabinet materials savings are perhaps the most tangible and immediate benefit of surface mounting on raw materials costs.

When automation is considered, surface mounting also compares favourably with leaded component assembly. While automated production equipment for radial components will typically not be able to handle axial devices, for example, pick-and-place machines for s.m.ds are generally more flexible.

A single type of machine will be equally capable of placing resistors, capacitors, inductors and active components. Surface mount assembly can require less factory space and labour and is generally simpler and cheaper to implement. Savings of up to 50% on assembly costs are currently being claimed by proponents of surface mounting.

The use of solder creams in surface mounting, which must be applied and processed within perhaps 10 to 12 hours, also provides a potentially cost-saving discipline to the assembly process. The time that partially assembled boards spend languishing on the shop floor will tend to fall – along with storage space and cost.

COSTLY EXERCISE

Despite all these advantages there will be many cases where the time for surface mounting is not yet right, especially for companies that have already invested heavily in conventional insertion machinery. The real cost of throwing out existing automation equipment and remodelling the factory can make surface mounting actually more expensive in the short to medium term.

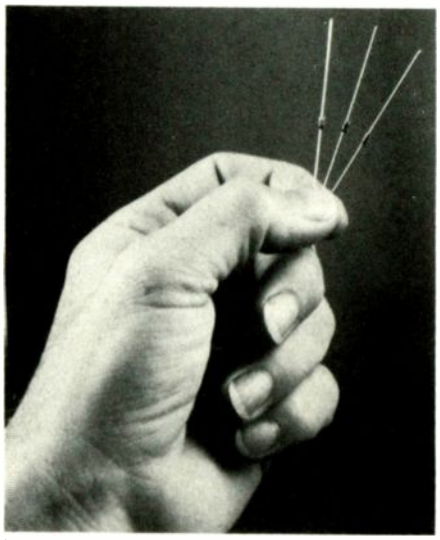
If there is an existing design which perhaps requires minor modifications rather than major redesign, then a conversion to surface mount may be an unnecessary and costly exercise. In some cases there may even be a requirement for the product to be made using conventional technology. Some telecomms equipment falls into this category.

Another field where designs will stick with leaded components is military applications where there is no particularly strong pressure towards miniaturization. In large parts of this inherently conservative and protected business, designs will change only slowly over to surface mount. Paradoxically, however, the military industry, because of its need in some areas, such as airborne and man-carried equipment which need to be as small and light as possible, is in a better position to adopt surface mounting than most commercially based companies.

In the consumer area, it may often not be possible to realise one of the major benefits of surface mounting, i.e. smaller and cheaper cabinets, so designs may stick with conventional leaded components for some time yet – there is little to be gained from making telephones smaller. And until there are radical improvements in television tube technology or flat panel displays there will be little incentive to reduce the size of tv electronics. The same applies to sound reproduction equipment whose size is dictated more by the number of knobs and buttons on the front than by the electronics inside.

LIKELY CANDIDATES

If, on the other hand, a project calls for a new design or a substantial re-design of an essentially obsolete product, then this is a likely candidate for surface mount. Even when a company has significant investment in through-hole assembly equipment, it should still implement the new design practices and embrace surface mount when appropriate, even if this means subcontracting in the first instance.



Leaded Schottky diodes from ITT

Every design, especially a new one, should now be considered for surface mount. The benefits are clearly there. There are lessons to be learnt, but these should be tackled as soon as possible if British industry is not to miss the boat. Just as component manufacturers have had to adapt their production methods to the trend towards surface mounting, s.m.d. users need to adapt their thinking to the new technology.

Stuffing boards with leaded components is essentially a mechanical job based around producing good solder joints between component leads and copper tracks. It is a skill at which many assemblers are masters. But with the reflow processes widely used for surface mounting, a new range of skills needs to be gained. Screen printing, the use of solder creams, reflow profiling and thermal shock all need to be carefully managed to avoid disaster. Rework on through-hole boards is bad enough, but on surface mounted boards is even worse.

Graham Foster is with AVX Ltd of Aldershot.

Telecom '87: standardization at Geneva

The Telecom series of events, held every four years by the International Telecommunications Union (ITU), are the most important events in the Telecom calendar. As such, companies spent vast sums of money and put on impressive displays. For example, it was rumoured in Geneva that IBM had spent $8M on its stand and that it had already been sold so that, after the show, it was going to be dismantled and rebuilt elsewhere as a disco. This indicates the way that reality and future prospects are mixed with pure hype – but which is which?

Virtually all the major companies are demonstrating their ISDN capabilities with, for example, Northern Telecom showing that its switches are capable of interworking with terminals from a variety of vendors. And on the APT stand the Hayes (of modem fame) ISDN PC Card was shown connecting the ubiquitous p.c. through an AT&T and Philips Telecommunications (APT) 5ESS-PRX switch. This product occupies one-full length expansion slot in an IBM p.c. or compatible and is controlled by Hayes telecommunications software to give the computer full access to the Basic Rate Interface (2B+D).

However, the most impressive ISDN demonstration at Telecom '87 was the first multi-exchange working using two satellites linking System X switches in the UK network and the USA with the System X exchange at the show. A remote concentrator in Washington was operating as an integral part of this System X exchange 4 000 miles away. With the co-operation of British Telecom, the Geneva System X was operating as an integral part of the UK telephone network and was providing a 'London' exchange and ISDN lines to five other exhibitors at Telecom '87. These were Comsat Corporation, BT, STC, Plessey and GEC.

To date, BT, System X's largest customer, had operated a commercial ISDN revenue-earning service using 80kbit/s connections. However, System X has now been upgraded to provide 144kbit/s ISDN connections (CCITT I 420) with full interworking between 80kbit/s and 144kbit/s.

Even though a growing number of PTTs are making their intentions public, with 1990 being the date by which enough ISDNs will be implemented and connected to form the nucleus of a global network, there is a question mark over the real arrival of ISDN. As with any service, this is because it can only be considered to exist when a critical mass of subscribers has been reached and its growth becomes self-sustaining. Commercial offerings of ISDN should appear in countries across Europe and around the rest of the world within the next year, with international interconnection following from 1989/90. For example, the Norwegian Telecommunications Administration announced that it is planning an ISDN test programme from 1988. This will lead to a field trial in 1989 and a pilot service for customers in 1990 A limited number of large customers owning ISDN-compatible p.a.b.xs will participate in the pilot scheme, with a gradual extension to small and medium sized users. A nationwide ISDN service is due to operate in Norway as a commercial operation from 1992. This will include telephony, Group 4 facsimile, teletex and teledata.

Even if there is some uncertainty regarding ISDN, the X.400 message handling system appears to be going critical. X.400 is a series of recommendations published by the CCITT to define the mechanisms for interworking between different message handling systems. A noticeable proportion of the users of the two million or more mail boxes on electronic mail systems are no doubt already fretting at their inability to communicate with uses on systems other than their own. Thus, the potential user base for X.400 already exists in the user bases of existing e-mail systems.

The Geneva demonstration, following on from one by 14 companies at the CeBIT trade fair in Hanover, West Germany last March, involved 21 of the world's leading developers of X.400 products and services. The PTTs and service providers included AT&T, British Telecom, Deutsche Bundespost, Dialcom, KDD (Kokusai Denshin Denwa of Japan), NTT, the Swiss PTT, Telenet Communications Corporation and the French packet-switching service, Transpac.

Vendors included DEC, Hewlett Packard, IBM, Nixdorf, Olivetti, Philips, STR, Telic-Alcatel and Unisys. Their concerted presence underlines the fact that the X.400 market is perceived as potentially very large.

Work on X.400 is truly international and it now appears that in due course it will provide the universal e-mail access required by users. Even though over 500 tests have been completed by the participants to prove that the different systems and services interwork correctly, services will not be introduced overnight. A representative of Telecom Gold, the UK Dialcom service, said that as soon as all the tests are satisfactorily completed they will start "populating" their database. As this is a task that will apparently take two or three months to complete, a service cannot be expected to start before next March.

AT&T and Philips Telecommunications were stressing the importance of their SLC 120 Network Access System which is intended to offer PTTs a cost-effective and versatile way of allowing them to introduce digital and optical technology into the subscriber loop quickly and economically. It is an advanced primary 4×30 channel multiplexer capable of connection to any higher order metallic or optical fibre transmission system with a 2Mbit/s CCITT-compatible interface. It can group any combination of voice and data services and is capable of handling the ISDN services of the future. In particular, the SLC 120 is claimed to be ideal for quickly supplying extra line capacity; for modernizing and replacing smaller public exchanges; and for providing a broad range of services to PTT customers. SLC 120, to be manufactured by APT in Malmesbury, Wiltshire, is expected to account for a major portion of the company's business.

Alliances being announced highlight the reality of the convergence between telecommunications and computers. Under the terms of agreement between IBM and Siemens, the two companies will examine how the former's expertise in database and network management can be combined with Siemens' experience in switching technology to create new telecommunications services. This study is part of a worldwide effort within the industry to develop and offer innovative services that combine telephone networks and computers.

Similarly, Plessey is to collaborate with Digital Equipment Corporation, the world's third largest computer equipment manufacturer, on the development of computer integrated telephony (c.i.t.) services. The aim of the project is to develop products that will enable the processing power of the computer to be married to the communication power of Plessey's ISDX, in such a way that the unique capabilities of each technology will be available to the user as if in a single system.

Much of the applications work within the c.i.t. programme has been completed in co-operation with British Telecom in the UK and Northern Telecom in the USA under joint development agreements with DEC. Within the next twelve months, software capabilities that extend c.i.t. across a broad spectrum of telecommunications equipment manufacturers and service providers will be available. Digital is also working with other telecommunications companies to implement a variety of c.i.t.-based products and services. These include Sweden's Ericsson, Philips Telecommunication and Data Systems in the Netherlands as well as Siemens.

However, Geneva was not just for the giants. Austin Taylor, part of the British joint venture, attracted much attention (including that of Prince Michael of Kent) with its key-and-lamp systems. Not only has it introduced a smaller version that supports four lines and four desk units, but it has designed a portable electronic key-and-lamp system. It is essentially a Sprite 16×16 system configured into two robust aluminium cases which can be easily transported and set up in minutes. The system is aimed at meeting temporary communications needs, such as at special events or in emergency incident centres, or for back-up for main switch failures.

Pan-European cellular alliances

The international cellular radio industry is starting to polarize in preparation for the pan-European digital radio systems that will enter service in the 1990s. The aim is to enable costs to be spread among more than one company and also to ease entry into national markets.

Alcatel NV, Nokia and AEG have announced that they will form a European consortium to design, produce and sell cellular mobile telephone systems. Ericsson and Orbitel, the joint venture between Racal and Plessey, have similarly announced that they are to co-operate, while reports emanating from Germany indicate that Robert Bosch, Philips Kommunikations Industrie and ANT are discussing a similar co-operation.

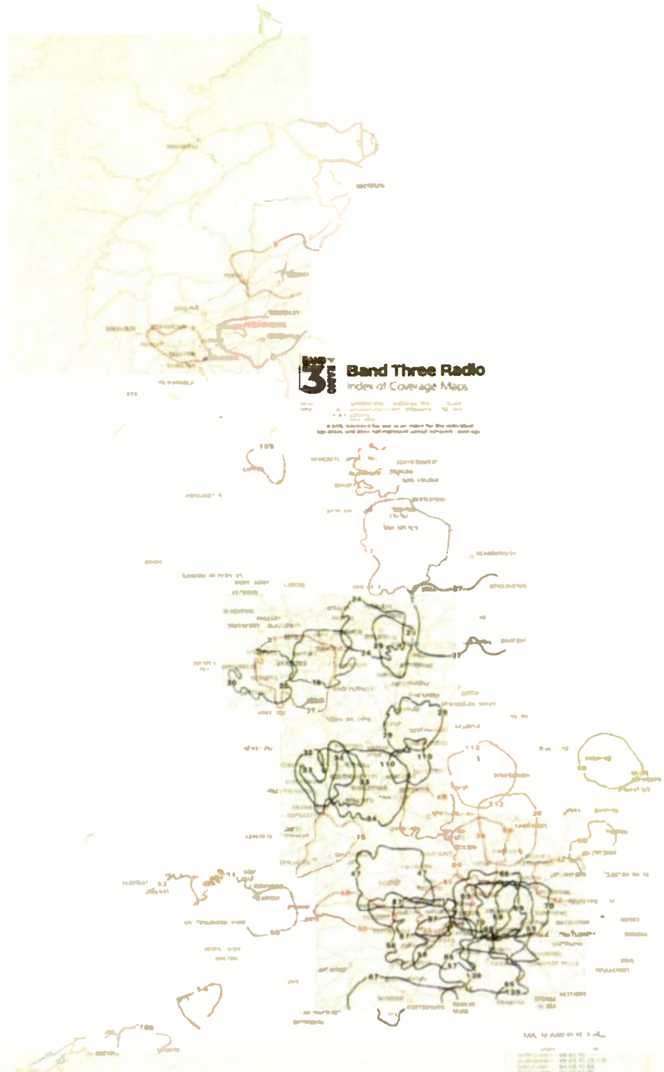
Alcatel, the largest telecommunications company in Europe, has digital switching and radio technology capability, while both Nokia and AEG have complementary expertise in mobile communications.

Ericsson, through its subsidiary Ericsson Radio Systems, is a major supplier of analogue cellular radio systems, including the Vodafone network. Orbitel will develop, manufacture and market the radio base stations required by the network.

The third group, all-German at present, could well extend to the UK where Philips Telecom (previously Pye Telecom) is the lead company in mobile radio for the whole Philips group.

Euro cellular r&d in UK

Motorola is to establish a new Cellular Group r&d centre in Europe. It will be located at Stotfold in Bedfordshire, where the company already has a cellular subscriber products manufacturing plant. The centre, which will begin operations early 1988, will become an integral part of a worldwide r&d team, its initial main thrust being on research for the pan-European digital cellular system.



UK trunked radio goes live

New v.h.f. trunked mobile radio systems have been launched in the UK, using the Band 3 channels previously occupied by 405-line television.

One operator, Band Three Radio Ltd, claims that it will offer the user a truly nationwide mobile radio service for the first time, covering 60 per cent of the population by mid-1988 and 80 per cent when the network is fully developed. The first public call on this service was made by Prince Michael of Kent from the Comex mobile communications exhibition on November 3. Band Three Radio's first customer is Bass, the brewing and leisure group. Its initial subscription order, won by Philips Telecommunications, covers 100 mobiles all over the UK.

GEC National One, the rival service, will open in January and will extend its coverage to the major part of the UK mainland by mid-1989.

Compromise on error-correction

CCITT Study Group XVII, whilst backing LAPB (X.25) and LAPD (Q.921) as the basis for modem error-correcting standards, has recommended that a method should be defined for interworking with existing MNP modems.

During the deliberations, six European administrations (Germany, Belgium, France, the Netherlands, Italy and Sweden) together with IBM Europe supported the use of MNP (Microcom Networking Protocol). MNP has an installed user base of 300 000 and is currently used by over 100 data communications companies internationally, including more than 40 modem manufacturers and several value-added networks. The use of a modified version of the Link Access Protocol (LAPB or LAPD) was supported by the United Kingdom and Japan while the US delegation stated that it was "inclined to favour" a protocol based on these standards. However, since CCITT requires unanimous consent on such matters, no standard was officially selected.

Camden's Mercury phones

Cable Camden, the North London cable tv company, now offers Mercury's switched telephone service. Already a number of business customers in its service area have been connected and will enjoy the advantages of the latest digital transmission and switching technology employed by both companies.

The arrangement will provide Cable Camden with an added dimension that will broaden the range and attractiveness of its service to potential customers. In return, Cable Camden will give Mercury a ready-made distribution network enabling it to expand into the local residential and business sectors quickly and cost-effectively.

TACS in Japan

Cellnet has been awarded a consultancy contract by Japanese Cellular Network Licence holders Daini Denden Inc. (DDI) for work leading towards the introduction of a cellular network in Japan. DDI will design and operate the new system which will operate on the TACS specification used by the UK cellular operators.

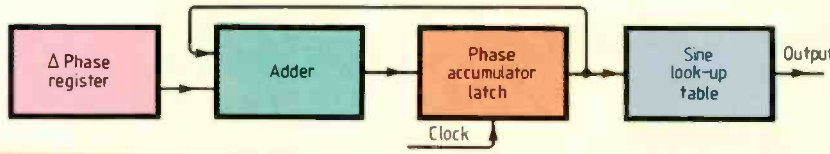
System X order from China

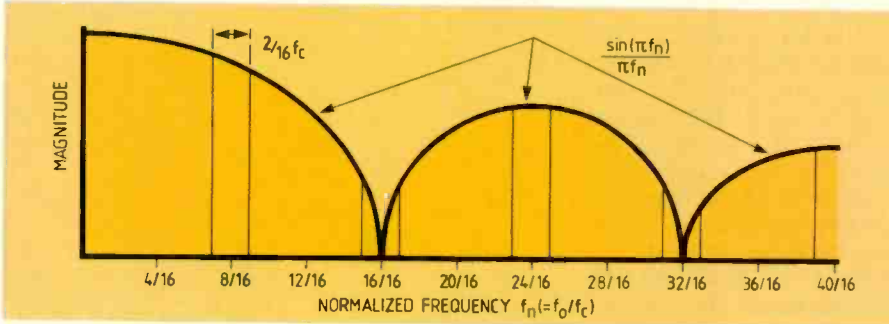
Plessey is to supply 26 System X exchanges with a capacity of 24 000 lines to China. It will supply the local exchanges and remote concentrators as part of the modernization programme for China Railways.

Telecomms Topics is written by Adrian Morant.

APPLICATIONS SUMMARY

Numerically-controlled oscillators





In frequency synthesis, frequency hopping and digital signal processing, numerically-controlled oscillators produce digital sine and cosine waveforms of very precise frequency. One of their great advantages is that their frequency can be changed almost instantaneously. How these oscillators work is briefly discussed in Stanford Telecommunications note AN002.

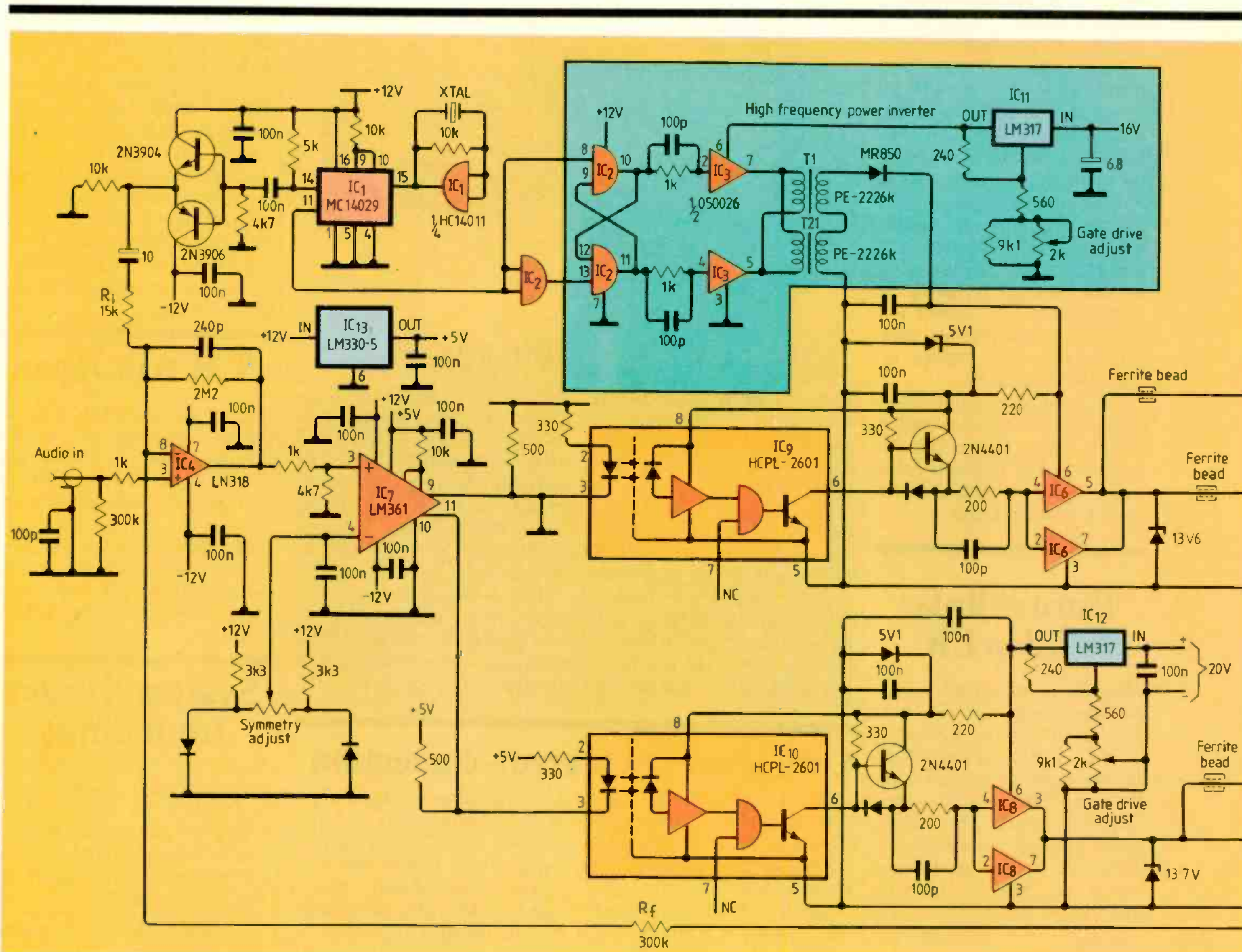
An n.c.o. consists of an adder, a phase accumulator, a look-up table (rom) and a parallel-input phase register holding a value representing output frequency. To obtain an analogue waveform, a d-to-a converter is connected to the look-up table output.

On each clock cycle, the input register value is added to the phase accumulator value so look-up table addresses are stepped through at a rate determined by the clock frequency and an increment determined by the value in the input register. Increasing the value in the input register increases frequency but decreases resolution of the output waveform.

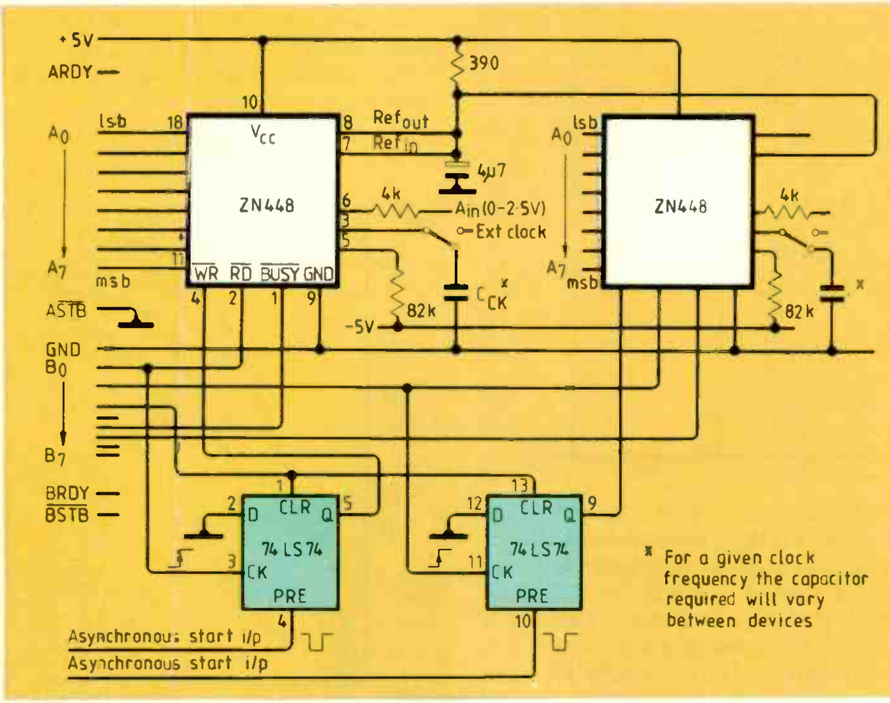
Most of the note discusses the effects of altering the modulus on purity of the output waveforms. Stanford makes two n.c.o. i.cs, one designed for a 25MHz clock with 32bit resolution and a 28bit resolution device with a 300MHz clock specification.

ADDRESSES

Stanford Telecommunications
Chiptech Ltd, Alban Park, Hatfield Road
St Albans, Hertfordshire AL4 0JJ
0727 40476
Motorola, Stirling Robertson, ITT
Multicomponents, 346 Edinburgh Avenue
Slough, Berkshire SL1 4TU 0753 824131
Ferranti Electronics, Fields New Road
Chadderton, Oldham, Lancashire OL9 8NP
061 624 0515



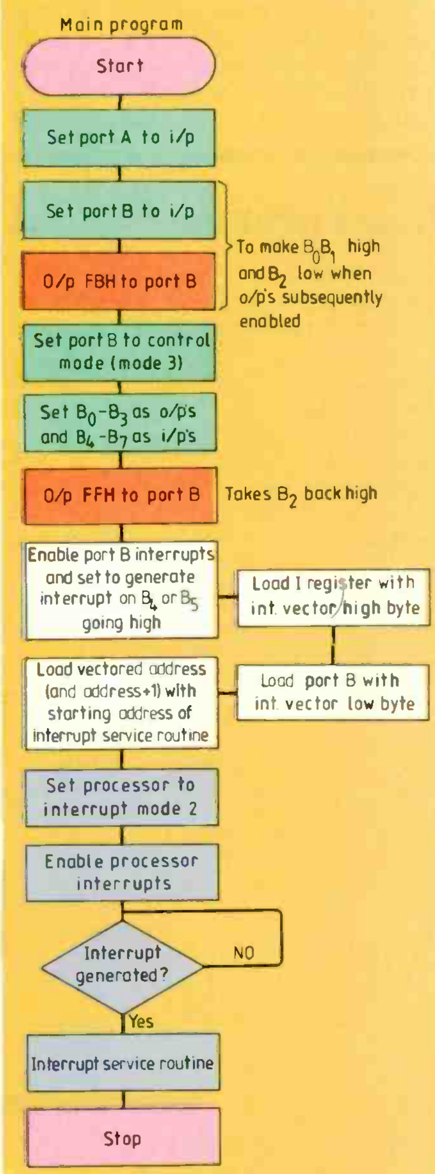
APPLICATIONS SUMMARY



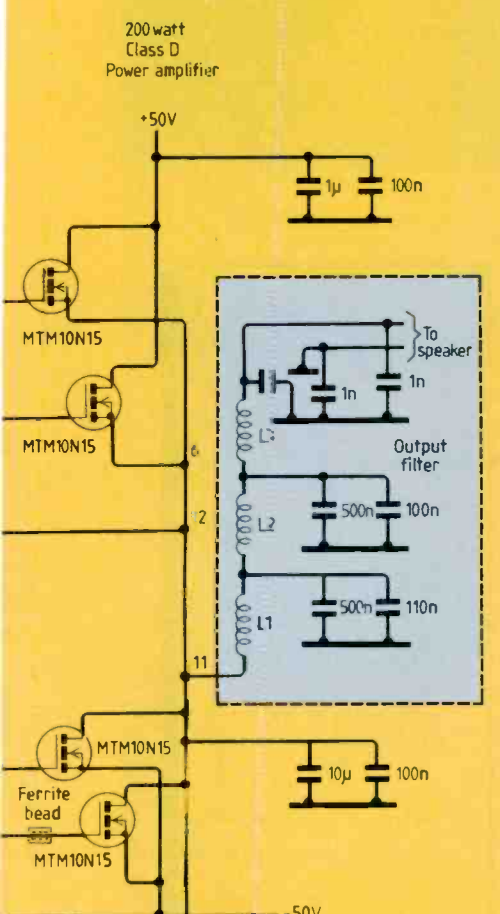
Interfacing a-to-d converters

Two notes from Ferranti describe connection of eight-bit a-to-d converterse to microprocessors. The first, Application report 20, details connection of ZN447/8/9 converters to a Z80 p.i.o. and the second, report 21, shows how to connect the ZN439 to 6500 family processors. Both notes discuss connecting single and multiple converters for poll or interrupt operation; software examples are included.

This example shows two ZN448 converters configured for connection to a Z80 parallel-interface controller. Port B of the controller is set up to cause an interrupt when any bit goes high, which means that all bits of port B must initially be low and set back low after the interrupt has been serviced.



200W class-D power amplifier



Requirements for a class-D power amplifier are much tighter than those for conventional amplifiers. Output devices must be capable of passing high currents and have an extremely low on resistance. This design, providing 200W continuous power into a 4Ω load, is one of about 50 designs illustrating the merits of Tmos power fets in Motorola's Tmos power-fet design ideas book.

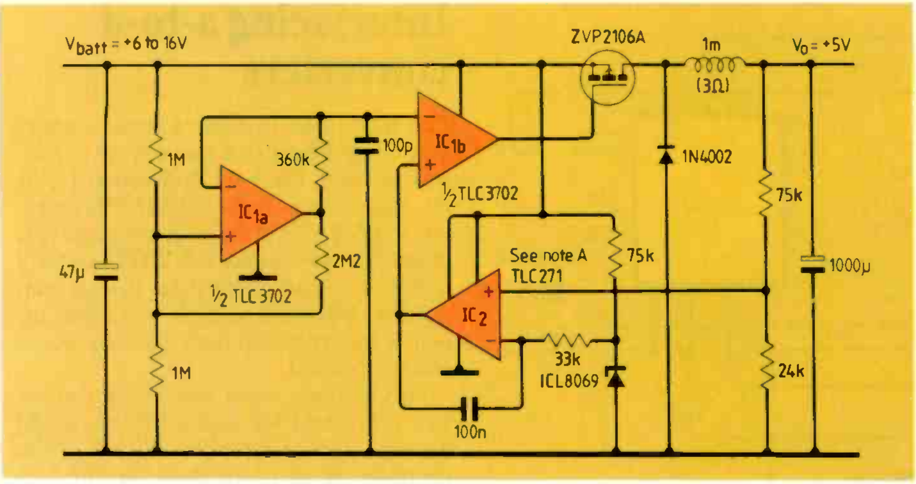
Output of 200W is obtained for a 1.5V input. At full output, response of the amplifier is +0.5 to −1dB from 20Hz to 20kHz and total harmonic and intermodulation distortion together are <0.5%. The amplifier's slew rate is 6.6V/μs and its A-weighted s-to-n ratio is 69dB.

A 2MHz crystal clock provides a stable 250kHz carrier for driving the input op-amp, which also serves as an integrator. Audio input is summed with the integrator triangle wave and fed to the LM361 comparator to produce a p.w.m. signal. Fast opto-isolators feed the p.w.m. signal to the power stages.

Upper and lower drive circuits are identical except for their power sources. An LM317 regulator feeds the lower circuit with −30V and the upper circuit is fed by the power inverter. The upper two output devices require V_{GS} to be referenced to the output line so a bootstrap supply is needed – hence the inverter.

Switching of the output devices between the +50V and −50V rails is complementary. Output passes through a sixth-order Butterworth low-pass filter which demodulates the audio signal and attenuates the carrier and high-frequency components. Feedback is provided by resistance R_f and amplifier gain is R_f/R_i.

APPLICATIONS SUMMARY

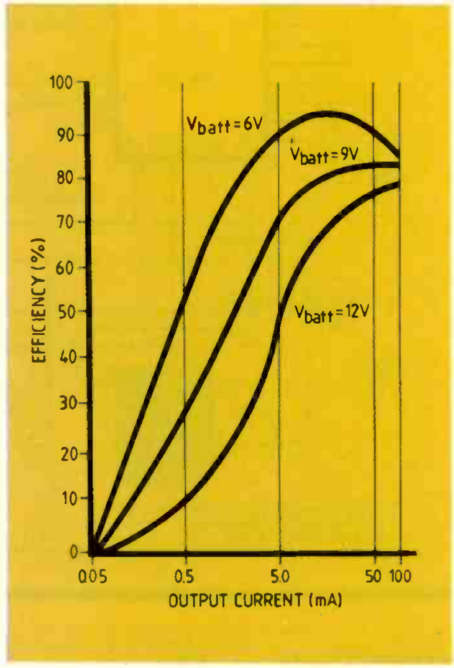


Switching regulator with low drop-out voltage

Designing a switching regulator in c-mos drastically reduces standby current. This 5V regulator, from a Texas linear applications brief, takes 350μA in standby mode and achieves greater than 90% efficiency at 5 at 50mA load currents with only a 6V input. Short-circuit protection is inherent.

Pulse-width modulation controls a non-isolated forward converter output stage. Comparator IC_{1b} oscillates, producing a triangle wave to feed the p.w.m. comparator, IC_{1b}. Output from error amplifier IC_2 varies the p.w.m. comparator reference level according to the difference between its inputs – the reference diode voltage and the output voltage.

The note, entitled Low-power Lincmos switching regulator, is only two A4 sides, but includes further details on how the circuit works and its performance.



Log-linear conversion routines for d.s.p.

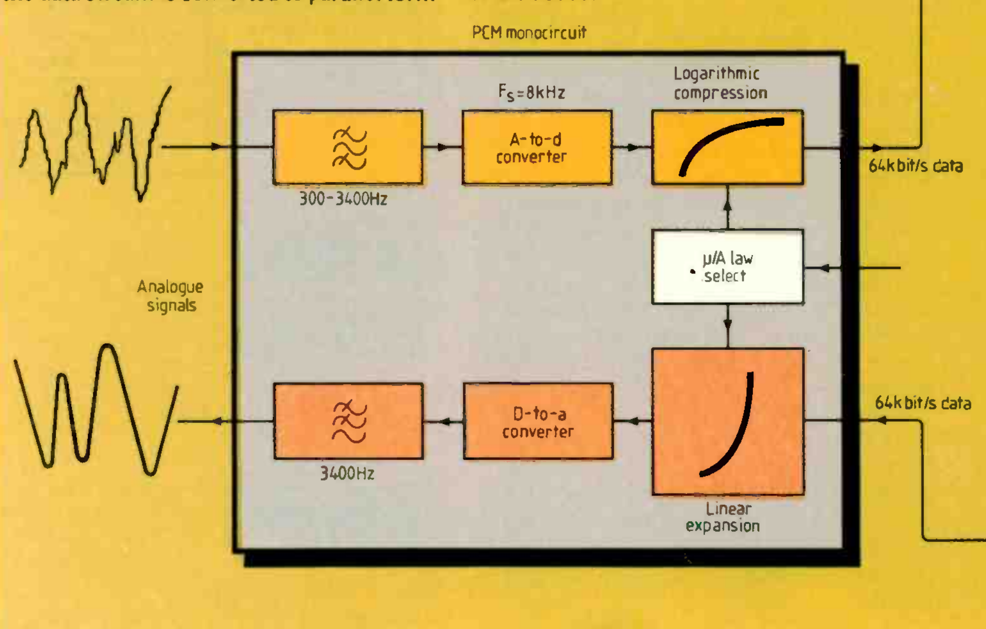
In telecommunications applications, digital signal processors perform many functions including multichannel d.t.m.f. receivers, p.b.x. mail-box vocoders, repeater line equalizers, echo cancellers and speech scramblers.

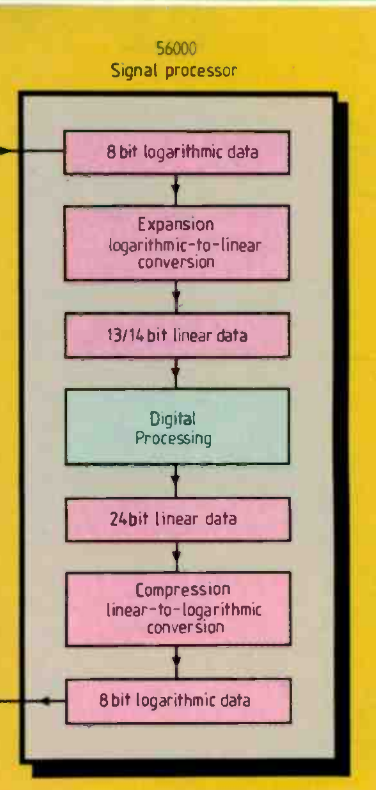
Monocircuits (coder-filter-decoders) convert analogue signals to eight-bit log-compressed data which is fed to the d.s. processor as a 64kbit/s p.c.m. stream. There the data stream is converted to parallel form and expanded to a 13 or 14-bit linear word.

Software routines for this log-to-linear expansion, and for the log compression needed for output data. are the subject of Motorola application note ANE008. The note, called Logarithmic/linear conversion routines for DSP56000/1, includes an introduction to digital signal processing in telecommunications, theory behind the companding, and specific conversion routines for the 56000.

Texas Instruments, Customer Response Centre, Manton Lane, Bedford MI41 7PA
0234 22300

Motorola. STC Electronic Services
Edinburgh Way, Harlow, Essex CM20 2DF
0279 442971





RESEARCH NOTES

Low-flammability transformers

ERA Technology has published a research report on low-flammability transformers of benefit to those involved in the selection and operation of distribution transformers in large buildings such as factories, offices or blocks of flats.

For many years two kinds of transformer have been used to satisfy safety requirements; the dry-type in which all or most of the materials used are non-flammable, and the liquid-filled transformer which until 1986 used askarels, a term generally applied to synthetic, fire-resistant liquids composed of polychlorinated biphenyls or p.c.bs. In 1986, regulations were introduced banning the installation of further askarel-filled transformers.

ERA's report provides a comprehensive review of dry-type transformers and the new liquids available in the UK for use as transformer impregnants and coolants. Information is provided on their composition, properties, handling, flammability, their use in transformers and their suitability for replacing askarels in older transformers. As many of these are still in service a summary of their properties is included.

The report concludes with the results of flammability tests conducted on filled transformers in simulated service conditions.

Who wants a human computer?

For a very long time scientists and engineers have puzzled over the efficiency of the human body. They have wondered how, for example, it is possible to have an intelligent brain that consumes only a few watts of power and needs no external data store.

Long ago, it was realised that the intelligent functions of the brain could not be duplicated efficiently by any machine that only processed a few bits of data at a time, however rapidly. Artificial intelligence reseach began to look for new parallel systems of architecture in which data could be acted on in different ways simultaneously. But the basis of virtually all today's computers is the philosophy that data resides in fixed places, such as points on a disc or memory elements on a chip. To make use of the data, it is extracted from its point of storage, processed in some way and returned to another storage location. From then it is retained or outputted to some peripheral device to perform a task.

Current brain research suggests that while data is undoubtedly stored in individual nerve cells, or neurons, it is also stored in the form of networks or connections. An extreme form of this argument suggests that a single bit of data exists more or less everywhere in the brain. A theory advanced by Professor Boris Kotlyar of Moscow University likens the brain to a symphony orchestra. Even by being silent, a musician takes part in the performance. By analogy, whatever kind of activity a person engages in, there are no resting neurons in his brain. According to Professor Kotlyar, the brain is always busy forming new functional states or neural networks in which the links are unique. He believes each experience or skill is represented by a separate neural network laid down in the memory. Learning consists essentially of the ability to form networks.

But, while this holistic view of intelligence is one explanation of how the human brain outstrips its mechanical counterparts, it is not the only one. Other experiments in Russia and the USA have shown that intelligence, or certain aspects of it, can reside in single neutrons. One isolated nerve cell can be conditioned, like Pavlov's dogs, to react to a stimulus that is no longer present. In the jargon of psychology, it has become habituated.

Returning to computers, it is perhaps hard to imagine how a single diode or magnetic particle could exercise intelligence, but on the holistic level considerable progress is being made. Simulating neural networks electronically is now becoming a popular academic exercise. *Electronic Letters*, Vol.23, No 18 describes one example from a group at Columbia University in New York based on switches, capacitors and inverters.

How far this approach will lead in the development of artificial intelligence remains to be seen. The Columbia group are realistic when they state that the field of neural networks is far from being mature and that it is difficult to know what will eventually prove to be relevant, even as far as principles are concerned, let alone v.l.s.i. implementations. Nevertheless this uncertainty has not deterred a number of US groups from attempting limited implementations in software. Critics have commented, however, that such implementations are already becoming too human-like to be of any use. They are said to be desperately bad at arithmetic and disinclined to explain their reasoning! Worst of all, but predictably, they sometimes have a mind of their own. One neural network at Colorado, when left with nothing to do, would doodle random patterns on its screen – the electronic equivalent to daydreaming?

Electromagnetic interference to pacemakers

Those who wear cardiac pacemakers are usually warned about the dangers of deliberately exposing themselves to radiation fields, be they X-rays or r.f. fields associated with metal detectors or baggage-screening equipment. A problem is that with the growing use of electromagnetic devices such as radio-telephones it is not always easy to avoid the danger.

Mikrowellen Vol.13 No 5 reports experiments undertaken at the Institute of Aviation Medicine in Zemum, Yugoslavia, to discover how susceptible pacemakers are to r.f. fields and what can be done to protect patients against them. Dr Zoran Djordjević and his team used as their source a microwave generator operating at 2.45GHz, the frequency allocated to microwave ovens and industrial microwave heaters.

The first part of the experiment consisted of taking five different pacemakers and subjecting them to fields varying between 10 and 60 mW/cm^2. Under these conditions all the pacemakers malfunctioned in various ways, usually going into their 'inhibit' mode. This is the standby condition which normally exists when the heart to which they are connected is beating of its own accord. Modern pacemakers, of the 'demand' variety are rate-programmed pulse generators that respond to the natural electrical activity of the heart. So however much the pacemaker itself may be electrically screened, it has to be sensitive to external fields to work properly.

The second part of these bench-top experiments consisted of repeating the microwave exposure but with the pacemakers covered with a metallized fabric manufactured by Bayer A.G. of West Germany. Under these conditions the pacemakers behaved normally.

The final exercise was to do the same comparison under clinical conditions with human volunteers. 20 pacemaker wearers were exposed to the 2.45GHz radiation for 10 seconds, first without any protection and secondly wearing protective vests made of the metallized fabric. A team of cardiologists stood by with e.c.g. equipment during the entire tests.

What the experiments showed was that the same modest r.f. levels caused pacemaker inhibition in 11 out of the 20 unprotected volunteers. E.c.g. records showed quite clearly that the pacemakers were being 'fooled' into their inhibit mode. The doctors say that this could be extremely dangerous for a patient suffering from complete atrioventricular heart block.

When the experiment was repeated with the protective vests, none of these problems occurred. The obvious conclusion is that pacemaker wearers who are especially likely to encounter r.f. fields in the course of their work should consider wearing a protective metallized vest. It is safe and simple.

Terabit transmission lines

Scientists at the University of Rochester and Cornell University have discovered that new high-temperature superconducting materials can conduct electrical pulses as short as 10 picoseconds without absorption or distortion at very high current levels. On this basis, they say, supercon-

RESEARCH NOTES

ducting digital data transmission lines could be built with 100 times the capacity of optical fibres for transmitting computer data, television pictures and telephone conversations. Also, future computers could use superconducting transmission lines to move massive amounts of data rapidly between processing elements.

Such a superconducting data transmission line could have information-carrying capacities of a terabit of information per second. In everyday terms, it could transmit the text equivalent of one thousand Encyclopaedia Britannicas per second, more than 15 million two-way voice conversations or more than 10,000 full-colour television channels.

The Rochester scientists worked with a thin film of superconductor made of yttrium, barium, copper and oxygen grown on a yttrium-doped zirconium oxide substrate at Cornell University and patterned into a high-speed circuit.

According to Robert Buhrman, a professor of applied and engineering physics who led the Cornell team that synthesized the materials, the ability to grow smooth, thin-film coatings of this superconductor on zirconium oxide has important economic implications for the application of the material. The zirconium oxide is at present about 10 times cheaper than strontium titanate that has until now yielded the best results.

More significantly, this result shows that high temperature superconducting films with very high current-carrying capacity can be grown on substrates whose crystal structure differs from that of the film. To form the superconducting transmission lines, Buhrman and his colleagues used their newly developed process of growing the ceramic by depositing vapours of yttrium, barium and copper in an oxygen atmosphere on the zirconium oxide substrate at a temperature of 700°. Previously, formation of the superconducting ceramic required temperatures of 850° or greater. The relatively low temperatures mean that the material can be produced as part of an integrated circuit with less likelihood of damaging other chip components. Growing the superconductor on a chemically inert zirconium oxide is necessary because the highly reactive superconductor reacts with silicon normally used as a substrate for electronics.

The Rochester scientists subjected a pattern of superconductor lines, cooled to its critical (superconductor) temperature, to tests in which they transmitted pulses between 10 and 15 $\times 10^{-12}$s.

In earlier tests using traditional low-temperature superconductors cooled to much lower liquid helium temperatures, the scientists had transmitted picosecond pulses more than 10m with virtually no loss. This experiment demonstrated that superconducting transmission links are superior to optical-fibre systems, currently regarded as the best way to transmit pulse-encoded signals between two points.

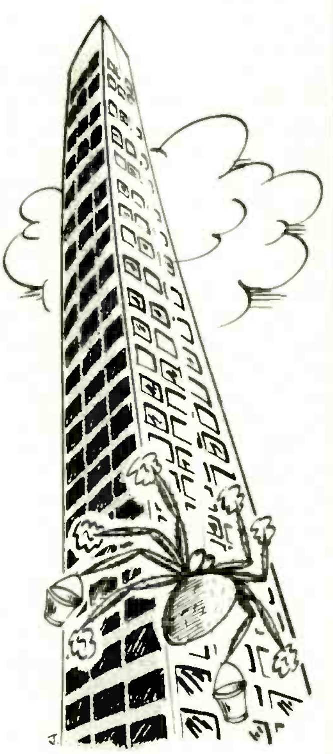
Beware the creeping robots!

The Massachusetts Institute of Technology could soon become the creepiest place on earth if the dreams of some of its robotics researchers are fulfilled. You may already have seen tv footage of some of the one, two, and four-legged robots they have already developed. But if these 'creatures' make you feel uncomfortable on account of their anthropomorphic behaviour, then prepare for worse!

Robots, claim the MIT group, don't need to be the large and clumsy devices that currently grace our factories. In fact, if their predictions are true, the robot of the future could be kept in a match-box. Moreover, such micro-robots would not be fixed to a pedestal; instead they would be able to creep about, rather like mechanized spiders.

Wild speculation? Not at all. Already the necessary intelligence can be accommodated on a single chip that would easily fit in the size of a spider. More remarkably, MIT engineers have produced a suitable motor and gear-train weighing only a few milligrams. These parts, like their controlling circuitry, are fabricated entirely by a process of etching – which makes them potentially as cheap. Although yet in the future, some researchers at MIT believe it may be possible to integrate fully all the functions of a simple beast like a spider.

But why do it? What is the value of a mechanical spider that costs £1 or so? The answer is that such mechanical beasties could be pre-programmed to do more



than just fill the laboratory with cobwebs. Program them to scrape rather than spin and it would be possible to feed a few into the end of a blocked-up sewer or similar inhospitable environment. At £1 each (+ battery) there'd be no need to retrieve them. Fit them with solar cells and rubber suction feet and they could spend all day climbing a tower block cleaning the windows.

The MIT group believes that the commercial impetus to mass-produce really cheap robots will come not from industry but from the toy market. And just as the *cheap* industrial micro-computer was a spin-off from the home computer, so they believe that the really useful, cheap industrial micro-robot will have as its progenitor a somewhat up-market, if rather creepy, domestic toy.

Why the stars are silent

The amount of effort spent trying to prove that we are not alone in the universe has been prodigious. It all started in 1960 with the US Project Osma that used a 26m radiotelescope to scan two nearby Sun-like stars for radio signals around 21cm wavelength. The choice of the 'hydrogen line' was based on the philosophy that such a universal frequency standard would be the obvious choice of any extra-terrestrial communications. Later on the Russians joined in efforts to scan the radio frequencies, as did Canada, Australia, France, West Germany and the Netherlands. Between 1960 and 1983, there were 45 major experiments which totted up a total of around 75,000 hours' listening time. Philosophies varied greatly, as did the frequencies of observation.

More recently, attention has moved from the technology even further into philosophy. At a symposium held recently in Hungary, Sir David Bates, professor of theoretical physics and member of the Royal Society, analysed a proposal put forward in 1982 by Carl Sagan and eight Nobel Prizewinners. This proposal – published in the American journal *Science* – urged the use of more radio telescope time for SETI projects.

Sir David has done the sums on the likelihood of finding E.T. and now concludes that the first requirements would be a telescope array of 5km effective diameter with a receiver capable of scanning a million channels very rapidly. That has already been proposed and the necessary budget is beyond all but the super-powers. Yet even that investment would only yield results within 100 years if the extra-terrestrial governments had similarly been persuaded of the need to establish omnidirectional signalling beacons with output powers of the order of 10^9 watts. If the alien civilisations restricted their transmitters to the puny sort used for earth-style broadcasts, then the chances of us hearing them in 1000 years would, according to Sir David, be extremely small.

Research notes is compiled by John Wilson.

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Please ask for full colour brochure and detailed specifications. Mk2 versions are available with coverage 60-950MHz, all units now have 'N' connectors fitted for VHF/UHF and SO239 connectors for LF/HF.

The **YAESU Mk2/3 RECEIVER** is only available from RWC Ltd earlier models can have the extended bands and HF module fitted and receiver sensitivity/'S' meter improved, please enquire for more details and prices

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NEW PRODUCTS

Data recorder for hire

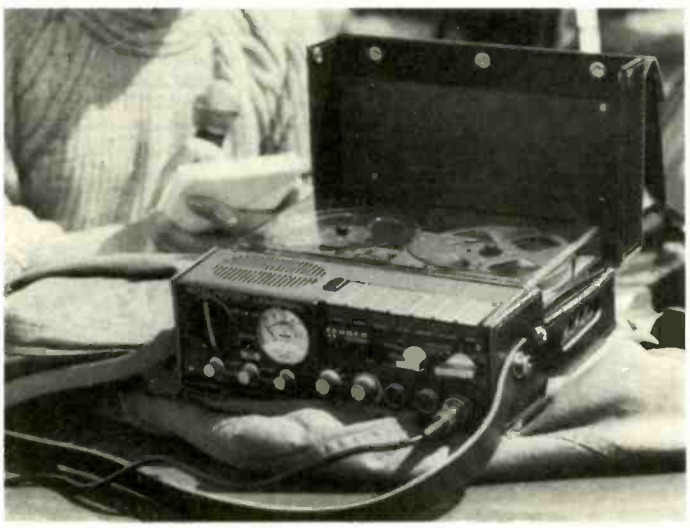
Digital anti-aliasing filters are included in the digital instrumentation recorder, EDR 8000 from Earth Data. The instrument is capable of recording up to eight analogue signals and eight different tape speeds are possible on a standard cartridge tape. Digital filters allow operation at varying bandwidths and different selections of channels without cumbersome and expensive analogue filters.

Bandwidth depends on the number of channels: one channel at 2048Hz or eight at 256Hz. Dynamic range switching is unnecessary as the instrument covers all the input ranges required by such recorders: 96dB at 320μV to ± 10V. Serial and parallel interfaces allow the instrument to be controlled remotely and for downloading recorded data.

EDR 8000 can be bought directly from Earth Data Ltd, Nutsey Lane, Totton, Southampton SO4 3NB. Tel: 0703 869922. Hiring has some advantages; the instrument is calibrated and ready to run, it eases pressure on capital expenditure and can be used to evaluate the instrument before purchase. Available through Livingstone Hire. Tel: 01-977 8866.

Slimmer optical drives

A 'second generation' of CD-rom drive is intended by Hitachi to fit the standard 5.25in floppy-disc drive slot on a PC-compatible computer. The drive is provided with a plug-in interface card for the PC but a SCSI is available for use with other computer systems. Access time is typically 0.4s. Up to four drives can be daisy-chained to give a total of 2.2Gbyte of storage. The CDR 3500 uses a new CD cartridge with an automatically-opening window which allows the disc to be read within its case. This not only protects the disc from dirt and handling damage but also allows the drive to be mounted vertically or horizontally. Hitachi New Media Products, Station Road, Hayes, Middlesex UB3 4DR.
Tel: 01-848 8787.



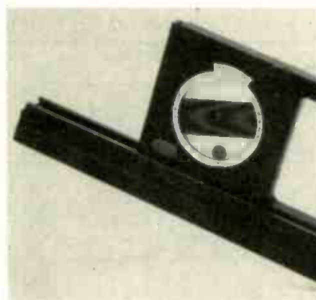
Newer Uher

Uher claims that there are over a million of its portable reel-to-reel recorders in use around the world. However, a new version, the 6000 Report Universal, has certain enhancements. The keys are easier to operate, being touch-sensitive; there are led status indicators, a 'repeat' function for fast transcription of recordings and a voice-activated switch.

The rugged, cast-aluminium body and head mounting have been retained from the earlier model, as has the 10mm diameter capstan, and a full range of components is available. The recorder has four tape speeds and offers a broadcast-quality frequency response of 20Hz to 22kHz at 9.5cm/s speed. Noise reduction circuits give a signal/noise ratio of 77dB. At the lowest speed, 1.2cm/s, for use in surveillance and the like, 12 hours of recording is possible with a response of 20Hz to 4kHz. A range of accessories completes the system. Telecommunications Information Systems Ltd, St Johns Road, Isleworth, Middlesex TW7 6NL.
Tel: 01-847 3033.

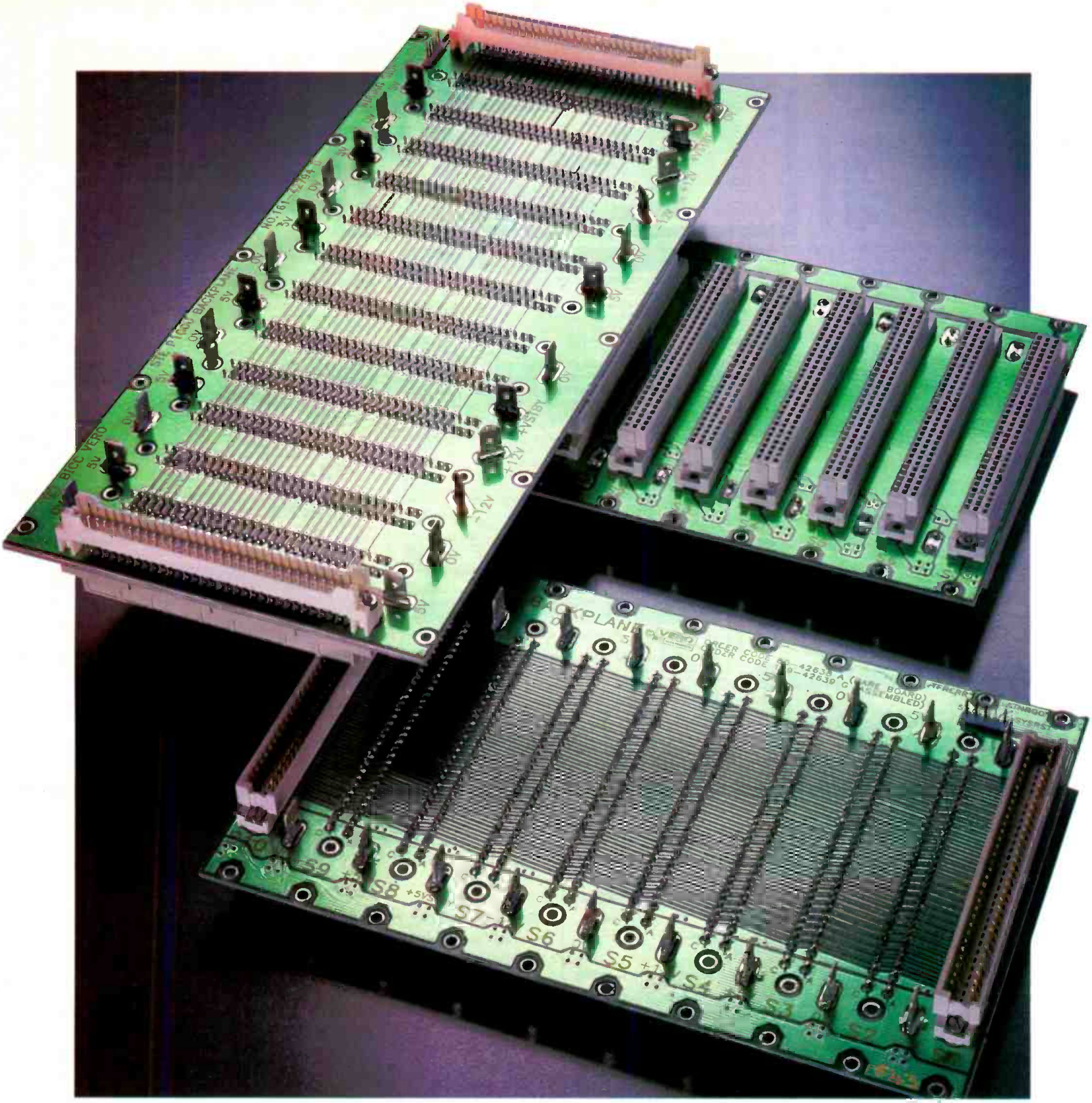
Multiscan monitor

Automatic adjustment to the required scanning frequency is a feature of a new colour monitor from Hitachi. Resolution of the 0.3mm tri-dot pitch allows 800 pels by 560 lines on a 14in screen. The Multi 560 uses l.s.i. circuitry to scan the input signal to lock on to the sync frequency and aspect ratio of the computer and so will work with IBM PS/2 VGA graphics as well as all the various graphics adaptors developed for the IBM PC. Hitachi New Media Products, Station Road, Hayes, Middlesex UB3 4DR.
Tel: 01-848 8787.



Angle gauge for dish installation

According to the OED, a goniometer is an instrument for measuring angles. This goniometer from Moagon in Sweden, has the specific purpose of measuring angles in parabolic aerials. The instrument is fitted with moiré grids. Light beams passing through the grids converge to produce an arrow pattern until the setting angle is correct, when the beams emerge as parallel lines. The goniometer can be secured to the aerial stand by magnets during vertical adjustments and can ensure an accuracy of 0.2°. Developed from earlier angle gauges, the instrument includes a number of refinements to improve its accuracy including separate moiré grids for coarse and fine adjustment. Moagon AB, Box 53232, S-400 16 Gothenberg, Sweden. Telex 27805 SEYDON S.



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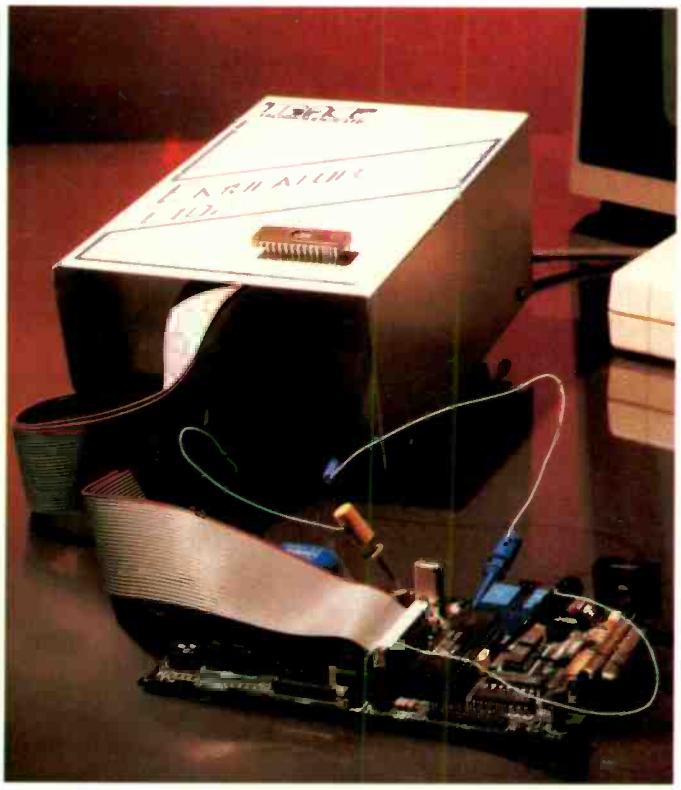
NEW PRODUCTS

Measuring low resistance

Automatic compensation for thermal e.m.f. effects is included in Ductor D203 from Megger Instruments. The micro-ohmeter has eight ranges from 199.9μΩ to 1999Ω with a resolution of 0.1μΩ. Battery or mains powered, Ductor is used for the commissioning and maintenance of power cables, metal-bond testing in aircraft frames and railway lines, measuring relay-contact resistance, p.c.b. track resistance and many other applications. Megger Instruments Ltd, Archcliffe Road, Dover, Kent CT17 9EN. Tel: 0304 202620.

Magnetic measurement – instrument

All kinds of magnetic fields; – steady, alternating, peak or pulsed – can be measured with the 701 Hall-effect gaussmeter. Autoranging between 0.1 and 39999 gauss, the meter comes with a variety of probes. For production testing, 'classifier' lights provide a rapid method of grading magnets. B.c.d. and analogue outputs are included for interfacing with other test equipment. Trilec Instruments Ltd, 17 Church Street, Market Lavington, Devizes, Wilts SN10 4DT. Tel: 038081 2361.



Eprom emulator

More facilities than normal are claimed for the Trace E102 which connects to a host computer through the RS232 port. This connection makes it useful for a variety of computers from powerful desktop systems to most home computers. Emulation of most available eproms is possible and a special feature of the system is the ability to define a window in the eprom space and write to it directly, allowing editing and debugging of a program interactively. A number of additional facilities include memory dump, string search, copy, automatic data-rate selection and an extensive 'help' menu. The current model can be expanded to emulate up to four eproms and a 'breakpoint' card with full memory trace is amongst other enhancements, available soon. Trace Technology Ltd, Swan Works, Box End Road, Bromham, Beds MK43 8LT. Tel: 0836 261643.

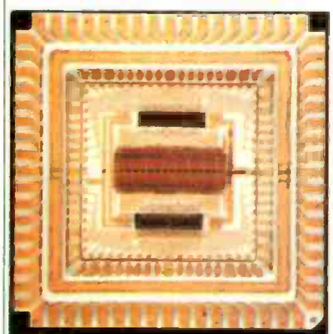
Digital temperature controller

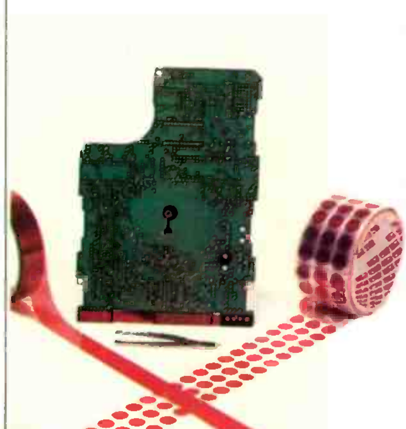
Flexibility of operational facilities makes the CAL 9000 series of temperature controllers suitable for a wide variety of applications. Fully adjustable and offering proportional, integral and derivative control, the 9000 can operate from any standard thermocouple or PT100/RTD thermistor.

Its small size makes it easy to fit into equipment and it can be programmed simply by the user with ranges, limits and alarm signals. Resolution is also selectable and the display can be toggled between Fahrenheit and Celsius. Available in the RS catalogue or direct from Controls & Automation Ltd, Bury Mead Road, Hitchin, Herts SG5 1RT. Tel: 0462 36161.

Thermal transducers

A 64-element array is one of a number developed by Plessey for infra-red sensor applications. Uncooled pyroelectric linear detectors find use in laboratory development work, thermal imaging and for detecting hotspots on a p.c.b. or even on heavy machinery. Intruder alarms and thermal mapping can also benefit from the improved performance of these devices. Special i.cs have been used in the construction of the arrays to improve reliability and allow a flexible interface for the system designer. A number of formats are available and can also be made to order. Plessey Research Caswell Ltd, Caswell, Towcester, Northants NN12 8EQ. Tel: 0327 50581.





Soluble masking tape

A self-adhesive solder-masking tape completely dissolves in the solvent cleaning and defluxing process, and yet can withstand the temperatures used in wave-soldering. The adhesive is silicone free, eliminating the risk of contamination to gold contacts. It totally dissolves in fluorocarbon solvent in about two minutes, using an ultrasonic washing system. The tape is available in various widths and there is a variety of disc masks. Intertronics, Allvalve House, 159 Brookwood Road, Southfields, London SW18 5BD. Tel: 01-871 2735.

NEW PRODUCTS

Talking chips

Alarm and emergency signals and a range of information services can be provided with high-quality speech from a miniature plug-in solid-state unit. Programming the Amesa Microvox is done through a recording unit which accepts pre-recorded speech from a tape submitted by the user. The makers can program the memory or, for volume production, a recording unit, Reprovox, can also be purchased. Thick film hybrid circuitry is used to integrate all functions into the Microvox unit so that the only external parts needed are switches to trigger it and a loudspeaker for output. Digital p.c.m. recordings ensure the maintenance of high-quality speech.
Amesa Technologies, 2 The Maples, Ottershaw, Surrey KT16 0NU. Tel: 093287 2471.

Computer-aided software

Computer-aided real-time design, has be on contracted to 'Card' as the brandname for a system which is claimed to offer the software engineer similar facilities to those available to the hardware designer. The system has a real-time performance verification facility, claimed to be unique. The design system, Cardtools, is designed to maintain complete and accurate documentation of all phases of software development and maintenance. It draws on a centralized data base which makes it possible to verify all stages of design and documentation. Cardtools offers support for real-time embedded computer systems, such as performance verification. The development tools were developed in Palo Alto, California by Ready Systems, and are available from their French office, 16 bis, Rue Grande Dame Rose, Velizy-Villacoublay (Paris), France. Tel: 33-1-39468986.

Transformers dispatched by return

A wide range of transformers: toroidal, low-profile, isolating, auto, p.c.b. mounting and low-voltage power types, are all held in stock by Parmeko Components and are available for dispatch on the same day in answer to a phone call. The transformers have power ratings from 2VA to 1kVA and conform to British Standards. Over 100 different types are manufactured by Parmeko, the parent company, and are kept in stock. Parmeko Components Ltd, Percy Road, Leicester LE2 8FT. Tel: 0533 440044.

Processor system faultfinder

Pre-defined test sequences can be run by a processor-board tester plugged into the microprocessor socket. The bench-top instrument is provided with a number of test pods to simulate the processor used in the system and it is used to trace faults in the board down to component level and even off-board peripheral circuits.

Tests include short-circuits on any of the buses, dynamic memory tests, display of control pin status, toggling of data and address lines and the generation of test data patterns. Firmware is disassembled into mnemonic codes. Other features include a synchronous logic/frequency probe and an RS232 port for remote/automated testing. Polar Instruments of Guernsey, make the B3T which is available from Antron Electronics Ltd, Hamilton House, 39 Kings Road, Haslemere, Surrey GU27 2QA. Tel: 0428 54541.

Code analyser for radio pagers

All the test facilities for radio pagers, bleepers and message systems are included in Solartron's 4922 radio code analyser. Intended for production and repair testing it is also a useful development tool. Generation and analysis of all the signals used by the various devices is possible along with selective calling and cellular systems. Messages can be structured and analysed, all directed through the menus on the instrument. Plain-text entries are converted into 'data telegrams' which can be displayed and manipulated on the screen. The majority of regular transmission modes are catered for, but user-defined transmission protocols can be programmed into the 4922. The instrument can be programmed or controlled through a GPIB link and received messages can be output to a printer. Solartron Instruments, Victoria Road, Farnborough, Hants GU14 7PW. Tel: 0252 544433.

Integrated digital-to-analogue

The discovery of a matrix method for constructing integrated circuit d-to-a converters led to the development of a whole company, Brooktree Corporation, in California. The Brooktree Matrix, developed by Dr Henry Katzenstein, offers a d-to-a converter with greatly improved conversion speed, linearity, stability and power dissipation. The company was not content to produce d-to-a converters and therefore found ways of integrating the converter into other products, particularly computer video circuits.

Ramdac

As the name suggests, Ramdac combines memory with a d-to-a converter. The memory is principally used as a colour look-up table and several other functions are combined on an integrated circuit to provide a complete computer video system. A recently released example is the Bt471 which incorporates three 6-bit d-to-a converters. It has a 256-colour look-up table, a 15-colour overlay palette and microprocessor interface, compatible with the IBM PS/2 computer system. The chip includes 15 overlay registers for manipulating windows, cursor position menus and for the simulation of IBM EGA graphics, used with SECAM, PAL, or EIA (NTSC). The 80MHz operating speed gives it a 1024 by 768 display.

Bt478 has all the same facilities but the d-to-as are 8-bit devices and the colour look-up memory is consequently increased to 256 by 24. It also adds sync on input as well as the output sync available on both models. Further facilities and higher definition are available on the Bt461 which has a single output, so three are needed for a colour system.

Timing

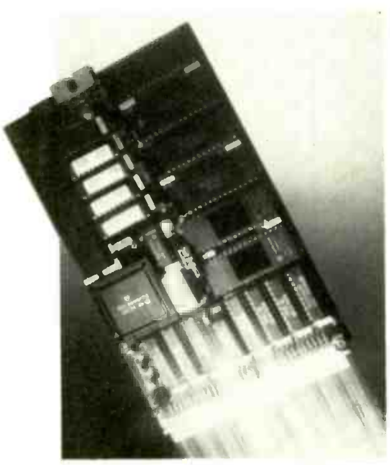
The Brooktree Matrix also finds applications in high-speed testing applications. Intended for use in test and measurement facilities, the Bt6xx series offer a timing resolution of 20ps. The timing range is set externally in a range of 4 to 40ns. The devices produce a pulse of fixed width at a programmed delay after a trigger pulse. There are versions in which the rise/fall time of the pulse can also be programmed. As test signals need to be an order of magnitude better than the components under test, the precision and accuracy of these devices can become necessary. The Brooktree Corporation is in San Diego, California. Their products are available in the UK through Thame Components Ltd, Thame Park Road, Thame, Oxon OX9 3XD, Tel: 084 421 4561.

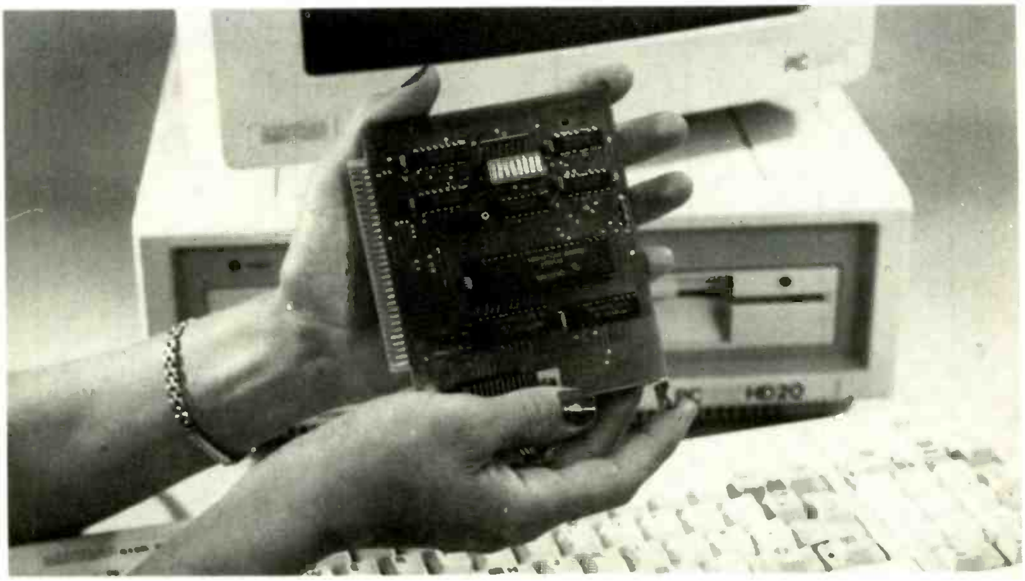
ENTER 35 ON REPLY CARD

68000 STEbus processor

Full 16-bit processing is available on the STE bus through a 68000-based single-board computer. Although the STE bus is limited to eight bits, the 4020 card from the British Telecom maintains a 16-bit wide implementation internally and is claimed to have sufficient memory to allow the c.p.u. to operate locally in most applications.

Up to 500Kbyte of rom, ram or any combination of memory types can be fitted on the board. Three pairs of 32-pin memory sockets will be able to contain up to 6Mbyte of memory when devices become available. The card includes bus arbitration protocols and can be used in a multiprocessor system. An RS232 link can be connected to a terminal for development, and then used as an i/o port in a target system. The board forms part of a range of STEbus-related products and is designed for systems that require extensive processing facilities. It may be used with multi-tasking operating systems such as OS/9 and Tripos. British Telecom Microprocessor Systems, Martlesham Heath, Ipswich IP5 7RE. Tel: 0473 643101.





Half-price GPIB for personal computers

An add-on card for IBM-compatibles allows the computer to be a GPIB (IEEE-488) controller and, at £195, is claimed to be half the price of rival products. Using a low-cost PC, such as the Amstrad, it is possible to have a complete controller for about £700. The GPIB-1000 card comes complete with the necessary drivers and diagnostics for use with Microsoft Basic. Further software packages for assembly language, C, compiled Basic and turbo Pascal are available. Roalan, Britannic House, 28 St. Peters Road, Bournemouth, Dorset BH1 2LP. Tel: 0202 298676.

Uninterruptible power supply

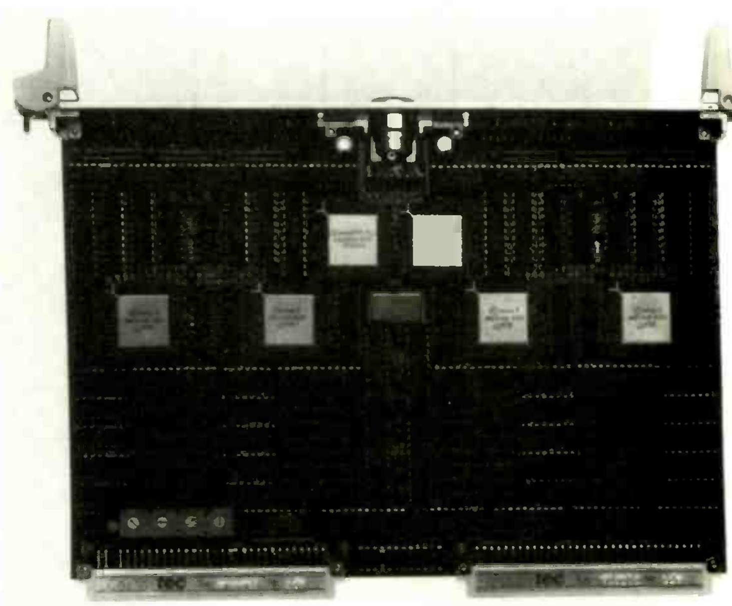
Standard UK mains output of 240V at 50Hz is available from the UPS250 for up to ten minutes at 250W in the event of power failure. Lower output loads are backed up for longer but the figure is typical of a personal computer system. Back-up power takes only 4ms to take over the supply. It emits warning bleeps while it is operating. At a selected threshold the supply cuts out to prevent over-discharge of the batteries. Current-limited p.w.m. inverter circuits ensure a high-quality sinewave output at <5% t.h.d. Alphacam Products Ltd, The Old Maltings, 135 (9) Ditton Walk, Cambridge CB5 8QD. Tel: 0223 214214.

Asic design enhancements

At a recent Custom Electronics Show, a high proportion of the application-specific i.c. manufacturers were displaying products designed using the GenRad Hilo circuit simulation system. GenRad themselves were showing enhancements to the Hilo system which added a range of new facilities.

HiGen is a library modelling tool. Whenever a new device is produced, its characteristics need to be added to the simulation library. Each device is often produced in many versions with different speeds or other variations, every version must be added to the library for the library to be comprehensive. With HiGen it is possible to enter the characteristics directly from a specification sheet and the software will complete the model, thus saving a lot of time.

The other major addition to the Hilo suite is HiTest, a new method of generating test patterns for device testing. Using a 'toolbox' of test patterns, the user is guided by the menu-driven software into generating the pattern that will achieve the level of fault detection required. The system offers an interactive process to ease the problems of test-pattern generation and to speed production. All of GenRad's tools interact with each other and several of them work in collaboration with other design systems as well. GenRad Ltd, Norreys Drive, Maidenhead, Berks SL6 4BP. Tel: 0628 39181.



Multi-Transputer VME card

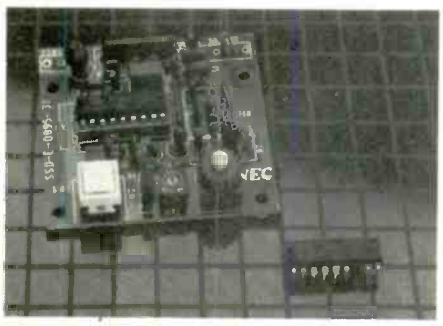
Four Transputers, T800 or T414, are included on a single p.c.b. for VME applications. Each 'processing node' has 1Mbyte of local memory and each is switched into the bus independently. VMTM, from Parsytec in Aachen, can be used as a supplementary processor within a VME system with a conventional host processor, or with the company's own BBK-V2 master Transputer module. It is also used in a multi-user development system and each board can support up to four users. Any number of VMTM boards are combined within the same VME system. Each performs 40mips or 6 million floating-point operations/s (mflops). The system is supported with the Occam parallel-programming language as well as compilers for C, Pascal and Fortran 77. For development work, a package is available for OS/9 systems and for Sun workstations running Unix. Parsytec GmbH, Juelincher Strasse 338, D-5100 Aachen, Germany. Tel: (241) 1822275.

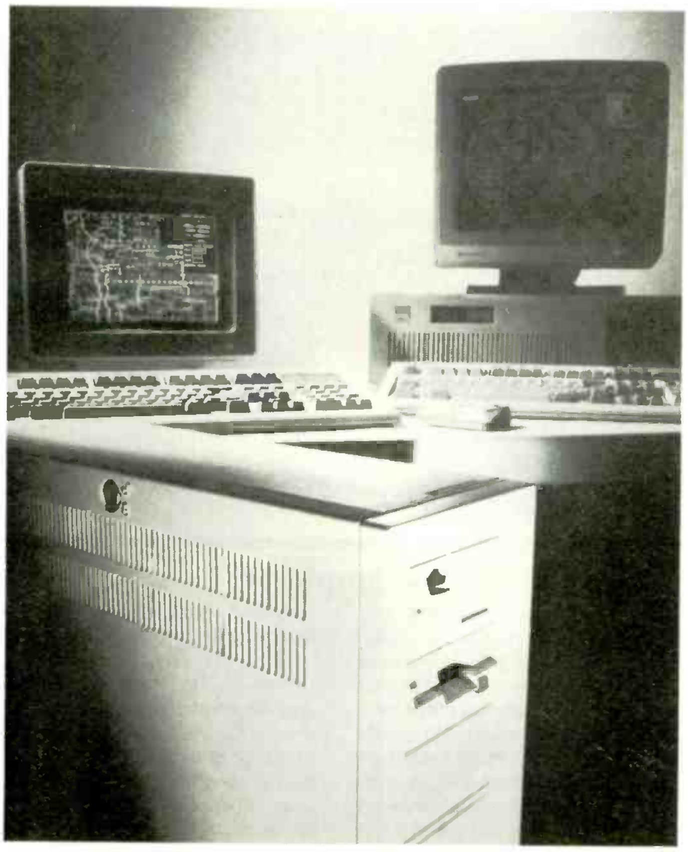
NEW PRODUCTS

Speech on an i.c.

Adaptive differential pulse code modulation is the coding system used in a family of speech synthesis i.cs from NEC Electronics. The family is intended for use in telecommunications, car systems, toys and many other applications. Three members of the family cater for different internal mask rom capacities, while one can address up to one megabit of external memory.

A complete evaluation kit is provided by a demonstration box which includes low-pass filters, an audio amplifier and loudspeaker. EBIBM-7759 can be programmed from an IBM PC and software is provided on a disc. NEC Electronics UK Ltd, Cygnus House, Linford Wood Business Centre, Sunrise Park Way, Linford Wood, Milton Keynes MK14 6NP. Tel: 0908 691133.





AT-based p.c.b. cad

Racal-Redac lists 50 advantages that its Cadstar p.c.b. design system has over competitors. Without reproducing the complete list, it is possible to pick out some of the major features. The program accepts a list of components and connections (netlist) from the Redlog design capture program.

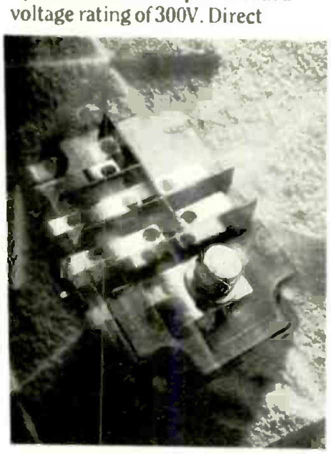
It starts with a rat's nest of all the components to be used in a circuit piled up in a corner of the screen and a blank p.c.b. pattern. The user can select those components that are deemed to have critical positions and place them on the board, so that i/o control, for example, is near the edge connector. All other components can be placed automatically by the system which will optimize route lengths for connectors. The user has full control if needed and can adjust and move components. All connections are moved with the component and when all the components are positioned the program will automatically route the tracks. Up to 3500 connections can be accommodated.

Surface-mounted components can be used on either or both sides of a board with up to 16 layers. If a component is transferred to the other side, the connections are automatically reversed. Through-holes, or 'vias' are automatically kept to a minimum. Component icons are available in a library but can be changed by the user so that if, say, a transistor of a different housing is used, its 'true' shape can be represented.

When a design is complete, components can be renumbered to give them a logical sequence in assembly. The system can run a 'rule check' to make sure that there are no unconnected pins or short circuits, or that conductors are not too close together. The software runs on an IBM AT-compatible computer or on the PS/2 computer. Outputs are to a pen plotter or a photoplotter and include patterns for silk screen printing and a program for a drilling machine. Racal-Redac Ltd. Tewkesbury, Glos GL20 8HE. Tel: 0684 29161.

High-power Darlington

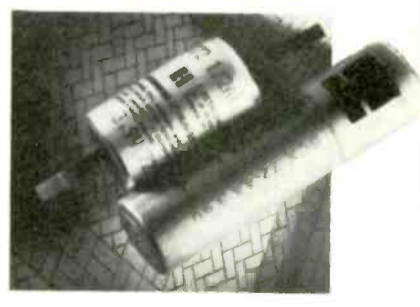
Connecting the collector directly to the baseplate gives the Fuji ID500A Darlington transistor improved thermal conductivity and higher power dissipation. Collector currents up to 500A can be coped with at a voltage rating of 300V. Direct



current gain is a minimum of 500 at V_{CE} of 2V and I_c of 500A. Such devices are suitable for electric vehicles, and uninterruptible and high-current power supplies. ECC Electronics UK Ltd, 9 Blenheim Road, High Wycombe, Bucks HP12 3RT. Tel: 0494 36113.

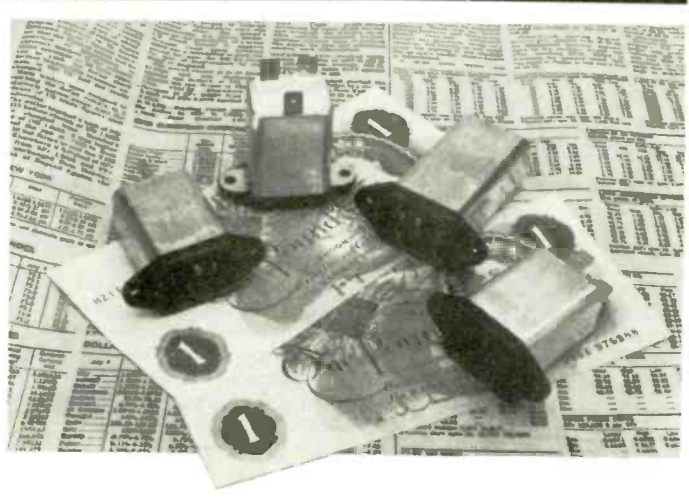
High-voltage lithium cells

An open-circuit voltage of 3.9V is claimed by Suvicon to be higher than any other type of primary cell. This gives an energy density up to 16-times greater than the equivalent carbon-zinc cells. The BCX range is available in a variety of sizes with nominal capacities from 1Ah to 30Ah. Continuous discharge currents have maxima between 1mA and 350mA. The standby life is claimed to be more than 10 years to make the cells suitable for low current-drain applications; memory back-up and remote power supplies. The cells are manufactured in the US by Electrochem and available in the UK through Suvicon Ltd, The Square, Broad Street, Birmingham B15 1AP. Tel: 021 643 6999.



Mains inlet filters

Protection against mains-borne interference is offered by these inlet filters which are designed to be a replacement for standard CEE22 sockets. The filter is intended for use with such interference-sensitive equipment as v.d.us, computing equipment and digital instruments. Versions are rated from 3A to 6A and fused versions are available. To distributors and manufacturers its price is £2. Roxburgh Suppressors Ltd, Haywood Way, Ivyhouse Lane, Hastings, East Sussex TN35 4PL. Tel: 0424 442160.

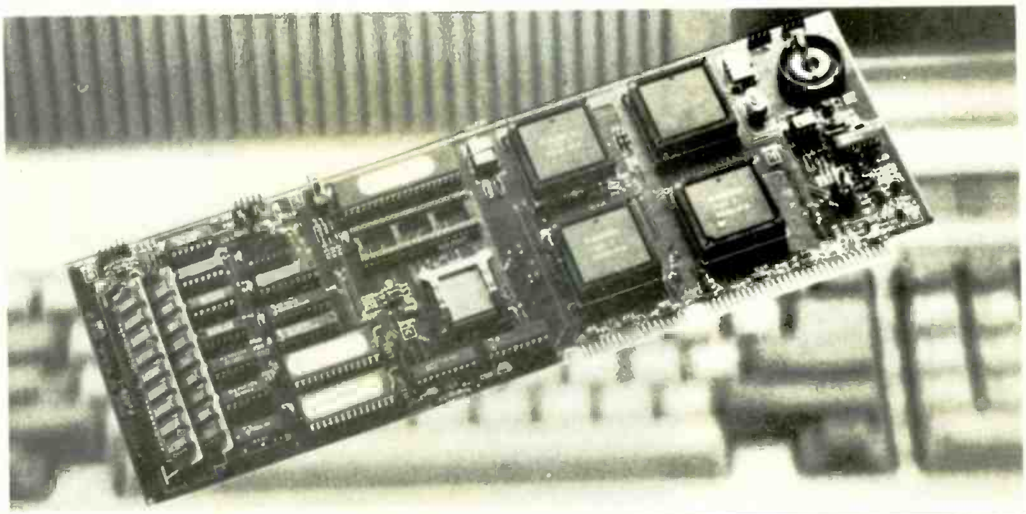


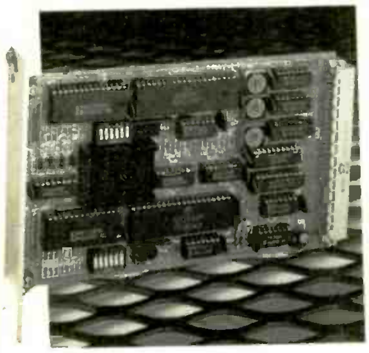
NEW PRODUCTS

AT on a PC expansion card

All the functions of an IBM AT, including 512Kbytes of ram, keyboard controller and a co-processor socket are available on a single PC expansion card.

ZyATB-1 was designed as an evaluation system for the Zymos Poach chip set and operates at up to 8MHz. Included is an IBM-compatible Bios. The high density of the Poach chips makes the board very compact. There are only 26 components. This enables an AT to be incorporated into instrumentation systems. Chiptech Ltd, Alban Park, Hatfield Road, St Albans, Herts AL4 0JJ. Tel: 0727 40476.

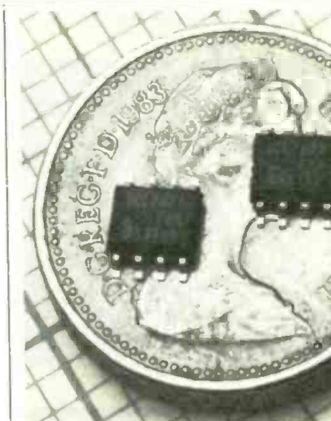


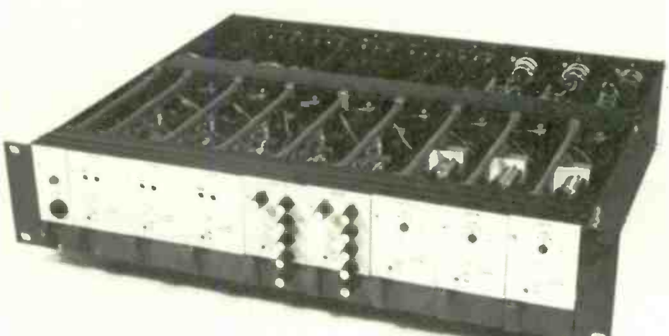


Video distribution amplifier

By adding or changing the plug-in daughter boards the Link 280 pulse and video distribution amplifier can solve cable equalization problems. The high-impedance amplifier has six isolated 75Ω outputs. Up to eight can be accommodated in a standard rack giving a capacity of 48 channels. Nine versions of the daughter boards are available with fixed or variable gain and cable equalization.

A variant of the amplifier, model 282, replaces the daughter board with five front-panel controls for direct manipulation of active elements in the equalizer network. Different parts of the response curve are independently adjustable, making the unit particularly useful in outside broadcasts with varying qualities on the incoming video lines. Other variants are also available. Bal Components Ltd, Bermuda Road, Nuneaton, Warwicks CV10 7QF. Tel: 0203 341111.





Laboratory network for Archimedes risc computer

A range of products has been introduced to interface the Acorn Archimedes computer to laboratory instrumentation. Paul Fray Ltd, producer of the Spider 2 real-time interfacing system for the BBC micro, has added the Cobweb expansion card which allows the computer to address up to 16Mbytes through a backplane. The same backplane can be used with a number of interface and memory cards including: a four-channel serial interface with connectors and termination characteristics chosen by the user; 16-channel opto-isolation is offered on a digital interface cars with up to 30V d.c. Each channel can be configured as an input or an output; eight inputs and two outputs are provided on an analogue card which gives 12-bit resolution at high speed. The system is available for all Acorn computers. The company is offering technical support and consultancy for the Spider 2 system which has already found such diverse applications as robot monitoring, car endurance testing and satellite telemetry. Paul Fray Ltd, Willowcroft, Histon Road, Cambridge CB4 3JD. Tel: 0223 66529.

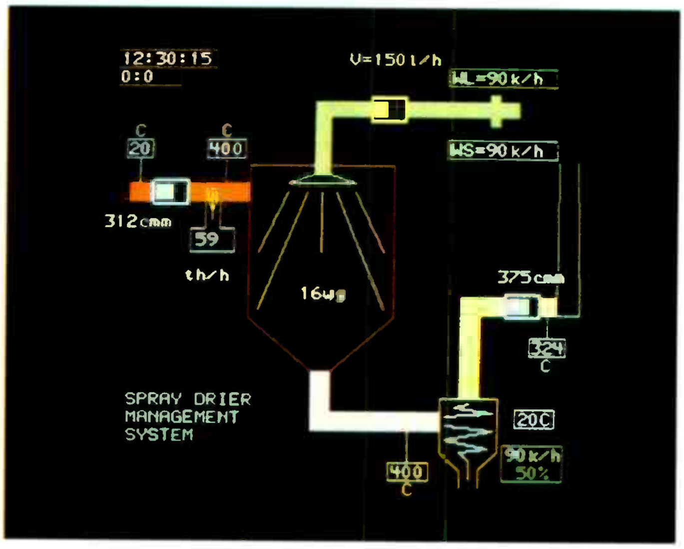
Battery back-up switch

Intersil claim that their ICL 7673 is the only device which will automatically connect its load to the higher of two inputs. So for ram, real-time clocks and other devices, the i.c. will switch in a battery back-up supply if the main supply fails and then switch back as soon as it is restored. VSI Electronics Ltd, Roydonbury Industrial Park, Horsecroft Road, Harlow, Essex CM19 5BY. Tel: 0279 29666.

Slimmer d.c. converter

Mounting directly on a p.c.b. the PKA 4411 40W d.c. to d.c. converter from Rifa has the same footprint as the company's standard 25 to 30W models. The 19.8mm high package allows p.c.b. spacing of 30.48mm in electronic shelving. A wide temperature range and very high reliability are claimed for the device which is also available for chassis mounting. Input voltage is +48V and output is 5V. Rifa AB Power Products, Market Chambers, Shelton Square, Coventry CV1 1DJ. Tel: 0203 553647.

Advanced graphics card



Latest in CMS's range of industrial controller cards based on the 6502 microprocessor is an advanced graphics card offering 512 by 512 resolution. One use for it is in creating mimic diagrams, such as the milk powder freeze-drying plant illustrated here.

Built-in features include circle and polygon drawing and filling routines plus a lightning-fast block move and copy. Up to 800 user-defined soft characters can be stored, each of user-defined dimensions. Picture elements can be set, cleared or inverted; and areas of memory can be protected from reading or writing. The screen memory is splittable into two 256 by 512 screens which can be swapped instantly. Additional on-board memory can expand resolution to 2000 by 2000 picture elements.

Despite its advanced features, the graphics card can be controlled very simply – through extended VDU commands from BBC Basic running on the 6502 card at the heart of the system. This controller card combines the hardware features of the BBC Micro with additional software developed by CMS, including a multi-tasking Basic extension rom designed especially for real-time measurement and control.

Up to eight active background tasks can be handled whilst the main program is running: these can include accesses to the built-in real-time clock or to analogue and digital i/o devices on other cards.

The special Basic commands for each i/o operation make control programs easy and quick to write and debug: the programmer has no need to grapple with inscrutable port addresses.

Up to three graphics displays can be supported by a single 6502: the high-resolution card occupies no more than 64 bytes of the memory map. Users can, for example, display a process diagram on a high-resolution colour monitor whilst simultaneously driving a separate text screen for the operator.

During program development, the 6502 card can be operated as part of CMS's stand-alone development system, or as a second processor connected to a standard BBC Microcomputer. When the program has been debugged, the card will operate alone. A paged memory feature in its operating system means that it can handle very large programs or data files.

But the 6502 card's powerful control capabilities come into their own when it operates in a distributed processing system in partnership with further 6502s.

Such a system can control an entire factory. With this decentralized approach, control tasks can be broken down into manageable units. Because each controller operates independently, it need not shut down because of some problem elsewhere.

Control of the system can be effected from a 6502 unit configured as a supervisory station. CMS's software enables the supervisor to monitor system status at a glance, to read or write to any memory location or vector and to transfer programs or data to any destination on the network.

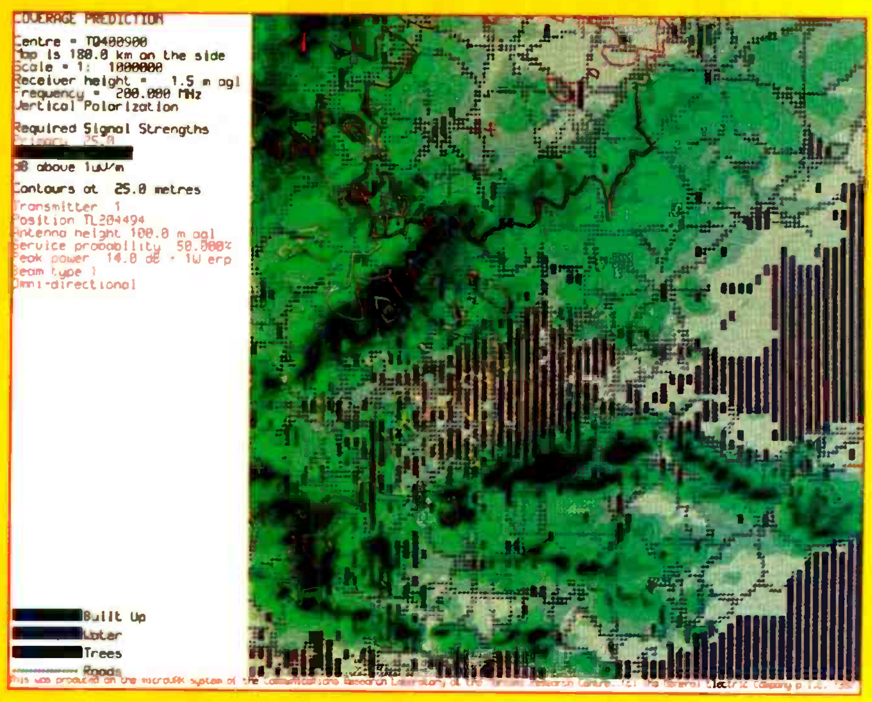
Details from CMS on 0954-51122.

Network planning service

This map of south-eastern England was plotted by Covmod, a software suite for predicting radio coverage developed at Marconi's communications research laboratory. Red contours illustrate coverage of a v.h.f. transmitter situated at Sandy Heath in Bedfordshire and yellow ones are those of a station at Hannington, Hampshire.

The software, which takes account of terrain, ground clutter in built-up areas and tropospheric ducting, is suitable for use at v.h.f. and u.h.f. and for broadcast or mobile radio applications. Its accuracy is said to be excellent – indeed, GEC used it in planning its National One band III mobile radio network, which opens this month (January).

A bureau service is offered by the laboratory to other radio users. Prices begin at £175 for a single plot or £1200 for ten. Details from the Marconi Research Centre at Chelmsford on 0245-73331, extension 3148.



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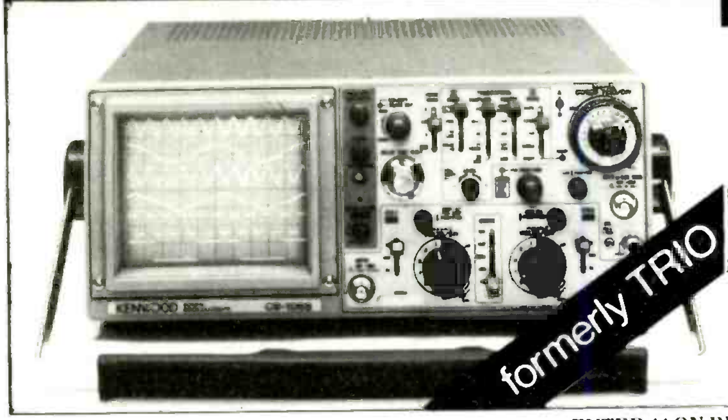

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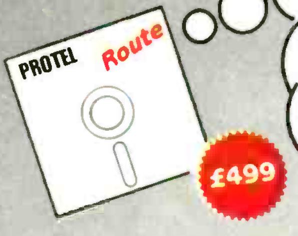

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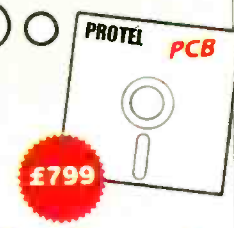

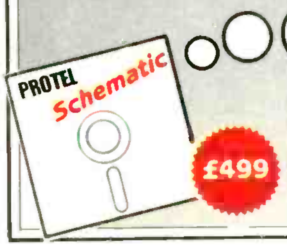

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Look no hands!

The new BBC overseas relay base in Hong Kong, with two Marconi 300kW h.f. transmitters, is the first BBC h.f. station that can be operated in a fully unattended mode and in practice the station is manned only during office hours. Automating the operation of an h.f. station involves many of the same problems as with the now well-established unattended television and domestic radio networks but in addition poses severe problems of the daily frequency changes and switching of the high-power r.f. outputs to any of a number of directive antennas, plus the operation of e.m.c.-vulnerable computer control units in strong r.f. fields.

A BBC engineering team led by David King has spent several years developing the new automatic control system, which is being progressively implemented at BBC h.f. stations in the UK and overseas. The older manually-tuned transmitters still require manning at all times, although on a reduced scale.

Equipping five monitoring and control centres at the stations has been made possible by: (1) capital funds from the Foreign & Commonwealth Office under the 'improved audibility' programme; (2) availability of h.f. transmitters compatible with computer control; and (3) the design and provision of a suitable control system basically involving a network of microcomputers, audio and r.f. matrices, transmitter and antenna interfaces etc. The control systems are housed in screened rooms.

The BBC is now about halfway through the 'audibility' programme and has been able to reduce staff at h.f. stations by 70 posts with a saving of £1M a year. With full automation as much again could be saved. Economics has dictated the adoption of automation but the integration of mobile maintenance of domestic transmitting stations has meant that h.f. field engineering has, in the management's view, become an attractive high-tech posting. Despite fears to the contrary, it has been found that not all existing station engineers over the age of 55 wanted to opt out of automation, with many becoming interested in the new computerized system and "rediscovering engineering" rather than routine antenna switching and transmitter tuning.

Phase 2, currently under development, will see all visual display unit facilities extended to Bush House with automatic performance measurement of the transmitters displayed there. A possible future development would permit direct transfer of data from the main scheduling computer.

As at Hong Kong, the new relay station now being built on the Seychelles and due in operation at the end of 1988 will be fully automated. BBC External Services currently operate some 90 high-power h.f. transmitters at eleven stations, both in the UK and overseas. With frequency changes and antenna switching every few hours, transmitters may be in operational use for 23 out of the 24 hours. Many of the beam antennas can be electronically skewed by up to ±25°.

During the first month of operation (October) the new Hong Kong transmitters suffered a significant number of outages ascribed to "teething troubles". Reliable performance of this fully automated station will obviously be crucial to the success of the automation project.

Doherty at u.h.f.

The search for higher overall conversion efficiencies and consequent energy cost savings for all high-power transmitters has led to continuing interest in such techniques as Tyler high-efficiency Class C amplifiers (with drive waveforms containing third-harmonic) and the various switching-mode Class D and Class E amplifiers. In the 1970s, the BBC undertook considerable experimental work on the high-efficiency system first proposed by W.H. Doherty (*Proc. IRE*, September 1936) and this technique was used for the re-engineering of the BBC medium and long-wave network of 10 and 50kW transmitters with pulse duration modulation used for the 1kW units.

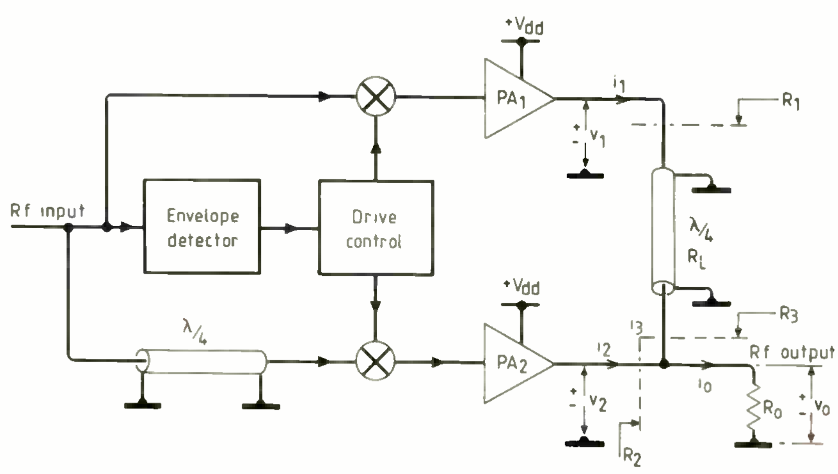
Basically a Doherty amplifier combines the outputs of two or more linear r.f. power amplifiers through an impedance inverting coupler. At low output levels the first amplifier provides all the output until it reaches saturation, but above a transition voltage the second amplifier operates linearly providing the peak output with good conversion efficiency. In effect, with conventional a.m., the first amplifier provides the carrier, the second the envelope peaks and hence is often called the peaking amplifier. The 50kW BBC (Marconi) transmitters use a screen-modulated Doherty circuit based on two neutralized 4CX35000C valves with positive 125% modulation capability. Valves operated in a Doherty configuration can have a higher h.t. potential, 16kV in these units.

A detailed look at the efficiency of Doherty amplifiers, for implementation by solid-state or thermionic devices, has been published by Frederick H. Raab (Green Mountain Radio Research Company) in *IEEE Transactions on Broadcasting*, September 1987. He shows that at u.h.f. and microwave frequencies the usual LC quarter-wave coupling networks can conveniently be replaced by quarter-wave transmission lines which can be implemented in printed-circuit form. He notes that many of the newer communications systems that operate in u.h.f. and s.h.f. (for example, a.c.s.b. land-mobile and mobile-satellite repeaters) as well as broadcasting transmitters require linear r.f. power amplifiers which, at such frequencies, would be difficult or impossible to implement with high-efficiency Class D or E amplifiers. The efficiency of Doherty amplifiers, he claims, is as good or better than can be achieved by alternative techniques such as envelope tracking or out-phasing.

His analysis shows that a three-stage Doherty system can improve effiency to nearly the p.e.p. efficiency of the individual amplifiers, even when the peak-to-average ratio of the output signal is large. A Doherty amplifier can be considerably more efficient than a conventional Class B linear power amplifier. For example, in multicarrier and s.s.b. applications, for a typical 10dB peak-to-average ratio, the 30.8% efficiency of Class B is increased to 58.7% for a two-stage Doherty system, and to 68.5% for a three-stage Doherty configuration, making the system an important candidate technology when transmitter efficiency, power consumption and/or heat dissipation are of interest to the designer.

Radio Broadcast is written by Pat Hawker.

Simplified diagram of Doherty's high-efficiency modulation method as applied to u.h.f.



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TELEVISION BROADCAST

Optical fibres into homes

R. Olshansky and V.A. Lanzisera of GTE Laboratories, Waltham, Massachusetts have reported successful experimental transmission of 60 frequency-modulated video channels over 18km of single-mode optical fibre (*Electronics Letters*, vol.23, no.22, pages 1196-8). They point out that the distribution of speech, data and video services all the way to the subscriber is one of the next major steps in the evolution of optical-fibre communications systems.

Completely switched time-multiplexed broadband subscriber networks have been proposed but the GTE team suggest that "at present the high cost of the digital electronics and the large data rates required for each video channel make such systems difficult to justify economically". Instead they propose that subcarrier multiplexing of video signals at microwave carrier frequencies provides an attractive alternative method for the distribution of video signals. They highlight the use of f.m. subcarriers in the range 2–8GHz. Since the required electronics have already been developed for microwave relay systems, much of it is relatively inexpensive and could provide a very attractive system that would take advantage of recent progress in high-speed lasers and photodiodes able to provide transmission bandwidths of the order of 10GHz.

The GTE engineers have implemented an experimental 60 f.m. video s.c.m. system in a 2.7–5.2GHz band, with the carriers then electrically combined and used to intensity-modulate a 1.3μm GaInAsP high-speed, vapour-phase-regrown, buried heterostructure laser. A dozen cable-television channels are used to form a 60-channel video source and the optical signal is transmitted over 18km of single-mode fibre, including four elastomeric splices, with a loss of 8dB.

At the receiving terminal, the signal from a photodiode detector is fed to a 2–8GHz low-noise broadband amplifier with a noise figure of 3dB and then downconverted to a 950MHz i.f. using a mixer and tunable oscillator. The f.m. signal is then demodulated and displayed using a low-cost 12-channel satellite video receiver with a 30MHz video bandwidth. A weighted s.n.r. of 56dB is achieved for a 16.5dB carrier-to-noise ratio at a modulation depth of 2% per channel (r.m.s. modulation depth of 15.8% for all 60 channels).

Stereo sound for tv

The determination of the French Thomson group to build up its consumer-electronics business is in marked contrast to the long retreat of major UK companies from this important branch of the elecronics industry. With the acquisition during 1987 of both the American RCA/General Electric and the UK Ferguson consumer businesses, Thomson is now the leading producer of television sets, having earlier acquired the West German Nordmende, Saba and Telefunken consumer-electronics operations. From about a 30% contribution to Thomson revenues in 1986, its 1987 contribution is estimated to have risen to just over 50%.

The increased reliability of television sets in a saturated European market means that Thomson, Philips and their Japanese competitors are increasingly relying on technological innovation to encourage viewers to buy new models, always a high-risk undertaking. Many years ago, a UK firm conducted a marketing survey to discover what made consumers buy new sets and obtained the answer "when they are convinced their old set is worn out" – a not very encouraging reply in today's market conditions.

The dependence on technical innovation is one reason why the industry has expressed so much displeasure at the BBC decision to postpone the operational introduction of its Nicam 728 digital stereo sound system. This was originally scheduled for 1988 but the recent five-year plan postpones this indefinitely with no review of the situation before 1991. Ferguson, in conjunction with Texas Instruments, is only one of several firms with a suitable Nicam 728 decoder chip.

Managing resources

With the BBC licence fee rising next April to £62.50 (black & white £21) but then linked for three years to the retail price index, and with both the BBC and ITV under Government pressure to increase to 25% their independent-sector production, there is little doubt that director-general Michael Checkland is being forced to seek significant economies in all sectors of the BBC, including engineering. At a recent IEE meeting on "The Management of Broadcasting Facilities", Cliff Taylor (BBC deputy director of resources) described the financial and resource problems involved in meeting within three years the BBC's more modest target of 500 hours (12%) per year independent production at a cost of about £24M. He stressed that the r.p.i has little relevance to labour-intensive broadcasting or to the 14% annual rise in capital equipment costs that stem largely from the need to introduce new technology. He pointed out that an electronic camera costing £50 000 may be needed to replace a film camera costing £15 000. Development of digital special effects has similarly meant high-cost new technology adding to capital costs.

The BBC aims at reducing staff and resource costs by 1 to 2% per annum. Cliff Taylor, however, emphasised that while the BBC "trains for the industry" it has no intention of discontinuing its training programmes. He admitted that the change to more independent-sector production could mean that "the best staff may leave and we will be left with ones that aren't very good". But he noted that in three years time the BBC expects to be still producing 88% of its programmes adding "I do not believe that people work in the BBC to make a fortune".

Paul Bonner (ITV Association) and Ellis Griffiths (Channel 4) explained how Channel 4 is organized on the basis of commissioning programmes from the independent sector (22% in 1986-87), from ITV companies (24%), ITN (8.2%) plus 45% "acquired material" not specifically produced for Channel 4. Channel 4 has only a single small studio of its own, used to produce the weekly *Right to Reply* programme. This is thus a very different situation from that of the BBC or ITV with their large studio complexes and staff.

Ellis Griffiths admitted that the question of acceptable technical standards of material commissioned from the independent producers gives rise to much discussion although, as Paul Bonner confirmed, the independent sector has proved capable of providing programmes of a standard not different from UK internal production and on time. But it is clearly one thing for a channel specifically set up to depend on independent production houses to show that this is a cost-effective technique, but quite another matter for this policy to be imposed on broadcasters which have developed a structure of massive studio and outside-broadcast resources. The transition will not be an easy one. It is not surprising in the circumstances that the BBC management considers stereo sound a luxury it cannot yet afford.

Universities EMC Group

To add to the teaching of electromagnetic compatibility (e.m.c.) at Hatfield (October 1987 issue) both the University of York and the Cambridge College of Arts and Technology have brought to my notice that they have electronic engineering courses placing considerable emphasis on this increasingly important aspect of electronics. In addition, a Universities EMC Group, comprising researchers in universities with an interest in e.m.c., is seeking to increase the awareness of government and industry of their activities and to encourage suggestions and support for their work. By the time these notes are published they will have held a presentation of their work in London at which speakers are expected to include Dr Peter Excell (University of Bradford) and Dr A.C. Marvin (University of York).

Television Broadcast is compiled by Pat Hawker.

RADIO COMMUNICATIONS

WARC-Mob87

The Radiocommunication Division of the DTI is continuing with its welcome glasnost policy. Its second glossy annual report, published recently, takes the story up to March 31, 1987. By then the number of UK radio communication licences was 283 127 of which 121 696 represented the diminishing number of Citizens Band licences, 57 692 were amateur radio licences (29 954 Class A, 27 434 Class B, 257 repeater, 47 beacon), 16 343 private mobile radio (p.m.r.) licences (covering 406 401 mobile units), 10 426 radio-paging licences, etc.

Equally impressive was the promptness with which Mike Goddard of DTI, who led the UK delegation to the ITU's World Administrative Radio Conference on Mobile Radio (WARC-Mob87) at Geneva from September 14 to October 16, reported the results to an IEE meeting on November 2. With ITU now including 162 member-countries there were nearly 900 delegates representing 108 delegations. The Final Acts of the conference ran to 388 pages including several new chapters for the Radio Regulations.

A new feature of UK strategy was use on an unprecedented scale of the machinery of the CEPT (Conference of European Posts and Telecommunications) both before and during the conference, with the active co-operation of 12 to 15 countries. The agenda for the conference was established in advance, the election of the Canadian chairman posed none of the political in-fighting of some ITU conferences. The conference was constrained by the need that any changes could have "only minimum effect on radiocommunication services not included on the agenda". The 60 or committees included over 50 *ad hoc* groups on technical matters.

Most of the decisions will affect land-mobile, maritime-mobile and aeronautical-mobile services from 1991, with major decisions involving the new Global Maritime Distress and Safety System (GMDSS), Aeronautical Public Correspondence (APC, i.e. passenger telephones in aircraft) and the Radio Determination Satellite Service (RDSS).

Requirements of maritime operators proved a contentious subject; the UK and 22 other countries voted against accepting an obligation for ships to carry personnel capable of providing full maintenance of the electronic equipment. The UK view is that maintenance is best served by carrying spare modules on the vessel, backed up by shore maintenance depots. The new GMDSS will eventually replace the existing, still largely manual, system by an integrated global system involving rescue co-ordination centres, automatic and satellite systems including 406MHz epirbs (emergency position indicator radio beacons) with later abandonment of the traditional 500kHz m.f. morse and auto-alarm distress frequency. It was agreed to introduce GMDSS in 1991, possibly with full implementation in 1997 but with no final cut-off date for the existing system. This has been left open so that for some years both systems will be operational.

The UK appears to have been particularly active in acquiring, often by footnote, additional frequency allocations for land-mobile. Several more European countries have joined the UK in making it possible for Band III (174–223MHz) television frequencies to be used on a secondary basis for land mobile. Television Bands IV and V (470–862MHz) have been footnoted as a 'secondary' allocation by the UK and a number of European countries. The band 1700–2450MHz has been raised to 'primary' status for mobile use in a footnote entered by the UK and nine other countries, similarly 5150–5250MHz by the UK and 17 other countries.

Diverse views were evident in respect of allocations for satellite-mobile services with the USA seeking significant provision, the UK seeing no urgent need and with every kilohertz fought over. However satellite service frequencies have been opened to some extent to allow low-priority passenger telephones (APC) in aircraft.

Frequencies for the new RDSS were approved on a worldwide basis but as primary allocations only in Region 2 and by 28 other countries, mostly in Africa. Elsewhere, including the UK, only on a secondary basis and with the constraint that RDSS should not be considered a 'safety' service.

Mike Goddard referred to the "footnote disease" now evident at the ITU conferences but it is clear that the UK is by no means immune to this infection which when endemic can make nonsense of many of the Radio Regulations. Some members of the audience were uneasy at the idea of the UK getting into bed with CEPT since the European PTTs "have never been bullish about satellite communications" and with differences of opinion between CEPT and the European Space Agency.

Nominally the conference also covered the amateur radio services, but no proposals were on the agenda. A Mexican proposal that would have seriously affected the amateur service was defeated. The Conference has recommended that another WARC be held not later than 1992 at which a full revision can be made to the frequency table between 1 and 3GHz, without the "minimum effect on other services" constraint, to make further provisions for mobile and mobile-satellite services.

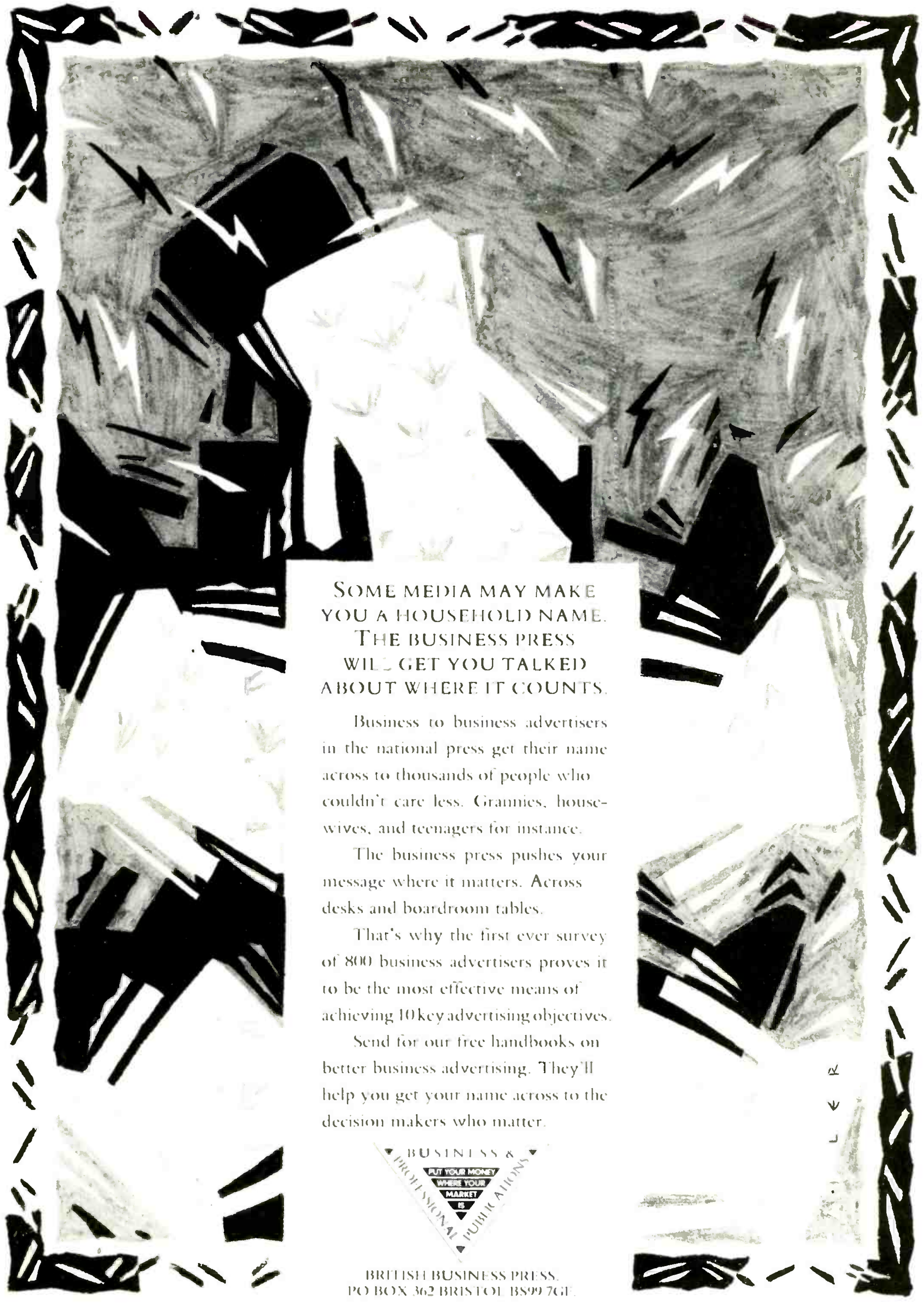
Costly r&d

In a keynote address to Radar-87, "consumer education in radar", David Barton (ANRO Engineering Consultants) pointed out that no less than 90% of major radar r&d projects end as failed projects, often due to the lack of understanding of the constraints of new technology on the part of the 'consumers' who always want the latest state-of-the-art technology without recognizing that established technology can often meet their needs better – a problem that extends far beyond radar development. He quoted the classic dictum of Watson-Watt, the "Rule of the Third Best: the best you never get; the second best arrives too late; always go with the third best".

His address thus echoed the views of J.P. Costas of synchronous detector fame who wrote some 30 years ago: "We may be far better off to improve what we now have rather than to seek a cure for our present problems by discarding completely the old and accepting something entirely different... True progress is achieved when improvements are obtained without a significant increase in complexity".

David Barton noted that although the now fashionable complex phased array antennas offer important advantages for radar, for some applications they are inferior to mechanically-pointed antennas in having dwell times so brief that detailed target information cannot be achieved by signal processing. Similarly he noted inconsistencies in customers now demanding solid-state transmitters: "For years, radar designers demanded that maximum power be obtained from a single thermionic device, as a result of which they were pushed to the limits of emission density, heat dissipation and breakdown voltage, with resulting reliability problems that remain today. About ten years ago, advances in transistor technology made it possible to consider development of solidstate radar transmitters. Even with advanced devices power levels were (and are today) pitifully low in the microwave bands. But the solidstate industry was not discouraged and their marketing efforts found assistance from the reliability engineer. The deficiency in power output was presented as a fundamental advantage: many separate sources would have to be combined, giving redundance and reliability. Radar customers who previously would not accept dual-tube transmitters, now began to insist on modular transmitters having hundreds or thousands of solidstate sources, in the name of reliability. Even with its multiplicity of modules, the usual solidstate design cannot compete economically with tubes unless the radar waveform is changed to permit use of very high duty factors. As a result, radar systems are being designed today in which the high-energy pulse, needed for maximum direction range, consumes almost half of that range as dead time."

Radio Communications is compiled by Pat Hawker.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Satnav from Inmarsat

Test position-determining signals are being transmitted by Inmarsat as part of a series of trials aimed at the eventual implementation of a radio-determination satellite system.

Transmitted spread-spectrum signals are generated by direct modulation with a pseudo-noise (p.n.) sequence at 1.023Mbits/s. A comparison of such signals from several sources enables the precise position of a receiver to be determined.

The p.n. signals are similar to those used by the US Global Positioning System (GPS), and it is intended that the same receivers could be modified to receive both. Inmarsat signals are including an almanac of the GPS satellites and it is intended that both systems can be coordinated to produce an integrated navigation service combined with the two-way communications capabilities of Inmarsat.

Test transmissions will be confined to the Atlantic Ocean region initially. A variety of power levels will be emitted to determine the minimum power that can provide an effective performance and to demonstrate that the navigation signals can coexist with the communications channels within the same band.

A technical specification of the test signals has been prepared and any organizations with L-band, and especially GPS, receiving equipment are invited to report on the reception of signals and suggest improvements to the implementation and format of the trials. At present, Inmarsat satellites provide only one signal source for many areas. However, they do have standby satellites in flight and further services will become available in 1989 when three of the second-generation Inmarsat II satellites will be launched. After the spread-spectrum trials, another system using coherent narrowband carriers is to be tested.

• One manufacturer who makes GPS receivers, Magnavox, has only just heard of the Inmarsat trials and has been unable to comment on the feasibility of the scheme. However it believes its equipment could be fairly easily adapted if the signals are as similar as Inmarsat says.

Magnavox has just annouced a new generation of receivers which are now reduced to a modular system that can be used as a stand-alone receiver or integrated into a wider system. The basic elements of a two-channel receiver are two p.c.bs, a receiver and a c.p.u. A third card can be added to recover the time codes transmitted by GPS satellites. Further channels can be received by the addition of extra receiver p.c.bs; two channels on each card.

Cad for replacement hips

A particularly beneficial application of computer-aided design is used for the disabled. Replacement hip, knee or other joints can be made to suit a particular patient by digitizing an x-ray picture of the joint and then designing the replacement by superimposing directly on to the image. The system was developed by Michael Tuke, managing director of Finsbury Instruments of Chessington, in conjunction with IDO Systems of Worcester, whose CadSolve workstation was used in the development.

The development has won an Archimedes award, sponsored by SKF (UK) with Cahners Exhibitions and *Eureka* magazine.

Science base needs funds –BA

In response to a discussion document from the Department of Education and Science, the British Association for the Advancement of Science (BA) has commented that an adequate science base is essential to the national economic and social aspirations. "The fundamental problem for British science is the shortage of funds. Additional funds are essential if an adequate science base is to be maintained.

"It is important to distinguish between research which extends the frontiers of science and scholarship which maintains the awareness of the frontiers.

"Concentration of human and financial resources is essential and should be undertaken on the basis of departments or subject areas within and between institutions, not on the basis of institutions as a whole. BA will not support the proposed R (research), T (teaching) and X (limited combination of research and teaching) classification of institutes of higher education.

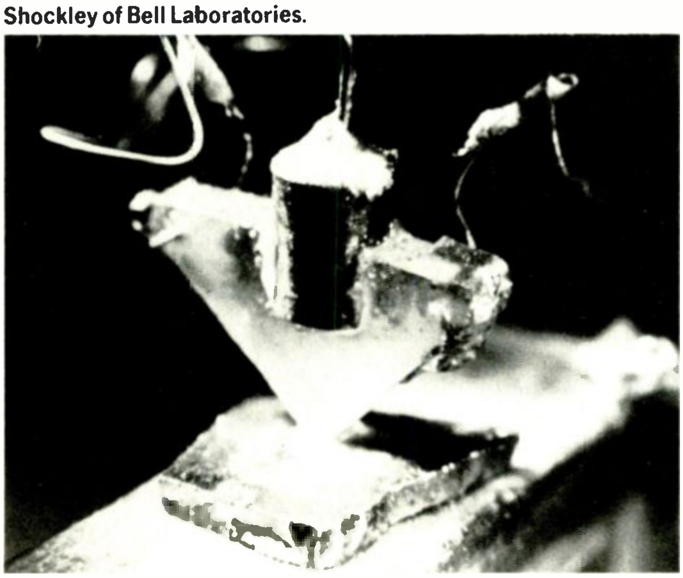
"Effective management of research in Universities is to be strongly supported. This enables ideas to flourish and individuals to achieve their potential.

"Development of interdisciplinary research is crucial. Effective methods of developing such cooperation must be developed, especially in areas where the interests of Research Councils overlap.

"Closer links between industry and higher education are essential to the effective exploitation of scientific research. The BA itself will play a more effective role in linking science and industry and in creating a climate of public understanding to lead to greater support for science."

The transistor – aged 40

Two days before Christmas 1947 came the appearance of this unprepossessing chunk of Germanium. It had the ability to transfer resistance hence the name transistor, coined by a colleague of the inventors, John Bardeen, Walter Brattain (see p.98) and William Shockley of Bell Laboratories.



Tape levy dropped in copyright Bill

Copyright, designs and patents are covered in a comprehensive Government Bill which is intended to reform and restate existing laws. Of particular interest to the electronics industry is the dropping of the proposed levy on blank tapes lobbied for so long by the recording industry. Kenneth Clarke, Trade minister, said that "any financial benefit to copyright owners and performers would be outweighed by the adverse effects the levy would have on consumers, especially visually handicapped people."

The bill extends copyright protection to computers, computer software and satellite broadcasts, and is "future proof" by making provision for such developments as artificial intelligence.

Amongst the other provisions are: higher penalties for copyright piracy; legal protection for original designs; easier litigation for patent and design protection; criminal proceedings against unauthorized use of trade marks; the protection of authors and directors who 'will have the right to be identifed on their works and to object to any unjustified modifications'.

Superconductors get Nobel prize

Researchers at the Zurich Laboratories of IBM have been awarded the Nobel prize for physics for "their important breakthrough in the discovery of super conductivity in ceramic materials."

Dr Georg Bendorz and Prof

Alex Müller made their discovery by abandoning hitherto conventional materials and experimenting with barium on crystals of lanthanum-copper oxide. Their success has led to a renewed search for high-temperature superconductors and many more materials have been found. The new materials have a critical temperature, i.e. when they become superconducting, of that of liquid nitrogen. This is quite easy and a lot cheaper to attain than that of previous superconductors which had to be cooled down to that of liquid helium, close to absolute zero.

Dr Jan Evetts of the Department of Material Science at Cambridge University offered his congratulations to the Nobel laureates and was pleased that the Royal Swedish Academy should be able to recognize the importance of the research so quickly, a matter of months after the discovery.

Dr Evetts told us that there is still much controversy between "competent people" as to the exact physical model of the superconductor. Anti-ferrous magnetic materials are doped to become superconductors, but *exactly* how they work is still a matter of some conjecture. Delays in further advances are inevitable until the mechanics can be better specified. The next step is to improve the critical current flow in the materials, rather than to seek even high temperatures.

Transputer take-off

Less than two years after the availability of the transputer processor from Inmos, a wide range of products is becoming available. An Inmos representative told us that this is the length of time needed to develop products and Inmos is now finding it difficult to keep up with the burgeoning numbers of even the major applications; from computer and workstation accelerators to digital signal and video processing, and even an embedded controller for a Japanese videophone.

Unix accelerator

One system, developed in the US by Microport, is the V/TT. Using an Inmos four-transputer plug-in card for the IBM PC, the computer can run the Unix operating system with "15 times the power of a VAX 780 or 50 times that of an IBM AT running Unix". This has proved to be a relatively easy implementation of the Unix system as the software 'pipes' that interconnect tasks in Unix have a hardware parallel in the inter-processor links of a transputer network; so the tasks can be re-allocated between processors, speeding up the system dramatically.

Microport Inc. specializes in implementing Unix systems on the PC.

Atari workstation with Mips

Another major announcement is the Abaq workstation from Atari. A prototype, on display at the Comdex computer show, was a plug-in add-on for the ST1000 home computer but the final product will be a self-contained workstation. The first appearance in Europe will be at the Hanover fair in March.

The prototype is housed in an expansion box which plugs into the computer and contains a T800 25MHz transputer with 4Mbyte of memory which may be expanded up to 64Mbyte. The box also contains three expansion slots and up to a further 12 transputers can be added to give a processing speed of 130Mips or 20Mflops.

The display software permits up to 4096 colours on a 1280 by 1024 pel screen or up to 16 million colours on 512 by 480 pels. Brooktree Ramdac video drivers and look-up tables are used. The price is likely to be about £3000.

Abaq has been designed in Cambridge (England) by Perihelion and is still being developed. It will incorporate a 'bit blitter', designed on a gate-array which will allow very rapid screen changes and animation. Perihelion Software, a sister company, is developing Helios, an operating system for the workstation which it hopes will become a standard for the transputer. Written in C, the o.s. will include support for occam, the Inmos parallel processing language.

Inmos for sale?

Rumour has it that Inmos is to be sold by Thorn-EMI who bought it from the National Enterprise Board. We are told that although Thorn has offered stalwart support through a difficult period, there seems to be little return on the investment. Semiconductor manufacturers rarely make a profit unless they also make products that incorporate their own integrated circuits, which is not the case with Thorn.

Transputer price cut

Meanwhile, Inmos has announced a considerable price reduction on the first generation of transputers, the T212 (50% off) and T414 (20% off) for buyers who want 100 or more.

In Brief

Walter Brattain, who along with John Bardeen and William Shockley invented the transistor, has died aged 85. The three were research scientists at Bell Laboratories at the time of the invention and were joint winners of the 1956 Nobel Prize for physics (*see also page 97*).

OS/2. The operating system for the new-generation IBM personal computer will be available from January. Several extensions to the system have been announced including AIX, an Unix-based o.s.; local-area networking; and a new version of the 3270 workstation program.

Brian Long, managing director of **Acorn Computers**, has resigned from the company having completed his assignment of returning the company to profit. His responsibilities will be taken over by Bruno Soggiu, chairman of Acorn. Mr Soggiu looks forward to further development of the risc system used in the Archimedes computer and to a series of Unix workstations, currently under development.

High-speed, high-capacity **eeproms** are to be developed jointly by Seeq technology and National Semiconductor. Each company will manufacture the other's products acting as second sources for each other. The flash eeprom can be erased and overwritten in a minute compared with about 20 minutes needed for u.v. eprom. This takes a single operation and can be completed in the host device, unlike the u.v. eprom which needs an eraser and a programmer.

An evaluation service for compilers of the **Ada** programming language has been set up by the British Standards Institute. The language has found use particularly in military applications. Checks on a compiler will include quality of code produced by the compiler; performance of optimizers; efficiency of the tasking system; quality of diagnostics and information provided by the system and the compile time performance. A 'test harness' is provided to allow the entire test suite, or selected parts of it, to be run automatically and to produce reports.

A prototyping service for electron-beam-produced asics has been set up in Hong Kong by Cambridge-based Qudos. Peter O'Keeffe of Qudos said: "We already supply a number of Hong Hong companies from the UK, so a local design centre will consolidate our position as an on-the-spot supplier of low-cost design and fabrication.

"It will also be a reference site for the increasing interest in asic technology shown by the People's Republic of China."

EXHIBITIONS & CONFERENCES

2 February, 1988
Electromagnetic compatibility seminar and exhibition. Heathrow Penta Hotel, London Airport. Organized by ERA Technology, tel. 0372 374151.

29 February to 4 March
Electrex 88. International electrical and electronics exhibition, NEC Birmingham. Electrex Ltd, tel. 0483 222888.

March 8 to 10
CIE 88. Components in electronic exhibition. Business Design Centre, Islington. Nutwood Exhibitions, tel. 04868 25891.

March 21 to 24
Video, audio and data recording. Seventh international conference. University of York. Details from the IERE, tel. 01-388 3071.

March 21 to 24
OCC 88. Offshore computer conference. Aberdeen Exhibition and Conference Centre. Offshore Conferences Ltd. tel. 01-549 5831.

March 22 to 24
Radionav 2000. International conference of the Royal Institute of Navigation. City University, London EC1. Details from the Institute, tel. 01-589 5021.

Cad/cam

STEPHEN HORN

Computers are fast becoming as much a part of the workplace as machine tools and tea breaks. The ever-increasing need for higher productivity and shorter lead times has created more and more interest in computers and their industrial applications. This has translated into an insatiable demand for qualified people who can get the most out of these new machines. "A lot of companies are expanding into computer automation, creating a big demand for experienced people – the problem is there just aren't that many on the market," said Maxime Dandy from Castle Recruitment.

One of the first stages towards complete automation is computerization of the design stage. According to a recent survey carried out by the British Institute of Management (BIM), companies are experiencing severe teething problems with automation and are hesitant about going too far, too fast. However, over one half of the firms surveyed said they were prepared to put a high emphasis on computer-aided design (cad).

"This is a very, very fast growing market with a very severe skills shortage, especially in certain areas," said Hilde Bartlett from Silicon Valley Recruitment. In terms of the electronics industry there are three specific areas of design interest, microchips, printed-circuit boards and general design work.

So what skills are most in demand? According to Bartlett, chip design is really taking off. "It's expanding like crazy and I don't think we'll see it stop in the next fifteen years," she said. Bartlett recognized shortages in this area, but described the market as buoyant with a good number of qualified people in it. She described it as an exciting area which readily attracts well qualified people.

The more mature p.c.b. market seems to be causing companies more of a headache. "I can't seem to get hold of people and when I do they charge the earth," she said. More and more companies are looking to computerize their design facilities in this area and there are too few people to meet the need. Bartlett illustrated this shortage by pointing to the number of contract people working in this area of the market.

Mike Patton from RNW Engineering Recruitment agrees and says the problem is especially acute when it comes to engineers experienced in 3D design. "There aren't that many 3D designers out there, pretty much the same as software engineers a few years ago.... there's a real shortage of these people." According to Graham Heaton from ATA Selection, 3D modelling skills are in such demand it took one automobile manufacturer 18 months recently to put a top-quality team together to work on the design of a new range of cars.

In general design work there seems to be shortages of certain systems. Some recruiters point to problems attracting Racal-systems-skilled people, while Bartlett says she needs more Medusa-trained people. For all these systems, the amount of training available is at a premium. A number of conversion courses and college courses are available, but it takes time for these to come through to the labour market.

The priority is for people to have experience so they can come straight in to a company and perform. Firms are anxious for their employees to be able to get on with the job straight away. "There is a very short honeymoon period," according to Patton. Some companies don't have the expertise to train people in new systems. "It's a chicken and egg situation," added Bartlett, "some companies haven't the experience to do the training, so they need to bring the skills in from outside."

With such a shortage of skilled personnel available, companies with the necessary expertise are prepared to take on trainees. A recent survey carried out by recruitment consultants Kramer Westfield showed that over 70 per cent of companies in the cad field are willing to take on new graduates, compared to an average of nearer 40 per cent in other, comparable occupations. Two thirds of the 784 companies surveyed would welcome more information on the candidates. Firms are particularly likely to take on people with some cad experience and then train them up in other aspects of the business, according to Maxime Dandy.

Graham Heaton from ATA Selection said that companies look favourably on youngsters who have completed a sandwich-type course. After finishing a B/TEC or HNC the trainee has "five years of street savvy.... they're presentable, articulate, and can genuinely think for themselves," he said. Interpersonal skills are clearly vital. "There's no reason why a young man with an HNC won't get employed – it's only when people walk into an office in jeans and a tee shirt as if they're owed a living that they won't get very far," Heaton said.

To be able to think for yourself is an asset employers look for when employing people for fast changing technologies. High on the list also comes communication skills. "Firms will often take somebody's who's not the last word in cad, if he has the personality to fit into a team," said Heaton.

Developing skills is important as the engineer moves up the corporate ladder. Too many engineers, it seems, can use the equipment without developing it to its full potential. "A lot of people can use the system, but only around 15 per cent get the full use out of it," said Heaton. A similar point was made by other consultants. "The cad/cam revolution has a good side and a bad side – a lot of youngsters can come up with designs, but they don't really know what they are doing." The elite engineers, and those most in demand, are those who can write cad programmes for others to use.

The need for cad engineers trained to get the best out of systems is well illustrated by looking at the experience of Flight Refuelling Systems (FRS). The company is one of the pioneers in deploying sophisticated manufacturing computer equipment in this country. Its present cad system, bought from US suppliers Computervision, was installed in 1982 and has been updated since to give faster access and better functionality. Company employees were sent on a Computervision training course to familiarize them with the system. As with many systems, it didn't quite do all the things FRS expected it to do, according to computer manager Graeme Stapenhill. Fundamental gaps had to be bridged and the system tweaked to meet the firm's needs. In addition, standard designs and data had to be built up before new designs could be attempted. "You're re-inventing the wheel for the first 18 months of operations," said Stapenhill. FRS's cad engineers clearly needed to know their system inside out to develop it to meet the company's needs.

Test and measurement specialists Wandel and Golterman recently conducted a recruitment campaign in the national press for design engineers. The company was looking for recent graduate trainees, engineers with two to three years experience after graduation, and senior engineers with analogue experience. Personnel officer Nigel Nightingale said they found these vacancies hard to fill. "We did fairly well in terms of numbers but not in quality," he said. "We had to work very hard to get the sort of people we needed."

The salary on offer seems to depend on the company and its location. On the question of money, according to Patton, academic qualifications do count. Again, while they may open the door, they are not the final word. "If somebody is a hot prospect, if they're good at what they do, they should have no problem in getting a good job on a good salary," he said.

For a trainee coming into a company with an HNC or a degree, starting salaries appear to be in the £8-9,000 range. After a couple of years experience wages tend to vary, but £12,000 to £15,000 seems to be fairly common. "It's after two years salaries really start to take off," according to Bartlett. With five years experience, senior engineers can command salaries of £20,000 or more. According to Patton, senior salaries often depend on how much responsibility the engineer is able to take on.

Wages also depend, to some extent, on location. With high costs of living and skills shortages, Thames Valley companies often have to offer the higher salaries. Even then, according to Patton, some engineers just don't want to relocate. Courses run by the National Computer Centre are one example, with no lack of takers in the north of England but a slow response in the south. However, for an engineer chasing a top salary, Patton describes this reluctance to relocate as an "unrealistic attitude".

Stephen Horn was formerly Employment Editor of Electronics Weekly

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Ref No: T4/87

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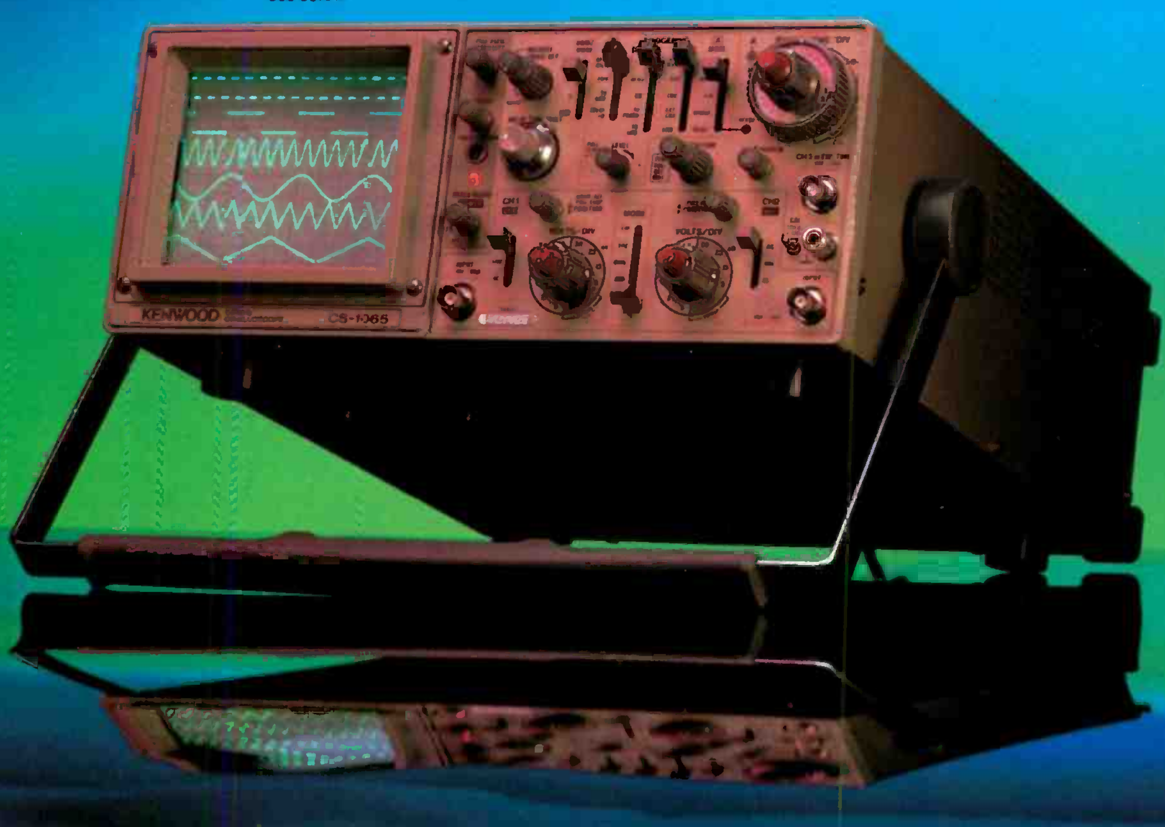

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