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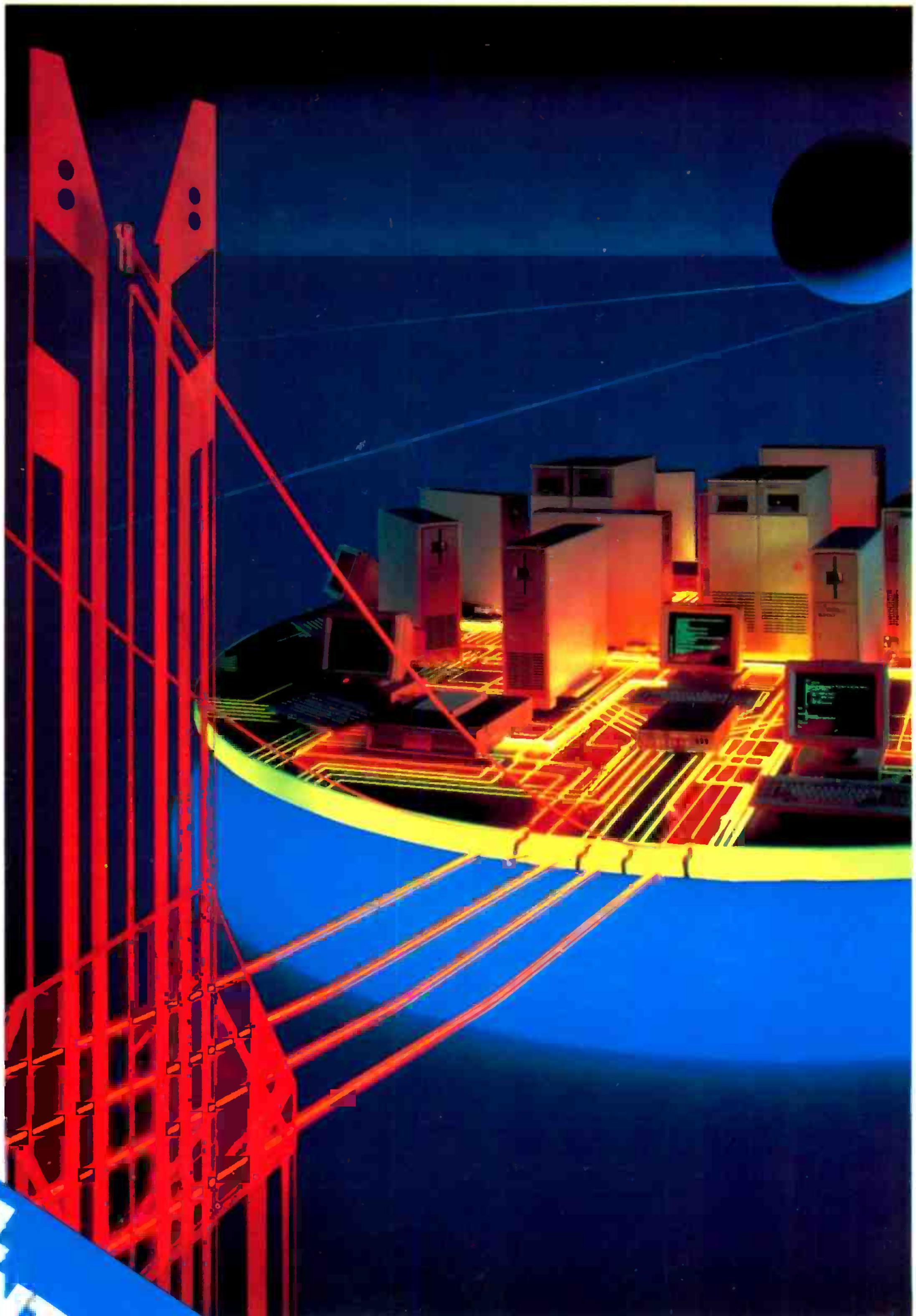

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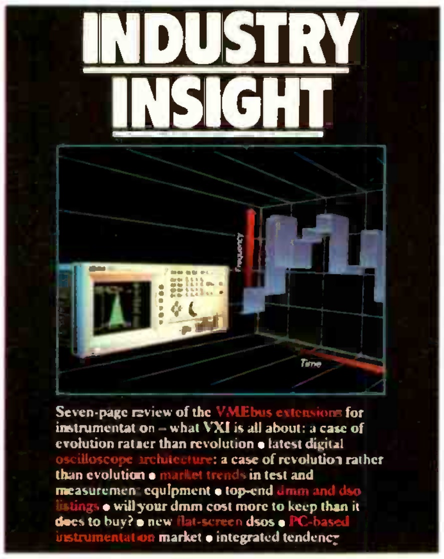

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REED BUSINESS PUBLISHING

It has been said – indeed, in our own columns – that there are literates and numerates, but not many literate numerates. Engineers, runs the common comment, might be brilliant at explaining the operation of the newest better mouse-trap by means of circuit diagrams and flow charts, but less than breathtaking when they have to describe it in words. Their lack of education in the skills of written communication has failed them.

Countering this criticism, those whose facility resides in doing rather than writing claim that, if their use of the diagram and flow chart provides a clear description of the mouse-trap, then they have suceeded in communicating and have no need of a polished prose style.

Both these arguments are, of course, simplistic: the first being the result of generalization and the second of reduction almost to absurdity. Engineers have probably been practical, green-fingered types since early youth, with only a long-way-second interest in "the arts", including writing, but nevertheless *are* able to express themselves in prose of one standard or another; and it is not sufficient to rely solely on pictures when explaining one's work to the public or even to the management.

The fact remains that the early education of both engineers and arts people has indeed failed them. While engineers can, as has already been mentioned, express themselves in prose to some extent and arts people have been known to exhibit an interest in science and engineering, there is still a divide and the inability to use the written language in an effective and attractive manner exists on both sides of it. Since the teaching of young children started to go wrong in the 1950s, English being considered unimportant and mathematics mis-taught to such an extent that vast numbers of people in their thirties and younger are hard put to it to add fifteen per cent v.a.t. to a hundred pounds, it seems that only an innate interest in a subject has allowed success in its study, the others being too difficult to progress in against a headwind of misguided teaching practices forced on teachers by "forward-thinking" educationalists.

These comments themselves are clearly over-simplified generalities, but contain a core of fact. There are outstanding schools and many outstanding teachers, but the base from which they stand out is plainly very low indeed.

Articles submitted to this journal are, in the main, successful at communicating their content, but some are far from easy to read and are unattractive. The comment applies over the whole spectrum of contributors: some of those who have a valuable point to make send in material which is badly written, scrappy, disorganized and generally presented in a manner which verges on the insulting, allegedly literate arts graduates being little, if any, better than their more practical brethen. The impression that must be gained from such experience is that the English language simply has not been properly taught.

David Brancher, writing in *The Times* for 26 November, 1987, expresses the opinion that a major corporation and a good university should co-operate in developing a "communications-competence" module, to be taught in universities. He goes on to say that "..any graduate who had taken the module, and passed well, would be interviewed by (the corporation) on the milk round, as a matter of priority". Surely, if the student has arrived at the age of 18 or so without the ability to communicate in words or pictures, one might begin to wonder what he is doing at university and how his teachers at primary and secondary schools whiled away the time during English and science classes. The time for learning "communication" is between the ages of 5 and 18 and it is an indictment of British post-War education that this is even a matter for discussion.

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Convolution – time-domain signal processing

Modern signal processing requires discrete-time versions of sampled-data systems and signals.

HOWARD J. HUTCHINGS

Historically, signal processing in the time domain has been avoided and the equivalent operation carried out in the complex frequency domain. But modern signal processing is compelling engineers to revise traditional methods and concentrate on discrete-time versions of sampled-data systems and signals. This approach is particularly rewarding because it unifies the signal processing operations in time and frequency domains.

Consider for example the dynamic behaviour of a linear system described by a differential equation in the time domain; it can be modelled either by a Laplace transform in the complex frequency domain, or by a Fourier transform in the frequency domain. Similarly, the dynamic behaviour of a sampled-data system is described by a difference equation in the time domain and by a z transform in the z domain.

In each of these examples the time-domain behaviour may be determined by the solution or inspection of the appropriate time-domain model. This article describes the operation of convolution and explains how it provides a time-domain solution of the dynamic behaviour of both analogue and sampled data systems, Fig.1.

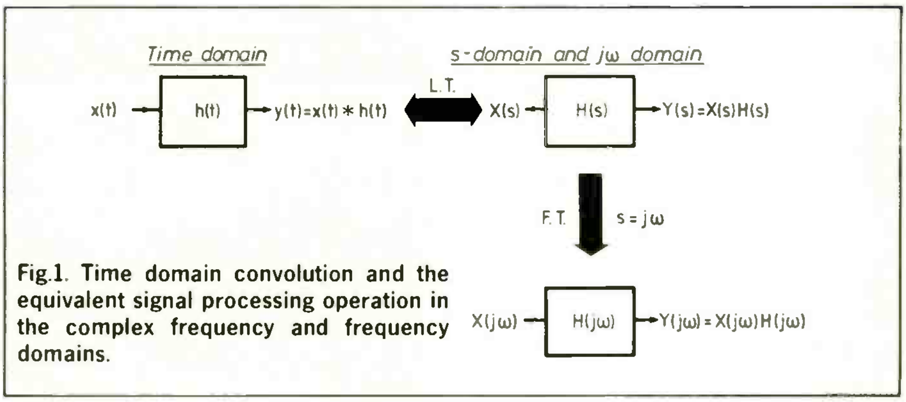


Fig.1. Time domain convolution and the equivalent signal processing operation in the complex frequency and frequency domains.

There is no distinction between the Laplace transform of signals and systems. This becomes clear when you examine the effect of applying a decaying exponential signal to the first-order system. Initially the signal processing will be accomplished in the complex frequency domain, Fig.2.

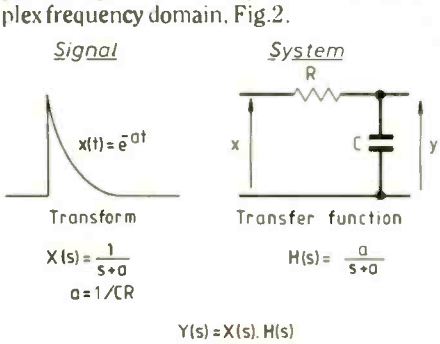


Fig.2. The signal and system are matched in the sense that the system impulse response is identical to the characteristics of the signal.

Clearly, the system's response is obtained by the operation of *multiplication*. This is equivalent to the operation of *convolution* in the time domain as the following contrasting examples illustrate.

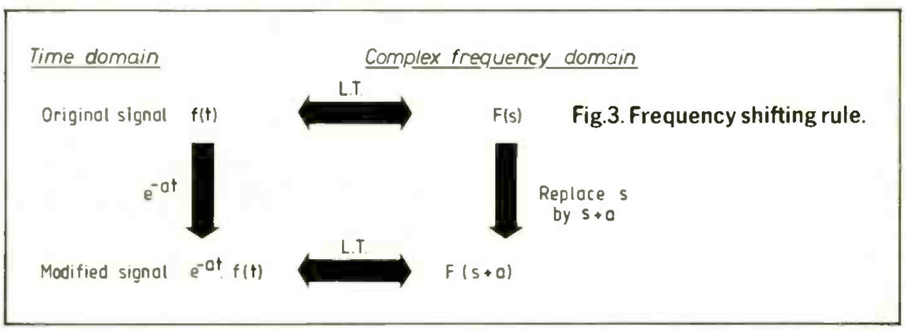


Fig.3. Frequency shifting rule.

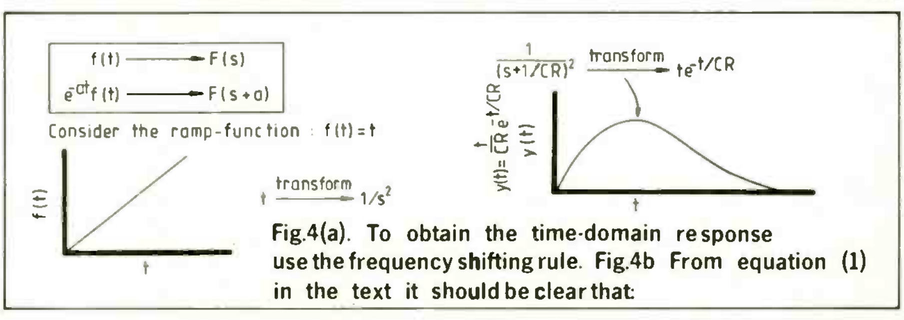


Fig.4(a). To obtain the time-domain response use the frequency shifting rule. Fig.4b From equation (1) in the text it should be clear that:

Consider first signal processing in the complex frequency domain.

$$y(s)=\frac{1/CR}{s+1/CR}\,\frac{1}{s+1/CR}$$

$$y(s)=\frac{1/CR}{(s+1/CR)^2}. \qquad (1)$$

To obtain the form of the time domain response it is expedient to use the frequency-shifting rule together with a table of Laplace transform pairs[1].

In a previous article[1] I demonstrated that a shift or delay of T seconds in the time domain gives rise to a multiplication by e^{-sT} in the complex frequency domain. A similar pattern exists for the frequency-shifting rule. If s is replaced by s+a in each term of the transform, the effect corresponds to multiplication of the original time domain signal by e^{-at}, Figs 3-5.

Now consider signal-processing in the time domain. Convolution is the name given to the ordered combination of multiplication and summation. The analogue operation of convolution is particularly unpleasant and difficult to visualize. Convolution of two continuous functions x(t) and h(t) is defined by the integral.

$$x(t)*h(t)=\int_{-\infty}^{\infty}x(\tau)h(t-\tau)d\tau$$

$$=\int_{-\infty}^{\infty}h(\tau)x(t-\tau)d\tau$$

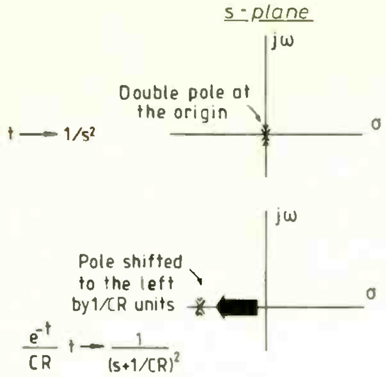


Fig.5 The Laplace transform of the ramp function $t \rightarrow 1/s^2$ gives rise to a double pole at the origin of the s plane. The frequency shifting rule has the effect of moving the poles to the left by $1/CR$ units.

Where the asterisk denotes the operation of convolution. Dummy variable τ symbolises excitation time, while the real variable t symbolises response time. The mathematical scaffolding states; multiply the input signal $x(\tau)$ by the time-reversed impulse response $h(t-\tau)$. Finally integrate the product over all time.

Applying the convolution integral to the signal and circuit shown in Fig.2,

$$y(t)=x(t)*h(t)$$

where,

$$x(t)=e^{-at}\quad h(t)=1/CRe^{-t/CR}$$

and,

$$y(t)=\int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau$$

$$=\int_0^t e^{-\tau/CR}.1/CRe-\left(\frac{t-\tau}{CR}\right)d\tau$$

$$=\frac{e^{-t/CR}}{CR}\int_0^t e^{-\tau/CR}.e^{\tau/CR}d\tau$$

$$=\frac{e^{-t/CR}}{CR}\left[\tau\right]_0^t$$

Finally, the processed output is

$$y(t)=\frac{t}{CR}e^{-t/CR}$$

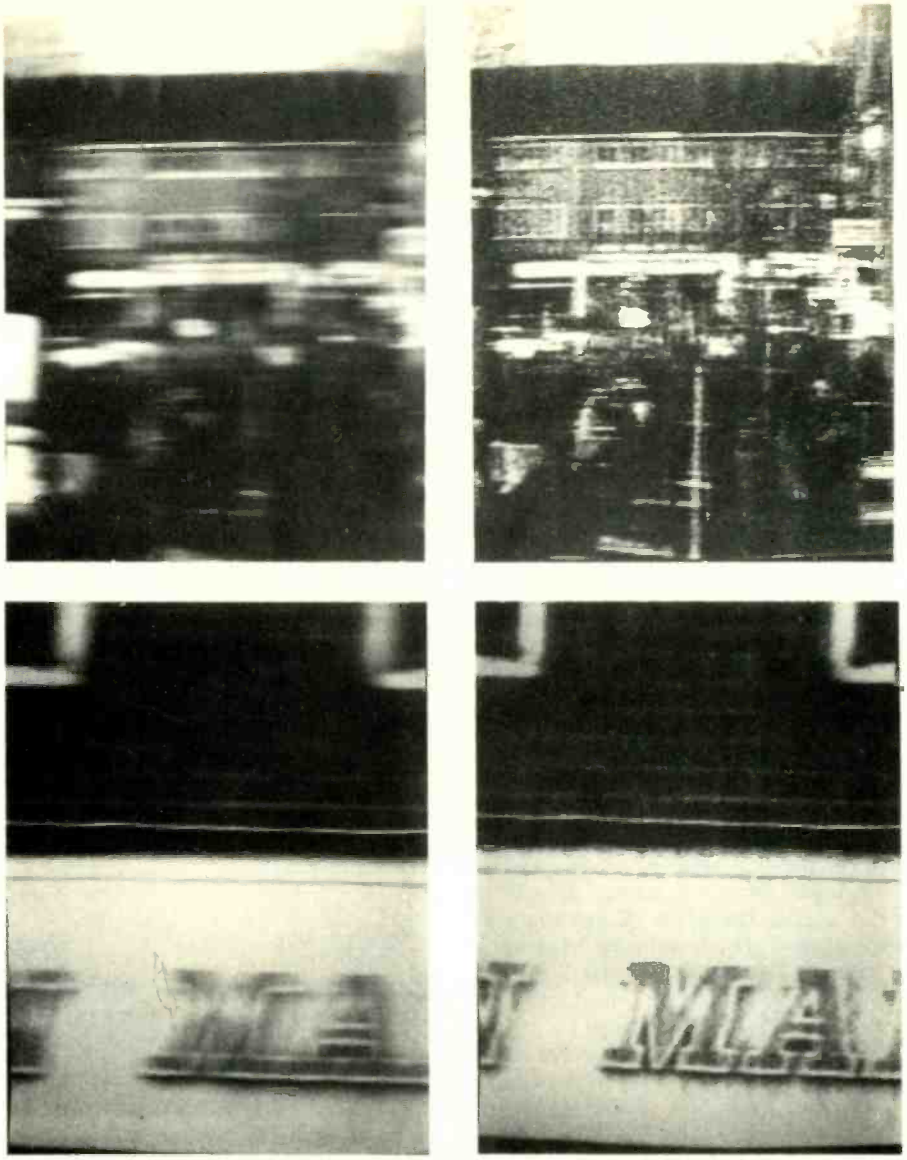
Compare this result achieved by time-domain convolution with the equivalent operation carried out in the complex frequency domain.

Reference

1. Hutchings H.J., Closing the loop (t,s and z domain representation of delayed signals), *Electronics and Wireless World*, January 1988, p.44.

Howard Hutchings is a senior lecturer with Humberside College of Higher Education and a part-time tutor with the Open University.

In his next article, Howard describes the digital-system equivalent of the first-order low-pass filter.



There is little that can be done to improve a blurred image by optical means but when the image is represented in digital form, the information can be manipulated mathematically. These blurred images, produced by a rotating camera, were deblurred using a convolution filter developed by Smith Associates of Guildford. The convolution filter is part of a high-speed image processing computer.

BOOKS

Music through Midi: using Midi to create your own electronic music system, by Michael Boom. Microsoft Press, £17.95. Non-technical introduction to the musical instrument digital interface and computer-controlled music-making, with a detailed look at four practical Midi systems: in a recording studio, on the stage, in a college's electronic music laboratory, and at home with a composer. Soft covers, 304 pages.

Computers and Telecommunications Networks by Michael Purser (Trinity College, Dublin). Blackwell Scientific Publications, £18.50. Lucid guide to the converging technologies of data processing and telecommunications: an explanation of networks for computer people. Sections cover basic concepts and switching techniques; store-and-forward systems; local area networks; ISDNs; OSI and message-handling systems; and the integrated broadband networks of the future. Soft covers, 323 pages.

Data communications and networks edited by R. L. Brewster. Peter Peregrinus for the IEE, £25. Detailed survey of present-day data communications and networks and a look into the future, with contributions from Plessey, Case Communications, STC, BT and universities. First principles; modems; transmission standards and interfaces; information services; local area networks; the UK ISDN; ISDN international standards; wide area networks; multiplexers and concentrators; communicating terminals and distributed intelligence. Hard covers, 231 pages including index (text is reproduced from camera-ready typescript); number 16 in the IEE's telecommunications series.

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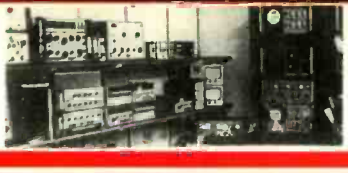

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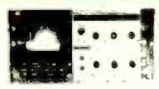

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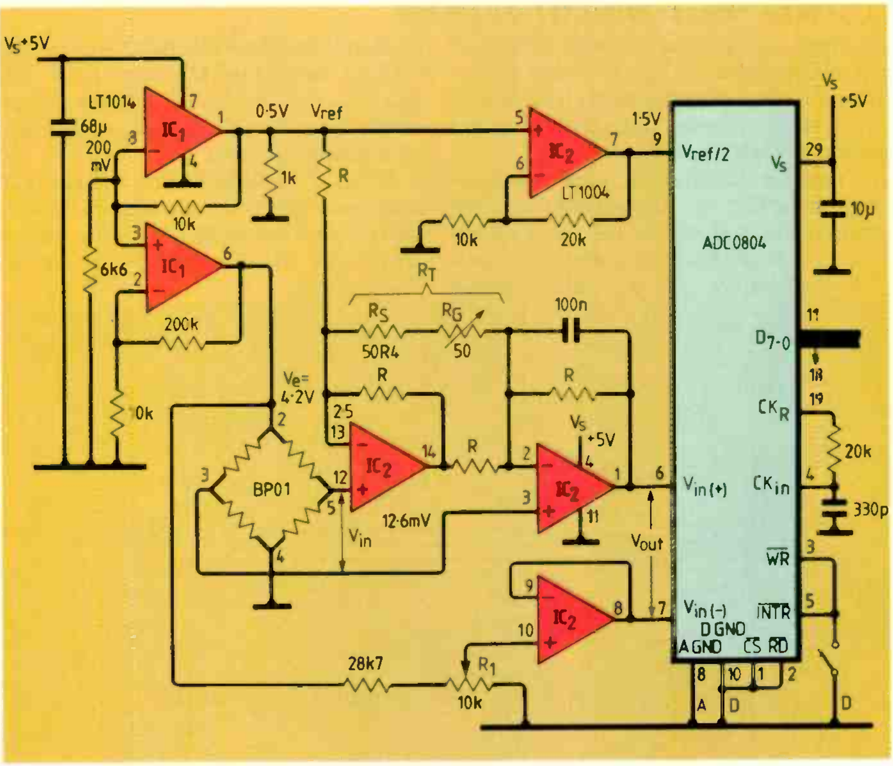
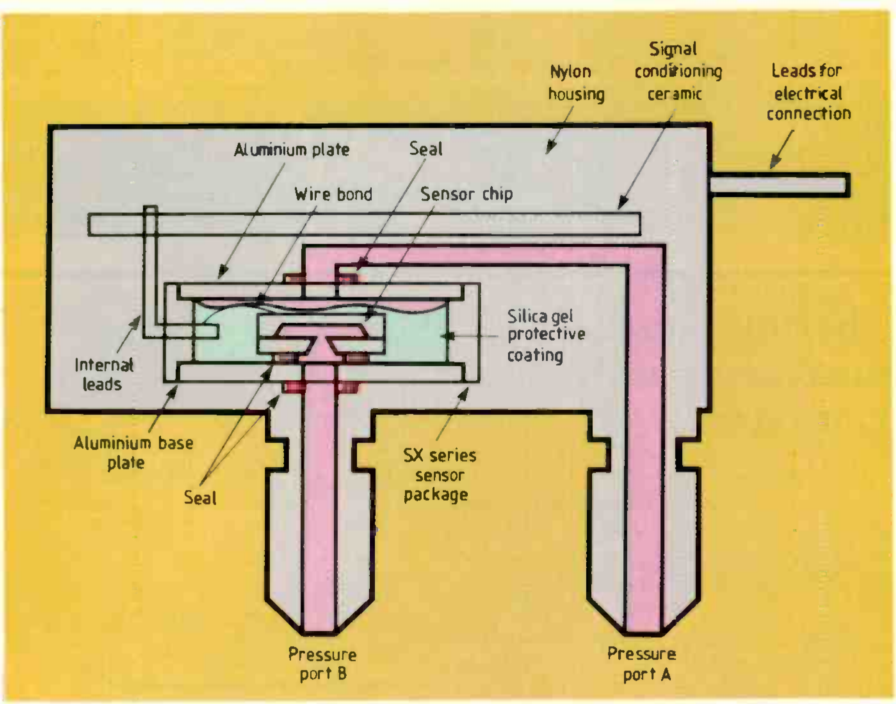
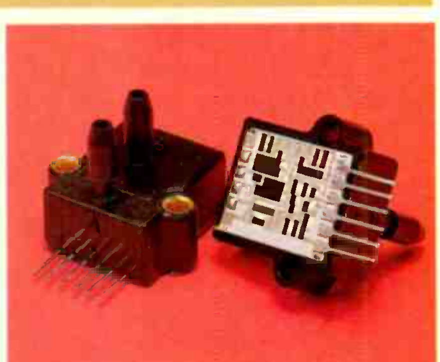




Sensor for blood pressure

Semiconductor blood-pressure sensors are more reliable than mechanical sensors since they have no moving parts. They have better long-term stability and they are more easily interfaced to computers and data loggers, as this circuit from the SenSym BP01 data sheet shows.

Within a 0 to 300mmHg pressure input range – the BP01 sensor's limits – the circuit provides free-running eight-bit parallel data proportional to pressure. Calibration of the circuit is easy and only a 5V supply is needed.



Reference and excitation voltages, which are independent of supply changes above 5V, are provided by the LT1014 op-amp and reference (or LM10). Reference voltage at pin 9 of the ADC0804 a-to-d converter is amplified to 1.5V so a full-scale output of all ones occurs when converter input is 3V.

When input pressure is 300mmHg, a senor excitation voltage of 4.2V results in a differential sensor output of 12.6mV. Before entering the converter Vin(+) input, this voltage is amplified to a level depending on the setting of R_G. Initial offset is adjusted by R_1.

On the digital side, data output is free running; the only requirement is that the WR and INTR signals must be momentarily grounded or taken to logic low on power up.

For many applications, elaborate calibration of the BP01 non-invasive blood pressure sensor is unnecessary since the difference between its output voltage at zero and full scale, nominally 15mV, is precalibrated to within 1%. At 0mmHg pressure input, output is within 300µV of 0V.

Response time of the sensor is 1ms, its peak-to-peak noise is 0.04mmHg and its impedance is 4kΩ, making it suitable for portable pressure monitoring apparatus.

The data-communications line interface shown in the photograph is BABT recognized and so reduces modem design approval time.

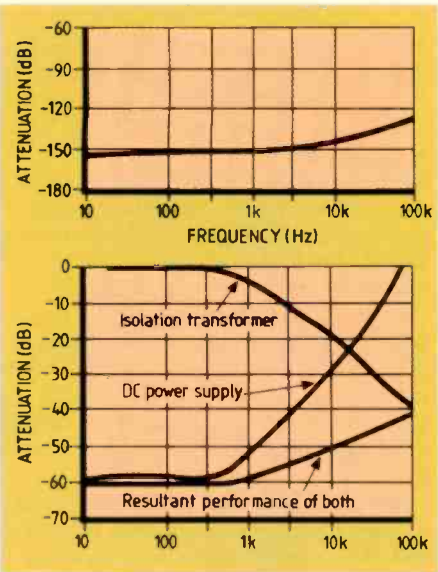
Modem routines

Standard routines and demonstration programs for Rockwell signal-processor-based modems are contained on an applications disc from RCS Microsystems.

The £30 disc — in IBM PC/XT/AT 360K format — is intended to simplify the writing of modem-driving software by providing software designers with subroutines written in 6500 code.

Demonstration programs included are specifically for RCS Zero-One-Q and Eleven-Q computers but they can be modified to run on other systems. Assembly language used is for the Avocet macro cross-assembler.

APPLICATIONS SUMMARY



Power-line disturbances

Of three publications covering aspects of mains interference, 'How to correct power-line disturbances' is the latest. It deals with types of interference, line monitoring and methods of reducing interference.

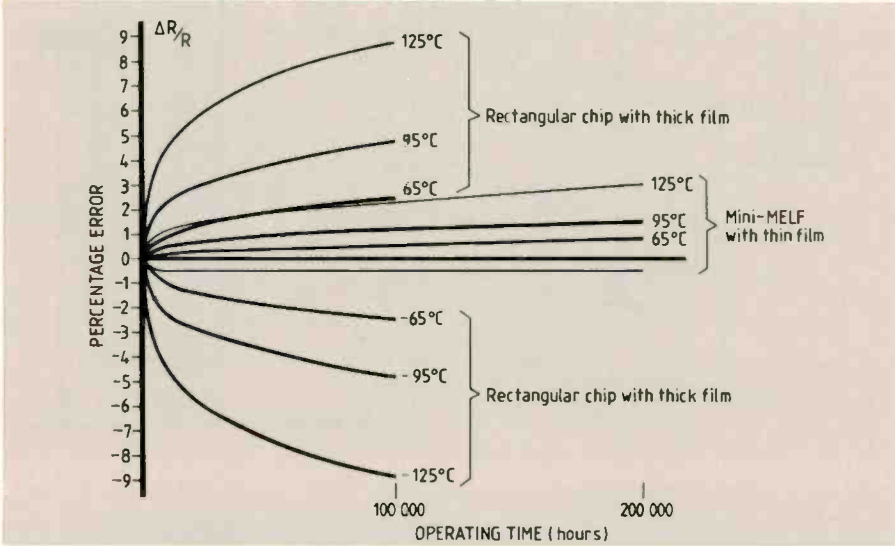
Typical common-mode impulse-attenuating capability of a high-quality isolation transformer is shown in the top diagram. The bottom diagram illustrates how isolation transformer and d.c. power supply combine to yield normal-mode impulse attenuation over the full frequency range. Fortunately, well designed d.c. power supplies exhibit considerable normal-mode noise-attenuating capability.

Producer of the brochure, Dranetz, publishes two other notes on mains interference called, 'Understanding power line disturbances' and 'How to identify power line disturbances'.

Resistors for surface mounting

In applications where stability is more important than cost, thin-film resistors with a vacuum-deposited metal film may be more appropriate than thick-film types. 'How to select SMD resistors for best efficiency' discusses the merits of using Beyschlag thin-film resistors against ordinary rectangular thick-film devices.

Long-term stability of resistance at various surface temperatures is shown in the graph on the right. Figures for rectangular chip capacitors are drawn from IEC draft 40(CO)620, 1985.



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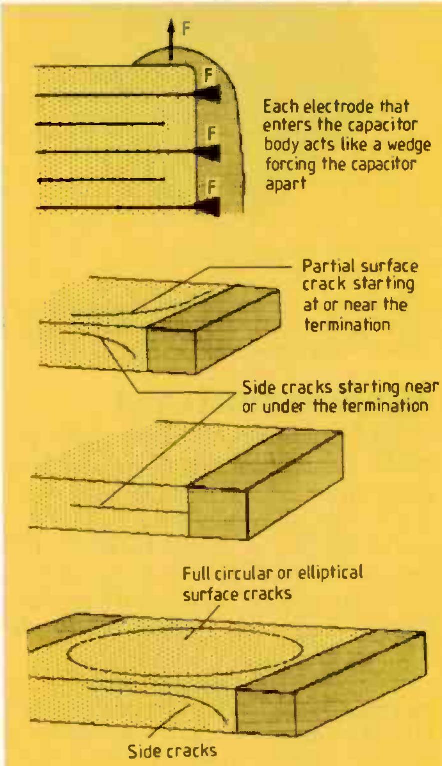
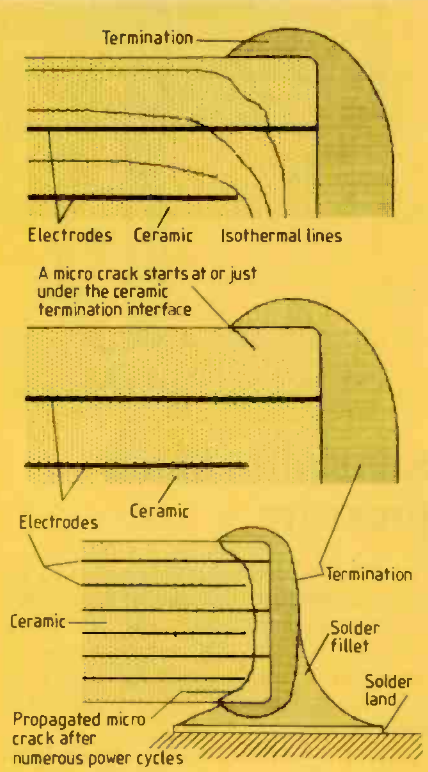


Thermal shock in surface-mounted capacitors

Surface mounted components are directly exposed to soldering temperatures. This direct exposure causes reliability problems when the temperature rises too rapidly, especially with multilayer ceramic capacitors.

During a temperature transient, mechanical stress is unable to spread throughout the component and fractures can occur. This is compounded by differences in thermal expansion coefficients and conductivities of the various materials within the capacitor.

Reducing thermal stress in multilayer capacitors is discussed in 'Surface mount soldering techniques and thermal shock in multilayer ceramic capacitors' from AVX; two other recent publications related to this are 'Factors responsible for thermal shock behaviour of chip capacitors' and 'Temperature profiles: the key for proper surface-mount assembly process control'.



Poynting the way

Another look at transmission lines

JOULES WATT

In many of my recent discussions, fact has often shown up stranger than fiction. In the present case our slight surprise rests on the fact that encoded data transmission – and digital at that[1] – developed before telephony. The wheel has turned full circle and we are back to sending messages by similar encoded digital methods. In the interim, telephones conveying direct speech dominated the scene.

The early engineers placed wires, and even used wires with earth return to save materials, alongside railway lines, on poles around the towns and countryside and in ducts underground. This is all a familiar piece of history now. The whole telecomms system went into very successful commercial operation with hardly any theory of signalling being properly understood. Workers managed just about everything with Ohm's Law – even sometimes without it. In other words, the bulk of the earliest work developed empirically.

Then came Maxwell[2] with his promise of *wireless* telegraphs and telephones. Although an amazing revolution at the time, and eventually put to very convenient use in telecommunications, wireless propagation and the earlier wired, or line, propagation differed little in basic principles. Both used electromagnetic waves, in the one case 'broadcast' to all and sundry, in the other, guided along the conductors.

What really became significant in all the methods of telecommunication turned out to be the wider and wider frequency bandwidth needed as the rate of signalling went up, together with the differing effects of the propagation media on the various frequency components in the signal. People only gradually realised the effects of these, although we note the genius of Oliver Heaviside, who fully grasped what delay and distortion produced by lines would do to the telegraph and telephone signals as the speed of sending and distances increased. Engineers soon experienced these problems, especially with undersea cable systems. Professor Pupin put Heaviside's theory to use in equalizers, which gave early line communication a new lease of life.

The other effect, the connection between bandwidth/signalling rate and noise, eventually gave rise to whole new disciplines, Communication and Information Theory. But the understanding of such ideas and relationships came surprisingly late, through the thinking of Hartley, Nyquist, Shannon and others[3].

ENERGY OF THE SIGNAL

Most people still imagine, like the early telegraph workers, that the electrical energy 'goes in the wires' by current driven by the e.m.f. But Maxwell's theory showed that energy can be propagated in space with no wires at all. This problem of what conveys the energy still causes argument. The 'circuit' view bases the energy flow on the voltage-current product VI (watts) operating in the circuit. It makes no assumptions about what is the current – whether 'electrons' convey it, and so on. In other words, the concept is only a simplified model. The explanation is quite sufficient for simple applications – wiring a house, operating loudspeakers across the room, getting the brake lights working on the car. There are no philosophical problems to worry about. Engineers are pragmatic. "If it works, then use it" and leave the niceties of what *really* happens to theoreticians.

We never know if such models are 'true'. In fact we suspect they probably are not, only good enough for the job in hand. Mind you, when the simplifying assumptions work and become accepted, an august body of (usually) mathematical modelling and theory builds up, to say nothing about conservative professional bodies, which to the unwary look very authoritative indeed. However beautiful the theory, it only models the situation in the way I mentioned – 'good enough for the job in hand'.

In this context, other than the circuit approach, there is another model, the 'field' view of things in which the watts flow in the space containing the **E** and **H** vector fields of the signal, whether conductors figure in the picture or not. We find the field view looked upon as somehow more fundamental than the circuit concept, which is often thought of as a simplified field view for 'small' circuits, i.e. those whose dimensions are small relative to the wavelength of the **E** and **H** waves. Any size circuit is 'small' for d.c., so wave aspects do not surface at all. Yet even in d.c. circuits there are electric and magnetic (static) fields of course.

POYNTING THE WAY

Earlier I mentioned what Maxwell said[2] and how Heaviside smartened up the notation and (with Willard Gibbs) gave us the modern vector field theory[4]. From that revisionary nibble at the ideas involved, the divergence and curl turned out to be most significant. The salient features of this mathematical modelling gave us the notation that div measures the scalar source strength generating a vector field, while curl measures the non-source ('closed loop') vector field that gives rise to another one *always at right angles* to the first.

In electromagnetic situations, we saw that a curl field turns up only if we *change* the generating vector field. Thus arose Maxwell's equations No 1 and No 2 in free space,

No 1. $\text{curl}\mathbf{H} = \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$ ϵ_0, the permittivity, describes the capacitance of free space. (farads m^{-1})

No 2. $\text{curl}\mathbf{E} = -\mu_0 \frac{\partial \mathbf{H}}{\partial t}$ μ_0, the permeability, is to do with the inductance of free space (henries m^{-1})

In a medium such as the ionosphere, for example, which conducts current, there will be a conduction term in No 1, so we have,

$$\text{curl}\mathbf{H} = \sigma\mathbf{E} + \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

You can see that No 2 states Faraday's Law, in which $\mu_0 \frac{\partial \mathbf{H}}{\partial t}$ acts as a magnetic displacement current.

No.1 shows Maxwell's contribution, in which he spotted that $\epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$ forms an electric displacement current.

We notice an important point arising from either or both of these equations. The field **E** *must* be at right angles to **H** at all places and at all times, because the curl operation is a vector product that always gives an orthogonal result. If you remember this, then sketches and mental pictures of fields in space, waveguides, coax. cables, around aerials and so on, all have the **E** and **H** fields at right angles.

In my earlier article[4], one theoretical vector identity turned out to have great importance in giving the wave equation, namely,

$$\text{curl curl}\mathbf{A} = \text{grad div}\mathbf{A} - \nabla^2\mathbf{A}$$

You will find that another one of these vector expansion identities turns out to have very useful properties[4,5],

$$\text{div}(\mathbf{A}\times\mathbf{B}) = \mathbf{B}.\text{curl}\mathbf{A} - \mathbf{A}.\text{curl}\mathbf{B}$$

This is a scalar equation, because div of any vector results in a scalar and the dot, or scalar products on the right hand side, also means a scalar result in each term.

Professor Poynting put this vector relation to good use in the case of electromagnetic wave radiation.

Place the vectors **H** (amps m^{-1} and **E** (volts m^{-1}) into the relation so that we have,

$$\text{div}\,(\mathbf{E}\times\mathbf{H}) = \mathbf{H}.\text{curl}\mathbf{E} - \mathbf{E}.\text{curl}\mathbf{H}$$

But from Maxwell, we know curl**E** and curl**H** in terms of the displacement currents,

$$\therefore\ \text{div}(\mathbf{E}\times\mathbf{H}) = -\mu_0\mathbf{H}.\frac{\partial\mathbf{H}}{\partial t} - \mathbf{E}.\left(\sigma\mathbf{E} + \epsilon_0\frac{\partial\mathbf{E}}{\partial t}\right)$$

Now from your elementary school calculus, you might remember that if $y = (x(t))^2$ then $\frac{dy}{dt} = 2x\frac{dx}{dt}$. Differentiation of vectors proceeds the same way via the vector dot product, so that we can re-write the first and last terms on the right hand side above as,

$$-\,\text{div}\,(\mathbf{E}\times\mathbf{H}) = \frac{1}{2}\mu_0\frac{\partial H^2}{\partial t} + \frac{1}{2}\epsilon_0\frac{\partial E^2}{\partial t} + \sigma E^2$$

Remember that in vectors, $\mathbf{E}.\mathbf{E} = E^2$.

As engineers, we get a little kick of satisfaction out of interpreting such modelling as this. Does the above vector equation give us anything from an engineering point of view? Remember the physical dimensions of all the quantities. The conductivity of the medium in the last term, σ, has dimensions siemens (for the old hands, "mhos") per metre. **E** has units, volts per metre; therefore σE^2 has units,

$$\frac{\text{volts}^2}{\text{ohm}}\times\frac{1}{\text{m}^3}$$

We know that V^2/R gives watts dissipated in a resistor as heat with V volts across it, so σE^2 means the watts dissipated by the EM wave field per cubic metre at the point in question.

Glance at the other terms. **H** has dimensions amps per metre, μ_0 is the henries per metre of the space so,

$$\frac{1}{2}\mu_0\frac{\partial H^2}{\partial t}$$

literally means "half the amps squared times henries per unit volume, per second". In other words, as $LI^2/2$ gives the joules stored in the field of an inductance, and

$$\frac{\partial}{\partial t}\left(\frac{1}{2}LI^2\right)$$

indicates the rate at which this energy is stored, i.e. the watts flowing into space inductance. This means

$$\frac{1}{2}\mu_0\frac{\partial H^2}{\partial t}$$

tells the story of the rate at which energy is being stored in the inductance of space per unit volume, by the growth of the magnetic field there. Similarly

$$\frac{1}{2}\epsilon_0\frac{\partial E^2}{\partial t}$$

gives the energy rate going into and stored by, the capacitance of space, per unit volume.

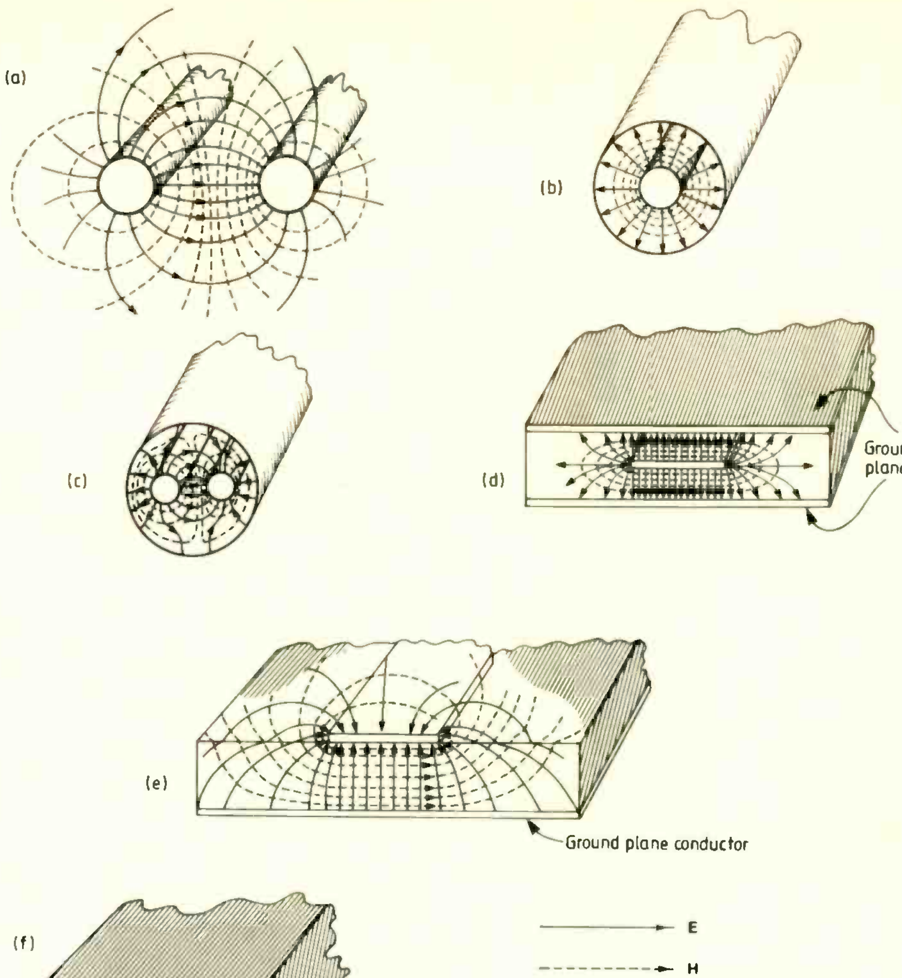
From your knowledge of energy conservation, you can see that the total energy rate going into storage and being dissipated as heat in the unit volume described by the right hand side of the above equation, must mean that its left hand expression, that is $-$div(**E**×**H**) describes the flow of this amount of energy per second into the volume through its boundary surface.

Notice the operation 'div' has dimensions "per metre", and **E** producted with **H** (the vector product is still a multiplication of units) is (volts × amps)/sq. metre, so that with the div operation, the result is "watts per cubic metre", just as we require.

The most interesting point here comes from looking at the product **E**×**H**, which is a vector normal to **E** and **H**, with dimensions power per unit area, watts/m^2. We call this vector **P**, Poynting's vector, which shows the magnitude and direction of the power or of energy current in the EM wave at any point. Now **E** is always at right angles to **H** in the same EM wave, so that in ordinary cases the requirement for the vector product doesn't come into it. Only the ordinary multiplication of the field magnitudes become involved, with the proviso that the energy flow is at the speed of light (in a vacuum) in the direction of the EM wave propagation.

$\therefore$ **EH** = energy flux density, or power density (watts m^{-2})

Radio astronomers use a small fraction of this quantity in their measurements. They call the unit $J = 10^{-26}\,W\,m^{-2}$ a *jan* after Janski – an early pioneer.



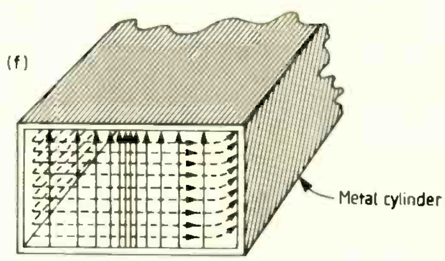


Fig. 1. In (a) the standard fields around the parallel wire pair show the right angle property of E and H well. Also evident is the spreading out, and therefore the likelihood of radiation losses and cross coupling when using such lines. The coaxial line (b) also has the fields crossing at right angles. But they are now confined to the interior of the outer sheath. The twin wire shielded line exists, as shown in (c). Triplate stripline and microstrip illustrated in (d) and (e) have become quite common in m.i.cs (microwave integrated circuits). These, and the waveguide shown in (f), also support fields at right angles, although in the waveguide whatever the mode, pure transverse wave are not possible.

All this indicates that the energy in electrical circuits, as well as in free space waves, propagates at or near the speed of light in the space around the conductors. How fast the actual charges (electrons?) move *in* conductors is a question that isn't asked.

TRANSMISSION LINES

Most students soon arrive at consideration of lines via the standard bookwork examples; parallel-wire lines and coaxial cables shown in Fig. 1(a) and 1(b). Other transmission lines now figure significantly in modern equipments, notably microstrip and, to a lesser extent, stripline. Dielectric guides also crop up, together with the now venerable single-conductor pipe lines called waveguides, still affectionately called r.f. "plumbing". Figure 1 also illustrates some of these.

You will notice usual methods used to analyse lines involve voltages and currents. The only unusual thing in addition to ordinary circuit theory is dealing with a time delay to account for the finite velocity of wave propagation. This is a kind of half-way house. Circuit concepts like voltage, current, inductance, capacitance and so on, all figure (see box) and a wave equation solution in terms of these quantities models the line. Heaviside again gave us all this.

When waveguides turn up for consideration, you have to use the full field treatment. Concepts like voltage, current and so on have little meaning for a single conductor which has a size significant compared to a wavelength. Maxwell's equations do the job again. In using these, Lord Rayleigh gave the propagation solutions for rectangular and circular cross section waveguides in 1896[6].

TEM SOLUTIONS FOR TWO-CONDUCTOR LINES

We can show off our growing knowledge of the div and curl operations on **E** and **H** fields by using it to revise the theory of propagation of r.f. energy along transmission lines, (and show that the results agree with the more usual 'circuit' method outlined in the box). The field integrals you end up with, doing it this way, would apply to any kind of Transverse Electro-Magnetic (TEM) wave guided system – if you could solve them! (These days, powerful numerical methods on computers can solve any finite integral by a vast series summing operation.)

I expect by now you have a reasonable picture of electromagnetic fields moving as transverse vibrations in space. Guided TEM waves only travel if we provide two separate conductors. You will find that if the conductors possess randomly shaped cross sections, waves still propagate along them, but difficulties occur with the awkward boundary conditions, so the messy numerical methods I mentioned with regard to the integrations become the only hope of solution. Even shapes interesting from an engineering point of view, such as those used to fashion dielectric supported microstrip lines, complicate the mathematics required and you will find it necessary to use 'guesstimation' from experience, computer-aided numerical design, or various approximate formulae/graphs.

We often refer to the TEM waves on transmission lines as the *principal waves* and you will see in a moment that there are no frequency cut-off limits. A principal wave will propagate from d.c. upwards in frequency. In practice, limitations at the high-frequency end are concerned with increasing dissipation in the dielectric and conductor losses, and with energy radiating away when the spacing between the conductors becomes comparable with the wavelength. Coaxial types of line screen against the radiation, but TE and TM wave modes (where there are longitudinal vector components of the fields) can be set up. These troublesome modes have differing velocities of propagation and loss factors, so tend to cause havoc. In spite of this, small-size, high-quality 'semi-rigid' coaxial lines appear in applications up to 18 GHz or so.

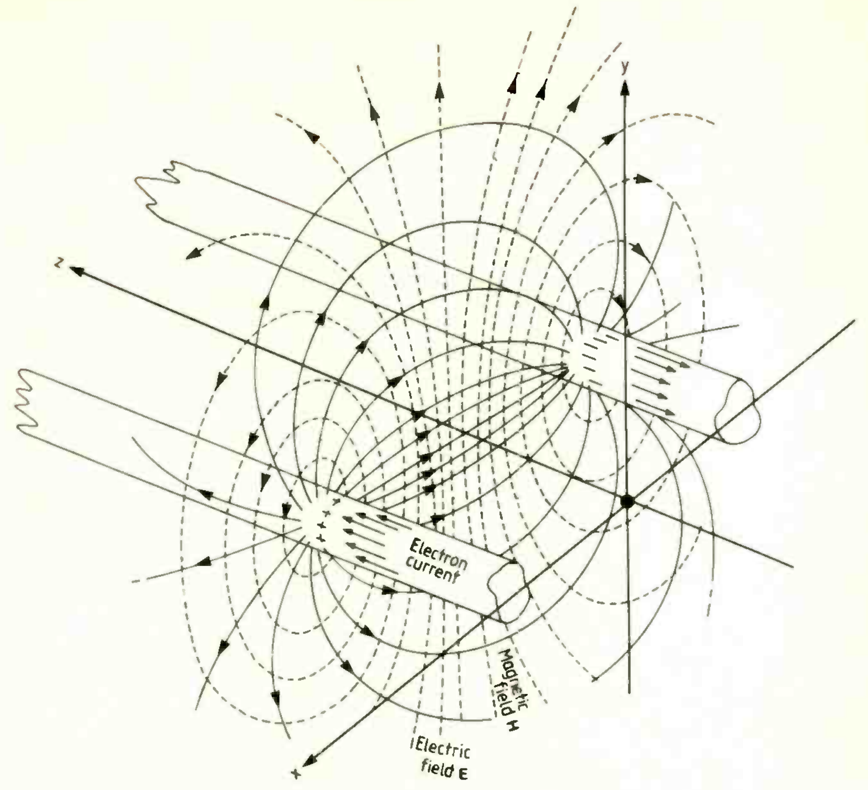


Fig. 2. The fields, currents and coordinate system for the parallel line shown in detail.

The lossless line guides the EM waves without a progressive decay in the energy density, unlike free space waves obeying the inverse square law. The attenuation that does occur arises from the conductor resistance and dielectric losses. We call this the Joule heating. A uniform line has an unchanging conductor cross section geometry along the line. This indicates we should use at least one linear axis coordinate system. Nearly everyone knows the Cartesian system, so the axis scaffolding on Fig. 2 seems most appropriate.

The electric field lines terminate at right angles on the conductors, (but see later for a slight modification to this statement). The magnetic field lines completely encircle one or other conductor; they all lie in the x, y plane, and cross all the E lines at right angles everywhere.

How would you apply the basic EM principles to show how waves propagate along the line, how the attenuation goes and what the impedance levels are and so on? If you can answer this question, then you could use the mathematical models to go some way towards designing real cable and transmission systems. Notice that, in Fig. 3, I have taken advantage of the orthogonal properties of **E** and **H** to construct a small volume whose edges lie along lines of **E** and **H** and also along the z – axis.

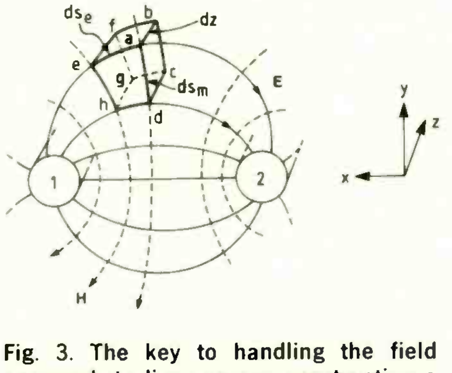


Fig. 3. The key to handling the field approach to lines means constructing a small volume in the space around the line, bounded by the E field lines, the H field lines and direction of propagation, z.

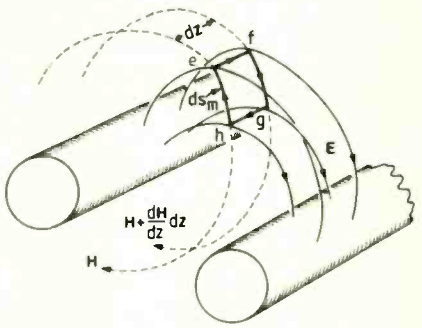


Fig. 4. This shows a curl journey around the H field loop.

FIRST, THE H FIELD AND THE CURRENT

Imagine looking along the **E** lines into the surface efgh. The circulation of **H** around the perimeter equals the total current flowing through the surface, by an application of Maxwell's No 1. This is the same as taking the line integral of **H** around the closed path efghe, as you can see from Fig. 4. Remember that the circulation *per unit area* at a point in a vector field is the curl of the vector there. In our example, we hardly have a line *integral* to do around efghe – it is too small. All we have to do is add the components of the field multiplied by the lengths along each side all the way round, to get the magnitude of the circulation of **H**. This gives in symbols,

$$\mathbf{H}ds_m + 0d_z - (\mathbf{H} + \frac{\partial \mathbf{H}}{\partial z}dz)ds_m - 0dz$$

I have deliberately shown the zero contributions from the journeys along the dz's. The result is

$$-\frac{\partial \mathbf{H}}{\partial z}dzds_m \qquad \text{(amps)}$$

(For interest, notice that if we divided this circulation by the area, $dzds_m$, what remains amounts to the curl of **H**, which is very simple for this problem.)

The total current through the dielectric has two components. You will notice a conduction current if the medium is leaky with conductance σ_d (siemens m^{-1}). Maxwell's displacement current forms the other part, with a density $\partial D/\partial t$ (amps m^{-2}). Use Ohm's Law on σ_d with the force field **E** setting up a current flux density **J**, according to $\mathbf{J} = \sigma_d \mathbf{E}$ (amps m^{-2}). You should now see that the total current through efgh amounts to,

$$\sigma_d \mathbf{E}dzds_m + \frac{\partial \mathbf{D}}{\partial t}dzds_m \qquad \text{(amps)}$$

The last two results for the current say the same thing,

$$\therefore \quad -\frac{\partial \mathbf{H}}{\partial z}ds_m = \epsilon\frac{\partial \mathbf{E}}{\partial t}ds_m + \sigma d\mathbf{E}ds_m$$

where I have cancelled the dz right through, so everything works "per unit length" along the line (z – axis . . .) now. Resist cancelling the ds_m because the next move is to integrate along the **H** field lines completely round the closed loop produced by them. In other words,

$$-\frac{\partial}{\partial z}\oint \mathbf{H}ds_m = \epsilon\frac{\partial}{\partial t}\oint \mathbf{E}ds_m - \oint \sigma_d \mathbf{E}ds_m$$

in which I have changed the order of differentiation with respect to time and integration with respect to distance (along **H**).

The line integral along **H** right round the conductor equals the current flowing through, see Fig. 5. That is,

$$\oint \mathbf{H}ds_m = i \text{ (amps) (this is Ampère's Theorem.)}$$

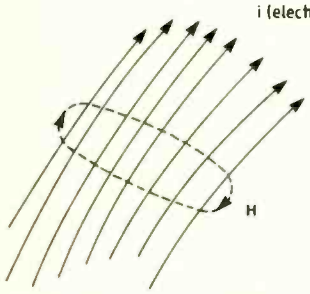


Fig. 5. A journey round the H loop gives the total current through the loop, by Ampère's Theorem.

NOW THE ELECTRIC DISPLACEMENT AND VOLTAGE

Have a look now at the surface integral for **D** taken right round the conductor. The result gives the total lines of displacement passing from one conductor across to the other per unit length of the line at our position along it and at the instant in time we are talking about. These lines end on charge, so you see we have the charge per unit length on the conductors of the line. In other words,

$$\oint \mathbf{D}ds_m \qquad \text{(coulombs } m^{-1}\text{)}$$

gives the instantaneous coulombs per metre on the conductors. $\partial/\partial t$ of this gives us the displacement current per unit length between the conductors – and in turn, this equals $C\partial v/\partial t$, where C is the capacitance between unit length of the conductors; in other words, the Farads per metre along the line. The voltage v is that existing between them. If you find difficulty seeing this, remember that q=Cv and in the situation I am discussing here, q is the charge per unit length on the line, which equals,

$$\oint \mathbf{D}ds_m \text{ and } v = \int_1^2 \mathbf{E}ds_e.$$

Notice that the integral for v is a line integral along a line of electric force from conductor 1 to conductor 2.

$$\therefore \quad C = \frac{\oint \mathbf{D}ds_m}{\int_1^2 \mathbf{E}ds_e} = \frac{q}{v} \text{ (farads } m^{-1}\text{)}$$

and I have already said,

$$\frac{\partial}{\partial t}\oint \mathbf{D}ds_m = C\frac{\partial v}{\partial t} \text{ (amps } m^{-1}\text{)}$$

INTERPRETING THE CONDUCTION TERM

The conduction term in the equation for the current above involves consideration of the transverse leakage per unit length which is

$$i_c = \oint \sigma_d \mathbf{E}ds_m \quad \text{(amps } m^{-1}\text{.)}$$

You have already seen from the preceding discussion that the potential between the conductors is

$$v = \int_1^2 \mathbf{E}ds_e$$

and from these quantities we can finally write,

$$\frac{i_c}{v} = G = \frac{\oint \sigma_d \mathbf{E}ds_m}{\int_1^2 \mathbf{E}ds_e} \quad \text{(siemens or mhos } m^{-1}\text{)}$$

This means we now have the conductance G between the conductors. By substituting all these results, the current equation becomes,

$$\frac{\partial i}{\partial z} = -C\frac{\partial v}{\partial t} + Gv \qquad \text{(amps } m^{-1}\text{)}$$

and we end up with one of the 'Telegrapher's Equations', see box.

THE SECOND TELEGRAPHER'S EQUATION

I was tempted to suggest you derive the other equation, which involves the resistance and inductance per unit length. Perhaps you still might like to attempt it, but there are one or two pitfalls that make it a little more difficult to account for the resistive losses along the line. In Maxwell's field theory no series resistance loss arises in space, no matter how lossy the medium.

We can manage the interpretation by

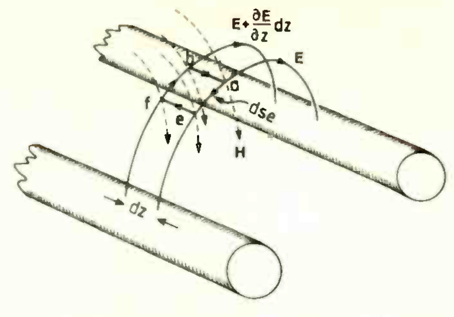


Fig. 6. Illustrated is the similar E field curl loop. The result this time is the magnetic flux rate of change through the loop. This is used to derive the second Telegrapher's Equation.

going round efbae with **E**, which gives its line integral (Fig. 6). You might notice that the magnetic field lines go perpendicularly through the small plane area of efba. Recall Maxwell's No 2 and use it like the previous derivation. You should end up with

$$-\mu\frac{\partial \mathbf{H}}{\partial t}ds_e = \frac{\partial \mathbf{E}}{\partial t}ds_e + \frac{\partial \mathbf{E}_z}{\partial s_e}ds_e \quad \text{(volts } m^{-1}\text{)}$$

(after cancelling dz again). The left hand side is the rate of change of the magnetic flux, with the minus sign of Lenz's Law in place. The first term on the right arises from the survival of curl **H**. The last term makes a contribution from any longitudinal component of the electric field. This requires some interpretation, as Maxwell says nothing about a longitudinal component. In fact, if there is one, we do not have a purely TEM wave.

I cannot think of a more suitable discussion than that from Oliver Heaviside, the master himself[7].

> "A line of electric force does not now start quite perpendicularly from the positive lead and end similarly on the negative lead. It has a slight inclination to the perpendicular, and therefore curves out of the reference plane to a small extent. In the dielectric itself, this peculiarity is of little importance. But the slight amount of tangentiality of the electric force at the surface of the leads . . . attenuate(s) and alter)s) the shape of the waves . . . "

So the problem looks like arising in the final term of the last equation and finding the longitudinal component of **E** that sets up a loss current in the conductors. We ought to integrate first right across from conductor to conductor to get the full effect, giving a brief interpretation of each term again,

$$-\frac{\partial}{\partial z}\int_1^2 \mathbf{E}ds_e = \frac{\partial}{\partial t}\int_1^2 \mu\mathbf{H}ds_e + \int_1^2 \frac{\partial \mathbf{E}z}{\partial s_e}ds_e \qquad \text{(volts } m^{-1}\text{)}$$

We identify $\int_1^2 \mathbf{E}ds_e$ as the potential between the conductors, and $\partial/\partial z$ of this is simply $\partial v/\partial z$ (volts m^{-1}).

The integral $\int_1^2 \mu\mathbf{H}ds_e$ (webers m^{-1}) is the magnetic flux per unit length linking the conductors. We know the definition of self inductance (henries) as the magnetic flux linking the circuit per unit current. We also know the current $i = \oint H ds_m$. From this we have

$$\frac{\int_1^2 \mu H ds_e}{\oint H ds_m} = L \qquad \text{(henries m}^{-1}\text{)}$$

∴ from the rate of change of flux,

$$\frac{\partial}{\partial t}\int_1^2 \mu H ds_e = L\frac{di}{\partial t} \text{ (volts m}^{-1}\text{)}$$

There remains the last term. The integral only has contributions at the surfaces of the conductors 1 and 2. Think of integrating element by element along the **E** lines; each longitudinal side dz cancels the one before as I attempt to show in Fig. 7. Another way you could look at this is to see that for this integration,

$\frac{\partial E_z}{\partial s_e} = \frac{dE_z}{ds_e}$ and you can write down the following relation,

$$\int_1^2 \frac{dEz}{ds_e} ds_e = \int_1^2 dE_z = E_{z(2)} - E_{z(1)} \text{ (volts m}^{-1}\text{)}$$

We have nearly completed our transformation of above voltage equation,

$$\frac{\partial v}{\partial z} = -\left[L\frac{\partial i}{\partial t} + E_{z(2)} - E_{z(1)}\right] \text{ (volts m}^{1}\text{)}$$

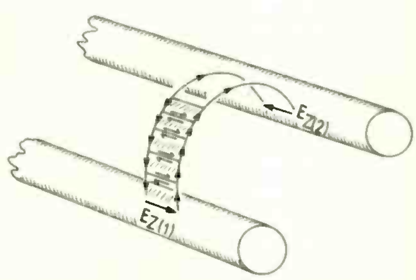


Fig. 7. This illustrates that if there is a longitudinal component of E field, the only place where it is significant is on the conductors.

During the discussion you may have been questioning how there can be a longitudinal electric field at all. Or more probably you have already seen that because of the voltage drop along the conductors, set up by the current flowing in their resistance (per unit length . . .), there must be a small resultant electric field component tangential to them, as Heaviside said. So write R(ohms m^{-1}) for the resistance per unit length along the conductor (for the moment, consider just one of them), then you can see from Ohm's Law that $dv_z = iRdz$ volts.

Therefore, $iR = \frac{\partial v_z}{\partial z} = -E_z$ (volts m^{-1})

This arises by dividing through by dz and making use of the relation between electric field and negative potential gradient.

The conductor might have a variable current density over the cross section. It may also have a non-uniform resistivity ρ (ohm m), which is unlikely – but you could give a moment's thought to silver-plated copper conductors or, very likely with modern technology, a microstrip line formed by

WAVES ON LINES

A pair of conductors of any cross sectional geometry that forms a transmission line, has a certain amount of inductance, L; capacitance, C; resistance, R; together with conductance, G – all defined per unit length. The diagram shows an equivalent circuit of this situation, from which we obtain the standard 'Telegrapher's Equations'. One further step yields the wave equation for TEM waves on the line. Assume a simple sinusoidal wave at this point and we get a straightforward result, even if the wave dies away exponentially because there are losses (the R and G) on the line.

The voltage decreases by dv as we go forward a distance dx. By Kirchhoff's Law, this equals the sum of the drop

$$L\frac{\partial i}{\partial t}dx$$

across the inductance and iRdx across R,

$$\therefore dv = -(L\frac{\partial i}{\partial t} + Ri)dx, \text{ that is, } \quad \frac{\partial v}{\partial x} = -(L\frac{\partial i}{\partial t} + Ri)$$

We get similarly for the shunt path (by using Kirchhoff's Current law),

$$di = -(C\frac{\partial v}{\partial t} + Gv)dx, \text{ in other words, } \quad \frac{\partial i}{\partial x} = -(C\frac{\partial v}{\partial t} + Gv)$$

These are the 'Telegrapher's Equations'.
We expect a wave on the line so, as such a wave varies as a function of time t and distance x, then a glance at the Telegrapher's Equations shows we have the appropriate variables in place.

Consider the sinusoidal wave in the form we have seen before[8].
The voltage wave: $v = Ve^{(j\omega t - (167 + j\beta)x)}$
In this, ω is the angular frequency as usual, α is the attenuation constant for the line and β is the phase change constant along the line.
This kind of assumed solution means that we can write $\partial v/\partial = -j\omega v$ and $\partial v/\partial x = -(\alpha + J\beta)v$ in the equations above, and similarly for the current. Now the two equations look like,

$$(\alpha + j\beta)v = (j\omega L + R)i \text{ and } (\alpha + j\beta)i = (j\omega C + G)v$$

If we divide the second of these into the first, we get the rate v/i which has the grand title of 'Characteristic Impedance', Z_0.

$$\frac{v}{i} = \sqrt{\frac{(j\omega L + R)}{(j\omega C + G)}} = Z_0 \qquad \text{(ohms)}$$

By multiplying the two equations together, v and i disappear and this is the result.

$$(\alpha + j\beta) = (j\omega L + R)(j\omega C + G).$$

This relation turns out to be quite tricky to handle. The multiplying out and taking the square root of the complex number on the right to get a and b on their own, is tedious. But if R and G are tiny with respect to ωL and ωC (true at high frequencies, because ω is large . . .),then neglect them, so that $\alpha = 0$ and $\beta = \omega\sqrt{LC}$.
Now our assumed wave function is (slightly re-written),

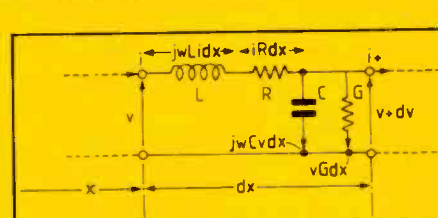
$$v = \hat{V}e^{-\alpha x}e^{j(\omega t - \beta x)},$$

so that the exponential decay clearly shows up in the "α" factor, and at the same time the phase varies both with time and distance along the line (as shown by the "j" exponent factor).
When we go along the line a distance x equal to the wavelength 1, the phase exponent decreases by 2π radians, therefore,

$$-\beta(x + \lambda) = -\beta x - 2\pi \text{ so that } \beta = 2\pi/\lambda$$

which shows us clearly the phase change property described by b. Finally in this short review $\omega/\beta = 2\pi f \div 2\pi/\lambda = f\lambda = c$ which is the velocity of the wave, and for the assumed lossless line $c = \sqrt{LC}$
If the line conductors work in a vacuum (or near enough, in air) then c for the wave on the line turns out to be the velocity of light.

The usual circuit equivalent to a small increment of the line enables the Telegrapher's Equations to be derived by applying Kirchhoff's and Ohm's Laws . . .



a very thin lower layer of nichrome, followed by a layer of gold and/or copper.

The voltage drop along a filament of conductor of length dz and cross section dA (m^2) can be easily written down if you assume a resistivity ρ, which is constant across the small section dA and with a current density of J (amps m^{-2}) flowing along in the z direction. Also assume this current density remains constant across dA. (If these quantities do vary as functions of, say, the radius, then working out possibly fairly complicated integrals will give an accurate result). The simple case gives

$$JdA\rho\frac{dz}{dA} = J\rho dz = dv_z \qquad \text{(volts)}$$

So from the potential gradient/**E** field relation, this is,

$$Ez = J\rho \text{ (volts m}^{-1}\text{)}$$

For our special case of uniform ρ and J (highly unlikely in practice) you can write

$$JA = i \text{ (amps) and } \frac{\rho}{A} = R \text{ (ohms m}^{-1}\text{)}$$

where A now represents the whole cross section. From this,

$$iR = JA\frac{\rho}{A} = J\rho = -E_z$$

and you see immediately $E_{z(1)} = -i_1R_1$ and $E_{z(2)} = -i_2R_2$. If you allow further that $i_1 = i$ and $i_2 = -i$, in other words that we have

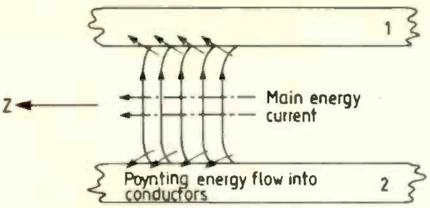


Fig. 8. The losses in the conductors 'distort' field direction, so that there is a net movement of energy current into the conductors from the field (seen by the direction of the Poynting vector).

equal forward and reverse currents at the same point z along the line, then

$E_{z(2)} - E_{z(1)} = i(R_2 + R_1) = iR$ (volts m^{-1})

where R is the total, or 'loop' resistance per unit length of the line. In the derivation, the values of R_1 and R_2 correspond to the d.c. values. This is never true in r.f. practice, because the skin effect ensures that the current crowds into a thin layer near the surface. The a.c. resistance differs often greatly from the d.c. value. Nevertheless if we place the appropriate R into the equation, a correct result turns up. So finally,

$$\frac{\partial v}{\partial z} = -\left(L\frac{\partial i}{\partial t} + iR\right) \qquad \text{(volts m}^{-1}\text{)}$$

. . . this is the second 'Telegrapher's equation.

There remains just one small comment that beady-eyed readers may already have noticed. This concerns the total inductance. By integrating from the surface of conductor to conductor, I neglected any internal inductance from flux linking current inside the conductors. The same argument about the skin effect now enables us to say that as the current is a thin surface sheet – then there is negligible internal inductance on r.f. lines.

CONCLUSION

In concluding this substantial discussion, if you have followed thus far, may I sum up by saying that a basic grasp of the field ideas the various integrations and the geometry in any particular case, should now enable you to see a way towards a solution.

The comment that there is a current shortage of r.f., microwave, and analogue engineers; plus the point a colleague made that students judge the subject 'very badly taught', or even as someone else said, 'I find it boring' – might I hope, result in this discussion being particularly useful. Boring indeed!?!

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Single op-amps or instrumentation amplifiers?

The apparently magical properties of the standard three op-amp instrumentation amplifier are explained. A straightforward analysis shows the circuit designer that the instrumentation amplifier is not always better than a simple single op-amp differential amplifier.

JOHN LIDGEY

The ideal differential voltage amplifier is a circuit providing an output voltage, generally with respect to ground, that is linearly related to the potential difference between two input terminals. The constant of proportionality is the differential-mode voltage gain, A_{vd}. In an ideal amplifier, if there is no voltage difference between the two input terminals but both terminals are being fed with a common voltage with respect to ground, the output should be zero. In practice, such a common-mode input voltage will be significantly attenuated but not totally absent at the output. The ratio of common-mode output voltage to common-mode input voltage is termed the common-mode gain, A_{vc}. In point of fact, the term common-mode attenuation would really be more appropriate, since the term gain generally implies an output greater than the input, which is almost never the case. Mathematically, the output voltage can be written as

$$V_o = (V_2 - V_1).A_{vd} + \tfrac{1}{2}(V_2 + V_1)A_{vc} \qquad (1)$$

where the differential input is $(V_2 - V_1)$ and the common-mode input is $(V_2 + V_1)/2$.

The term common-mode rejection ratio, c.m.r.r., is defined as the ratio of A_{vd}/A_{vc}. It is a useful figure of merit for comparing various differential amplifiers. The ideal differential amplifier with zero A_{vc} would clearly have infinite c.m.r.r. In practical circuits, this figure might be in the range 100 to 1,000,000, depending upon the particular design and component matching.

Probably the other most important parameter to be considered when using differential amplifiers, is the input common-mode voltage range (input c.m.v.r.), defined as the range of common-mode input voltages that the amplifier can tolerate and still perform correctly as a linear differential amplifier. The input c.m.v.r. is limited because of the necessity to keep the op-amp or amps operating within their linear active region, with inputs neither excessively high or low in potential nor the outputs reaching voltage or current clipping levels. The value of input c.m.v.r. for a particular differential amplifier circuit depends very much on the choice of amplifier topology and is likely to range in practice from 10 volts to 5000 volts.

Generally higher values are achieved with either an opto link or an a.c./d.c. link of some description.

CONVENTIONAL DIFFERENTIAL AMPLIFIER

The standard differential amplifier circuit shown in Fig.1. is designed to have $A_{vd} = N$. However, as the following analysis shows, the c.m.r.r. is critically dependent upon precisely matched resistors.

Assuming that the op-amp is ideal and using normal op-amp analysis for circuits with negative feedback (that is $V(-) \simeq V(+)$ and $I(-) \simeq 0 \simeq I(+)$), then the output voltage is given by

$$V_o = k_1 V_1 - k_2 V_2 \qquad (2)$$

where

$$k_1 = \left(\frac{R_4}{(R_3+R_4)}\right)\cdot\left(\frac{1+R_2}{R_1}\right); k_2\left(\frac{R_2}{R_1}\right)$$

Now, if the input signals are common-mode only, that is $V_1 = V_2$, then (2) gives the common-mode voltage gain,

$$A_{vc} = k_1 - k_2 \qquad (3)$$

Similarly, if $V_1 = V_d/2$ and $V_2 = -V_d/2$, that is the differential-mode voltage is V_d and the common-mode voltage now is zero, then (2) gives the differential-mode voltage gain,

$$A_{vd} = \tfrac{1}{2}(k_1 + k_2) \qquad (4)$$

and from the definition of c.m.r.r.

$$\text{C.m.r.r.} = A_{vd}/A_{vc} = \tfrac{1}{2}(k_1 + k_2)/(k_1 - k_2) \qquad (5)$$

from (3) and (4). Rewriting (5) by substitution for k_1 and k_2

$$A_{vd} = \tfrac{1}{2}(R_1R_4 + R_2R_3 + 2R_2R_4)/(R_1R_3 + R_1R_4) \qquad (6a)$$

$$Av_c = R_1R_4 - R_2R_3)/(R_1R_3 + R_1R_4) \qquad (6b)$$

$$\text{c.m.r.r.} = \tfrac{1}{2}(R_1R_4 + R_2R_3 + 2R_2R_4)/(R_1R_4 - R_2R_3) \qquad (6c)$$

Remember that in all this we have assumed that the op-amps are ideal: however, unless the matching of the resistors is perfect, the c.m.r.r. will not be that high. The match condition from (6c) that gives highest c.m.r.r. ideally infinite, is clearly

$$R_1R_4 = R_2R_3 \text{ or } R_1/R_2 = R_3/R_4 \qquad (7)$$

The best choice from the viewpoint of satisfying (7) and simultaneously providing bias current compensation to minimize output d.c. offset is to make

$$R_1 = R; R_2 = NR; R_3 = R \text{ and } R_4 = NR \qquad (8)$$

Now these components will each have the value shown in (8) subject to variation due to normal manufacturing and practical tolerances and therefore it would be more appropriate to write the values of (8) as follows

$$R = R(1+\delta_1); R_2 = NR(1+\delta_2); R_3 = R(1+\delta_3) \text{ and } R_4 = NR(1+\delta_4) \qquad (9)$$

where δ_1 refers to the departure of the R_1 from its nominal value and so on. That is, the set of equations (8) are the nominal values of the resistors and the set of equations (9) refer to the exact values of the resistors. If the components are, say, ±1% tolerance then the range of δ will lie within −0.01 and +0.01.

Returning again to (6a) for the differential-mode voltage gain, substitution of the nominal values of resistors from (8) gives

$$A_{vd} = N \qquad (10)$$

this being the expected (nominal) value of differential-mode voltage gain. Clearly the nominal value of c.m.r.r. from (6c) is infinite, but what is of greater interest is the exact value of c.m.r.r. for any particular set of resistors or, even more useful, the worst-case c.m.r.r. for a given tolerance of component. This is relatively easily obtained by substituting the expression for resistors from (9) into (6c), which if $\delta_1\delta_k$ terms are neglected as they are relatively small for high-tolerance components, gives the c.m.r.r.

$$\frac{N(1+\delta_2+\delta_4)+(1+\delta_2+\delta_4)/2+(1+\delta_2+\delta_3)/2}{(\delta_4+\delta_1)-(\delta_2+\delta_3)} \quad (11)$$

which further approximates to

$$\text{c.m.r.r.} \simeq (N+1)/(\delta_1+\delta_4-\delta_2-\delta_3) \quad (12)$$

for high-tolerance components in which $\delta_j << 1$.

So what does equation (12) actually tell us? Suppose we are dealing with a unity differential-mode voltage-gain amplifier and we have used ±1% tolerance resistors, then (12) provides a figure for the worst-case c.m.r.r.

$$\text{Worst-case c.m.m.r.} = \pm\frac{2}{0.04} = \pm 50$$

This means that, unless the resistors are accurately trimmed to better than ±1% we might obtain a circuit with unity A_{vd} that only attenuates common-mode voltages by a factor of 50; not a particularly high value of c.m.r.r. At first sight, one might be tempted to think that trimming to better than ±1% is simple. Initially, perhaps, but will the trim be that accurate over the temperature range that the circuit is to operate and will the trimmer setting be a once only operation? Clearly the answer to both these questions is almost certainly no.

DIFFERENTIAL INSTRUMENTATION AMPLIFIER

The conventional differential instrumentation amplifier is shown in Fig.2. Essentially there are two identifiable voltage gain stages: the one to the right hand side of the broken line AA being exactly the same circuit as Fig.1, the analysis of which we have already carried out. The circuit to the left hand side of AA is a differential-input to differential-output amplifier which, as the analysis will show, has unity common-mode voltage gain, and the differential-mode voltage gain, determined by R_6, R_7 and R_5, can be very high.

Let us analyse the pre-amplifier stage to the left of the line AA and then consider the total performance of the amplifier. Again assuming that the op-amps are ideal, then inputs V_1 and V_2, will produce node voltages of

$$V_w = V_1 \text{ and } V_z = V_2$$

and, using Kirchhoff's laws, the output nodes X and Y of this circuit are given simply by

$$V_x = V_1 + (V_1 - V_2)\,R_6/R_7$$
$$\text{and} \quad V_y = V_2 - (V_1 - V_2)\,R_5/R_2 \quad (13)$$

There is zero differential-mode input if $V_1 = V_2$ and then $V_x = V_y = V_1$, giving a common-mode voltage gain of unity.

If we now consider the situation in which the inputs are differential only, that is

$$V_1 = V_d/2 \text{ and } V_2 = -V_d/2$$

then, from equation (13), we obtain the node voltages of

$$V_x = (1/2 + R_6/R_7)V_d$$
$$V_y = -(1/2 + R_5/R_7)\,V_d \quad (14)$$

and the differential-mode voltage gain of the first stage is

$$A_{vd} = (V_x - V_y)/V_d = (1 + (R_5 + R_6)/R_7) \quad (15)$$

As nodes X and Y are at low impedance, then the overall gain of amplifier is simply the product of the gain of each stage calculated separately, that is

$$A_{vd(total)} = A_{vd1}.A_{vd2};\ A_{vc(total)} = A_{vc1}.A_{vc2}$$
$$\text{c.m.r.r.}_{(total)} = \text{c.m.r.r.}_1.\ \text{c.m.r.r.}_2$$

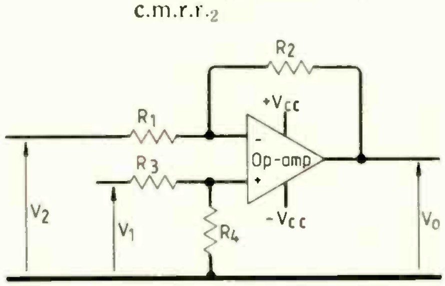
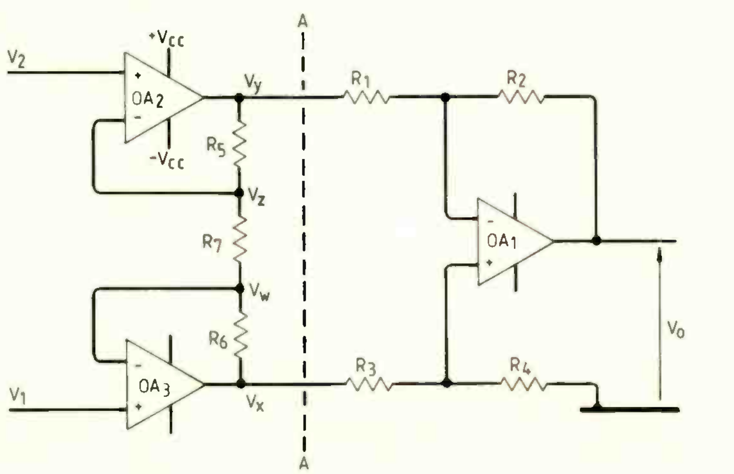


Fig.1. Standard differential amplifier, in which common-mode rejection is heavily dependent on resistor matching.

Fig.2. Conventional differential instrumentation amplifier. The circuit to the right of the dotted line is identical to that in Fig.1.



The nominal value of total differential-mode voltage gain is

$$A_{vd(total)} = (1 + (R_5+R_6)/R_7).R_2/R_1 \quad (16)$$

where, as before, $R_2/R_1 = R_4/R_3$

The most interesting feature of the instrumentation amplifier is the fact that the common-mode voltage gain of the total circuit remains determined solely by the common-mode voltage gain of the second stage. Since $A_{vc1} = 1$ then c.m.r.r., is

$$Avd_1 = \left(1 + \frac{R_5(1+\delta_5)}{R_7(1+\delta_7)} + \frac{R_6(1+\delta_6)}{R_7(1+\delta_7)}\right) \quad (17)$$

Generally, to preserve circuit symmetry and enable equal value components to be used, R_5 is nominally set to equal R_6 and may be written as $R_5 = R_6 = MR_7$, and so equation (17) reduces to

$$\text{c.m.r.r.}_1 = \left(1 + M\frac{(1+\delta_5)}{(1+\delta_7)} + M\frac{(1+\delta_6)}{(1+\delta_7)}\right) \quad (18)$$

and, since we recognise that component tolerance must be good, we can neglect the δ_j terms and equation (18) approximates to

$$\text{c.m.r.r.}_1 \simeq (1 + 2M) = A_{vd1(nominal)}) \quad (19)$$

We can now obtain an expression for the total c.m.r.r. using equation (19) and (12).

$$\text{c.m.r.r.}_{total} = (1 + 2M).(N + 1)(\delta_1 + \delta_4 - \delta_2 - \delta_3) \quad (20)$$

STANDARD DIFFERENTIAL v INSTRUMENTATION AMPLIFIER

The additional differential input-output stage of the conventional instrumentation amplifier (Fig.2.) has improved the overall differential-mode gain and the c.m.r.r. compared with the simple standard differential amplifier (Fig.1), both the total A_{vd} and c.m.r.r. apparently increasing by a factor of (1 + 2M), the differential-mode voltage gain of the first stage of Fig.2. The key question to be answered is, "when should the more complex, and therefore more expensive, circuit of Fig.2 be chosen in preference to the simpler circuit of Fig.1?" The answer to this question is not simple; however, a clear answer can be obtained with some care.

Since the differential amplifier of Fig.1. is a sub-circuit of Fig.2, to make a comparison between the two we will assume that the same quality of components are used in both circuits. Also assume that the required closed-loop differential gain-bandwidth product is less than that of a single op-amp, so that the circuit of Fig.1 could satisfy the designer's needs in terms of differential-mode performance. Using the equations described earlier a comparative table can be drawn up and it is shown in Fig.3. Since the circuits are to be independently designed, resistor designations for the circuit of Fig. 1 have been changed to R'_1, R'_2, R'_3, R'_4 so that they are not confused with the resistors used in the circuit of Fig.2.

The same quality of components will be used in both circuits and this means that the terms $(\delta'_1 + \delta'_4 - \delta'_2 - \delta'_3)$ and $(\delta_1 + \delta_4 - \delta_2 - \delta_3)$ will lie within the same range.

Refer to the c.m.r.r. of the two circuits of

Fig.1 and Fig.2 as c.m.r.r.$_1$ and c.m.r.r.$_2$ respectively. From Fig. 3 we may write

$$\text{c.m.r.r.}_1 = (1 + k)/(\delta'_1 + \delta'_4 - \delta'_2 - \delta'_3) \quad (21)$$

and

$$\text{c.m.r.r.}_2 = (1+k + 2R_5/R_7)/(\delta_1+\delta_4-\delta_2-\delta_3) \quad (22)$$

where k is the overall differential-mode voltage gain required.
Nominally the δ terms equate so that

$$\text{c.m.r.r.}_2 = (1+(2R_5/R_7)/(1 + k))\,\text{c.m.r.r.}_1 \quad (23)$$

Equation (23) shows that c.m.r.r.$_2$ is indeed greater than c.m.r.r.$_1$. However, since the total differential-mode gain is k, the term $(2R_5/R_7)/(1+k)$ must be less than unity, so that c.m.r.r.$_2$ is not even twice that of c.m.r.r.$_1$.

In practical electronic engineering terms, an improvement of c.m.r.r. of less than a factor 2 does not warrant using the instrumentation amplifier of Fig.2. with its additional complexity over that of the standard differential amplifier of Fig.1. This conclusion does not mean that the circuit of Fig.2 is never worth using, since we have yet to examine the case where the specified closed-loop differential gain-bandwidth product required is greater than that of the op-amps that are to be used in the circuit.

CASCADED-STAGE DIFFERENTIAL AMPLIFIER

In many differential-amplifier applications a very high differential-mode voltage closed-loop gain is required perhaps 10,000 or more over a specified bandwidth, and the total amplifier gain-bandwidth product may well be too high to be obtained with a single-stage circuit such as the standard differential amplifier of Fig.1. If this is the case, there are two basic options available to the electronics engineer. Either the circuit of Fig.2 can be used, or a simple, single-ended post amplifier can be added to the standard differential amplifier, as shown in Fig. 4. On the assumption that with either arrangement the specified differential gain-bandwidth product can be achieved, the circuit of Fig.2 is, without doubt, the best, as it can be designed to provide a much better c.m.r.r. than is possible with the circuit of Fig.4, as the following discussion shows.

The second gain stage of Fig.4 is a single-ended input/output stage, and so the total c.m.r.r. of this amplifier (c.m.r.r.$_4$) is equal to the c.m.r.r. of the first stage, which is identical to the circuit of Fig.1, hence

$$\text{c.m.r.r.}_4 = \text{c.m.r.r.}_1 = (1+R'_2/R'_1)/(\delta'_1+\delta'_4-\delta'_2-\delta'_3) \quad (24)$$

Rewriting equation (20), which is the c.m.r.r. of Fig.2, we have

$$\text{c.m.r.r.}_2 = (1 + 2R_5/R_7)(1 + R_2/R_1)/(\delta_1+\delta_4-\delta_2-\delta_3) \quad (25)$$

Comparison can now be made between equations (24) and (25), giving

$$\frac{\text{c.m.r.r.}_2}{\text{c.m.r.r.}_4} = \frac{(1+2R_5/R_7)(1+R_2/R_1)}{(1+R'_2/R'_1)} \quad (26)$$

where the δ_i terms have been cancelled as it is again valid to compare the two circuits only if the same tolerance of components are used in both. Equation (26) cannot be simplified further, as the choice of relative values of resistors for each circuit is made independently. But a specific example will serve to illustrate that the circuit of Fig.2 will produce a much higher c.m.r.r. than that of Fig.4.

Suppose identical op-amps, each with open-loop gain-bandwidth products of 1MHz, are used and that the application demands a closed-loop differential voltage gain of 10,000 over a bandwidth of 1kHz. The total differential closed-loop gain-bandwidth product is therefore 100 MHz. To maximize signal-to-noise ratio, both Fig.2 and Fig.4 circuits should be designed with maximum gain in the first stage. The maximum possible closed-loop gain for a 1kHz bandwidth is 1000 and so, for the circuit of Fig.2,

$$R'_2/R'_1 = 1000 \quad (27)$$

and similarly for the circuit of Fig.4

$$(1+2R_5/R_6) = 1000 \quad (28)$$

In both cases the second stage gain needs to be equal to 10 which in the case of the circuit of Fig.2 gives

$$R_2/R_1 = 10 \quad (29)$$

The comparative ratio of c.m.r.r. between the two amplifiers can now be calculated using equation (26) from which we obtain

$$\frac{\text{c.m.r.r.}_2}{\text{c.m.r.r.}_4} = \frac{(1000)\cdot(1+10)}{(1001)} \simeq 11 \quad (30)$$

So, the c.m.r.r. for the circuit of Fig.2, the instrumentation amplifier, is 11 times, or 21dB, greater than the best that can be achieved using the circuit of Fig.4. The reason for such a significant advantage is because both gain stages in the instrumentation amplifier provide high c.m.r.r. whereas the amplifier of Fig.4 has a c.m.r.r. equal to that of the first gain stage.

The analysis is above shows that if a closed-loop differential amplifier is needed with a gain-bandwidth product which is greater than that of the op-amp to be used, implying at least two gain stages are required, then the conventional instrumentation amplifier shown in Fig.2 will give the best total c.m.r.r. available. But if a closed-loop differential amplifier is needed with a gain-bandwidth product which is less than that of the op-amps available then no significant advantage is gained in terms of c.m.r.r. by using the instrumentation amplifier and it is probably perfectly acceptable to use the simple, standard, single-op-amp differential amplifier.

In passing, it should be noted that the instrumentation amplifier does provide a buffered high input impedance at both non-inverting and inverting input terminals. The same cannot be said of the rather asymmetrical input impedances of the standard, single-op-amp differential amplifier. A further point to note is that none of the circuits described in this article are particularly useful in the presence of high common-mode voltages.

parameter	standard differential amplifier	conventional instrumentation amplifier
total A_{vd}	$R'_2/R'_1 = R'_4/R'_3$	$(1 + 2R_5/R_7)R_2/R_1$ where $R_2/R_1 = R_4/R_3$ and $R_5 = R_6$
total c.m.r.r.	$\left(1 + \frac{R'_2}{R'_1}\right)/(\delta'_1+\delta'_4-\delta'_2-\delta'_3)$	$(1+2R_5/R_7)\left(1+\frac{R_2}{R_1}\right)/(\delta_1+\delta_4-\delta_2-\delta_3)$

Fig.3. Characteristics of the two types of amplifier. At first sight, the improvement in c.m.r.r. is not spectacular.

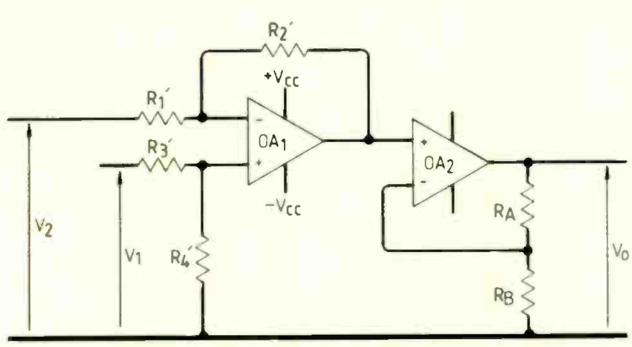
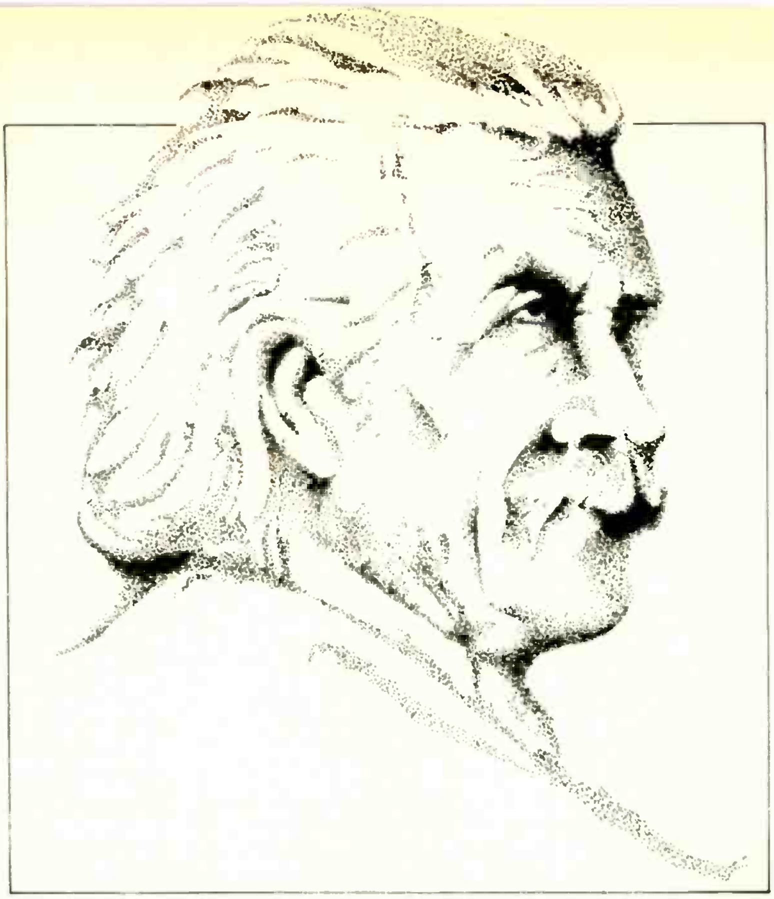


Fig.4. One way of obtaining a high gain, which can only provide a c.m.r.r. equal to that of the first stage.

Dr F.J. Lidgey, B.Sc., Ph.D., M.I.E.E., is Principal Lecturer in the School of Engineering, Oxford Polytechnic, Oxford.



RELATIVITY – joke or swindle?

Louis Essen re-states his view that Einstein's theory of relativity contains basic and fatal flaws

L. ESSEN

Some of your contributors find it difficult to accept my contention (*WW* October, 1978) that Einstein's theory of relativity is invalidated by its internal errors. Butterfield for example (*EWW*, February, 1987) denies that there is any duplication of units or any harm in obtaining results from thought-experiments. Moreover, if my contention is correct, the new experimental work described by Aspden (*EWW*, August, 1987) is not required to disprove the theory, although it might confirm that his assumptions were wrong. This is not to suggest that experimental results are not important but they should be considered as steps in the development of new theories.

Discussions about the theory tend to be very involved and your readers may be interested in a brief history of the subject which I wrote some time ago for a friend who wanted to know what the controversy was about and in particular what was the significance of the clock paradox.

The theory was an attempt to explain the result of an experiment which had been made to measure the velocity of the earth through space. Scientists reasoned that, since light is an electromagnetic wave travelling through space with a velocity denoted by the symbol c, and the earth is travelling through space with a velocity v, it should be possible to measure v by an optical experiment carried out in the laboratory. Michelson and Morley designed and used an interferometer for this purpose. A beam of light was split into two parts which were directed along the two arms of the instrument at right angles to each other, the two beams being reflected back to recombine and form interference fringes. The instrument was turned through a right angle so that, if one of the arms was initially parallel to earth's motion, it became at right angles to this direction. It was expected that there would be a movement of the fringes, from which the velocity of the earth could be calculated, but no change at all was observed.

There have always been... critics: Rutherford treated it as a joke; Soddy called it a swindle; Bertrand Russell suggested it was all contained in the Lorentz transformation equations; and many scientists commented on its contradictions

Fitzgerald and Lorentz pointed out that this result would be obtained if the arm of the interferometer which was moving parallel with the earth was, in consequence of this movement, reduced in length by the amount $(1-v^2/c^2)^{1/2}$. Such an arbitrary assumption did not constitute a satisfactory explanation and scientists tried to think of a more fundamental cause.

Einstein came to the conclusion that the answer rested on the way time was measured and the simultaneity of two events was defined; and on the basis of these ideas and two additional assumptions he developed his theory, published in 1905. It was essentially the electromagnetic theory of Maxwell and Lorentz modified to incorporate the Michelson-Morley result. Later, in 1907, he extended the theory to include gravitational effects and predicted that light would be deflected as it passed near the sun. The prediction could be tested only by observing the path of the light from stars during an exlipse of the sun and in 1919 Eddington led an expedition to the island of Principe, where the eclipse was total; and when the results had been studied, announced that the prediction was confirmed. The theory was then gradually accepted, eventually being regarded as a revolution in scientific thought.

But there have always been its critics: Rutherford treated it as a joke; Soddy called it a swindle; Bertrand Russell suggested that it was all contained in the Lorentz transformation equations; and many scientists commented on its contradictions. These adverse opinions, together with the fact that the small effects predicted by the theory were becoming of significance to the definition of the unit of atomic time, prompted me to study Einstein's paper. I found that it was written in imprecise language, that one assumption was in two contradictory forms and that it contained two serious errors.

...he concluded that, at the end of the journey, the time recorded by the moving clock was less than that recorded by the stationary clock. The result did not follow from the experiment, but was simply an assumption slipped in implicitly during the complicated procedure

The essential feature of science is its dependence on experiment. Results of experiment are expressed in terms of units which must not be duplicated if contradictions are to be avoided and units of measurement are the only quantities which can be made constant by definition. When Einstein wrote his paper, two of the units were those of length and time. Velocity was measured in terms of these units. Einstein defined the velocity of light as a universal constant and thus broke a fundamental rule of science.

One of the predictions of the theory was that a moving clock goes more slowly than an identical stationary clock. Taking into account the basic assumption of the theory that uniform velocity is purely relative, it follows that each clock goes more slowly than the other when viewed from the position of the other. This prediction is strange but not logically impossible. Einstein then made his second mistake in the course of a thought-experiment. He imagined that two clocks were initially together and that one of them moved away in a number of straight line paths, at a uniform velocity, finally returning to the starting point. He concluded that on its return the moving clock was slower than the stationary clock. Moreover, since only uniform motion is

...I do not think Rutherford would have regarded (the theory) as a joke had he realised how it would retard the rational development of science

Einstein defined the velocity of light as a universal constant and thus broke one of the fundamental rules of science

involved there is no way of distinguishing between the two and each clock goes more slowly than the other. This result is known as the clock paradox or, since the clocks are sometimes likened to identical twins, one of whom ages more slowly than the other, the twin paradox.

Hundreds of thousands of words have been written about the paradox but the explanation is simple, arising from Einstein's use of the expression, "as viewed from". Clearly if the time of one clock is viewed to be slower than the other even when it has returned to the same position as the other then it must indeed be slower. But the rates of distant clocks are not compared by viewing them. Ticks from them are received and counted on a separate dial, a process now carried out continuously throughout the world for the synchronization of atomic time. It is the reading on this subsidiary dial which would be less and not that on the dial of the clock itself. If the thought-experiment is carried out correctly, the result is that the time of the moving clock as measured at the position of the stationary clock is less than that of the stationary clock. This is the same as the initial prediction, which is as it should be since a thought-experiment cannot give a result differing from the information put into it.

Einstein's use of a thought-experiment, together with his ignorance of experimental techniques, gave a result which fooled himself and generations of scientists. He convinced himself that the theory yielded the result he wanted, because the contraction of time is accompanied by the contraction of length needed to explain the Michelson-Morley result.

The round trip could not have been made without accelerations being applied, but Einstein ignored their possible effect on the rate of the clock, thus implicitly assuming that they had no effect. Some years later, in 1918, he used another thought-experiment in an attempt to answer criticisms of the paradox result. One of the clocks again made a round trip, the changes of direction being achieved by switching gravitational fields on and off at various stages of the journey, the time recorded by the moving clock was less than that recorded by the stationary clock. The result did not follow from the experiment, but was simply an assumption slipped in implicitly during the complicated procedure. The slowing down of clocks which he had previously attributed to uniform velocity, acceleration having no effect, he now attributed to acceleration, a line of argument followed in many textbooks.

Claims frequently made that the theory is supported by experimental evidence do not withstand a close scrutiny. There are grave doubts about Eddington's claim, both as regards the predicted value which was increased by a factor of 2 from that first given by Einstein and the way the results were analysed – some of the readings being discarded. The same criticism applies to a more recent experiment performed, at considerable expense, in 1972. Four atomic clocks were flown round the world and the times recorded by them were compared with the times recorded by similar clocks in Washington. The results obtained from the individual clocks differed by as much as 300 nanoseconds. This absurdly optimistic conclusion was accepted and given wide publicity in the scientific literature and by the media as a confirmation of the clock paradox. All the experiment showed was that the clocks were not sufficiently accurate to detect the small effect predicted.

Why have scientists accepted a theory which contains obvious errors and lacks any genuine experimental support? It is a difficult question, but a number of reasons can be suggested. There is first the ambiguous language used by Einstein and the nature of his errors. Units of measurements, though of fundamental importance, are seldom discussed outside specialist circles and the errors in clock comparisons are hidden away in the thought experiments. Then there is

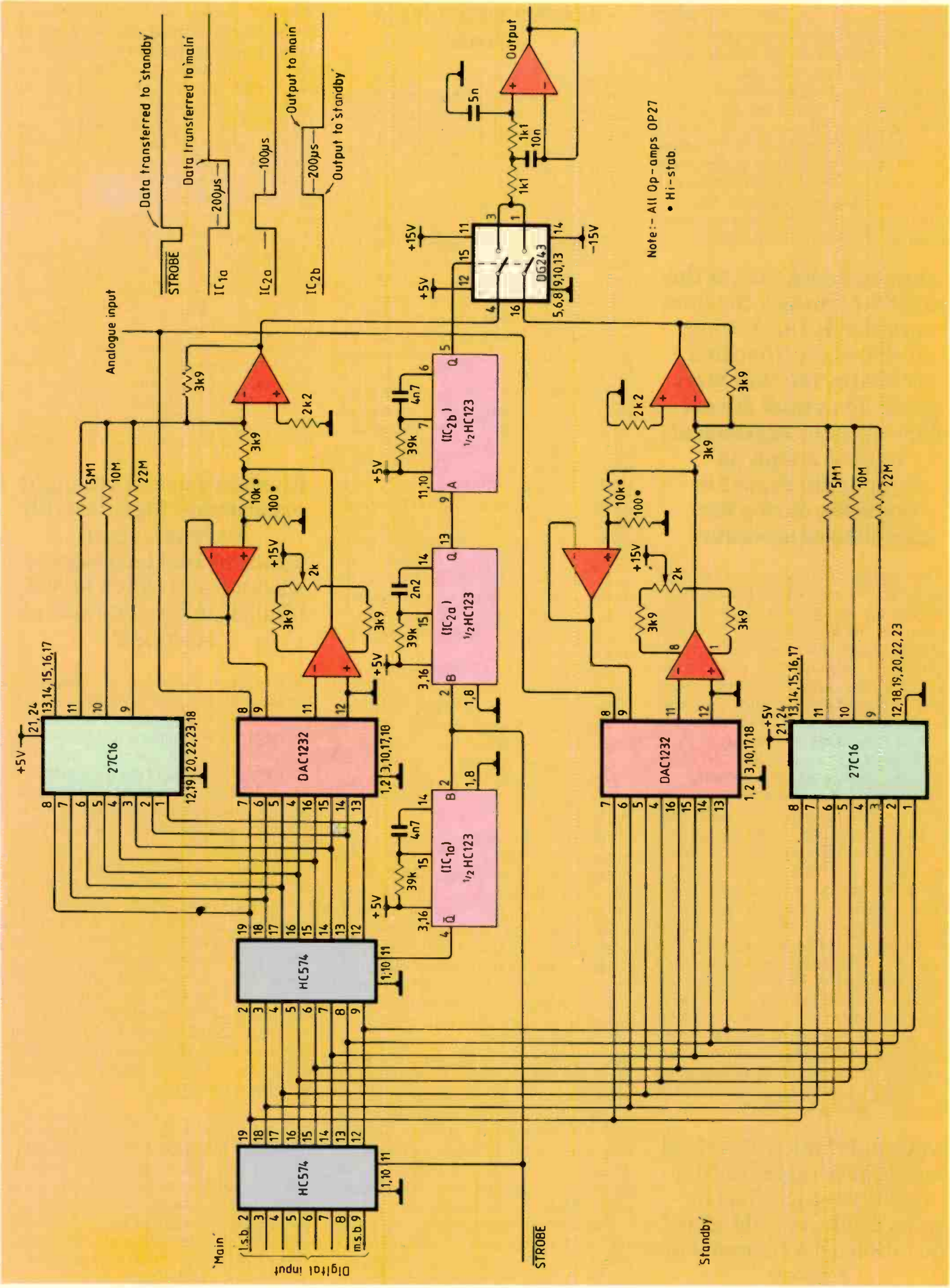
Einstein's use of a thought experiment, together with his ignorance of experimental techniques, gave a result which fooled himself and generations of scientists

the prestige of its advocates. Eddington had the full support of the Royal Astronomical Society, the Royal Society and scientific establishments throughout the world. Taking their cue from scientists, important people in other walks of life referred to it as an outstanding achievement of the human intellect. Another powerful reason for its acceptance was suggested to me by a former president of the Royal Society. He confessed that he did not understand the theory himself, not being an expert in the subject, but he thought it must be right because he had found it so useful. This is a very important requirement in any theory but it does not follow that errors in it should be ignored.

Insofar as the theory is thought to explain the result of the Michelson-Morley experiment I am inclined to agree with Soddy that it is a swindle; and I do not think Rutherford would have regarded it as a joke had he realised how it would retard the rational development of science.

Dr Louis Essen, D.Sc., F.R.S., has spent a lifetime working at the NPL on the measurement of time and frequency. He built the first caesium clock in 1955 and determined the velocity of light by cavity resonator, in the process showing that Michelson's value was 17km/s low. In 1959, he was awarded the Popov Gold Medal of the USSR Academy of Sciences and also the OBE.

CIRCUIT IDEAS



CIRCUIT IDEAS

Programmable amplifier with wide dynamic range

Amplifiers with programmable gain tend to be based on analogue multipliers or, if under digital control, may use a multiplying d-to-a converter or op-amp with switchable feedback. Analogue multipliers can drift and in a digitally-controlled circuit considerable output spikes can occur when the digital input value changes.

Neither of these problems occurs with this low-noise, low-drift and transient-free programmable amplifier. It has two identical amplifying paths, called main and standby, each using a 1232 d-to-a converter. One path at a time feeds the output buffer depending on the position of a DG243 single-pole two-way switch.

Initially, output comes from the main amplifying path. New data is latched into the first HC574 and transferred to the standby amplifier, setting it to the new gain value. Next, output is switched to the standby path, the main amplifier is set to the new gain, and output is returned to the main path.

Neither converter is switched through to the output while its digital input is being changed so switching transients do not occur. Transients produced by the DG243 make-before-break switch are negligible.

Normally d-to-a converters provide attenuation but here, amplification is needed. A high-stability potential divider with buffering determines amplification. This does not degrade temperature performance since temperature tracking of the converter resistor network is still used.

In this mode however, leakage current through the converter switches introduces output offsets of up to several millivolts, depending on the digital input word; eproms programmed to suit the converter compensate for this. Data values for the eproms are quite easily determined and are reasonably predictable once the individual contribution of each converter switch is known.

Gain accuracy is eight bits but twelve-bit converters are used because of their superior noise and leakage-current performance. In this configuration, the four least-significant bits of the twelve track the four most significant so gain error introduced remains less than one bit.

Overall bandwidth is limited to the 20kHz required for the original application by a second-order low-pass filter. Circuit performance is degraded if the source impedance is greater than 50Ω since transients from one converter feed to the other through the common input line. Adding an input buffer solves this problem at the expense of noise performance.

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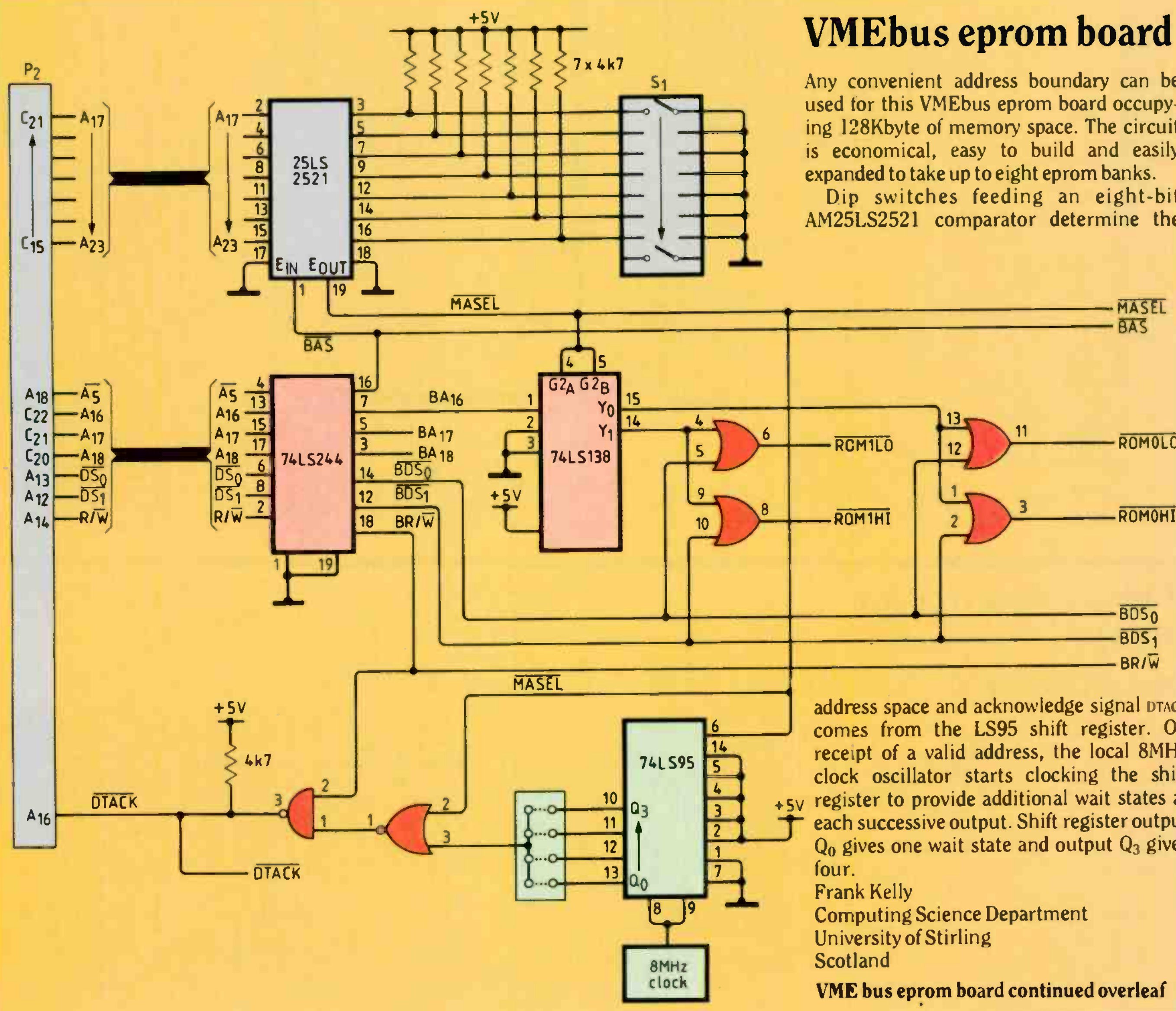


VMEbus eprom board

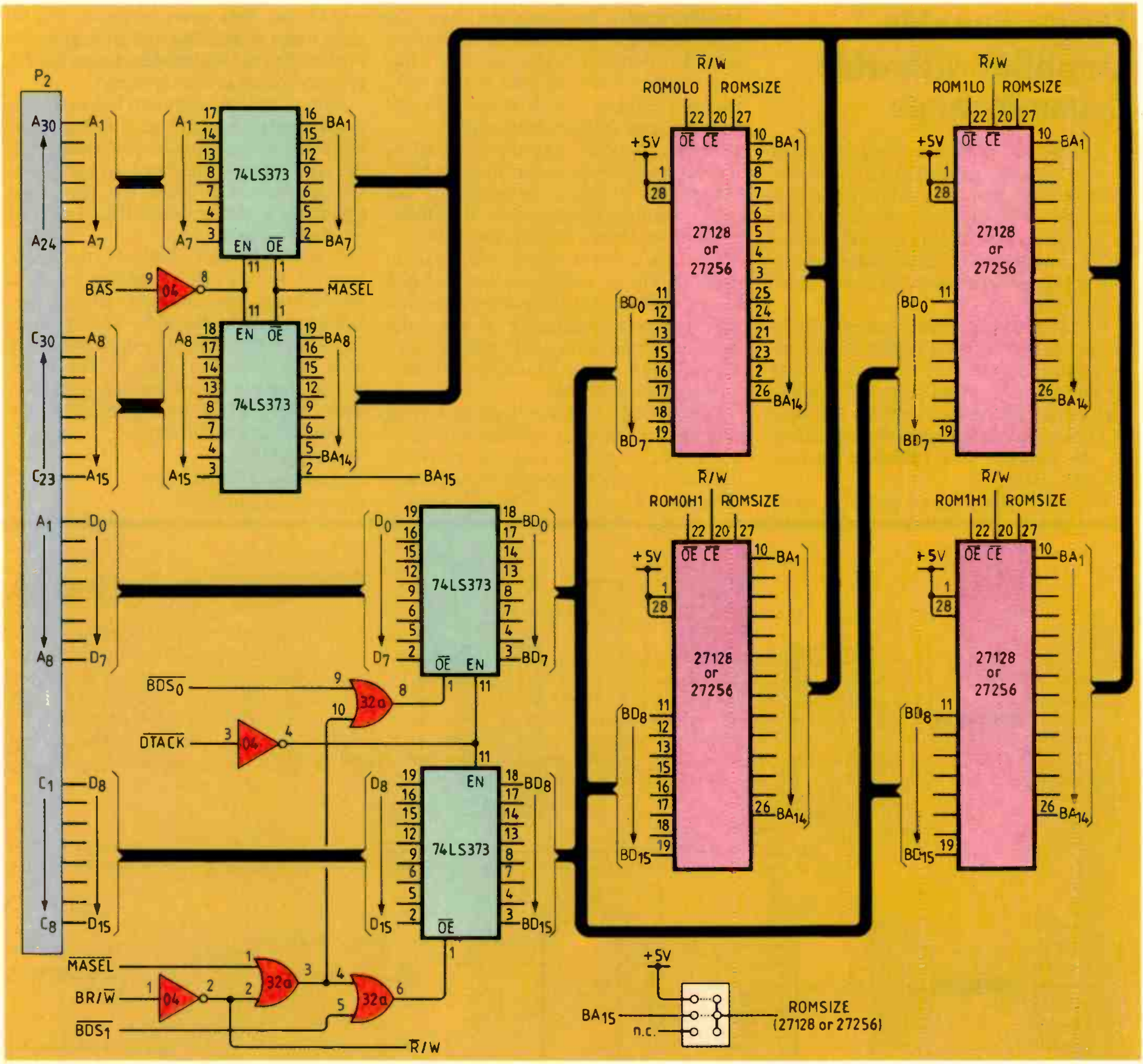
Any convenient address boundary can be used for this VMEbus eprom board occupying 128Kbyte of memory space. The circuit is economical, easy to build and easily expanded to take up to eight eprom banks.

Dip switches feeding an eight-bit AM25LS2521 comparator determine the address space and acknowledge signal DTACK comes from the LS95 shift register. On receipt of a valid address, the local 8MHz clock oscillator starts clocking the shift register to provide additional wait states at each successive output. Shift register output Q_0 gives one wait state and output Q_3 gives four.

Frank Kelly
Computing Science Department
University of Stirling
Scotland

VME bus eprom board continued overleaf

CIRCUIT IDEAS



Video converter for RGB to composite monochrome

Video RGB signals compatible with extended-graphics-adaptor systems can be turned into monochrome composite video without the need for a separate power supply.

Line sync. at 21kHz is a short 5V pulse while the 60Hz frame sync. signal is a longer negative-going 5V pulse. Using the normally-high frame sync. line as supply, the transistor inverts the line sync. pulse while the 47μF capacitor and diode shift the combined sync. signals consisting of negative-going pulses.

Sync. signals are summed with the RGB signals into the 75Ω load. Variable resistors allow adjustment of the relative RGB levels; a blue background may look good on a colour monitor but a grey background does nothing to enhance the appearance of a monochrome picture.

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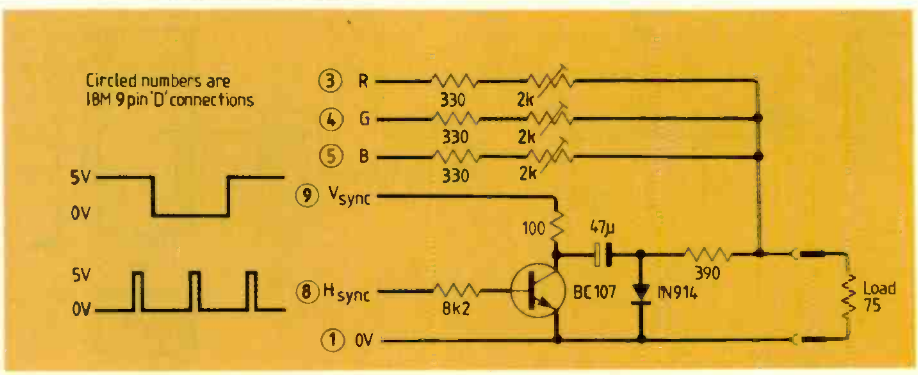
Reading
Berkshire



The New Generation

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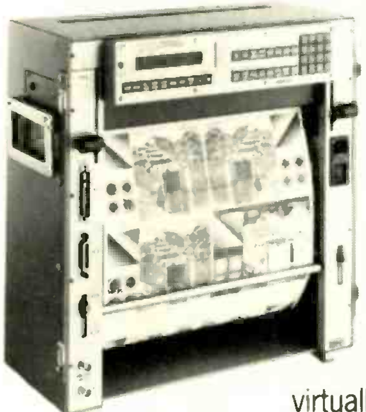

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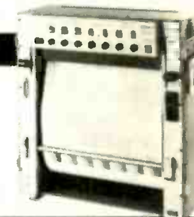

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ENTER 13 ON REPLY CARD

Programming p.l.ds

Control software for programming and verifying a programmable logic device is often fed by output from a Boolean-logic assembler.

V. LAKSHMINARAYANAN

Programming a p.l.d. takes three programming and verifying steps, one for output polarity, one for the And matrix, and one for the Or matrix. In my program these tasks are independent of each other and the overall program integrates these functions in the proper sequence.

Before the p.l.d. can be programmed it has to be checked to make sure that it is in the virgin state which is characterized by the presence of all the NiCr links, presence of both the true as well as complement terms of the input variables, the presence of all 48 P terms in the Or matrix, and the active-high polarity of all the outputs. Software should therefore be modular and each of the above tasks performed by a subroutine. My program was written in Intel 8085 assembly language.

Coding of output-polarity data. There are eight output functions and each of them can be programmed to be active high or active low. Thus each function requires one bit of data to store its status and a byte to store information about the polarity of all the output functions, with b_{0-7} in F_{0-7}. Data b_i is zero for active-low output polarity and one for active high output polarity.

Coding of And-matrix data. There are 48 And gates each with 16 input variables present in both the true as well as complement form. Each input may be present or absent, and, if present it may be in the true or compelement form; one bit is required to store this information for each input line to the And gate.

Since there are 32 input lines to each And gate and 48 And gates, four bytes are required to store the programming data for each And gate and a total of 48×32 bytes, i.e. 192 bytes, for the entire And matrix. Programming data for P term 0 has I_{15-8} in the first byte, I_{7-0} in the second, $\bar{I}_{15-8}$ in the third and $\bar{I}_{7-0}$ in the fourth. The next byte of programming data in the memory for P term 1 contains I_{15-18}, and so on.

Presence of an input variable is indicated by a logic one, and absence by a logic zero. For example, if P Term 0 in a particular Boolean function contains I_0, $\bar{I}_2$, I_4, $\bar{I}_6$, I_7, I_9, $\bar{I}_{11}$, I_{14}, $\bar{I}_{15}$, the four bytes of programming data for P term 0 would be,

Byte	Data
1	01000010
2	10010001
3	10001000
4	01000100

While forming the fusing pattern care should be taken to see that the input links corresponding to unused P terms are not fused.

Coding of Or-matrix data. There are eight Or gates each with 48 inputs from the And matrix. Each And gate output may or may not be present as an input to a particular Or gate, i.e. a particular P term may be present or absent. The presence or absence of a P term is indicated by a logical one or zero as in the case of input variables. Therefore, each Or function requires 48 bits i.e., 6 bytes of information for programming, and a total of 8×6=48 bytes are required for the entire Or matrix.

Or-matrix data for programming is stored in memory for function F_0 with P_{7-0} in the first byte, P_{15-8} in the second, P_{23-16} in the third, P_{31-24} in the fourth, P_{39-32} and P_{47-40} in the sixth byte. The next byte in memory will be programming data for output function F_1, and so on.

For example, if F_0 is defined as

$$F_0=P_1+P_3+P_7+P_9+P_{11}+P_{20}+P_{24}+P_{31}+P_{32}+\ldots+P_{47}$$

fusing data stored in the memory would be;

Byte	Data
1	10001010
2	00001010
3	00010000
4	11111111
5	11111111
6	11111111

You will notice that P terms P_{31-47} are not being fused; it is assumed that these P terms are not being used in the function F_0.

PROGRAMMING PROCEDURE

Programming a p.l.d. involves the following steps,

- check the virgin state of the p.l.d.
- program and verify output polarity.
- program and verify the And matrix.
- program and verify the Or matrix.

Before programming, the necessary data should be stored in the memory in the correct format and the routines performing the above tasks should be sequentially called.

To illustrate the programming technique, a specimen set of Boolean equations is given in List 1, and the corresponding fusing patterns in List 2. I will now look at the way the fusing patterns are formed for output polarity, a P term and an output function.

From List 1 you can see that outputs F_0, F_2, F_4, F_5, F_6 are to be programmed active low and F_3 is to be programmed active high; outputs F_1 and F_7 are not used. Therefore, the polarity fusing pattern is,

F_7	F_6	F_5	F_4	F_3	F_2	F_1	F_0
1	0	0	0	1	0	1	0

i.e., $8A_{16}$ which, as you can see from List 2, is stored in location 1000_{16}.

Coming to P-term 1, you can see that it contains I_0, I_2 and I_5. Therefore, the links to be blown are all of $\bar{I}_{0-15}$, and all but I_0, I_2 and I_5 in I_{0-15}. Corresponding bytes stored in memory are,

I_{15-8}	0000 0000 (0)
I_{7-0}	0010 0101 (25_{16})
$\bar{I}_{15-8}$	0000 0000 (0)
$\bar{I}_{7-0}$	0000 0000 (0)

These bytes are stored in locations 1005_{16} to 1008_{16}. Fusing patterns for other P terms are formed in a similar way. To program output function F_0 the fusing pattern required would be in the form of six bytes defined as follows,

P_{7-0}	0000 0110 (6_{16})
P_{15-8}	0000 0000 (0)
P_{23-16}	1111 1110 (FE_{16})
P_{31-24}	1111 1111 (FF_{16})
P_{39-32}	1111 1111 (FF_{16})
P_{47-40}	1111 1111 (FF_{16})

These patterns are stored in locations $10C1_{16}$–$10C6_{16}$. Fusing patterns for other ouput functions are formed on similar lines.

ASSEMBLER REQUIREMENTS

In preceding sections I have explained how a p.l.d. can be programmed by using the fusing patterns for the And and Or matrices and the output polarity. Essentially the c.p.u. reads the fusing patterns stored in memory and as decided by the assembly-language algorithm either fuses the NiCr links or leaves them intact.

SOFTWARE

The 48-page p.l.a. programmer listing in 8085 assembly language is too long for us to print in the magazine. We also have the author's 15-page Pascal listing for reading an input file for the And and Or terms and outputting data in Intel hex form. They can be obtained by sending an A4 s.a.e. with your address on it and a £3.75 copying charge to PLA listing, E&WW Editorial, Room L303, Quadrant House, The Quadrant, Sutton, Surrey. Cheques should be payable to Reed Business Publishing.

List 1. Specimen programming data for p.l.a.

Product terms

$P_1 = I_0.I_2.I_5$
$P_2 = I_0.I_3.I_{11}$
$P_3 = I_0.I_3.I_5.I_{10}.(I_{13}).I_5$
$P_4 = I_0.I_4.I_{11}$
$P_5 = I_1.I_2.I_5$
$P_6 = I_0.I_2.I_{11}$
$P_7 = I_0.(I_5).I_7.I_{12}$
$P_8 = I_1.(I_5).I_7.I_8.I_{12}$
$P_9 = I_1.I_2.(I_5).I_{11}$
$P_{10} = I_0.I_3.(I_9).(I_{10}).I_{11}$
$P_{11} = I_1.I_6.(I_{13})$
$P_{12} = I_0.I_6.I_9.(I_{13})$
$P_{13} = (I_{13}).I_{14}$
$P_{14} = I_0.I_2.I_6.(I_{15})$
$P_{15} = I_{0.12}.I_5.I_{13}$
$P_{16} = I_0.I_3.I_5.(I_9).(I_{10})$

Other P-terms are not used.

Sum terms

$(F_0) = P_1 + P_2$
$(F_2) = P_3 + P_4 + P_5$
$(F_3 = P_1 + P_6$
$(F_4) = P_7 + P_8$
$(F_5) = P_9 + P_{10} + P_{14} + P_{15} + P_{16}$
$(F_6) = P_{11} + P_{12} + P_{13}$

Outputs F_1 and F_7 are not used.

Note: Terms in parentheses are active-low outputs/complementary variables.

List 2. Example of programming data for the p.l.d. programmer produced from Boolean equations in List 1 by the author's assembler.

Here the fusing pattern for output polarity data for F_{7-0} is stored in location 1000, for the And matrix in locations 1001 to 10C0 and for the Or matrix from 10C1 to 10F0.

```
1000  8A  ;Polarity
1001  FF  FF  FF  FF  ;P0
1005  00  25  00  00  ;P1
1009  08  09  00  00  ;P2
100D  84  29  20  00  ;P3
1011  08  11  00  00  ;P4
1015  00  26  00  00  ;P5
1019  08  05  00  00  ;P6
101D  10  81  00  20  ;P7
1021  11  82  00  20  ;P8
1025  08  06  00  20  ;P9
1029  08  09  06  00  ;P10
102D  00  42  20  00  ;P11
1031  02  41  20  00  ;P12
1035  40  00  20  00  ;P13
1039  00  45  80  00  ;P14
103D  20  25  00  00  ;P15
1041  00  29  06  00  ;P16
```

To prevent fusing input links of unused P terms, terminate program after P16. Or matrix fusing pattern follows.

```
10C1  06  00  FE  FF  FF  FF  ;F0
10C7  FF  FF  FF  FF  FF  FF  ;F1
10CD  38  00  FE  FF  FF  FF  ;F2
10D3  42  00  FE  FF  FF  FF  ;F3
10D9  80  01  FE  FF  FF  FF  ;F4
10DF  00  C6  FF  FF  FF  FF  ;F5
10E5  00  38  FE  FF  FF  FF  ;F6
10EB  FF  FF  FF  FF  FF  FF  ;F7
```

My Pascal assembler is described in this section to give you ideas for writing your own software. The assembler produces the fusing patterns for the And and Or matrices directly from Boolean equations. In other words, the assembler converts user-readable inputs into machine-readable format.

Final output of the assembler is a file in the Intel hex form which can be directly read from disc into microcomputer ram for use by the c.p.u. The assembler accepts data in a particular form. For example, the representation of a typical P term and an F term is

/P07=I00.C05... I09/ (1)
/F2 =P00+P12+P23+... P19/ (2)

Here P stands for the product term, its index varying between 0 and 47 for the 48 And terms. In (1), it is set as a combination of I's (true inputs) and C's (complemented inputs) which are specified by the accompanying indices.

Similarly, in (2), F is a sum term designated by its index which lies between 0 and 7 for the eight outputs, and is set to be the combination of the P terms on the right of the equal sign. Both these equations are enclosed within obliques to indicate the field of each And/Or term. For each p.l.d. the required Boolean equations are written for the And and Or matrices in the form explained above, and an input file is produced. The assembler is structured to that it reads the input file and creates an output file in the Intel hex format.

ASSEMBLER ALGORITHM

My assembler assumes that input data, that is to say the P and the F terms, is present in an input file called DATA.IN. First, data is read from this file. The assembler recognizes the end of P term data when it encounters an asterisk in the field of the character P (each line in the input file is declared as a record); similarly the end of F-term data is indicated by a hash symbol.

Each P term has a combination of I and C terms. Since these cannot exceed 32 (I_{0-15} and C_{0-15}) a four-by-eight matrix is associated with each product term. Each row is equivalent to a byte. The structure of each matrix is,

I_{15} ——— I_8
I_7 ——— I_0
C_{15} ——— C_8
C_7 ——— C_0

These matrices are initialized to null matrices for the P terms; the I and C terms present in each P term decide which of the matrix elements become 1 (logic one in a byte is equivalent to presence of that input variable and hence the corresponding NiCr link need not be blown).

Once the matrices are formed, each matrix row is converted into hexadecimal form by grouping the bits four at a time. The hexadecimal code lies between 00 and FF. An absent P term requires none of the links to be blown; hence it will have FF FF FF FF.

Thus all P terms have a hexadecimal code whether they are present or absent. These codes are combined to form the Intel hex file in which each line has 16 bytes of hexadecimal-form data.

A similar procedure produces hexadecimal code for F terms. Since there are 48 P terms (0 to 47), each F term has a six-by-eight matrix associated with it. Procedures for both And and Or matrices have numerical test facilities built into their algorithms to arrange the terms in ascending numerical order.

CONCLUSION

With this programmer it is possible to transform a blank p.l.d. into a device containing a custom algorithm, microprogram, or Boolean transfer function in a few seconds. Such a logic i.c. has applications including character generators, look-up and decision tables, function generators, microprogramming, sequential controllers and frequency synthesizers.

I would like to thank Dr N.W. Nerurkar and Mr V.B. Taneja of the Centre for Advanced Studies in Electronics, New Delhi, for their encouragement during this work and for their permission to publish this article.

Further reading

Bipolar and mos memory data manual, Signetics, USA, 1980.

Programmable-logic data manual, Signetics, USA, 1986.

PAL/PLE programmable-logic handbook, Monolithic Memories USA, 1985.

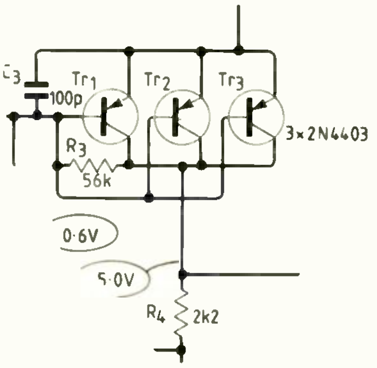
Programmable logic data book, Advanced Micro Devices, USA, 1986-87.

V. Lakshminarayanan obtained his B.E. in Electronics Engineering from Bangalore University in 1981 and an M.E. in Electrical Communication Engineering from the Indian Institute of Science in 1983.

He is currently on the technical staff at the Centre for the Development of Telematics in Bangalore, involved in the design of digital telephone exchanges and v.h.f./u.h.f. communication systems.

Moving-coil head amplifiers

In the article by Doug Self which appeared in the December issue, an error appeared in Fig. 6, the complete circuit diagram. A correct version of the relevant part of the diagram is shown below. Apologies to readers and to Mr Self and thanks to Mr D. Symons, who pointed out the error.



FEEDBACK

A.m. stereo

With reference to the item "A.m. stereo for Europe" in *EWW*, November, 1987, page 1167, I would like to point out that, in my opinion, it is much better for Europe to have a.m. higher-fidelity than a.m. poor stereo.

That is, instead of sending L and R, which are two band-limited (5kHz) audio channels, it would be more enjoyable if the added information extended the bandwidth of the transmitted programme (at the speaker).

The latter could be done by shifting down (e.g. by 5kHz) the higher frequencies of the audio programme (probably from 5kHz to 10 kHz) and then adding them (now bandlimited to 5kHz) to the old programme (also bandlimited to 5kHz) in quadrature as proposed in stereo systems.

Kerim Fahme
Aleppo
Syria

Mechanical television

I was most impressed to read the letter by Mr A.S. Henderson in your December issue on mechanical tv under *Feedback*. I was the first engineer to join the Scophony Company in 1932, and probably I am more fortunate than Mr Henderson in that I have kept records and photographs of most aspects of the Scophony system for over fifty years.

Adam Hilger Ltd produced our first high-speed scanners in both stainless steel and glass, but when it became established that the definition of television would be either 240 lines 50 frames or 202.5 lines interlaced to produce a 405 line picture, the polygon was designed for 20 facets and was in stainless steel and not glass. We manufactured 50 polygons on a mandrel, using a very accurate Zeiss optical dividing head, and it was possible to use 35 of these in the centre of the mandrel – the outside polygons were discarded. We could carry out this work when Ted Wilson joined us and I am obliged to Mr Henderson for reminding me of his name. I retain all the cost sheets, which were carefully prepared, and note that the high speed motor and stainless steel polygon as a complete unit had a total material and labour cost of £8.12.6, the polygon representing the magnificent sum of £3.10.0.

I am at a loss to find the reason for the 49 facet polygon; we were thinking in 1939 of front projection rather than the rear projection of our standard cinema systems, and the 49 facet would reduce the angle between each facet and so give us a longer projection distance than the 20 facet polygon. I have known of multi-facet polygon tests for front projection, and for a 405 line picture the lower-speed high-speed scanner would mean an increase in the distance between the ultrasonic light cell and the scanner from 13 to something like 35 cm. in order to obtain the immobilising of the waves in the liquid column. Another reason for the 49 facet polygon was to accommodate the intended 441 line 60 frame standard in the United States to reduce the high-speed scanner speed which, on the British standard, was running at 30,375 r.p.m.

Incidentally, the total cost including labour of the complete 24in Scophony Home Receiver was just under £52, excluding cabinet, the reason being that Ted Wilson was getting £3 a week and I, as a Design Engineer, got £450 a year! Converting £.s.d. into present day metric pounds by multiplying everything by 2.4 and 50 years of inflation, multiply by at least 20 and you will get a cost of nearly £2,500!

Joshua Sieger
Poole
Dorset

Coupling coefficient

We thank Mr Clifford for his interest (Letters, December 1987) in the article "Does your coupling coefficient matter?, by Tom Ivall, June 1987 issue, and are ourselves interested that he has written on allied topics (any reprints left, Mr Clifford ?).

May we reply to three of the points he raises:

1. If the receiving part of the circuit shown in Fig.2 were indeed a "test circuit", then of course it would be better to do away with the transformer and measure I_2 as the voltage dropped across a small (0.5 ohm) resistor, as Mr Clifford suggests. But what the figure portrays is not a test circuit; it is a practical circuit for an implantable receiver whose output must match the resistance of the tissue to be stimulated – of the order of half a kilohm, rather than half an ohm, with a typical electrode setup. Hence the need for a step-up r.f. transformer, which does indeed degrade the range-independency of the link, but not by much.

2. Tongue doubtless in cheek, Mr Clifford suggests that if one expects the frequency to fall as one approximates oscillator and receiver, it will in fact surely rise, and vice-versa; and that this is undesirable. On the contrary, it would not matter which way the frequency went, but in practice, with the various series oscillators the MRC Unit has published, the frequency always falls and never hops to the higher, theoretically possible, value.

3. Using an operational amplifier to drive Vmos transistors has thrown up no noticeable problems with reliability. In any case, it is the implanted receiver which must be ultra reliable; the external-to-the-body series oscillator need only be reliable.

P.E.K. Donaldson
MRC Neurological Prosthesis Unit
London SE5
T.E. Ivall
Staines
Middlesex

In an article in the June, 1987 *Electronic & Wireless World*, entitled "Does your coupling coefficient matter?" Tom Ivall reports work funded by the Medical Research Council. He purports to report a "little-known, possibly hitherto unknown, fundamental property of inductively coupled oscillating circuits".

I am sure that by now you will have received many other letters in addition to this one from 'old-timers', protesting that far from being the "unknown" property claimed, the results are well known (even to a now non-practising ex-electronics person as I am). I referred to one of my text-books last used in 1951 when I took my physics degree, "Principles of Electricity" by Page & Adams (first edition June 1931, second edition 1949) by D. Van Nostrand Company, Inc, New York. Pages 509-517 deal explicitly with coupled circuits in forced oscillation and contain analogous results.

I trust that Mr P. E. K. Donaldson will make an acknowledgement of at least this prior work in future publications.

D.C. Chadney
Chinnor
Oxfordshire

Catt's anomaly

There is no rigid rod in my story (January, 1987). Indeed, I chose the two examples, a cable and a body of water, in order to steer clear of such dubious idealizations. Any number of other examples could have been used, such as ordinary sound in air. The point of them all would be the same – that the speed of the elements of the medium can be far below (and is certainly quite a separate issues from) the speed with which displacements propagate. Indeed, I mention in the case of the water, but the point holds also for the cable, that the displacement propagates at the speed of sound. There is a close mathematical parallel between the mass (or density) of an acoustic medium and the inductance (or inductance per unit length) of a transmission line, as there is between elasticity and capacitance. There is simply no problem about a pulse of charge travelling at the speed of light while the electrons themselves move at speeds that are orders of magnitude slower, and Catt's self-named anomaly is no more than an elementary misunderstanding.

At the time of writing my letter it did seem funny, and at least has the merit of being on a level of pottiness comparable to Mr Catt's declamations.

Alex Wilding
Redditch

The Conquest of thought

Ivor Catt (December, 1987) seems to think I have been going on about Bohr's Correspondence Principle in articles on electromagnetism and vectors recently.

FEEDBACK

If I put my physicist's cap on, the principle is familiar and could be discussed, but I did not have anything like it in mind while writing the tutorial articles.

Regarding the little bit that I related to Kuhn's statement – and Kuhn says quite a number of contradictory things – I would only add the following extracts:

"Second, the new paradigm must promise to preserve a relatively large part of the concrete problem-solving ability that has accrued to science through its predecessors."

and:–

"paradigms...usually preserve a great deal of the most concrete parts of past achievement and they always permit additional concrete problem-solutions besides".

These, by the way, are on page 169 of his book "The Structure of Scientific Revolutions", in case Ivor Catt gets time to read the book.

On the correspondence from C. F. Coleman in the November issue, I wonder what point he was making? One flavour in his letter seemed to be the delusion arising yet again that 'progress' is everything, and frenetic at that. "O", "A" and BTEC level people should study tensors, number pairs, up-to-the-minute bits and pieces that the 'maths pushers' say is in fashion. Many of us do not go along with the fiction that progress is occurring in this naive way at all. What about the chlorinated compounds and the ozone layer – and the nuclear fiascos?

Much closer to home, how would Mr Coleman offer the budding electronic engineer expressions for the reactance of an inductor, $j\omega L$ for example, or Fourier transforms. More to the point even than that, all the exams I have seen from engineering institutions contain questions about j and the concise way phasors show phase and frequency and so on.

On the other topic, vectors, I'm afraid it is the same story. Yes, division by a vector is not defined, and that's O.K. as there is no physical or engineering need for it anyway. Would Mr Coleman throw away all algebras that didn't commute? Out would go matrix algebra too, I suppose. Tensors might very well turn up with anisotropic media, like permeability and ferrite material, or birefringent dielectrics. If Mr Coleman's students study General Relativity, then sure, tensors will turn up. But I'll wager they'll not turn up until all the students have a good knowledge of vector analysis for electromagnetism studies, and so on.

No, I repeat, Mr Coleman must be reading some remote esoteric stuff to think he can argue about obsolescence in the way he did. In any case I disagree entirely that everything studied 20 years ago has gone – we still use Newton's laws and those of thermodynamics for nearly all engineering design (ask any motor engineer), and for rocket design and launching – to say nothing about those Maxwell's equations I discussed in the article...

Joules Watt
Staple
Kent

Moving-coil preamplifier

I read with great interest Doug. Self's article on m.-c. stages in *EWW* for December 1987. I'm glad to see at last a proper, practical approach to circuit design. The article was well written, fluent and not bogged down with largely irrelevant mathematics. Figure 2 clearly demonstrated the fact, little known amongst most engineers, that Bi-fet and J-fet op-amps are extremely noisy. Any engineer will tell you, after reading any data sheet on modern op-amps that they are all very low-noise, very high-performance devices. That fet op-amps are low noise devices is sheer nonsense. Any engineer worth his salt who can wire up a circuit and measure it will find that, for impedances below 50kHz, bipolar junction transistors are quieter than fets. A fet only comes into its own in two areas; for high impedances or for r.f. from 50MHz to 500MHz. Above this frequency, b.j.ts again exhibit superior noise specs. Fet op-amps are far noisier than even 741s in audio applications, as shown by Mr Self, their main use being for high input impedances and low bias-current usage in, for example, sample-and-hold circuits. Outside this limited area they are best put to use for building motorways.

However, I must point out that Mr Self fell down on the definition of which noise he is actually measuring. He measured unweighted noise and without RIAA correction. This is grossly in error for a practical m.-c. stage.

The reason is that a high-gain (h_{FE} typical 1200) BC650 will exhibit exceptionally low flicker noise (low frequency), but unweighted measurements show high wideband noise in excess of that of virtually any other type. Since an RIAA stage has roughly 30dB differential gain between low frequencies and mid audio-band frequencies, a transistor must be measured under these conditions to give a true indication of whether it is audibly quiet or not. Secondly a CCIR filter fitted with a true peak detector must be used to simulate the ear's response. Unweighted measurements are meaningless even for comparisons. A selected low r_b ZTX655 will give a very good performance in Mr Self's setup due to its low-gain, low white-noise level. However, when fed through a RIAA circuit it is dominated by flicker noise, which makes the system almost useless, with a continuous growling sound.

One last point on noise; the key to the whole performance is running the input transistor at the optimum collector current for a given source impedance, as Mr Self mentions. He then uses a standard 3R3 resistor as a source load. I have found many times that optimum I_c for minimum noise cannot be set on a pure resistor. Presumably one intends to actually use the circuit with a particular cartridge, therefore I_c should be optimized for that cartridge. I have found that if a cartridge (carefully screened) is actually substituted for the 3R3 resistor, the audible and measurable noise is significantly worse, typically by 8-10dB. The reason is that the cartridge is inductive exhibiting a rising impedance with frequency. Since noise with most low-noise transistors is subjectively worse at mid-audio frequencies, the input stage's I_c must be lowered to give a better match. Empirically, this optimum operating current with an actual cartridge connected has been found to be around 1/3 that obtained with a shorted input, and gives a real, practical noise voltage within 2dB of that of a 3R3. It is also interesting to note that a lower input-stage noise in medical electronics is normally obtained by operating the input device at optimum collector current and with a fixed V_{CE} of less than 3V. Mr Self's is a little high at 5V and with an op-amp output stage linearity is not a problem.

Whilst I agree entirely with Mr Self's view of a single input stage and the avoidance of differential inputs due to 3dB worse noise, I cannot agree with the idea of using an electrolytic at the input. Whilst I myself cannot measure any degradation in t.h.d. down to 1p.p.m., it has been demonstrated many times that there is an audible difference between a short circuit and a high-quality polypropylene capacitor. The use of a 220µ input capacitor is rather excessive; whilst I appreciate the value has to be large in order to present a low impedance at the base terminal at low frequencies, low-frequency noise is of impulse nature, with most of its energy at higher frequencies, and little at the fundamental pulse-repetition frequency. Subjectively, a 22µ is satisfactory with no audible change even at 4µ7. To stabilize the individual transistors' collector currents, as emitter degeneration would degrade the noise, the first stage's d.c. loop being local, individual collector resistors, say 220ohms, and individual base-collector feedback resistors would serve this purpose without noise degradation as the signal level at this point is greater than at the base-emitter input. This would then allow three separate input coupling capacitors, say 10µ polypropylene filmcaps, connecting to each isolated base.

Les Sage
Bingley
Yorks

ELECTRONICS AND WIRELESS WORLD 1988 COMPETITION

For news of our 1988 competition, do not fail to see this issue. The prizes are truly spectacular and there is no hardware design involved – simply writing. All will be revealed in the March issue, on sale Thursday, 18 February, 1988.

V-series microprocessors and 'C'. Two articles from NEC describe the V-series of high-speed c-mos micros, which are pin-compatible with 8086 and 8088 types. The V25 incorporates features which allow efficient handling of internal peripherals, residing in separate I/O address areas, directly from the C language – a process which is normally difficult in high-level languages.

The goniometer. Gregor Grant contributes a piece on the goniometer and its decades of application in direction-finding equipment for air navigation, from the Bellini-Tosi antenna to the standard VOR beacons.

High-definition television. Geoff Lewis reviews the proceedings of the Third International Colloquium on h.d.tv held on Ottawa recently. The NHK Muse/MAC controversy continues.

Shockley, Bardeen and Brattain are the subject of this month's Pioneers piece, by W. Atherton. It is forty years since the world first heard of their invention, the point-contact transistor, which took several years to find any serious application.

Einstein's relativistic ether. Einstein has the reputation of having killed off the ether. Dr Ludvik Kostro, of the University of Gdansk, points out that this is not the case: Einstein denied the fixed ether, but proposed a new conception of the ether which is non-stationary.

Confessions of a frustrated inventor. Heinz Lipschutz, who invented inertial navigation in 1939 but was unable to interest anyone in the system, recounts his experiences over many years of trying to exploit his work. "Unless an inventor has... financial muscle... he is better off growing roses on the centre lane of the M1".

International programming language

A computer language that can be used on almost any desk-top or home computer *without change* is the aim of I-APL, an international version of APL (A programming language) which conforms to ISO and proposed British standards. The language is *free* to users.

APL was originally devised as a method of notating mathematical expressions in a language that could be understood by a computer. Its first practical use in 1956 was a paper-and-pencil exercise to design the microprogramming of the IBM 360 computer. Since then the original 400Kbytes of code have been reduced to the 25Kbytes of I-APL which will fit into two 16K roms on, for example a BBC micro, with enough space left for a character font and a printer driver. The main advantage of APL is that it is particularly good at maths. Formulae can be entered almost as written. Consequently programming time is reduced to a tenth of that of other programming languages. Typically, statistics students can be shown how formulae are entered without needing to know that they are using a specific programming language at all. This method is used at the Statistics department at University College, Swansea, by Prof. Hawkes. Similarly, Prof. Spence of Imperial College, London has written a book on circuit theory with the equations in APL notation. A disadvantage is that on smaller computers APL is slow; benchmarks to complete a given task compare poorly even with Basic. However this is offset by the complexity of mathematics possible, such as matrix transformations.

I-APL is free to all who wish to use it. The only cost is the disc or eprom copying fee and for the manuals and textbooks. Tutorial, encyclopaedic and installation manuals are in preparation and will cost less than a photocopy of the same texts. Versions of I-APL are in preparation for IBM-PCs, BBC, Sinclair Spectrum, Commodore C64, Apple II, Atari ST and many other computers. Details from Anthony Camacho, Chairman I-APL Project, 2 Blenheim Road, St Albans, Herts AL1 4NR.

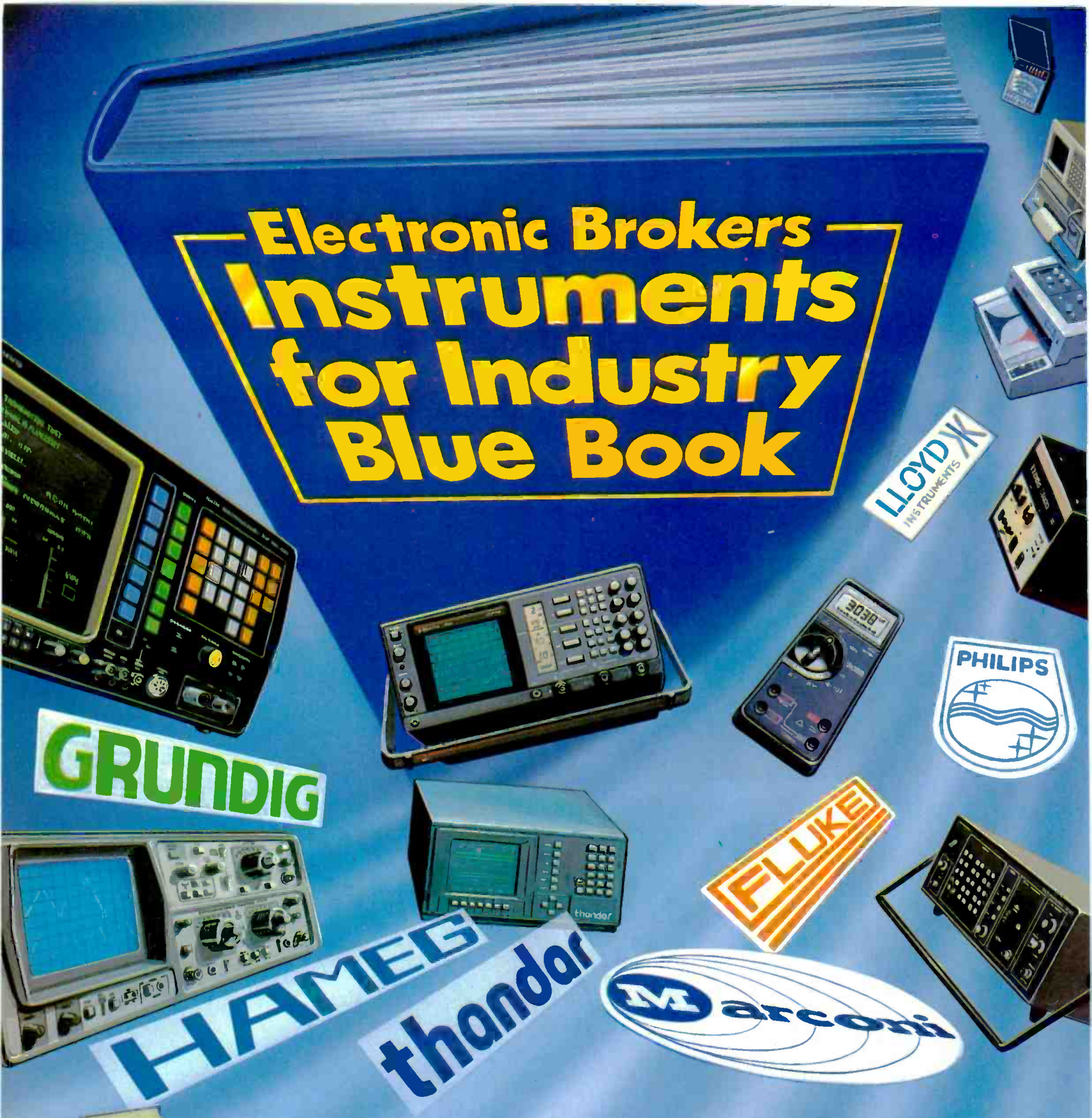
Enhancing IBM PCs, XTs and clones

In this article presented in the November issue, the reference to jumper E was incomplete; it is in fact jumper E2. The photograph on p1094 is of IBM's new PS2 computer, which would not benefit a great deal from the modifications described in the article.

FEBRUARY 1988

INDUSTRY INSIGHT

Seven-page review of the VMEbus extensions for instrumentation – what VXI is all about: a case of evolution rather than revolution • latest digital oscilloscope architecture: a case of revolution rather than evolution • market trends in test and measurement equipment • top-end dmm and dso listings • will your dmm cost more to keep than it does to buy? • new flat-screen dsos • PC-based instrumentation market • integrated tendency



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INSTRUMENTATION

FIRST VXI PRODUCTS EMERGE

Only five months after the announcement of the VMEbus extensions for instrumentation, VXI for short, the first products to be designed around it are revealed. Companies active in the high-speed instrumentation business – the 30 or so registered potential users highlighted elsewhere in this *Insight* – have been keeping their instrument cards close to their chests, some aiming to release details at January's ATE Show West in Anaheim, California. But what we have been able to establish as we go to press in mid December is included in this report.

● First product details came from one of the smallest companies in the business, United Test Equipment of Anaheim. The VXI Modular Test & Monitor System is based on an A-size card using the P1 connector and measures 25 by 30 by 15cm without the computer. It is software-driven from an IBM PC or compatible and the monitor screen shows i.c. pinpouts, logic signals with labels (just visible in the photograph on page 167), and connector details when cable testing.

● Another product on show in Anaheim is Colorado Data Systems VXI Prototyping System, which they claim is the first VXI product. According to Lou Klahn of CDS it is the first of many: "We plan to announce a new product at the rate of one a month throughout 1988" he told *Insight*.

The prototyping system, type 73A, consists of a 488 mainframe, a 488-to-VXI interface board that also provides the required VME and VXI interface clock and control signals and other slot-0 functions two wire wrap cards with power filtering (one with VXI interface), an extender card, and an adapter to allow the 60 or so modules of CDS's 53A series of 'instruments-on-a-card' to be used. Detailed user and service manuals with circuits are included "One of the most exciting possibilities of having a number of instruments in a common, closely-coupled environment is tighter time coordination leading to a higher level of system performance than has ever been possible" enthuses Lou Klahn. "The 73A-PRT allows users to explore the ramifications of this capability in their own market place".

● Tektronix had been working on a VME-based architecture for Card Modular Instruments prior to the development of the VXIbus standard. Other instrument companies and a.t.e. end-users had independently determined a need for a card instrumentation architecture and, significantly, VMEbus had been indentified by them all as the foundation bus.

The VXI spec reflects the early Tektronix work, as well as that of the four other companies who participated in the VXIbus discussions. Many of the higher perform-

Continues on page 167

INSIDE

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INSTRUMENTATION

VXIBUS AND ITS IMPACT ON INSTRUMENTATION

Lou Klahn of Colorado Data Systems explains why the VXIbus is an evolutionary necessity in the world of test systems

The recent announcement by five major instrument manufacturers of a new bus standard for instrumentation, dubbed the VXIbus for VMEbus extensions for instrumentation, raises two important questions: why is the VXIbus necessary, and secondly, what is it and why is it important in the instrument world?

The fact that five instrument manufacturers who are traditional competitors have agreed to a new bus standard is a good indicator of the importance of this step. These companies, CDS, Hewlett-Packard, Racal-Dana Instruments, Tektronix, and Wavetek, have wholeheartedly endorsed the VXIbus, and believe that it will enhance the development of automatic test systems by allowing the user to more easily utilize modular instrumentation. By virtue of it becoming a standard, it will provide a great variety of available 'Instruments on Cards'.

In order to understand why VXIbus, although technologically an innovative concept, is an evolutionary rather than a revolutionary step, it is first necessary to understand the historical motivation that led to its development. Two fundamental and basically independent forces have combined to bring VXIbus to where it is today. The first factor, primarily driven by military requirements, is an increasing need for more capable test systems that are smaller and lighter. The second factor, driven by all users of a.t.e., is a growing requirement for test systems that have the higher levels of systems performance that can be achieved by integrating multiple instruments in a common instrument environment.

Since the VXIbus will be a standard, it will allow users to select from a wide range of instruments, interface cards and computers from different manufacturers, with full confidence that these modules will operate together when used in a single test system. Test system designers that use the VXIbus will be able to tailor their test to their actual needs, since they will be able to design the equipment for the test rather than the other way around.

A short history

Although test systems using modular technology have been around for a number of years, they have all suffered from the problems caused by a lack of standardization. A user could typically not get all or enough of the instrumentation that might be needed for a given requirement in a common format. (In fact, a system that uses a relatively large mainframe into which only a few of the needed complement of functions can be placed, can actually make a test system larger rather than smaller.) In addition, since some of these systems used either an unmodified computer backplane or an extension of the IEEE-488 bus itself, the problem of properly distributing instrumentation signals within a mainframe still remained, although these approaches did solve many of the command and control problems.

In 1985, the US Air Force asked the MATE User's Group (MUG) to make specific recommendations regarding standardization of instrument-on-a-card (IAC) technology. It was their intent to take these recommendations and turn them into a standard that could be added to the Air Force's Modular Automatic Test Equipment (MATE) Guides. This task was completed and the recommendations submitted to the Air Force early in 1986 – a set of recommendations that were based on extensions of, and minor modifications to, VME. The Air Force then undertook an extensive evaluation of those recommendations. The major stumbling block to Air Force adoption of an IAC standard was a lack of consensus on the part of industry, especially the manufacturers, as to the exact technical content of the standard. The actual *need* for a standard had already been endorsed by both industry and users.

In a parallel effort, each of the five companies was in some stage of developing an internal IAC standard. Colorado Data Systems was in the process of updating the IAC system they had been delivering since the mid-70's. In 1985, Tektronix had announced a concept, an open architecture, and initial products for a product line they dubbed CBI for computer based instrumentation. In 1987, Wavetek announced their Model 680, which included a product from Racal-Dana. Hewlett-Packard was in the process of defining upgrades and replacements for some of their modular equipment. The common denominator for all of these efforts was VME.

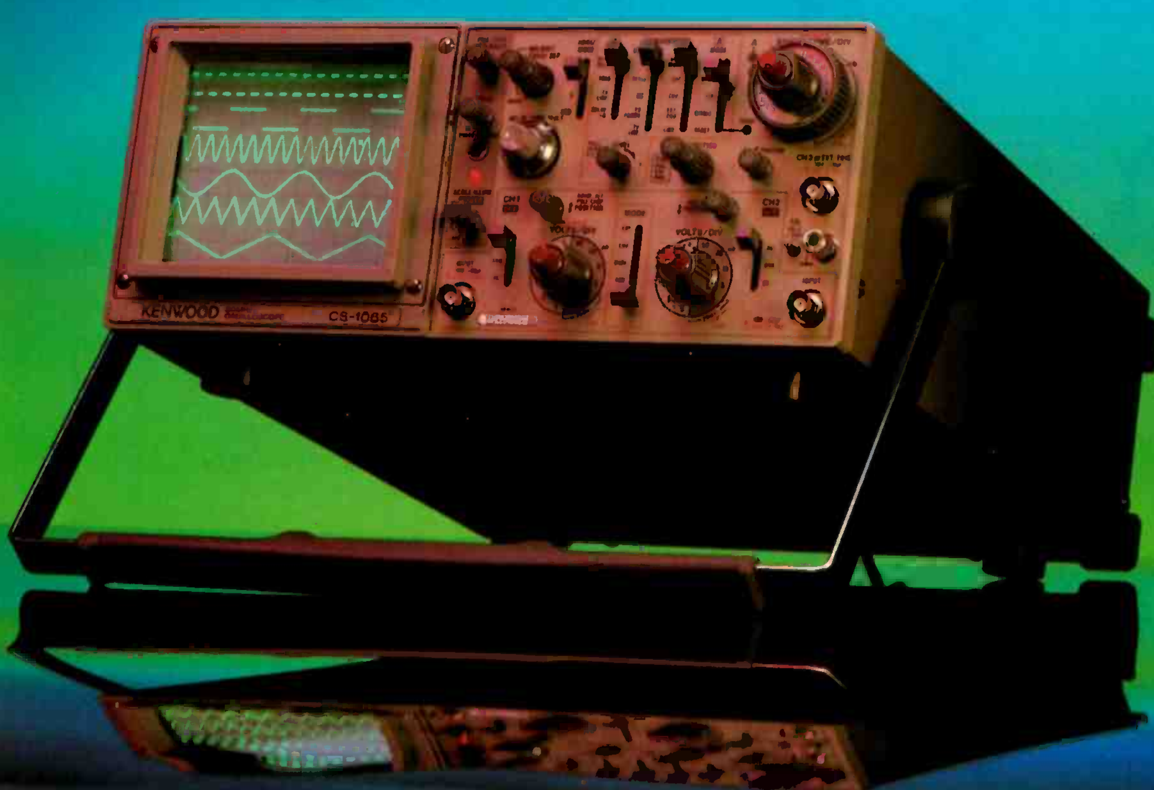
Private conversations between the five consortium companies started during 1986. By early 1987, it had become apparent that, for the good of the industry, it was necessary for these companies to temporarily set aside their differences and see if they could agree upon a working standard. A series of meetings started in April of this year that culminated with the announcement, in July, of the VXIbus. (An interesting sidelight – the VXIbus not only meets all of the recommendations of the MUG IAC Subcommittee, but its backplane is also functionally very similar to the backplane defined by that group). The consortium also intends to submit the VXIbus to the IEEE with the full endorsement of each of the five companies involved, and a strong recommendation that it be adopted and published.

What is VXIbus?

Before beginning to describe what VXIbus is and how it works, one basic question needs to be answered: why was it necessary to extend VME rather than use it intact? The fundamental reason is that VME is a computer bus, and while it solves the problems of command and control, it is not ideally suited to the world of instrumentation. For example, it tends to be somewhat noisy, a real problem in the world of low-level analogue and r.f./microwave instrumentation. In addition, it contains no provisions for handling some of the signals necessary to instruments, such as triggers and analogue signals.

Moreover, to create an environmental conducive to the higher level of system performance that instrumentation users want, the consortium found it necessary to define additional clocks and signal paths. Another problem with the VMEbus was that it did not supply the kind of power needed by instruments, so additional power and grounds had to be included.

The VXIbus standard builds on the existing standard for VME (IEEE-1014): it in no way violates VME and in fact contains specific provisions that help ensure that



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CS-1065

standard VME cards will operate properly within VXIbus systems. Where VME specifies two card sizes, VXIbus specifies four different card sizes (designated in the standard as A, B, C, or D), drawn from the Eurocard standard. Depending on the card size selected, these cards may use one, two or three 96-pin DIN connectors. The size-A card utilizes a single DIN connector (P1). Size B, which corresponds to the standard VME card, and size C cards also use P1, and optionally, P2 connectors. Size D cards use P1 and, optionally P2 and P3 connectors.

Like VME, each additional connector offers increased power and performance, but unlike VME there are no user-defined pins. All connectors are *fully* defined. The VXIbus P1 connector conforms exactly to the VME definition for the P1 connector, which is used for command and control. Likewise, row B of the P2 connector is exactly per VME. VXIbus uses rows A and C of the P2 connector, and all of the P3 connector, to define additional power and ground, two local buses, two additional clocks, trigger and sync signals, and a sumbus, all of which are explained in more detail later in this article.

Because the potential application areas for the VXIbus include all of the areas where automatic or semi-automatic testing is being used today, the architecture had to be extremely flexible. It also had to make provisions for the future growth of instruments on cards. As a result of these needs, special care was taken to ensure that the VXIbus could accommodate almost any system hierarchy or topology. It deliberately does not specify the use of any particular type of microprocessor, operating system or interface to the host computer. Similarly, the content of the individual instrument commands is left solely to the manufacturer, although IEEE488.2 is suggested as a guideline.

What the specification describes

If these areas are left up to the manufacturer, what then does the new spec. address? What the proposed standard describes, in detail, are the technical requirements (hardware and software) necessary for a variety of cards from different manufacturers to be used on a common computer/instrumentation backplane.

As a start, the VXIbus defines the hierarchy of device types with an automatic configuration protocol defined for all types. A set of configuration registers, which are accessible from the P1 connector, are specified for each device type. Through these registers, the system can identify each device and its type, together with model number and manufacturer, plus additional memory requirements, if any.

The simplest of these devices types, called "register-based devices", are normally "dumb" devices in that they will normally not contain local intelligence. A second class of devices, "memory devices", may include such things as rams and roms. A third class, "message-based devices", is required to have communication registers that are accessible to other modules within the system, and are intended for use where higher levels of communication are desired. The latter class will typically be a smart device that contains parsers that an interpret ASCII commands. They can also be designed to control register-based devices.

Communication between VXIbus devices is based on a hierarchical device relationship involving Commanders and Servants. Within a system containing multiple commanders, each commander can control its subset of instrument modules ("servants"). A VXIbus system can contain as many as 256 different devices if multiple chassis are used.

The most common VXIbus configuration, especially over the next few years, will probably be a system with an IEEE-488 to VXIbus interface card controlling the instrumentation within the cardcage. In this mode, the VXIbus can be made transparent to 488 users, although higher level users (so called "power" users) will have direct access to the bus if they need it. Another possible configuration is a stand-alone system with its own c.p.u., memory cards, and optionally its own mass storage. This would allow it to operate independently of, or in conjunction with, an external system controller.

Fundamental communication within a VXIbus system is based on a byte-serial protocol. This allows users to choose, for example, between the IEEE-488.2 for commercially-oriented systems, or CIIL for MATE-oriented test systems, as well as utilize other test languages now or in the future. It also means that VXIbus instrument modules can be configured in a wide variety of ways as required by the application, limited only by the user's imagination, and by the suite of instrument functions available at the time the test system is built.

One of the most exciting possibilities of having a number of instruments in a common, closely-coupled environment is tighter time coordination, leading to a higher level of system performance than has ever before been possible. The VXIbus trigger lines have been defined with just this possibility in mind. Traditional rack-and-stack instruments connected via cables cannot hope to match the control over signal characteristics and propagation delay that is possible in a well-defined and controlled backplane environment. Signals that have been added on the VXIbus specifically for this purpose include a 10MHz and a 100MHz e.c.l. clock, e.c.l. and t.t.l. trigger lines, and a "local bus". To give some idea of the performance levels possible, t.t.l. triggering is possible at rates in excess of 10MHz, while e.c.l. trigger rates exceed 50MHz. Data transfer rates well in excess of 100MHz can be generated.

The local bus, defined for both P2 and P3, is a daisy-chained structure between cards that allows manufacturers or users to define their own unique protocols and uses. For example, the local bus can be used to transfer analogue signals, t.t.l. data, and/or e.c.l. data between adjacent cards of a instrument set. IAC modules that use the local bus must follow a hierarchical classification scheme based on a given module's intended use of the local bus. This scheme includes a mechanical keying mechanism designed to insure that an IAC module that falls into a given class regarding its utilization of the local bus is not accidentally connected to an incompatible class, which could result in damage to either or both of the IAC modules. Classifications currently defined the VXIbus include t.t.l., e.c.l., low-level analogue medium-level analogue and high-level analogue. A given IAC module may occupy more than one classification.

One of the stickier problems faced by the architects of the VXIbus was that of power and cooling requirements. The standard solved the problem by requiring manufacturers to always specify the power and cooling requirements for each card using a standard, easily reproduced, method. Similarly, manufacturers of cages must also specify the power and cooling capacity for their cage. This means that users can easily determine whether or not a given card or set of cards can be used with a given card cage. A side benefit of this approach is that manufacturers can choose to build either IAC modules, or cages, or both, while still allowing users full freedom of selection.

Similar to VME's impact on the computer industry, adoption of the VXIbus standard represents a major step forward in the instrumentation industry. Some industry observers have stated that its potential long-term impact may even rival that of IEEE-488. Not only will it widen the areas where modular instrumentation is being used, but it will also, due to its ability to offer a higher level of systems performance, open new application areas. It is important to emphasize that the VXIbus architecture is an *open* architecture available to all manufacturers and users. In the short time since its original announcement, more than 25 different companies have expressed an intent to produce products designed in accordance with the VXIbus standard.

Designers desiring a copy of the VXIbus specification are free to contact the author at the address below.

Louis J. Klahn is vice-president of sales at Colorado Data Systems Inc, 3301 W. Hampden Avenue, Unit C, Englewood, Colorado 80110, one of the five originating companies of the VXIbus.

INSTRUMENTATION

THE VXIBUS

An emerging industry standard

VXIbus, a backplane bus specification, will enhance the construction of automatic test systems by providing greater flexibility in mixing and matching modular instrumentation. The name itself comes from VMEbus Extensions for Instrumentation, as the VXIbus builds on top of the VMEbus standard.

The VXIbus will allow users to select a wide range of instruments, interface cards, and computers from different manufacturers and to have these modules coexist within the same cardcage. Like the IEEE-488 bus, VXIbus users will be able to tailor their automatic test system to the application with a broad range of products offered by many manufacturers, while gaining the benefits of integrated instrumentation.

As shown below, there are four standard card sizes and up to three connectors. The size A card only uses the standard DIN P1 connector, which remains as defined by VME. This connector accesses the VME data transfer bus, and is capable of up to 20Mbyte/second data transfer rate between modules. Size B and C cards use P1, and optionally, the P2 connector. Size D cards use P1 and can also use P2 and P3. Each additional connector offers increased power and performance. The VXIbus is designed so that smaller card sizes can fit into the larger mainframes.

Since the application range for VXIbus products is extremely broad, the architecture was designed to be very flexible. For example, the VXIbus spec. does not define a specific system controller or topology nor does it specify the type of microprocessor, operating system or interface to the host computer. Likewise, instrument commands are left to the choice of the manufacturer. What is defined by the VXIbus specification are the technical interface requirements and protocols so a variety of cards can be used on a common backplane while ensuring compatibility between different manufacturers.

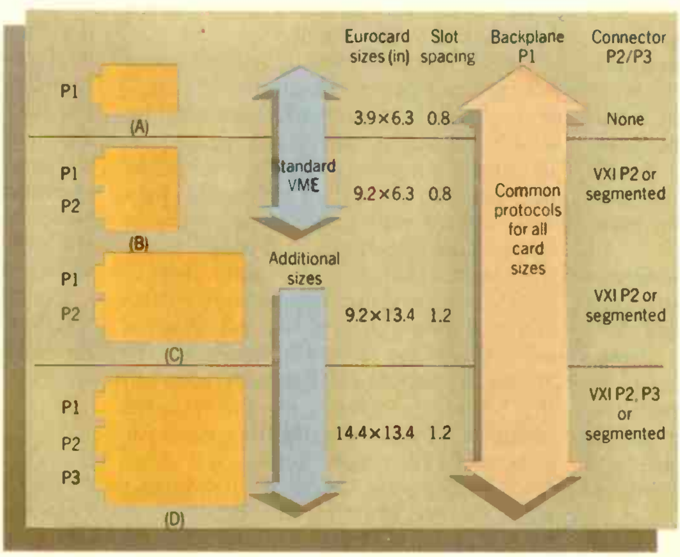
The VXIbus has an automatic configuration protocol that is required of all devices. A given device must

Larry DesJardin, of Hewlett Packard's Loveland r&d centre, analyses the VMEbus extensions for instrumentation.

have a set of configuration registers which are totally accessible from the P1 connector. This allows the system to identify the module, its device type, model and manufacturer, and memory space requirements.

The simplest of these devices are called register-based devices. Memory devices such as rams and roms have also been defined. Typically, register-based devices are dumb services, and only a few simple logic chips are needed to fully implement their VXIbus protocols. If a higher level of communication is desired, a class called message-based devices is defined to have standard communication registers accessible to other modules within the system. These typically are smart devices that interpret ASCII commands and may also be designed to control a number of register-based devices.

A device that controls other devices is called a commander, and its subordinate modules are called servants. When a multiple commander system is assembled, each commander can control its subset of instrument modules. In other words, the bus can be shared by more than one c.p.u., using the arbitration features of the VMEbus. A fully configured VXIbus system can have as many as 256 devices in a multiple chassis configuration.



By having the language of the message-based cards the same as for IEEE-488 control, VXIbus cardcages may be easily integrated into standard rack-and-stack 488 systems. Several possible configurations for VXIbus systems are shown on page 147.

One of the most popular configurations will be a system with an 488-VXIbus card controlling all the register-based instrumentation within the cardcage. The internal VXIbus will be transparent to '488' users.

Among other possible configurations is a 488-VXIbus card which interfaces with the other message-based cards in the system. In turn, each of these cards may have its own subordinate register-based instrument cards. By having each message-based instrument accessible through a unique IEEE-488 address or secondary address, the devices logically appear as separate instruments to the programmer. It is also possible for a complete system to stand alone with its own c.p.u. and memory cards, allowing it to operate off-line from a host controller.

The close proximity of instruments in a cage, combined with tight time coordination using the trigger lines, will lead to new levels of performance. The short and well-matched propagation delays, only possible on a well controlled backplane structure, substantially improve both performance and ease of configuration over the traditional rack-and-stack instruments connected via cables. Noise on the backplane, which can cause timing jitter, is reduced by surrounding the trigger lines with a.c. grounds, and sandwiching them between ground layers on the backplane.

Strict near-field r.f.i. limits effectively mandate the use of shields on most modules. These levels allow the precise analogue measurements many

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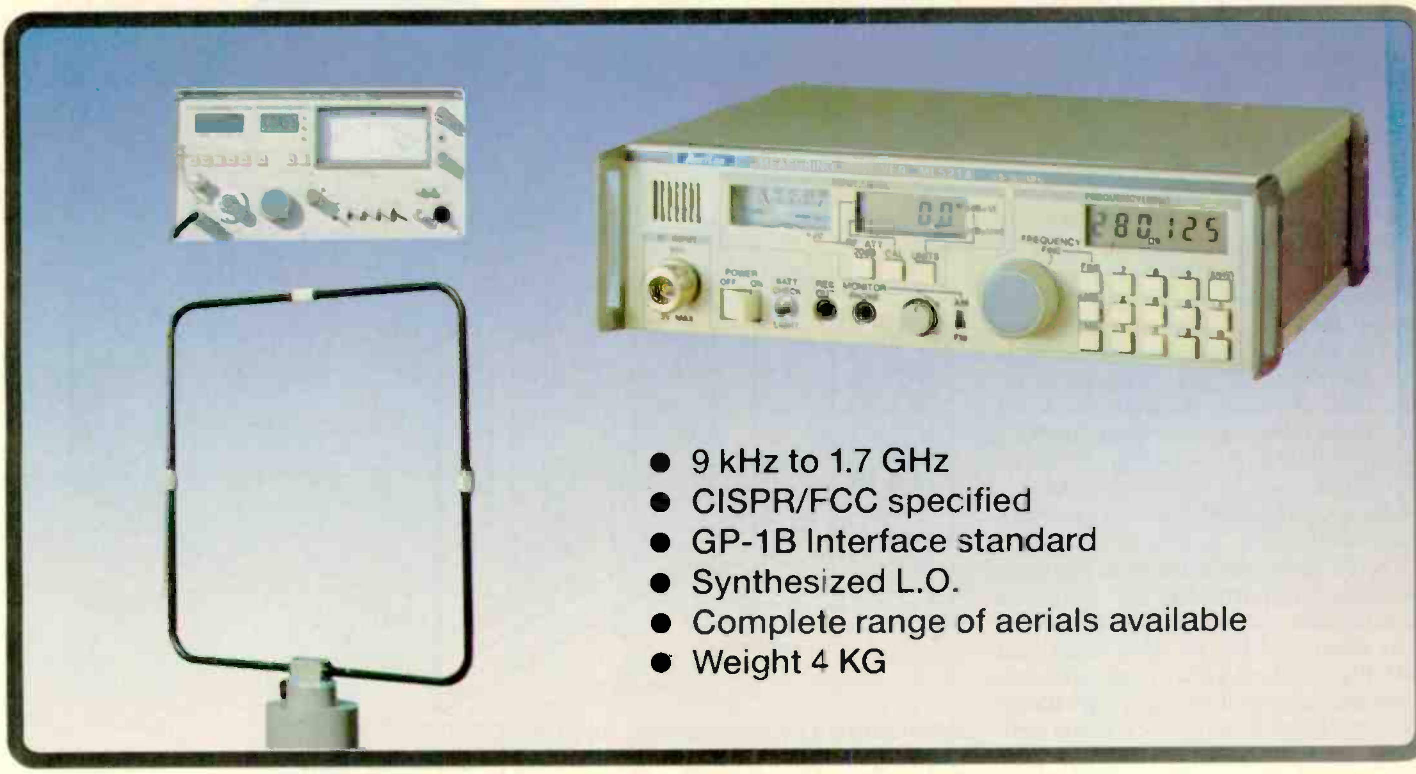

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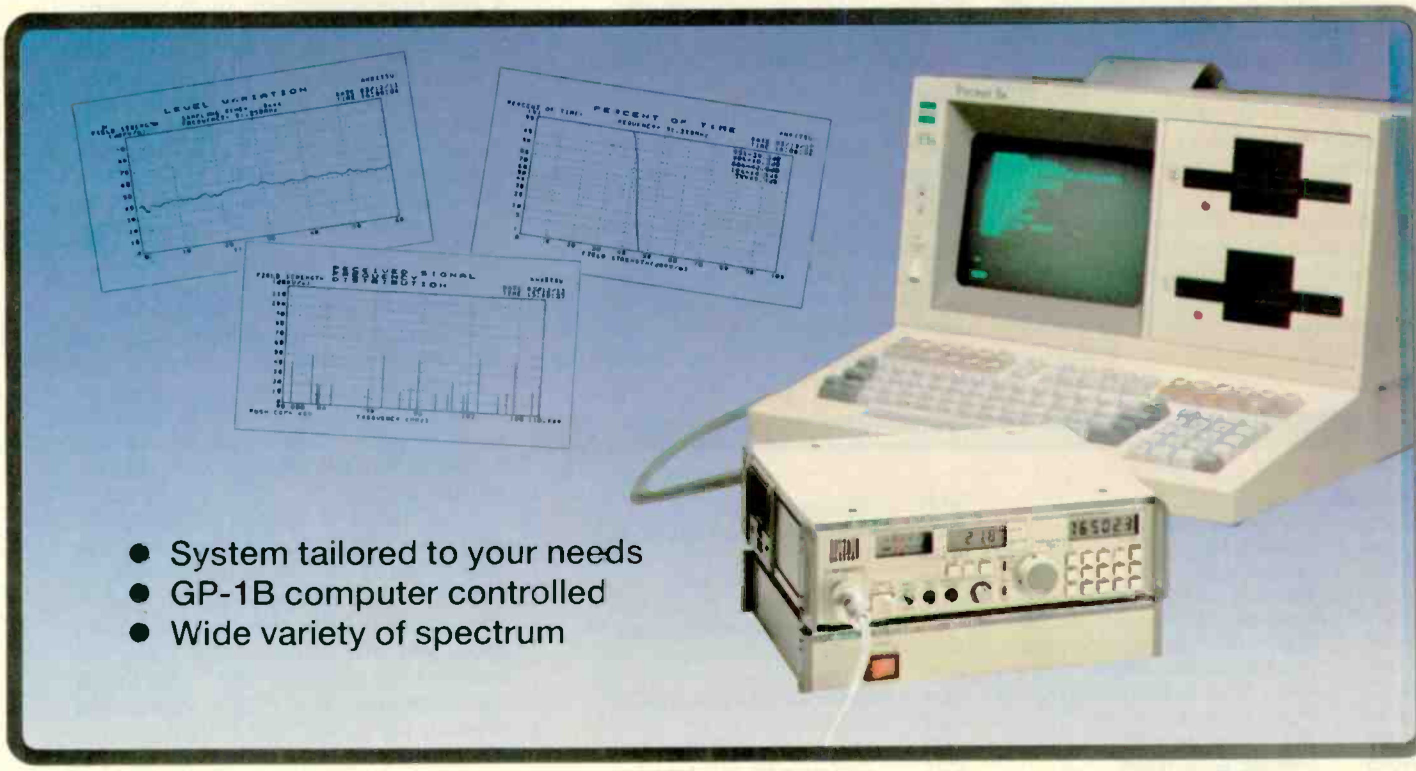

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had believed to be impossible in a bus-based environment. Performance ranging from six-digit voltage accuracies to measurements of signals in excess of 1 GHz are expected to be available on the VXIbus within the next year.

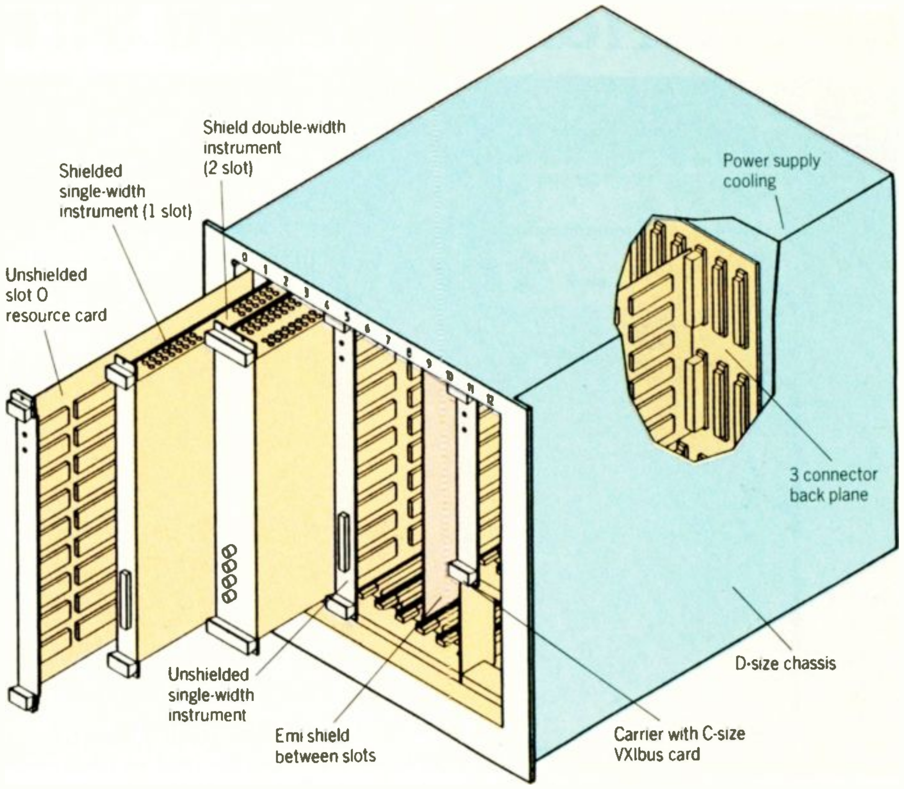
The VXIbus retains compatibility with the VMEbus solution of defining the centre row of the P2 connector to complete the 32-bit architecture. This doubles the system bandwidth to 40 Mbytes. The VMEbus standard further allows the 64 pins of the outer rows of P2 to be defined by the system. On these lines, the VXIbus adds a 10MHz e.c.l. clock, logic and analogue power supplies, e.c.l. and t.t.l. trigger lines and a daisy chain structure known as the local bus with 24 pins (12 lines in, 12 lines out); t.t.l. triggering is possible at rates exceeding 10MHz, e.c.l. trigger rates may exceed 50MHz.

The P3 connector is aimed at high performance instrumentation and includes a 100MHz clock and 48 additional pins for the daisy chain local bus (24 lines in, 24 lines out). It also defines a star trigger system to allow precisely matched triggering between modules regardless of module position within the cardcage.

Some cardcages may also 'segment' the VXIbus backplane. That is, they may conform to the P2/P3 VXI subsystem definition for some slots, and define these pins differently for others. They may even keep these pins undefined, to be connected by the user. This is useful for integrating some present VME cards that have implemented alternative bus structures on P2 (such as the VSB subsystem bus), or are using these pins for internal i/o. Of course, P1 will always remain as defined by VME and VXI.

To maximize compatibility between manufacturers, standard trigger protocols have been defined. Trigger protocols include a synchronous mode where a source module drives a single line. The semi-synchronous mode allows acceptor modules to handshake on the same line. Asynchronous triggering using a pair of lines further expands triggering capability, and will commonly be used to interface to standard rack-and-stack instruments.

For applications requiring very high data transfer rates – approaching 1 Gbyte/s using emitter-coupled logic – the local bus structure defined on P2 and P3 is available. It is daisy chained between adjacent cards, allowing manufacturers to define their own unique protocols and uses. The local bus can also be used to transfer analogue signals and t.t.l. data between neighbouring cards of an instrument set. A keying mechanism on the faceplate ensures that one signal class on a local bus is not accidentally connected to an incompatible class, which helps avoid potential damage.



Shown here is a VXIbus mainframe used for internal product development at Hewlett Packard Co. Also shown is a prototype instrument module and a carrier assembly that allows standard B size VME modules to be integrated into C size mainframes.

To become a VXIbus manufacturer, a unique manufacturer identification code is required by the VXIbus autoconfiguration protocol. There is no fee, and no further obligations. An application form is in the beginning of the VXIbus System Specification Rev. 1.1. Alternately, a company may apply by sending its official company name, VXI point of contact, title, address, and phone number to the author or any of the other VXIbus consortium representatives. The author's mailing address is Larry DesJardin, P.O. Box 301A, Loveland, CO.80539, USA. Identification codes are usually granted within a month.

First, there has to be a critical mass of modules on the market to choose from. The original set of five manufacturers has expanded to over 27 (see list), and product announcements are expected throughout 1988. Next, the user must check that the requirements of the modules match that of the mainframe. The VXIbus specification requires the power and cooling requirements for each module to be specified by the manufacturer. Since the power and cooling capacity of the cardcages must also be specified, users can intelligently match the requirements of their cards to be equal or less than the capacity of the cardcage.

The A and B-size modules, with their smaller, stiffer form factor, will be most suitable for portable and ruggedized applica-

VXI bus manufacturer list with ID codes

ID Codes	Company	ID Codes	Company
4095	Hewlett-Packard Company	4082	Grumman
4094	Wavetek, Inc.	4081	John Fluke Manufacturing Co., Inc.
4093	Tektronix, Inc.	4080	Bruel & Kjaer
4092	Colorado Data Systems, Inc.	4079	Sciteq Electronics, Inc.
4091	Racal-Dana Instruments, Inc.	4078	Westinghouse
4090	Electro Scientific Industries, Inc.	4077	Emerson Electric Company
4089	North Atlantic Industries	4076	Radix Micro Systems
4088	Systron Donner Instrument Division	4075	NH Research
4087	Elgar Corporation	4074	Autek Systems Corporation
4086	National Instruments	4073	ICS Electronics
4085	Analogic Corporation	4072	ILC Data Device Corporation
4084	Schlumberger	4071	California Avionics Labs, Inc
4083	LeCroy	4070	Universal Test Equipment
		3839	General Purpose Breadboards

General Purpose Breadboards refer to custom breadboard modules a user may build to add to commercially available modules. By having a unique code for breadboard modules, these will never be identified as belonging to a particular manufacturer, which could cause a system module to mistake a breadboard module as a commercially available VXI instrument. The breadboard modules we offer, as well as our competitors, will have this code, 3839 happens to be a simple code to implement.

tions, as well as where compatibility with present VME cages is important. C-size modules will find many of their applications reducing the size of present rack-and-stack test systems, while delivering a more integrated solution. Much of present day instrumentation can be implemented in this form factor. D-size systems will address applications requiring high bandwidth and tight time coordination that is difficult, if not impossible, to achieve using discrete instruments.

The acceptance in the industry looks extremely promising. The IEEE has formed a committee (IEEE P1155) to pursue adoption of the VXIbus specification, and Working Group 3 of the IEC is also tracking this effort. Defence contractors, needing to downsize test equipment for quick deployment, are welcoming the new standard and the United States Air Force is considering adopting the VXIbus as its standard "instrument on a card" architecture. Many commercial users, driven by needs of higher throughput, functional density, flexibility, and easily customized solutions, are also considering adopting the VXIbus as their future test platform.

A VXIbus standard will open new application areas for modular instrumentation by simplifying the configuration of an automatic test system. It will allow users to select from a variety of manufacturers and to mix and match their products within the same cardcage. The VXIbus architecture is open to all manufacturers, not just the original five. Already over 20 additional companies have been assigned identification codes to allow them to design to this emerging standard.

Larry DesJardin is R&D section manager and VXIbus consortium representative at Hewlett-Packard Co, Loveland, Colorado.

A FEW POSSIBLE VXIBUS CONFIGURATIONS

Host controller — **IEEE-488 bus**
IEEE 488 to VXIbus card with commander capability
Register-based Instrument-#1
Register-based Instrument-#2
Register-based Instrument-#3
RAM card

Host controller — **IEEE-488 bus**
IEEE 488 to VXIbus card
Message-based Instrument-#1 with commander capability
Message-based Instrument-#2 with commander capability
Register-based Instrument-#3 (subordinate to Instrument-#1)
Register-based Instrument-#4 (subordinate to Instrument-#2)
RAM card

Host controller on a card with commander capability
Message-based instrument-#1
Message-based Instrument-#2
Register-based Instrument-#3
RAM card

INSTRUMENTATION

WILL YOUR DMM COST MORE TO KEEP THAN IT DOES TO BUY?

The wide span of price tags attached to the many digital multimeters currently on the market presents a difficult selection problem to users anxious to secure the best value for money. In the absence of a Which? Guide to Multimeters there are no clear, independent recommendations on best buys, and the user is left to sift through reams of specifications which, at the end of the day, may give scant consideration to the underlying issues involved. Current thinking is that determination of the true life-cycle cost of ownership must take into account a large number of obvious or hidden factors which are often less a matter of specification than of the traditions and philosophy of the manufacturer.

Only one cost is obvious, that is cost of acquisition. It may come as a surprise to many to discover that widespread opinion in the T&M industry puts this cost at typically 30% of total lifecycle cost, or cost of ownership for the full lifetime of the instrument. Here is a summary of the costs that must be considered and their relative importance:

Initial purchase	30%
Integration into system	30%
Periodic re-calibration	15%
Support documentation	10%
Lifetime maintenance	10%
Upgrade/expansion	5%

It isn't enough to read specifications and price tags and leave the rest to chance. A little probing could pay off handsomely over an instruments lifetime.

It follows that the manufacturer who can minimize the hidden costs and ensure that his selling price is still competitive is giving the user a much fairer basis for his choice. A further, and fundamental requirement is that the manufacturer support the instrument during its entire lifetime – a point which should not be taken for granted.

British manufacturer Schlumberger (formerly Solartron) has a unique tradition in design and manufacture of these instruments, and the newly-launched 7150plus multimeter embodies the knowledge and experience gained over two decades of technological innovation. Minimization of the hidden costs is achieved through measures which include testing to military standards for optimum reliability, careful design for ease of use, and comprehensive measurement capability.

Down with cost of ownership!

The figures given show that it can cost more to install and operate the instrument than to buy it, so ease of use becomes a key factor in selecting a cost-effective instrument. Time to train operators and calibration personnel, to develop software, and to document test procedures and results, frequently have a big impact on total cost of ownership. A good manual is a benefit, but even better is an instrument which is so easy to operate that the manual is redundant. A simple front panel layout and a clear easy-to-read display giving total user information avoids costly errors and reduces operator training time. Autoranging is an essential practical step towards ease of operation. Features such as these, together with digital calibration and built-in IEEE interface, all help to minimize operating costs.

Second only to operating costs come calibration costs, and here the concept of calibration for life can have a profound influence on the choice of an instrument. Gone are the days when calibration intervals must be strictly adhered to because of the unpredictability of performance thereafter.

Careful choice of components and good design techniques, together with thorough manufacturing quality control and testing of the finished product, can eliminate the random variations of calibration and ensure that drift is attributable to the inherent stability of the critical precision components only.

For example, long-term drift to the best quality wirewound resistors is less than 10ppm, but by using them as matched pairs in the ratio mode actual drift can be reduced to one tenth that of individual components. Tests conducted over ten years on precision resistors reveal that drift is proportional to the square root of time, allowing drift to be predicted for long periods.

The reference voltage is usually derived from temperature-compensated zener diodes, with long-term stability one of the most important parameters. Optimum stability for d.v.m. applications is achieved by pre-conditioning or burn-in at high currents to produce accelerated ageing, followed by a stabilization period. Long-term drift can be reduced to less than 10ppm per square-root year by this method, and temperature compensation factors stored in non-volatile memory can be used in association with temperature-sensing circuitry to produce an overall change of calibration of well below five parts per million.

Excellent though the drift figure of commercially-available input amplifiers may be, amplifiers built with discrete components using drift correction techniques can be better, producing less than one microvolt per year drift.

The accurate prediction of long-term drift and performance of precision measurement instruments enables the user to select the calibration interval that best suits his application, to the extent of making calibration a thing of the past in some applications. The technique eliminates downtime for calibration and the need to provide backup instrumentation, particularly useful in a.t.e. applications or in remote locations. A higher initial purchase price with minimal re-calibration costs may thus provide the lowest cost of ownership.

When calibration is necessary, digital calibration with non-volatile storage of calibration constants eliminates the need for preset potentiometers with their inherent reliability problems. Another point worth a mention, storage of calibration constants is safer in floating gate semiconductor memory than in battery-backed memory, given the unreliability of batteries.

Maintenance costs, estimated to be at least 10% of cost of ownership, can be gleaned by the prospective buyer from mean-time-between-failures and mean-time-to-repair ratings, which will be freely available from the manufacturer who is proud of them! Decades of experience in designing for military markets gives Schlumberger the edge in manufacturing for built-in reliability, using techniques such as design type testing to Defense Standard 56-31, purchasing high-quality components from reputable manufacturers, and performing 100% hot soak testing. A high degree of mechanization allows for continuous soak testing for 168 to 1000 hours, using computers to weed out early failures to provide more thorough testing than manual methods at much lower cost.

A combination of component stress data in the circuit and historical test failure data is converted to m.t.b.f. ratings according to MIL specifications. The figure of 30,000 hours m.t.b.f. which Schlumberger quotes for its 7150plus means that there is a 63% probability that the unit may fail during that time; Schlumberger's verification procedures suggest that its instruments are at least three times better than this prediction, due in part to detection of early failures during hot soak test. When breakdowns do occur, self-diagnosis integrated in software locates the fault to board or part-of-board level for speedier repair. Analysis of failures

during test or in service is carried out to ensure a long-term improvement in quality.

Finally, although only 5% of overall cost of ownership is allocated to expansion it should be regarded as 5% too much, since careful consideration of requirements with an eye to future needs would ensure that measurement capability is adequate. If in doubt, it would seem sound policy to go for more capability than currently required to avoid subsequent need to update or purchase a second instrument. It is important that the benefits of some of the newer technologies are fully understood before a choice is made.

In summary, it isn't enough to read the specifications and price tags and leave the rest to chance. A little extra probing could well pay off handsomely over the instrument's lifetime; an instrument which has a short payback time, say one or two years, and then lasts seven to ten years can be considered the correct choice.

Umar Qureshi, is marketing manager for digital multimeters with Schlumberger-Solartron, Victoria Road, Farnborough, Hants GU14 7PW. Tel: 0252 544433.

INSTRUMENTATION

TEST AND MEASUREMENT MARKET TRENDS

Unspectacular money-value growth may hide increasing unit volume sales in some areas. Tony Leach finds the bus interfacing business thriving.

A study of the market for test and measurement instrumentation since 1984 indicates that it enjoys extremely steady but very unspectacular growth.

Growth figures for the overall market need to be examined against the background of falling prices – especially in the oscilloscope area. Limited growth in financial terms does not necessarily indicate a falling off in discrete instrument sales, which are obviously rising at a higher rate than the monetary totals might suggest.

In the breakdown of oscilloscope sales, more than 50% of the oscillscopes of 100MHz or below come from Japan. Above this freqency, Japanese manufacturers have a share of around 15% – but it is a growing share and a trend which UK manufacturers need to monitor very closely.

Whilst t & m equipment continues to advance in terms of the provision of facilites, better presentation of controls and other ergonomic aspects, and either progressively smaller footprints or more features packed into the same footprint area, the two factors that are really generating real growth and interest in t & m are in the area of bus interfaces and mini/micro computers.

The electronic industry's need for greater throughput, more data and greater versatility in t & m can only be effectively met by some form of systems approach. The power of today's micro and minicomputers can be employed in this area with enormous effect but such aids can only work effectively if they are linked to t & m instruments, printers, control systems etc in what is effectively a network system. The need is being met with the growing use of interface buses as integral parts of both instrumentation and computer products.

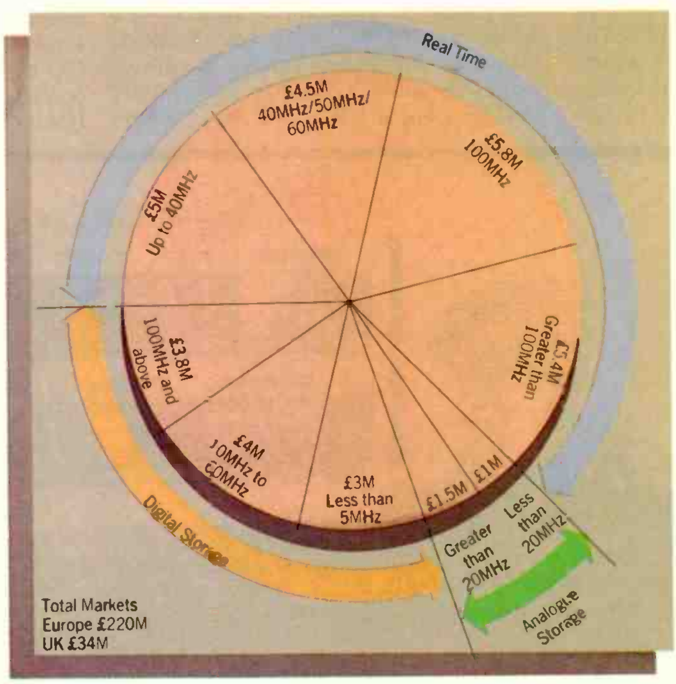
It is no longer necessary for most users to purchase highly expensive t & m systems – they can now create their own using readily available products and tailoring to meet both their technical requirements and budget limitations.

Bussed instruments

The Hewlett Packard Interface bus (HP-IB) development of the early seventies was designed as a means of externally connecting up to 14 independent devices, such as voltmeters, disc drives and oscilloscopes, onto a single computer port. This was a highly significant breakthrough as the previous requirement had been to provide a separate port for each instrument. In 1975, the concept was adopted by the Institute of Electrical and Electronic Engineers who, with slight revisions, published it as the IEEE488-1978 Standard with manufacturers (other than Hewlett-Packard) referring to it as the General Purpose Interface Bus. As with all such standards, similar concepts were already – or were to become – available. The most important of these was the IEC625 International Standard which used a different connector system to the IEEE version but was eventually brought into line in terms of compatability.

In a typical bus arrangement up to 14 instruments will be linked to a controller with the maximum cable length being limited to 20 metres in total. It is not, therefore, possible to use a GPIB over particularly long distances but this is rarely a requirement in the vast majority of automatic test equipment applications.

The advantages to the user include complete flexibility in that *any* instrument comforming to the standard can form part of a system. This means that a variety of instruments from a variety of manufacturers can be assessed to ensure that the technical and economic requirements can both be met. In addition, of course, a system can be upgraded at any time – often by the substitution of a single instrument.



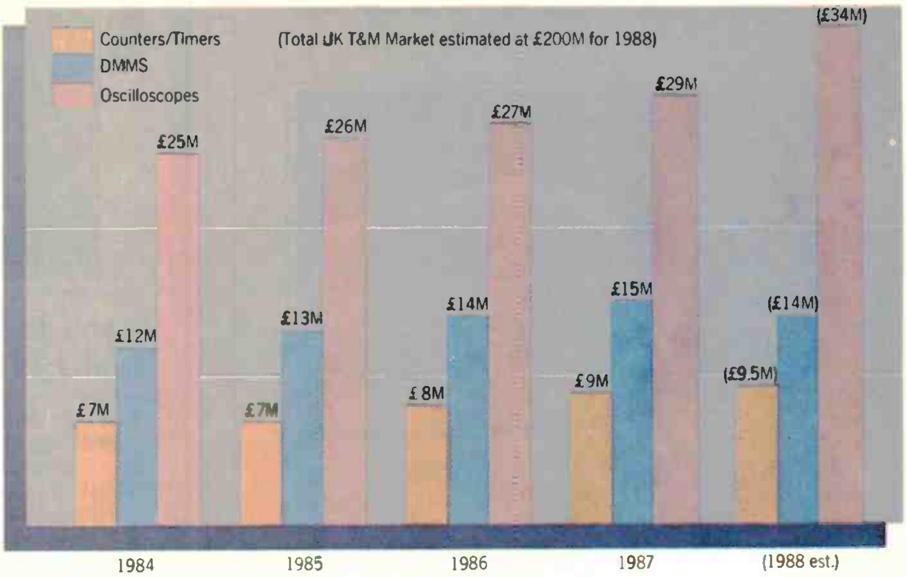
Typically, a controller such as the Hewlett-Packard Vectra can be programmed to set the ranges of any measuring instruments connected to the bus and adjust the output levels of operation. The test can be run through in the correct sequence and, further, since the controller is a computer, the information gathered can be processed in terms of averaging, fast Fourier transformation, and so on.

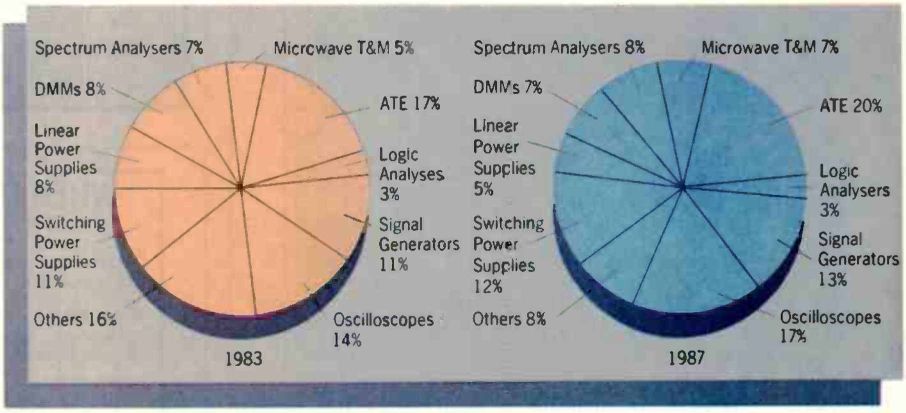
With improvements in technology and competitiveness being the main factors causing the price of the business computer to fall, both mini and micro computer manufacturers are anxious to seek out all possible avenues to increase their sales. A benefit arising from these has been the growing co-operation of these manufacturers with instrumentation companies specialising in computer interfacing to generate better and easier-to-use control systems.

In addition, the mini/micro

computer approach to solving industrial problems satisfies yet another need – this time in the laboratory and scientific environment. Here, by linking individual engineering and manufacturing functions into a unified automated system, elements of control systems can be physically or functionally separated yet also be part of a hierarchy of integrated computers.

It is the advent of bus interfacing that has placed instrumentation distributors in a unique position to provide advice to customers on building their own t & m system. Unlike a dedicated manufacturer, they are able to propose a wide selection of alternatives based on sound technical knowledge. They are not committed to plugging any one particular range of instruments or any one form of technology – they should be simply interested in giving the customer what he needs at the price he can afford.





The market sector figures provided in this article have been collected from a variety of industrial and other resources. These figures have been assessed in relation to STC's own market appraisals to provide the most realistic estimates possible.

Value for money

The number of instruments coming onto the market featuring GPIB and a host of features at a reasonable price is increasing at a quite dramatic rate. Three very recent introductions provide a guide to what is available.

Hitachi's VC6165 is a digital storage oscilloscope with a sampling rate of 100M samples per second, a 100MHz equivalent sampling bandwidth, a 100MHz real-time bandwidth, and a memory capacity of 4K words per channel. Other features include an ability to save stored data in 2 × 4K memories using battery back-up, and envelope mode to capture the glitch and extract the envelope, averaging and roll modes, x-y display, pre- and post-trigger functions, magnified display, and a plotter interface – all for under £7000.

In the area of function generators, the Global Series 8200 20MHz programmable instruments are available in three versions: the 8210 20MHz with burst, the 8230 with burst, phase lock and frequency counter, and the 8232 synthesized unit with burst and with phase lock and frequency count as standard. These provide universal sources of test stimulus waveforms – sinewave, triangle, ramp, squarewave, pulse (± or t.t.l.), – thus replacing many instruments in laboratory or production environments. The three units are available in the range £1895 to £2495.

And Marconi's latest synthesized signal generator, the 2022C, really does offer outstanding value for money due to novel techniques employed in its manufacture. Easy to use, the instrument offers comprehensive amplitude, frequency and phase modulation, a frequency range of 10kHz to 1GHz, 100 non-volatile memories, 10Hz frequency resolution to 100MHz, and 0.1dB level resolution. Additional features include a high r.f. output of +13dBm, auxiliary f.m. input on the rear panel, and a memory clear facility. The basic cost of the 2022C is just over £3000.

Options

Having expounded the merits of the GPIB, it should not, however, be assumed that other options are not available. Keithley, for example, have produced a new software package (Asystant+) for use with IBM-compatible computers that not only runs a range of functions specifically for scientists (calculation, graphics, curve fitting, file i/o, statistics, waveform processing, polynomials, waveform generation, differential equations, file-based processing), but also makes possible interactive data acquisition that is menu-driven and very easy to perform.

In general, other menu-driven systems required the filling out of extensive prompt lists to define i/o parameters. The software, however, simply requires that just one of eight modes is selected – such as strip-chart recorder or x-y recorder – that simulate common laboratory data collection instruments. The x-y recorder mode, for example, will display two channels of data in an x-y format. Such capability allows the user to concentrate on the meaningful parameters (acquisition speed, triggers and data storage options) and thus make data collection easy without the need to concentrate on unnecessary detail.

Tony Leach is marketing manager for STC Instrument Services of Harlow, Essex.

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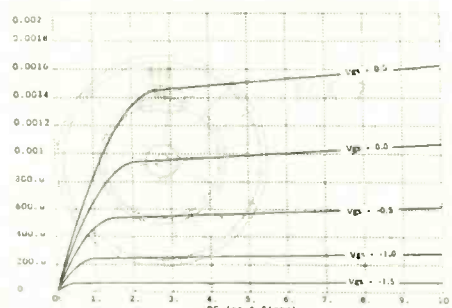

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INSTRUMENTATION

PC-BASED TEST EQUIPMENT

Market research analyst Mike New reports on bus and control issues in this fast-growing market.

The personal computer test equipment market has been going through significant changes during the late 1980s, centering about bus and control standards and technologies. Initially, most of the participants in this market had products that were based around the IBM Personal Computer or an Apple computer, or a clone of the PC. Now, however, even though there are still a lot of these products, manufacturers are no longer limiting the computer part of their systems to either of these buses. The market is beginning to be defined as a microprocessor-based computer test system that is dedicated solely to test applications. This puts the PC-based instrument in competition to what used to be minicomputer or mainframe systems. But there is a difference, which is why these are "personal" computer-based test systems.

In older computer-based test systems, testing was only one of the many functions carried out by the computer. The cost of the mainframe and minicomputers made it necessary to incorporate as many functions as possible into the system. With today's personal computer prices so low, test engineers are able to construct systems for themselves where every function of the computer, even word processing and graphics, is designed to enhance testing.

Today's personal computer instrument is basically a cardcage hooked up to a microprocessor-based computer. The cardcage can have a VME bus and be connected to the PC via an IEEE488 interface. If the cardcage has the bus of an IBM Personal Computer or an Apple computer, then the PC-based instrument looks more or less like the computer on top of an office desk. This is the way many of these instruments look. But an equal or greater number have either external cardcages tied to them or even standalone instruments with IEEE488 connections.

The component in these systems that is of most importance to test equipment manufacturers interested in the PC-based test equipment market are the actual boards or 'instruments on a card' that go into the cardcages. These boards allow data acquisition, signal analysis, recording, metering, frequency counting, and more. These boards are the substitutes for the stand-alone instruments.

Manufacturers of traditional stand-alone test equipment are acutely aware of the possible impact of the PC-based instrument on their sales and they are developing a number of strategies to counteract this. To make rack-and-stack systems easier to configure and develop programs for, new IEEE488 standards have been proposed and others are in the negotiating stage. Participants on the 488 committee, which is composed of companies such as Keithley, Fluke, Tektronix and Hewlett-Packard, hope to have significant changes made to the general purpose interface bus by 1989.

Source: MIRC. For further information on report A278 PC-Based Test Equipment, contact Bob Pearce (415) 961 9000.

At the same time they are certainly not putting all their eggs in one basket. Several instrument manufacturers have banded together and developed a modification of the VME bus which will make it easier to develop test systems. This new bus, described elsewhere in this *Insight*, has an open architecture which simplifies assembling modules from different manufacturers into a single chassis. What types of boards will be introduced? Undoubtedly, board development for the VXI will follow the trends in the rest of the PC-based market. There, in terms of board sales, the largest segment has always been data acquisition. Part of the reason for this is that end users with existing analysis equipment – scopes, logic analysers, spectrum analysers – can through an 488 controller take advantage of the personal computer's data storage ability and continue to use their stand-alone boxes for the analysis.

The most popular analytical boards are also the most popular analytical instruments: oscilloscopes, logic analysers, and spectrum analysers.

Since personal computers lend themselves readily to data acquisition it is not surprising that another popular instrument that is being replaced by these instruments is the graphics recorder. Especially in industries like the medical field, computers with associated peripherals for data acquisition are becoming well accepted.

($MM)

	Spect. Analyser	Logic Analyser	Freq. Counter	Oscillator	Recorder	DDM	Data Acq.	Total
1983	11.8	10.4	0.7	7.0	4.7	0.6	25.8	60.9
1984	15.4	14.0	0.9	9.1	5.9	0.8	37.7	83.6
1985	19.7	17.5	1.1	11.4	7.5	0.9	51.8	110.0
1986	25.8	23.0	1.4	14.7	9.4	1.2	112.6	188.1
1987	34.6	31.2	1.8	19.1	12.2	1.6	122.5	223.1
1988	46.7	43.7	2.3	26.0	15.9	2.2	136.1	273.0
1989	61.2	59.5	2.9	34.1	19.7	3.0	139.3	319.6
1990	79.5	79.1	3.5	43.3	23.6	3.9	149.6	382.6
1991	99.4	99.7	4.1	52.4	28.1	5.0	168.3	457.0
1992	116.8	120.5	4.7	61.3	33.2	6.1	196.2	538.9

The estimated total 1987 world market for PC-based test equipment is $223.1 million. With a projected compound annual growth rate for 1986-1993 of 19.0%, this market is expected to amount to $635 million by 1993. The largest and slowest growing segment of the PC-based test equipment market is data acquisition, representing 55% of the 1987 total. As shown, most product areas in the PC-based test and measurement market are projected to grow in the 25-30% annual range for 1986-1993.

Mike New is senior analyst with Market Intelligence Research Company 2525 Charleston Road, Mountain View, California.

INSTRUMENTATION

IEEE 488 CONTROL USING AN IBM-COMPATIBLE PC

THE usefulness of the decade-old IEEE488 bus is that it enables a computer to control many types of test and measuring instruments from multimeters to pressure calibrators. In computer control of instrumentation the collection of results is faster and more accurate, repetitive tasks need only be programmed once, calculations on data can be more readily carried out reporting of results can be completed automatically and there are convenient mass storage devices available.

Up until recent times the use of IEEE 488 instruments left few options. Generally the prospective purchaser bought basic instruments and wrote his own applications software or purchased expensive application software – usually running on dedicated IEEE 488 controllers. And the implementation of IEEE 488 controllers could be very expensive. But in the age of the £500 PC* it is possible to implement an IEEE 488 controller for as little as £600.

**By which is meant IBM-compatible MS-DOS personal computer*

International standardization of GPIB software should ensure a healthy future for bus-based instrumentation

Also, by using a PC as a controller it is possible to do many more things on the same machine. It is possible for instance to have a PC data logger which can say, control a multimeter or number of multimeters and a scanner (i.e. an analogue relay multiplexer) to enable the collection of widely divergent data such as voltages, currents or the output of various transducers. All data can be collected and conditioned and presented in a useful form for the end user.

Manufacturers of test and measurement equipment appreciate these advantages and can now supply a package which includes a multimeter, scanner and software package which will run on a PC to allow the implementation of a low-cost datalogger. The reasoning behind this type of package is clear, there are as many users committed to the use of IEEE 488 instruments as there are users committed to IBM compatible PCs. If the two are put together there are many advantages: IBM compatible PCs such as the Siemens Sicomp PC 16-20 offer more advantages than simply the portability of a single software package. They can, for example, run scientific spread sheets, wordprocessors for reporting, and c.a.d. software for design.

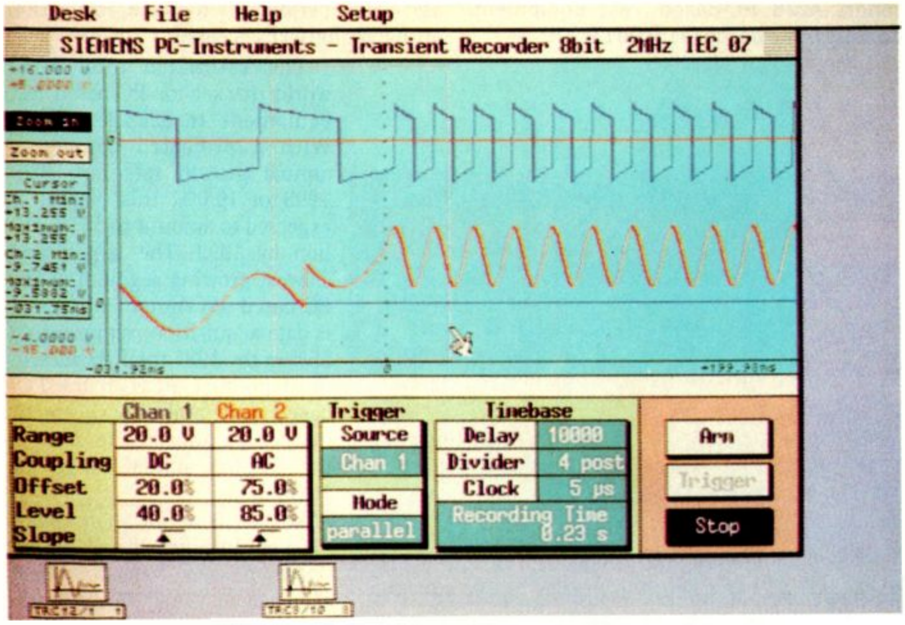
High-resolution, multi-colour displays can be used as can pointing devices such as graphics tablets and mouse systems. Mouse systems can be used interactively with the screen and select particular fields.

The example in Fig.1 shows a screen representing the control and display of a transient recorder. The graphic display used the IBM Enhanced Graphics Adapter screen which has a 640 × 350 panel display with up to 16 colours. This enables the clear, concise representation of data and controls. The top line of the screen shows one of the immediate advantages of this type of system, the names indicated are titles of menus which can be pulled down in conjunction with a mouse pointing device. This is one of the main features of the Graphics Environment Manager system as supplied by the Digital Research Company.

The first title shown for a pull-down is Desk which is a general GEM utility, it enables the user to have a real-time alarm clock, a print spooler and to save screen images. The second is File which is used in conjunction with the transient recorder, allows the user to save files which may have information on the way the instrument is set up. It also allows transients to be saved in GEM format. Once in this format the collected transient can be sent to a graphical output device such as the screen, plotter, printer or even an RS232 camera.

The next title shown is Help which can be called upon at any time and has specific information on the device being used.

The title Set Up allows the user to return to the instrument default set-up or display



the transient information in a different format.

The blue section of screen shows the representation of the collected result. In this example the captured transient data consists of a square wave and a sine wave. The signal has been captured by sampling at a 5µs period, which is shown in the window marked 'Clock'. This sampling period can be changed by using the mouse to point to the clock window and clicking the mouse button, a pop-up menu in the centre of the main screen gives a selection of sampling periods from 0.5µs to 1 second.

The titles in white boxes show the other features available for the transient recorder such as voltage range, trigger level, signal offset coupling etc. One of the most powerful features of this instrument shows the advantage of the PC-based IEEE 488 controller, this is the zoom feature. It enables a window to be opened over the signal, which is 16K of collected samples and any single or group of samples can be viewed. The zoom feature uses the high-resolution graphical display and mouse pointing device to the best advantage.

The main idea behind PC instruments is the fact that control and display elements are separated from the instrument and given to a more flexible device in the form of the PC.

If other instruments are installed into a system the same PC is used as the display and control element of the instrument by having a front panel which is a piece of software.

This has a major advantage in that the display and control element of the instruments has to be paid for only once.

The basic philosophy of modular instruments using a common PC has been taken further with the Siemens range of PC instruments. The range includes many other instruments such as a multimeter, voltage-current source, counter-timer, function generator, scanner, a range of transient recorders, digital input-output and a local area network tester. A common bus connection eliminates multiple IEEE cable connections and enables sets of instruments to be stacked neatly. A number of additional instruments are being developed as well as more software tools.

Future advances in user-friendly software for PC IEEE 488 controllers plus international standardization of the software standard of the IEEE 488 bus should ensure a healthy future for bus-based instrumentation systems.

Frank Healey is manager of Siemens electronic test and measurement instruments.

INSTRUMENTATION

OSCILLOSCOPE ARCHITECTURE

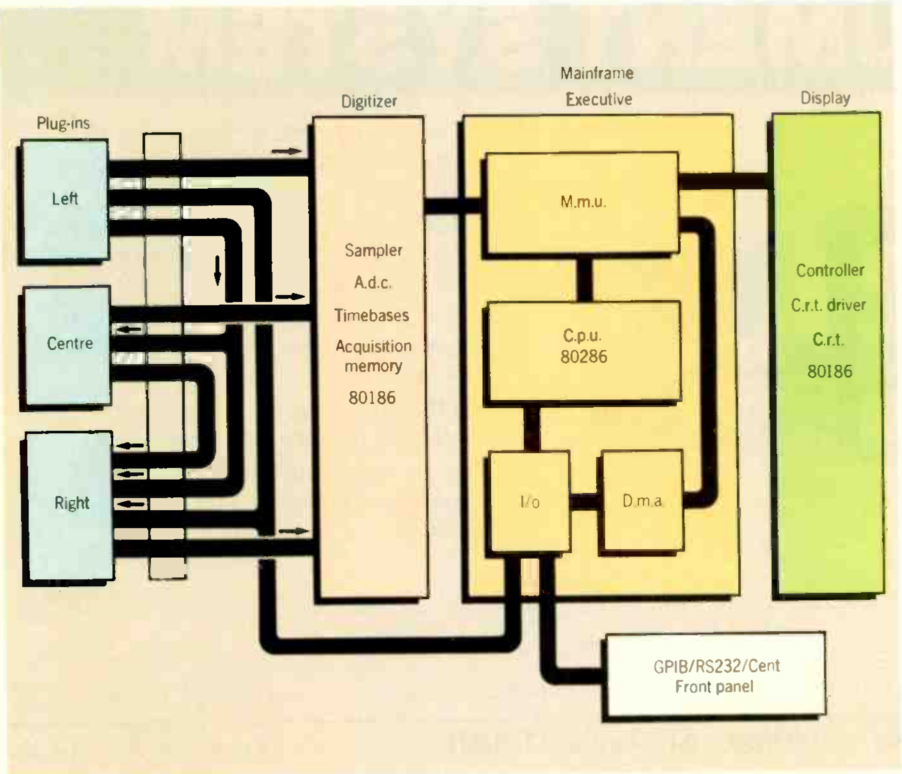
A case of revolution rather than evolution

The first microprocessor-based digitizing oscilloscope revolutionised the test and measurement industry. For the first time, users could analyse signals in ways which had not previously been possible. Because waveforms are stored in memory, they could be saved for future reference, output to hardcopy devices such as printers and plotters, transferred to computer for statistical analysis, averaged over time to remove noise, or plotted on the screen as an envelope, enabling the user to see change or drift. Digitizing also enabled users to examine signals with low repitition rates.

With the passage of time, however, capabilities such as these became commonplace. In addition, the performance demands placed on digitizing oscilloscopes increased to the point where a single microprocessor simply could not cope, and the industry was in need of another revolution.

When the Tektronix 11400 series of digitizing oscilloscopes was launched last spring, most of its advanced features were readily visible. Examples of these are the machines touch screen operation, pop-up menus and uncluttered control panel. Also, unlike conventional digitizing oscilloscopes, the 11400 series products feature real-time operating speed, which makes them feel and behave like analogue scopes. Underpinning all of the visible improvements, however, is something far less tangible.

> There is relatively little point in trying to improve performance in one particular area if the underlying architecture leads to a reduction in capability elsewhere.



The oscilloscopes incorporate a radically new architecture, which owes more to computers than to traditional oscilloscope technology. At the heart of the 11400 mainframes are three Intel microprocessors, giving the scopes the combined power of three personal computers. In addition to these, all the plug-ins incorporate dedicated microprocessors. The advantages that this brings over more traditional architectures, in terms of speed, flexibility and performance, are enormous. Before looking at these in detail, however, it's important to understand the Tektronix product development philosophy which has allowed them to be realised.

A little history

In 1946, when Jack Murdoch and Howard Vollum founded Tektronix, it was with the expressed intention of designing and manufacturing the world's finest oscilloscopes. There is no question that they achieved their goal, and that which became the 500 series dominated the oscilloscope market throughout the 1950s and '60s.

By the late '60s, however, it was apparent that the architecture on which the 500 series was based had been stretched to the limit, and that a new technology was needed. The result was the enormously successful Tektronix 7000 series, which again set new standards of quality and accuracy, and in its turn came to dominate the market. The range was continually developed throughout the '70s, and still sells well today.

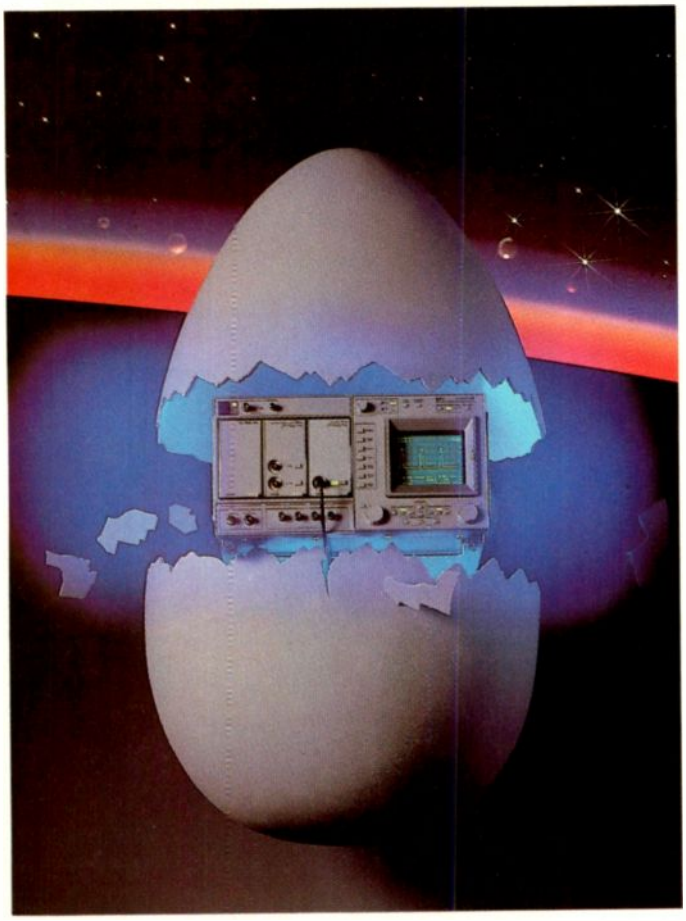
Despite the success of the 7000 series, however, by the mid-1980s it too had reached the limit of its realistic development, and another new architecture had to be sought. The pressure to do so was increased by the 1983 launch of the Hewlett Packard 54000 series of digitizing scopes which, throughout its lifespan to date, has sold well into a wide range of applications.

Digitizing oscilloscope or computerized measurement device?

By its nature, a digitizing scope is as much a computer as it is an oscilloscope. In the same way that a computer takes characters from a keyboard, processes them and displays them on a screen; a digitizing scope takes a sampled waveform and digitizes, processes and displays it. Similarly, just as a computer's overall performance depends on the power of its central processor and the extent to which that power is harnessed, so a digitizing oscilloscope will only be as good as the hardware on which it is based.

When the HP 54000 series was launched, the Motorola 68000 microprocessor was in its ascendancy. Not only did it form the basis of the HP 54100 design and all the models that have followed it, but it also spawned, among other things, a host of multi-user microcomputers running under the Unix operating system.

One of the drawbacks of 68000-based micros has been that as the number of users increases, so do the response times, and the overall performance of the system deteriorates dramatically. The essence of the problem is this. With one 68000 handling the tasks of central processing, polling of terminals, screen display, print spooling and all other i/o functions, there simply isn't enough raw horsepower for it to be able to cope. The HP 54000 series has had similar problems.



In the HP 54000 series, the 68000 microprocessor handles digitizing, processing and screen display functions. The overall performance of the system is therefore limited by the 68000's power. And as the 54000's single-processor architecture has continued to be exploited – up to and including the recently-launched 54112 and 54120 – so the demands placed on the 68000 have increased. Some of the drawbacks that this has resulted in, such as the long screen update times, are widely recognised. Others were not so obvious until an alternative approach was made available. This is precisely what has happened with the launch of the Tektronix 11400 series.

Three chips are better than one

The 11400 series is based on three 16-bit Intel microrpocessors. Specifically, the machines incorporate an 80186 which is used purely for digitizing; an 80286, used to handle the executive functions of the scope; and another 80186 which handles screen display. Clearly, the provision of three processors rather than one has a dramatic impact on the overall speed of the machines. Indeed, the raw processing power of the 11400 is about three times that of the 54000 series. What is equally important, however is the flexibility that the three processors offer, without comprising overall performance.

With a single microprocessor, performance is something of a juggling act. With variables such as bandwidth (both repetitive and single-shot), sample rate, record length and screen update to be considered, it is clear that with an oscilloscope performing at its limits, as one measure of performance is increased, another will suffer. To achieve longer record lengths, for example, the time between screen updates will almost certainly have to increase. If longer record lengths are needed, then the rate at which they need to be sampled should increase. Higher sample rates can then lead to less bits, and therefore lower vertical resolution. With only a single microprocessor in control, compromises are forced between the various capabilities of the scope.

Distributed processing, as used by the 11400 series, avoids these clashes of need. For example, the fact that the processor in charge of digitizing is having to work harder to sampie a longer record length will be transparent to the executive processor. Similarly, although the executive processor is working harder to process the longer record length, this will not affect the way that the resultant waveform trace is displayed. And because each processor is handling a specific task, none will be stretched to its operating limits.

The result is an oscilloscope design which guarantees high performance however it is being used. The following are just a few examples of what this means for 11400 series users.

Maximum bandwidth. The advance of communication technology is something of a chicken and egg situation. As transmission rates increase, so faster oscilloscopes are required that can analyse the signals being produced. Conversely, without adequate oscilloscopes, it is impossible to ensure transmission quality. As the technology currently stands, data transmission equipment capable of communication at 560Mbit/second is now in use, while large scale communication in the 1-2Gbit range is still in the future. As far as bandwidth is concerned, therefore, the fact that the 11401 and 11402 can handle bandwidths of 500MHz and 1GHz respectively, means that they are both well placed to deal with many of the needs of current technology.

Single-shot sampling. Two examples of events where a single-shot capability is important are in isolating non-repetitive 'glitches' in a microprocessor's clock signal, which would impair its performance, or in analysing its power-up sequence.

Single-shot samples can only be taken at 20MHz on the 11400 series. Indeed, the 11400 is not intended as a transient single-shot machine, and if this is a prime requirement of a particular installation, then there are a variety of other products, both analogue with higher bandwidth, and digital with higher sample rates, that are better suited to the task.

However, complete single-shot waveform records from up to three channels can be acquired at slow and moderate timebase settings, and a unique 'trigger-to-trigger' mode can measure time intervals as short as 20ns between trigger events on a single-shot basis. Even if incomplete records are produced, interpolation routines are available which enable them to be completed. As a result, the 11400 series can, in practice, be used for single-shot sampling.

Sample rate. The 11400 series samples at 20MHz, which is more than adequate to digitize repetitive signals containing frequencies up to 1GHz. This is combined with an interesting sampling method which is central to the overall performance of the machines.

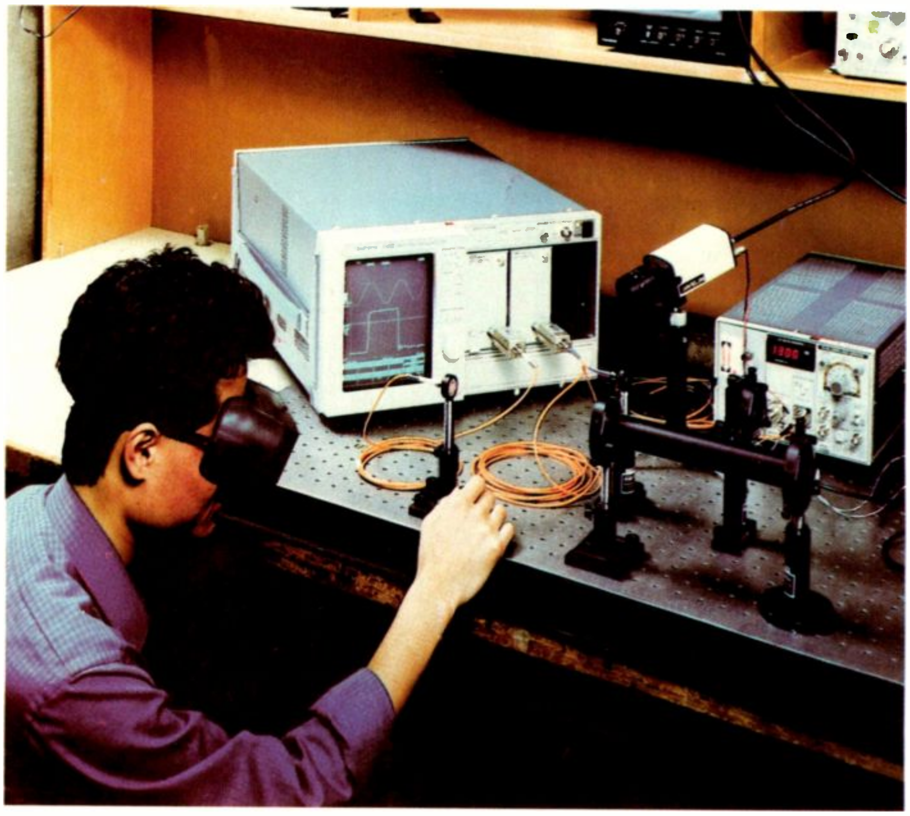
The Tektronix scopes use the random equivalent-time sampling method. With this technique, the time between the trigger point and the sampling strobe is measured for each triggered acquisition cycle. The trigger-to-strobe time is then used to sort data into its proper position in the final waveform record.

By combining random equivalent-time digitizing with a dedicated custom processor, d.m.a. channels for waveform data, and other special display hardware, the 11400 series scopes are able to acquire and display waveforms with the update rate of analogue scopes (between 30 and 40 waveforms per second). This gives them a major performance advantage over the HP products, which can generally display only two waveforms per second (and a maximum of 15 on the 54111). Indeed, the slowness of 54100 series screen updates has been one of the major criticisms that has been levelled against the entire family.

Record length. From the record length onwards, the key specifications of the 11400 series products point to the clear improvements in flexibility that they offer to their users. By offering variable record lengths – between 512 and 10K points – the 11400 series enables users to tailor their sampling to the complexity of the waveform being analysed.

Variable record lengths are combined with a unique windowing facility which enables users to 'window-in' on a particular part of the waveform being displayed. An example of where this would be useful is for a radar signal which could be analysed using a 512-point main record in order to maintain speed, with two 10K-point window records being used to re-sample specific parts of the overall trace. In this case, in-depth examination of the echo pulses in the 10K windows could clearly reveal target identification information which would be invisible in the 512-point main record.

The key here is that the part of the waveform displayed by the window is resampled as 10K points, rather than using more conventional delayed sweep technology. As a result, the resolution capability of the 11400 series is massively enhanced, way beyond anything else available on the market today.



Optical oscilloscope: Waveform analysis of the fibre-optic communication bands of 850, 1300 and 1500nm is possible on the 11400 oscilloscopes with new probes from Tektronix. The opto-electronic converters – believed to be the first in direct probes – enable the scopes to act as calibrated optical waveform analysers. "Having redefined the digitizing scope market with the introduction of the 11000 series" Robert Stubbings says "we're now expanding on its capabilities with some of the most innovative add-ons ever produced. And at around £2000 our 6701 and 6702 converters have a significant price-performance edge over their (non-probe) competitors". One extends from 450 to 1050nm with 700MHz bandwidth while the other covers from 1000 to 1700nm with 500MHz bandwidth.

Channels. Many advanced oscilloscope applications now require the ability to look at four or more channels. With the 11400 series any eight of 12 input channels which can be digitized and displayed at the same time. Example applications of this would be to configure the oscilloscope with up to twelve 300MHz channels for sophisticated data acquisition and timing analysis. Alternatively, three 150MHz differential channels could be used for power supply measurements; six 600MHz channels for a.c. parametric analysis on high-speed logic devices; or three 1GHz channels for high bandwidth analogue and digital testing. The 11400 series will support as many active and passive probes as there are channels.

In these ways, the 11400 series scopes are eminently suitable for application areas which the two channels offered by the HP 54100 series simply will not support.

bits	levels	vertical resolution
6	64	1.5625%
7	128	0.7813%
8	256	0.3906%
9	512	0.1953%
10	1024	0.0977%
11	2048	0.0488%
12	4096	0.0244%
13	8192	0.0122%
14	16384	0.0061%

Vertical resolution. The 11400 series offers 10-bit vertical resolution (14-bit with averaging), and has established new standards in oscilloscope resolution. The table left emphasizes what this leap in technology means.

The high resolution offered by the 11400 series is only part of the story. A new analogue amplifier design enables the accuracy of the scopes to be improved by a factor of between two and ten over the previous industry standard set by the Tektronix 7000 series. This enables accuracies of 1% on average, and in certain cases 0.25%, to be achieved. There is absolutely no point in building the best digitizer in the world if it isn't supported by the best analogue front-end.

Finally, the 11400 series can store over 100 waveforms concurrently. This obviously adds dramatically to its usability, since many waveform measurements need to be compared with standard or reference signals. The fast processing power of the 11400 series actually supports real-time analysis of multiple 10K record length waveforms, thus giving Tek a major competitive advantage in this area.

Specifications alone though are only part of the story. What is ultimately of prime importance, as with all products, are its users. For some time now, published product specifications have, not surprisingly, highlighted those areas in which a product is particularly strong, leaving the potential user to surmise what the downside of a particular performance characteristic is likely to be. The architecture of the Tektronix 11400 series removes this necessity completely.

Robert Stubbings is product manager for laboratory oscilloscopes and systems at Tektronix UK Ltd, Globe Park, Marlow, Bucks.

100MHz digitizing oscilloscopes on the UK market

Maker & supplier	Model	Equiv time bw(MHz)	Sample rate per ch (Ms/s)	Channel/ traces	Memory length/ch	Smallest glitch(ns)	Auto-setup	Mass kg	Price £	Comments/interface
Gould	4072	100 (k)	400	2/8	1K	5	√	11.4	7750	XY,RS,GPIB
	4074	100	400	4/8	1K	5	√	11.4		dual timebase
Hewlett Packard	5185T	110	250	2	16K	4	√	4.8	31,200	Discdrive. GPIB on all HP scopes
	16500A	100	400	2-8/2-8	4K	2.5	√	18-21	9-6-18.6K	RS237. Card options
	54112D	100	400	4/4	16K	2.5ss, 40p rep	√	25	17,800	Colour. Logic trigger. 6 bit
	54201A	300(50ss)	200	2/4	1K	5	√		5907	27 bit logic trigger. 6 bit
	54111D	500(250ss)	1G	2/4	8K	1ss 10 rep	√	27	18,600	Colour. Logic trigger. 6/8 bit
	54110D	1G	40m	2/4	1K	10 rep	√	25	15,100	Colour. Logic trigger
	54100	1G(4ss)	40m	2/4	1K	10 rep	√	1.9	10,000	£13k6 with logic trigger. 7 bit
	54120T	20G	10K	4/4	1K	0.25p	√	24	25,200	Vertical error 0.4%. TDR. 12 bit
Iwatsu (Datron)	8130A	12.4G	70K	2/2	1K	–	√	19.8		GPIB&RS. 10bit. 3.5GHz option
Kikusui (Telonic)	7101	100	50	4/8	1K	–	√ via	10	4695	dmm, freq. counter
	7201	200	50	4/8	1K	–	√ bus	10	5895	memories
LeCroy	9400	125	100	2/4	32K	–	–	14	7495	XY.7×5in screen. Setup store
Nicolet	4180	100	200	4/32	4K	–	–	25	14,300	FFT, disc option. 12 bit
Panasonic	5741A	35(100R)	100	2/4	10K	–	√	17		7×7in screen, mem. expn
Philips (Pye Unicam)	3320	200	250	2/8	4K	3	√	18	7995	GPIB, RS options. 12 bit adc
	3308	100	40	2	8K			6.5	N/A	8×4in l.c.d XY,RS, G PIB option
Schlumberger	5602	100(4R)	40	2/4	1K	–	√	13.6	4750	4MHz realtime. GPIB or RS232. XY
Tektronix	2230	100	20	2/5,52	4,1K	100n	–	8.3	2995	100MHz real time 52-w'form store
	2430A	150	100	2/6	1K	2	√	10.9	6249	Automodes, memory
	2432	300	100	2	1K	2	√	10.9	7995	GPIB
	7854	400	500k	4-40	128-1K	–	–		13,895	10bit. 14GHz option GPIB
	11401	500	20	12/100	512-10K	–	√	20	10,000+	with 11A52. 10bit. Cent. RS
	7912HB	700	100G	1/2	512	–	–	25	29,682	9 bit. GPIB. Digitizer
	11402	1G	20	12/100	512-10K	–	√	20	12,000+	10bit. Cent. RS. GPIB
	7250	6G	1T	1/15	512	–	–	60	90,318	5yr memory split screen

Vertical resolution based on 8 bits unless shown otherwise. R: real time, ss: single shot.

High accuracy multimeters on the UK market

Maker & supplier	Digits	Model	Sensitivity d.v.(nV)	Basic error d.v.(ppm/yr)	Speed rdg/s	Basic price	Interface (GPIB)	Microprocessor features	Other features	Options	Comments
Datron	8½	1281	10	±(5rdg+0.2fs)	150	3550	inc	1-5,7,10,11,13	frequency, Selfcal	a.v., Ω, I, analogue o/p	
	7½	1081	10	±(8rdg+1fs)	2	2950	250	1-5,7,10,11,13	temperature	a.v.,Ω, ratio, analogue	Rack mounting
		1071	10	±(20rdg+2fs)	2	2450	250	1-5,7,10,11,13		a.v.,Ω, I, ratio, analogue	kits available
	6½	1061A	100	±(30rdg+4fs)	200	1750	200	1-5,7,10,11,13		a.v.,Ω, I, ratio, analogue	
		1065A	100	±(60rdg+4fs)	200	1895	inc	1,4,10,11,13			
Fluke	7½/6½	8506	100	10	500	4995	572	1-5,10,11,13	highest rms accuracy	ohms, current	RS232 £471
		8505	100	10	500	2995	572	1-5,10,11,13	fast systems meter	ohms, current	RS232 £471
	6½	8502	1μV	20	500	4755	572	1-4,10,11,13	fast systems meter	ohms, current	RS232 £471
		8520	1μV	90	500	3115	inc	1-13	extended maths	extended s/w	—
Hewlett-Packard	7½	3457A	10	27	1350	2095	inc	1-13	1000rdg store	relay mux,CIIL,3yr w.	
	6½	3456A	100	25	330	2700	inc	1-13	350rdg store, o.c.	3yr warranty	Ωoffset comp(o.c.)
Keithley	6½	196	100	30	1000	1195	inc	1,2,4-7,9,10,13	Translator software, o.c.		300MΩ range
Prima (ppm)	8½	6048	10	7	30	4500	inc	1-13		20 way scanner	
Rohde & Schwarz	5½	UDS5	1μV	30	80	1590	inc	1,2,3,5,6,7,10,11	2/4 wire res.	shunts, probes	
Solartron-Schlumberger	8½	7081	10	$11/\sqrt{yr}$	100	4495	inc	1-13	true ohms, temp.	16 ch scanner	RS232 included
	7½	7071	10	$20/\sqrt{yr}$	100	3495	inc	1-13	true ohms, dig filter	16 ch scanner	RS232 included
	7½/6½	7061	100	25	1500	2595	inc	1-13	true ohms, temp, ratio	scanner, 9000rdg store	power fail recovery
		7062	100	25	1500	2395	inc	1-10,12,13	true ohms, temp, ratio	scanner, 8000rdg store	power fail recovery
	6½	7060	1μV	80	250	1355	inc	3,5,13	ratio	a.c.rms, I, scanner	

Microprocessor features: 1 auto calibration, 2 compute (offset, scale, % dev), 3 ratios, 4 max, min, hold, limits, 5 averaging, 6 results store, 7 dB, 8 linearizing, 9 statistics (variance, r.m.s.), 10 self test, 11 error display, 12 timer, 13 null facility.

Arbitrary waveform generators

Maker	Model	Channels	Sum mode	Vertical 'res' (bits)	D.S.O. readout	Clock rate (MHz)	Looping Linking	Operating memory	Waveform memory (nv)	Price £
LeCroy	9100	2	√	8	√	200	√	64K	350K	7500
Data Precision	2020-100	1	–	12	√	100	√	128K	–	
Hewlett Packard	8770A	1	–	12	√	50	√	128K	–	19,508
	8175A option 002	2	–	10	–	50	Link 255 files	1K	–	10,812
Wavetek	680/01	1-8	√	12	–	20	Link 4 files	28K	–	

INSTRUMENTATION

INTEGRATED TENDENCY

HP's latest CAT system combining measurement, control and computation in one box also features high-speed card-to-card communication.

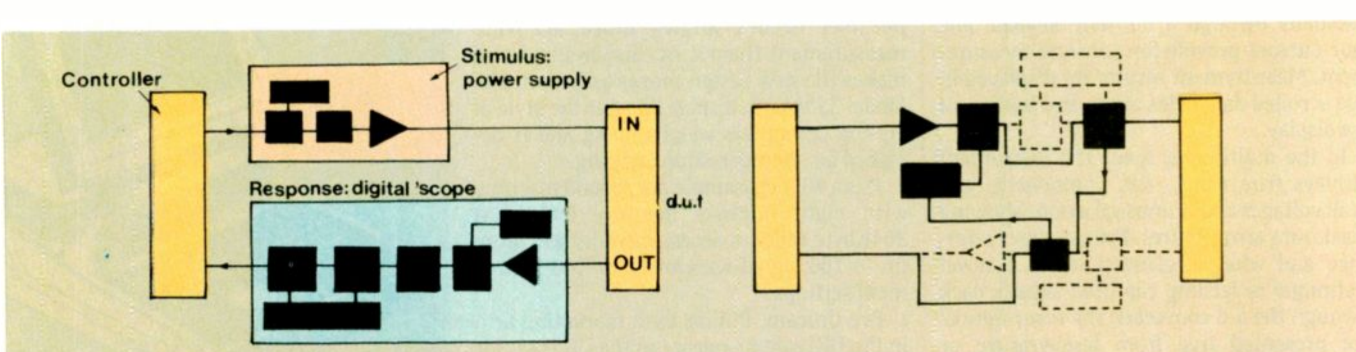
The tendency to integrate computers with test and measurement instruments has taken various paths. Plug-in cards for personal computers were an obvious starting point, but it soon became clear that this was not an optimum solution, not only for the noisy environment but also from the inherent limitations of power, number of slots, and even card size. Using PCs for GPIB controllers suffers from the complex programming required compared to dedicated controllers, as well as generally lower performance. Increasing intelligence within instruments can still have limitations in computational facilities – in general it's not programmable and a built-in processor will run a custom operating system and not standard software. And at the time when Hewlett Packard decided they needed to integrate a bus controller into their multi-instrument cardcage (6942), the VME-based VXIbus hadn't emerged.

It became clear to H-P's system designers that the additional cost of a computer board would justify its inclusion in a new instrument-computer. So with the object of achieving a more integrated solution, coupled with an overall cost reduction through shared housing, display and power supply, H-P developed a new cardcage instrument that would not compromise computational facilities. It is a highly integrated standalone test system controller that is based on standard 32-bit HP hardware and software. It has an operating system optimized for instrument control, but will run other programs as well, and H-P say interface boards will give it "compatibility" with future VXI solutions.

Called a 'multiprogrammer', which strange name dates from the 6940 multiple-use power supply programmer of the early seventies, the 6954A has eight slots, expandable in 16-socket frames to 120, a 300 series computer, 1Mbyte of ram and a 20Mbyte disc, whilst running Basic 5.0 and maintaining compatibility with the previous series software. The computer, actually a 310 series with 68010 c.p.u., replaces the 68000 series 300, which in turn supersedes the series 200 introduced six years ago.

In 'local mode' a keyboard and monitor will allow it to function as a development station, and in 'remote mode' a terminal or host computer can control the 6954A over RS232 or the interface bus. File exchange with a remote host is facilitated by an HPIB file transfer utility, Remcon (remote console driver), and Kermit. A 'run-only' mode with autostart program on disc can dedicate the 6954 to a specific task and eliminate operator intervention if required.

The cards, of which there are over 30 originally developed for the 6942, are designed to communicate directly with one another through common data lines, handshaking control, triggering and status signals. This permits the triple synchronization – stimulus to d.u.t., d.u.t. to response, and stimulus to response – for tests requiring complex timing. New cards are added to the range: 69774 3.5MHz universal counter, 69734 timebase and 69544 high-speed data capture and remote monitor for component evaluation, with an FFT card on the way (transforms are much faster in hardware form than software, typically 10ms rather than 200ms). The 6954 controls up to 14 other GPIB instruments, and does not of course require a separate interface bus controller. Price is £8000, keyboard and monitor for local control £460, and extension cardcage £2,938, with cards typically costing around £230. Contact H-P's enquiry office 0734 696622.



Simple stimulus response test using standard instrumentation (left) has limited adaptability and an excess of features. In the 6954A setup (right) the relationship between cards is not fixed and is determined by the test designer. Features can be adapted by 'rewiring' the blocks, and as the selection of i/o cards is determined by the test designer unnecessary functions can be omitted.

INSTRUMENTATION

Handheld digital oscilloscope

A combined digital storage oscilloscope, multimeter and frequency counter/timer weighs only 700g in a new 'Signal Computer', model SC02, made by Createc of Berlin. And the world's smallest d.s.o. also contains a signal processor and store for 46 waveforms. The miniaturization makes use of custom v.l.s.i. circuits in 2m cmos, four microprocessors, three layers of surface-mount boards, and a 128 × 128 element l.c. display. The two-channel instrument is an improved version of the SC01, first marketed 18 months ago (though not in the UK) whose two-channel inputs were multiplexed and which had nine waveform data stores.

The 7-bit oscilloscope with 10mV/div deflection factor samples at 20Ms/s with an overall bandwidth of 5MHz. Single-shot operation has a resolution of 1s/div or 50ns, while periodic signals can be displayed at 50ns/div giving a resolution of 2.5ns/pixel. Trigger and other measurement parameters can be set up automatically or entered manually through a numeric keypad, and four cursors provide for accurate measurement. Measurement results are displayed in two scrolled data fields at top and bottom of the display.

In the multimeter mode the instrument displays true r.m.s., d.v. component, and peak voltages and is unusual in also showing maximum error figures. Using a zener reference and what is claimed to be a novel technique of feeding captured signals back through the a-d converter, the error figures are presented free from temperature or range dependence. Bandwidth extends usefully to 5MHz with an error of around 1%,

continues on page 164

Multimeter takes in scanner for r&d production testing

Set for release early this year is Keithley's two-in-one multimeter/scanner. Given model number 199, its mainframe is a fully programmable 5½-digit multimeter with six functions while an eight-channel scanner can be incorporated for switching applications.

Measuring signals from multiple sources – transducers for example – is a requirement not only in r&d but also in production testing, incoming component acceptance, and quality control. Life test evaluation of a sample of eight cells or batteries is a typical situation in which the 199 would be an appropriate solution.

"Being microprocessor controlled the meter already has the 'intelligence' necessary to control a switching module" Bob Green of Keithley's parent plant in Cleveland, Ohio told *Insight* "and the eight-channel option can therefore be added to the basic instrument very cheaply".

In addition to the scanner option, the instrument will function as a data logger with a 500 memory store under computer or front-panel control. Other features include a thermal offset in the relay contacts of $<1\mu V$, running average filter to reduce noise effects, a controller message display, and Keithley's Translator software to allow emulation for existing software. Basic sensitivity is $1\mu V$, with a 12 month error of 70ppm. Further details from Keithley Instruments in Reading, 0734 861287.

100MHz flat-screen digital oscilloscope from Philips

Philips t&m have developed a 100MHz digital sampling oscilloscope with an unusually large display area – 96 by 192mm. The large-area flat screen with freedom from parallax errors allows more accurate measurement tham c.r.t. displays and also makes the new design more easily portable. Model 3308 with display lid after the style of lap-top computers weighs 6.5kg and is designed for shoulder-strap carrying.

It is a 40 megasample per second machine with eight kilobyte memory length. A 204Kbyte random access memory will store up to 100 signal waveforms or 100 instrument settings.

Pye Unicam, Philips t&m marketing arm in the UK, said its release in the UK is set for January – just before publication of this issue in fact – but they didn't want us to include it in our 100MHz oscilloscope listing!

INSTRUMENTATION

but no figures are given for direct voltage readings.

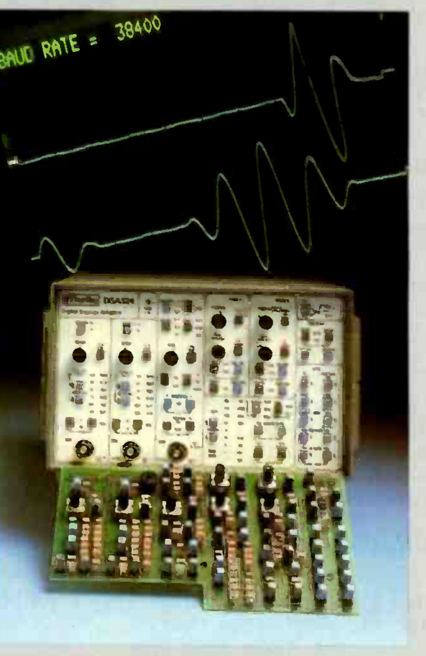
Settings for the frequency converter are fully autoranging, and readings from 1Hz to 7MHz are made with a best error of 0.04% at h.f.

During data acquisition incoming waveforms are tracked by the 'signal computer' to adjust timebase trigger, trace and cursor positions, and which also allocates memory space. Post signal processing on previously stored data allows analysis relative to a reference or across channels. Prices in Germany are DM2500 SC01, DM3750 SC02. CVG, Limburger Strasse 42, 1000 Berlin 65. Tel. Berlin 4535083.

New use for old scopes

Thurlby's new adapter DSA524 will convert any single-channel oscilloscope into a high performance dual-channel storage instrument – but at a fraction of the cost of a d.s.o. Sampling rate for single-event signals is 2×10^7 per second, and repetitive signals of up to 35MHz can be captured with an equivalent-time sample rate of 2×10^9 per second. Interpolation is either linear or sine, the sine giving near perfect reconstruction at four samples per cycle, with its 'cubic spline' algorithm. This gives the adapter a single-event bandwidth of 5MHz, substantially higher, say Thurlby, than most other 20M sample/s instruments.

DSA524 also features many of the facilities found on d.s.os – summation averaging for up to 256 recordings, cursor measurement, autoranging, program memory for 50 front panel settings, full programmability through RS232 (optionally GPIB), and memory for 16 waveforms. The adapter annotates the scope display with up to 30 characters of text to aid in operating the instrument. UK price is £585, from Thurlby on 0480 63570.



Crompton to sell Signal Computer

Negotiations for a new t&m division of Crompton Instruments to take on UK distribution of Createc's instrument were at an advanced stage as *Insight* went to press. Headed up by Steve Figures the new division will market handheld instruments – chiefly the d.s.o. – from its Witham base in Essex. "There are still one or two problems to sort out" said Figures. "One is that Tektronix may also be selling it, though their model should be a simplified version. Price has been fixed at £995 including mains adapter, with a Vidor battery pack still at the planning stage."

If the deal goes through Crompton t&m division will be exclusive importer, and as a sign of their confidence in the product are prepared to take on a field sales force of six. Crompton Instruments are at Freebournes Road, Witham, Essex CM8 3AH, tel 0484 862894.

○ Market research has revealed to Marconi Instruments that the demand for spectrum analysers with a frequency range upto 4.2GHz accounts for 35% of the existing market. Major users of spectrum analysers in this sector are civil and military v.h.f. and u.h.f. cellular and mobile radios to 1GHz, u.h.f. fixed links to 2.3GHz, tv and radio broadcast, 1.5 and 1.6GHz Inmarsat satellite links, high bit-rate p.c.m. and data links, and avionics systems and radios. MI therefore addressed the need to improve on critical specifications – resolution, accuracy and frequency range – in the model 2383 achieving a minimum resolution bandwidth of 3Hz and an unprecedented level accuracy of ± 1dB upto 1.5GHz. Marconi say that the extensive temperature cycling, environmental and performance testing carried out on the 2383 have been supported by an investment of over £1 million in test equipment for this one product. The 2383 is also one of the first instruments to benefit from the company's thin-film facility.

○ Increasingly complicated nature of multiprocessor systems makes analysis by conventional logic analysers extremely difficult, if not impossible, according to Dolch Logic Instruments. Their latest model M128 incorporates a twin-slot capability that allows two cards to be linked together and analyse data on two independently clocked and synchronized processors.

A typical system might be based on an 8086 c.p.u. with a Z80 i/o controller or graphics processor, or even a pair of 68000 processors, all operating at different clock speeds and with different synchronization making accurate time-correlations impossible. By providing three 64-channel card slots, two of which may be linked, the M128 allows accurate tracking of dual processors with proper time correlation. The two channels may also be combined for use on a single processor with up to 128 channels. Stimuli are provided by word generator modules with up to 48 channels and 20MHz clock rates. The M128's channels can be configured for static and timing analysis up to 200MHz. Dolch Logic Instruments are on 0635 48630.

○ Acquire is a new modular waveform acquisition and processing package from Datalab for use with HP200 and 300 Series computers. It provides an integrated system solution for Datalab Multitrap 1200 and 2000 Series multichannel waveform recorders and includes facilities for the acquisition, display and processing of analogue data, graphics plot generation and creation of permanent files. In addition to a comprehensive selection of time and frequency domain processing functions including FFT, Acquire enables users to easily create their own dedicated measurement routines through its sequence generation function and user hook capability. It requires a minimum of 1Mbyte r.a.m. and Basic 3.0 or later, a waveform digitizer and graphics plotter. Contact Data Laboratories on 01-640 5321.

○ Nicolet are back in the real-time spectrum analyser market as the newly appointed sole UK distributors for the Rockland Scientific FFT spectrum analysers. First product is a battery powered, portable FFT analyser, believed unique with large l.c.d. as seen on lap-top computers. Features of model 5840A include direct digital plotting via HPGL, RS-232 interface for post processing, optional non-volatile memory for up to 78 spectra, input for direct coupling to i.c.-piezo accelerometers, power measurement, and go/no-go comparator. Price below £5,000. Enquiries to Nicolet on 0926 494111.

○ Since Hewlett Packard introduced the first automatic network analyser 8542 19 years ago, and its 8510 successor four years ago, the US military build-up has created a new generation of phase-sensitive active components, systems, and antennas. These newer systems demand more agile, fast-acting test equipment, Wiltron Company say, who have stretched the upper frequency limit of their new vector network analyser to 40GHz using a new sampler design and new coaxial 'K' connector. Details from Wiltron UK on 0344 777778.

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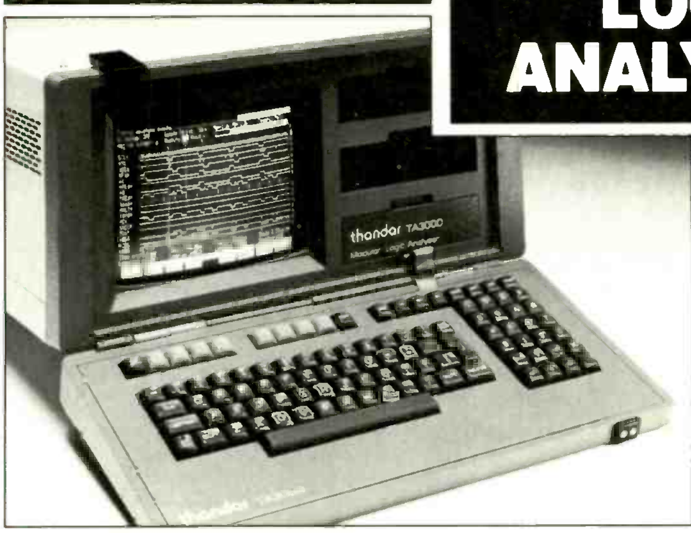

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LEVELL FUNCTION GENERATORS TG302/3
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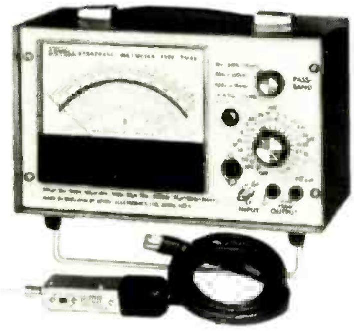

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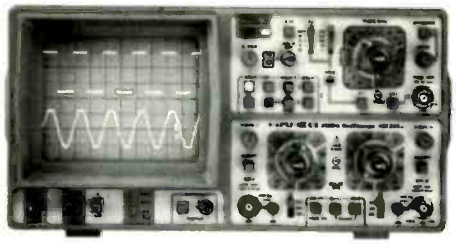

HITACHI DUAL 20MHz V212/222/223
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First VXI products emerge, from page 139

ance aspects of VXIbus, such as the data transfer rate of nearly 1Gbyte per second and precision timing, are a direct outgrowth of Tek's prior activities.

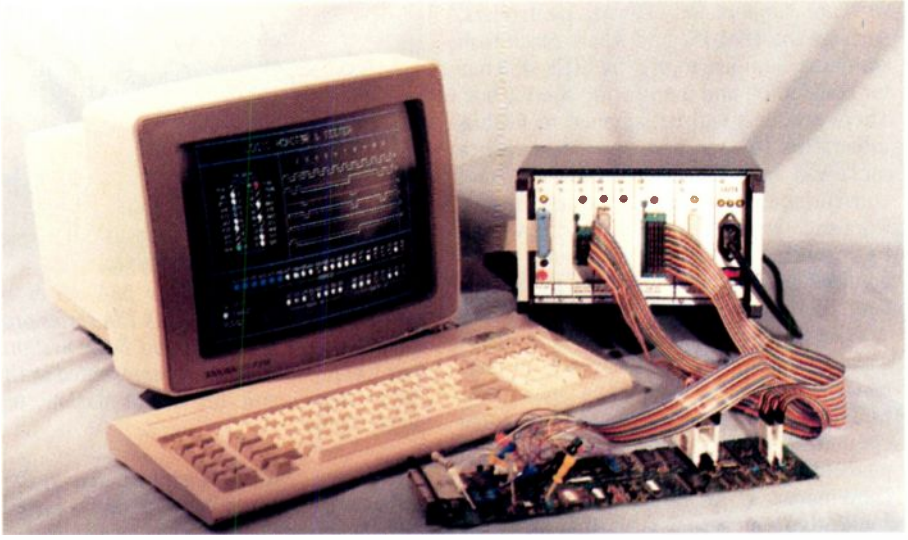
Tektronix is establishing a VXI product line to take advantage of the significant performance improvements made possible by the VXIbus spec and will be offering a D-size mainframe which provides the data coupling, tight timing, and power to support both current and future instrumentation technologies. The Tek mainframe provides necessary VXIbus slot 0 system resources, slots for 12 instruments, and power and will support a line of high performance stimulus and acquisition instruments.

Coupled with Tek's wide variety of programmable instruments, software, switching and d.u.t.-interface components, the Tektronix VXIbus products will offer a.t.e. system integrators and end-users a wide choice of configurations and functionality to support test and measurement needs. As GPIB-based a.t.e. suppliers for a number of companies, Tek feels it knows that market place quite well. "The VXI product range will complement existing products and will also add capabilities by exploiting the performance capabilities of the new VXI bus architecture", said Robert Stubbings of Tek's UK Instrument Marketing Group. "And it will be exploiting our prior knowledge and experience in card modular design. We think we have spotted some opportunities that others haven't" he told *Insight*.

● Racal-Dana are adapting their 1993 universal counter for the VXIbus. This counter, not shown in their current catalogue, is a card-based instrument developed specifically for the Wavetek 680 multifunction instrument system. Though VME based, this product was announced last April prior to VXI agreement, and is not VXI compatible.

● Among the group comprised by HP, Wavetek, CDS, Tektronix, Racal-Dana, and more, Sciteq of San Diego, California stands out for two reasons. "First", says president Henry Eisenson "we are by far the smallest of the players – a young firm with a staff of 30. Second, we control the frequency synthesizer technologies most needed by the VXI field. We plan to produce the only synthesized signal sources for the VXI industry. Many applications exploit the phase manipulation capabilities of our designs, because this technique provides a degree of accuracy not possible with other approaches, whether employed as a clock generator, r.f. source, phase shifter, general purpose signal generator, or modulator. "We currently produce several frequency synthesizers in VME/Eurocard format which we're converting to VXI." They include these four:

Band-width	Step size(Hz)	Phase control	Switching speed	Phase noise 1kHz
0-3MHz	0.001	0.36°	0.5 μs	–136dBc/Hz
0-15MHz	0.1	0.09°	0.3 μs	–130dBc/Hz
0-35MHz	<5	–	0.07 μs	–110dBc/Hz
0-110MHz	<1	–	0.15 μs	–110dBc/Hz



United Test Equipment's VXI Modular Test & Monitor System was developed within five months of the announcement of the VXIbus specification last July.

"We have applied for patent coverage on the circuitry that makes such performance possible, and have further embedded our designs in custom integrated circuits. We feel confident enough to place ourselves squarely atop the VXI juggernaut."

● Another VXIbus user is Universal Test Equipment which began three years ago in Anaheim, California. The initial product was a universal grid bare board circuit board tester which remains today as the only table-top grid tester. It operates using an IBM or compatible PC, XT or AT computer and includes simple fixturing, high speed, and component failure redundant circuitry that they claim no other manufacturer has incorporated.

What initially involved much custom hardware and software engineering has become a complete corrosion monitoring system operated remotely by computer on a serial cable because of the adverse radioactive environment. The system was originally designed around the VME cardcage due to its convenient size and availability, and at that time (mid 1987) used a backplane bus customized for the monitor system. The emergence of the VXIbus for instrumentation however prompted the company to re-design the corrosion monitoring system to comply with the newly proposed standards.

"The development of many electronic products created a requirement for signal and bus monitoring, interface monitoring, logic state analysis, and system testing" president Tom Reimer told us. "Investment in fixturing and expensive test equipment for the research and development process is not usually practical until the product is manufactured in quantity to support the cost of the test equipment, so with this in mind, and to fulfil future needs, we have designed practical solutions utilizing the new VXIbus proposed standards."

Their VXI Modular Test & Monitor System referred to earlier, is pictured above. For truly portable operation, this system may be operated from a laptop computer. It is software driven by an IBM or compatible PC, XT or AT computer. The software graphically presents information on the users' computer with most types of monitors although best results are obtained with an EGA monitor. ICs are shown complete with pin-out information. For logic monitoring, signals may be labelled on the screen showing address, data, and control lines on a bus. For cable testing, the cable connectors are shown so that in a production environment quick repair can be made.

● National Instruments of Austin, Texas, will supply VXIbus cards that will interface the VXIbus to the IEEE-488 bus, as well as

AN ALTERNATIVE VIEW OF VXI

The VXI specification is primarily targeted toward markets where density is a major requirement. Keithley, however, focuses on the worldwide semiconductor research and industrial test markets. At this point, Keithley feels that the best value for the customer still lies in traditional IEEE-488 GPIB boxes and systems. A VXI system will cost more than a comparable rack-and-stack implementation. VXI instruments are not targeted for non-programmable operation. There are not likely to be any push buttons or displays on the front panels of these instruments. And, of course, stand-alone operation and portability are not attributes of VXI.

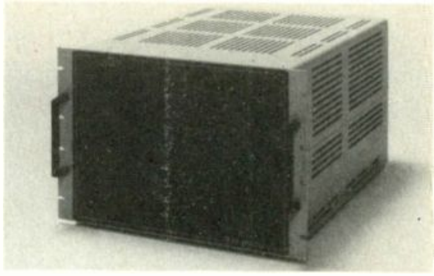
Keithley will be assuming a greater role in VXI standardization due to their experience in designing VME-based systems and their desire to have future products conform to an industry-accepted standard.

The proposed standard is a sound beginning. However, it will be a few years before all of the system integration and software issues stabilize. With VXI products only just emerging, the expected compatibility of different manufacturers' products is still in question. Until the standard has evolved to a steady state, IEEE-488 systems will clearly have the advantage. The initial GPIB implementations varied greatly between instrument manufacturers. A few years passed before the user could easily combine several manufacturers' products. We expect VXI to follow a similar path.

Steve Lekas, Keithley Instruments, Cleveland, Ohio.

software support for external controllers, such as the IBM PC and Apple Macintosh computer families, to use the IEEE-488 bus for controlling and monitoring the VXIbus. These products will be supplied to VXIbus integrators, o.e.ms and end users. Since most VXI bus instruments will not have conventional instrument front panels, software such as LabView and LabWindows can be useful because they provide user-configurable, graphic front panels on the computer screen.

They also provide the instrument driver code for communication between the personal computer and the VXIbus instrument. Linking the VXIbus instrument to personal computers provides an ideal way of implementing test and measurement systems. LabWindows is an integrated, interactive application software system that runs on IBM PC and PS/2 computers which features the function panel user interface and the instrument control library. LabView is a graphical system that runs on the Macintosh Plus/SE/II. With a VXI system interfaced to a Macintosh and LabView, a sophisticated system consisting of several VXI boards from different manufacturers can be made to look and "feel" like an off-the-shelf instrument. LabView provides the knobs, switches, meters, etc., on the Macintosh screen that allow the user to monitor and control system with the mouse.



Looking identical to their 53A series of card-based instruments, this 73A series prototyping system is Colorado Data Systems first VXI product. (CDS is represented in the UK by Instrumatic UK Ltd of Marlow, tel. 06284 76741.)

National Instruments are represented in the UK by Amplicon of Richmond Road, Brighton.

● As one of the five originators of the joint specification, HP is completely committed to modular instrumentation and is actively working on projects that will implement VXI. "Our products will be integrated offerings to span the very wide range of instrument system needs" is all that Bill Porter of the Loveland instrument division would say. "We are also taking care to ensure full HP-IB compatibility in our VXI products. Customers will want to mix and match VXI bus and HP-IB instruments in the same test system to solve their whole test problem."

● ICS Electronics (San Jose, California) believes that the proposed VXIbus standard will become one of the major standards for military a.t.e. systems in the next four years, with eventual migration into commercial a.t.e. systems after that. "We are currently examining several potential VXI products, some of which will be based on our existing IEEE 488 bus products" says Robert Prosin, vice president of marketing. "One product we are considering as a joint venture effort is a series of switching modules for audio-to-r.f. signals."

● Tailpiece. VXI is not yet standardized by the IEEE, despite frequent references to a "standard" in the press, but the five-company consortium of CDS, HP, Racal Dana, Tektronix and Wavetek are encouraging product development so that evaluation of the first products can be taken into account before the specification is put finally to the IEEE. The IEEE P1155 subcommittee met this January to discuss details of the software interfacing elements of the spec.

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IMAGE-10

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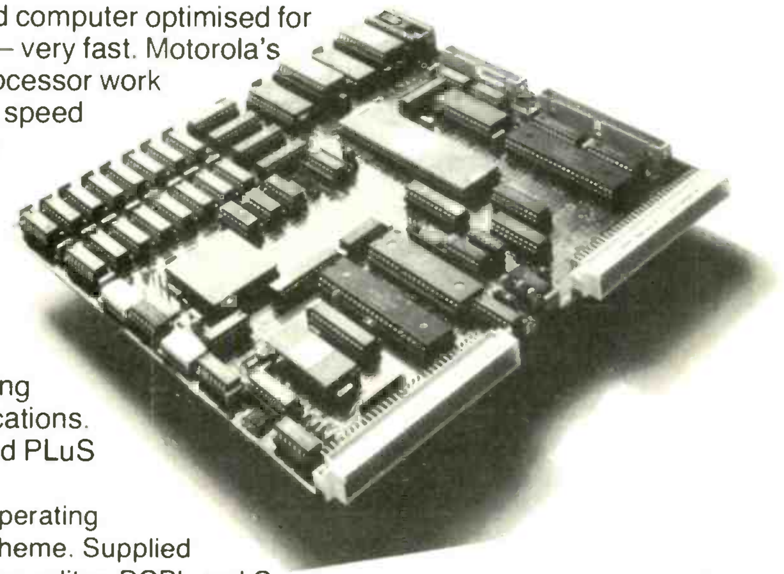

Image-10 is a high performance single board computer optimised for graphics intensive applications, and it's fast – very fast. Motorola's 68010 cpu and Intel's 82786 graphics co-processor work concurrently to produce displays of dazzling speed and quality. All graphic operations, including window manipulation, are generated by dedicated hardware which frees the cpu to concentrate on running your programs.

An impressive hardware specification is complemented by the availability of two professional disc operating systems.

OS-9/68K – A powerful UNIX like multi-tasking operating system supporting real-time applications. C, PASCAL, FORTRAN, BASIC, FORTH and PLuS languages available.

TRIPOS-3 – A well established multi-tasking operating system with propriety window management scheme. Supplied with assembler, disassembler, debugger, screen editor, BCPL and C compilers.

Image-10 Specification:

Central Processor – MC68010 16/32 bit microprocessor.
Graphics co-processor – I82786 running with 16Mhz pixel clock.
Display resolution is 768 by 576 pixels (user definable). Actual resolution limited only by memory with instantaneous scroll and pan in any direction plus independent horizontal and vertical zoom from ×1 to ×64. Displayed colours may be 256, 16, 4 or 2 at all resolutions.
Colour look-up table provides a pallette of 262,144 colours.
Hardware managed windows.
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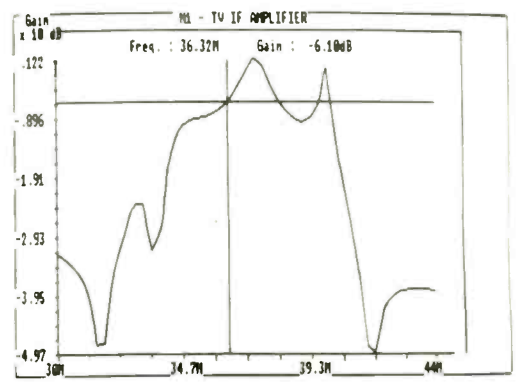

The photograph shows a screen plot with cross-hairs picking off a point on the curve.

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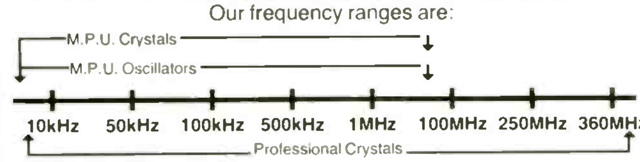

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INSTRUMENTATION

Cover story – frequency and time-interval analyser

A new type of instrument for analysing time-varying signals that is a cross between a spectrum analyser and a digitizing oscilloscope has been developed by Hewlett Packard. Called a frequency and a time-interval analyser, it provides statistical analysis and a time profile of frequency, phase, time-interval and jitter on dynamic transients, repetitive and non-repetitive signals up to 500MHz. The analyser is able to reveal phase, frequency or time-interval information on complex signals used in communications systems, both analogue and digital, in such applications as pulse-to-pulse jitter in p.c.m. systems, timing and data jitter in electromechanical designs, radar frequency profiling and phase coded demodulation, frequency-agile radio systems random event and error totalizing, zero dead-time variance measurements, and analysis of v.c.o. operation.

The patented time sampling technique, or 'continuous measurement technology', uses reciprocal counting at rates up to 10⁷ times per second to continuously track frequency. Because the register counters are not reset between measurements, thus eliminating dead time, count rate can be increased to 10MHz, and by sampling fast enough the time variation of frequency or time-intervals can be reconstructed.

The analyser measures carrier signals up to 500MHz for sampling intervals as short as 100ns, each sample having a 150ps resolution. A high-speed 1000-measurement memory stores the sampled input-signal timing information from the registers, and signal processing firmware then reduces the stored data according to the measurement mode selected. The fast measurement rate provides frequency or phase modulation analysis – if frequency is sampled often enough the plot of samples versus time shows the modulating waveform.

The new instrument's capabilities in modulation analysis, jitter analysis and frequency profiling should have application in a wide range of activities in electronics and communications. In f.s.k., the switching carrier is easily profiled, as is the distribution and mean value of each carrier frequency, and analysis of frequency overshoots now becomes possible. Data-to-clock jitter (h.f. errors greater than about 10Hz) in communications networks can be characterized with the histogram facility, which will display mean and standard deviation of timing variance. Timing jitter in magnetic or optical discs or magnetic tape can be analysed with the instrument's statistical and graphical analyses. (Though fuzzy oscilloscope traces can indicate jitter, the 5371A provides statistical analysis with a histogram of frequency or time-interval measurements to show whether the effects are random of systematic.)

The single-shot capability means that settling time of frequency hops and random-channel usage on the agile carriers of spread spectrum communications can be investigated, obviously including display of the hopping algorithm. In radar systems, chirp linearity is measured on a cycle-by-cycle basis in a single pass, and pulse risetime, width and repetition frequency are all measurable to within 150ps r.m.s. resolution. Step resolution in v.c.os. as well as overshoot, ringing and settling time are all easily found from the time-variation plot, and steady-state performance can be measured from the histogram feature. Further details in April's *Insight*.

The 5371A frequency and time-interval analyser costs £16,730 and is available from January. Hewlett Packard's enquiry office is on 0734 696622.

Increasing role of distribution in t&m

For many years, manufacturers of electronic components have appointed authorized distributors to stockhold their products and offer fast delivery to the customer. Test and measurement equipment manufacturers have always had a different approach to selling. The technical nature of the products necessitated the use of a highly skilled sales force, demonstrating each product to the customer. While this ensured that individual customers received good technical presentations, it did not give the manufacturer as wide a coverage as perhaps he would have liked.

It was in the mid-1970's that companies first began selling test equipment purely from a catalogue, and several high street electrical outlets started to stock multimeters and the like. The reason for this development was that the products involved had matured to such an extent that the majority of users knew enough about them to make a quick decision on what to buy. This meant that all they were interested in was the delivery. The first advantage of the distributor becomes apparent, since they hold the product in quantities, and are thus able to deliver ex-stock.

Since that time, much low-cost instrumentation is available almost exclusively through distributors, with the manufacturer having very little contact with the end-user. Several companies, such as Hameg, Thandar and Fluke have built their UK businesses almost entirely by having a set of stockists around the country. In these low-cost areas, a large distribution network gives the manufacturer far wider market coverage than they could achieve with only their own sales force. Probably 40% of oscilloscope sales, up to 100MHz, go through distribution, although the figure is nearer 80% up to 20MHz.

The majority of these distributors are themselves very small, either being high street outlets or 'one-man bands' working out of the upstairs bedroom. Such people operate on very low overheads and often give the customer discounts, leading to price wars in the low-cost sector.

The other end of the distribution spectrum is the larger company supplying a broad range of equipment, with exclusive agreements on certain high technology, high value equipment. These companies have grown in the 1980's and operate with large catalogues and a technical sales team. It is a sign that the market is becoming better educated and aware of products that such operations can exist, since the majority of sales are made to people approaching the distributor for a certain product, knowing exactly what it does and only requiring fast delivery. Thus, distributors offer the customer the advantage of delivery from stock.

Major manufacturers have also become aware of the advantages of having their products available through other outlets. Until a few years ago, it was almost unthinkable that companies such as Marconi Instruments or Philips would have their products available other than through themselves. But, as the overheads of a technical sales force became higher, they looked to certain outlets to offer a limited range and act as an additional salesman. A major move by Marconi was to appoint Electronic Brokers as their distributor, so that customers could be virtually guaranteed delivery of a £19,000 spectrum analyser from stock.

This 'top-end' of the distribution market is developing further, and companies are attacking niche markets with more specialized product ranges. As the rate of technological improvement gets faster, so products are maturing in the market earlier, and become available through distributors sooner. Customers have now become more technically aware and buying patterns are changing: the role of the distributor is likely to become even greater in coming years. As they become more specialized they will offer even greater service to the customer and a more efficient selling effort for the manufacturer.

Graham Sibley is marketing manager for Electronic Brokers.

RESEARCH NOTES

Using bubbles to spot faulty memories

Complex memory chips (or indeed other devices) can now have their faults pinpointed to an accuracy of 10^{-6}m using a technique developed by Standard Elektrik Lorenz in Stuttgart. It needs nothing more than milling or etching equipment, a microscope and a power supply.

The technique depends on the fact that many failures lead to short-circuits, latch-ups and the presence of spurious conductivity. This in turn causes the faulty area to overheat. Until now the only way to pinpoint such localized overheating has been to employ infra-red thermography or liquid-crystal thermography, techniques which are either expensive or imprecise.

What Standard Elektrik Lorenz have done is to exploit the fact that liquids, when heated, form tiny bubbles at points where heat is applied. Just watch a saucepan of water coming to the boil: it's possible to see thousands of bubbles forming at the points where most heat is being transmitted. To apply this principle to dud chips, the encapsulation is first removed, either by acid etching or careful milling according to whether it is plastic or ceramic. The exposed chip is then sprayed with a thin layer of some low boiling point liquid such as acetone or propanol. The precise chemical is immaterial as long as it has a well-defined boiling point and is non-conducting and non-poisonous.

Under a microscope, power is applied to the suspect chip, which is scrutinized for bubbles. Under carefully controlled lighting conditions, a bubble will appear as a black circular spot approximately 10^{-5}m in diameter. Such a spot is relatively easy to detect against the background of the chip's structure. In the middle of the black spot however, there is a bright dot which pinpoints the fault to an order of magnitude greater accuracy. This spot is in reality an artefact that marks the precise centre of the bubble. It is the point at which the bubble's surface is parallel to the chip substrate and at which incident light is not diffracted away.

Standard Elektrik Lorenz say that bubble thermography is as accurate as any other currently available technique for analysing chip defects, but is infinitely cheaper. No special equipment is required and it takes less than an hour to carry out a comprehensive bubble search of the chip.

New piezoelectric polymers

Piezoelectric polymer materials, although by no means new, were something of a rarity until the 1970s. Then it was realised that the relatively large piezoelectric (and pyroelectric) properties of polyvinylidine fluoride (PVF_2) could be used commercially in the manufacture of mechanical transducers and radiation detectors. In the former case the material acquires an electric polarization as mechanical stress is applied, this polarization having a relatively linear relationship to the stress. The polymer can thus be used to provide an analogue signal in response to a whole range of mechanical inputs.

Of the various polymers available today, the semi-crystalline forms such as PVF_2 are by far the most common. These materials are also known as electrets because of their readiness to acquire a permanent polarization when crystallized in the presence of an electric field. Because the polarity can be reversed by the subsequent application of an electric field, such materials are also said to be ferroelectric. Permanently polarized piezoelectric polymers find widespread use in domestic electret microphones where their movement relative to a fixed plate is translated into a changing voltage.

The search for alternative and better piezoelectric polymers is currently based on the starting point of a molecular bond with a high dipole moment. The carbon-fluorine bond is particularly good in this respect, which explains its universality. A polymer sub-unit (monomer) comprising these bonds must then add together with other sub-units to produce a chain capable of molecular rotation in response to an external field.

Within these constraints researchers have been looking at polyvinyl fluoride (PVF) and polytrifluoroethylene (PVF_3). Neither is ideal. PVF crystallizes only with difficulty and PVF_3 is a bulky molecule that does not rotate easily. Other related substances such as nylon have also been investigated.

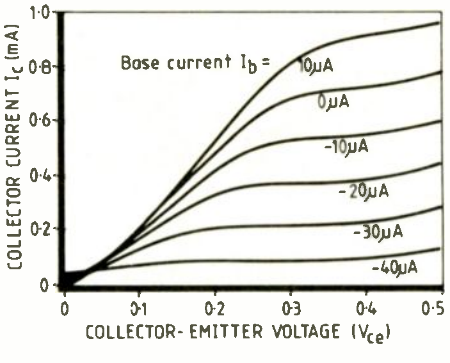
In a recent edition of the *GEC Journal of Research*, vol.5 no.3, experiments are reported in which a whole range of difficult materials and fabrication processes are analysed. Four VF_2/VF_3 co-polymers of varying compositions were assessed for stability and for their use in a particular transducer application – hydrophones. (A co-polymer is one in which different monomer sub-units alternate along the length of the molecule.) The paper concludes that these recently discovered co-polymers open up new areas of application and exhibit superior properties to many established ceramic piezoelectric materials. Much research also remains to be done on evaluating the piezoelectric properties of polymers in other chemical classes – a field that clearly holds much commercial promise.

Cadmium mercury telluride transistors

Transistor action continues to be demonstrated in an increasing number of exotic and unlikely materials. This is the result partly of a search for improved properties but more often than not through constraints of integration. It is no use having a circuit element that shows enhanced properties if its method of fabrication makes it incompatible with other essential circuit elements. Frequently, however, the incompatibility arises the other way round. Solid state lasers, for example, are difficult to integrate with their control circuitry; so too are transducer elements based on materials other than silicon or gallium. Difficulties with resistors are discussed elsewhere in this column.

In some cases an extreme solution may be to create new components that are compatible with their intended environment, even if this seems a bit like re-inventing the wheel. An interesting example of this philosophy, described in *Electronics Letters* vol.23 no.24, is the development of a transistor based on cadmium mercury telluride (c.m.t.). This material is extremely valuable as an infra-red detector, for which it has obvious military applications in areas such as heat-seeking missiles. But to integrate a c.m.t. detector with an amplifying device implies a c.m.t. amplifying device.

Last year transistor action was demonstrated for the first time in c.m.t., but only at low temperatures. As the temperature was increased there were leakage problems due to high base minority carrier generation. That situation has now improved as a result of research by the Royal Signals and Radar Establishment and Mullard Ltd at Southampton. At a temperature only a little below ambient (263K) they now have a device capable of maintaining transistor action with a current gain (h_{fe}) of 15 or more. Interestingly enough, this gain remains un-



Unusual characteristics of the cadmium mercury telluride transistor by Mullard and RSRE.

RESEARCH NOTES

changed as the base is driven into reverse bias (see curves). A reverse base-emitter bias of >40μA is necessary to turn off the collector current because of the thermal generation of minority carriers within the base region. These act as a sort of current offset.

The researchers believe that, given more development, especially geometry optimization, the c.m.t. transistor has the potential to become a practical high-gain device suitable for integration into specialist infra-red and other transducers.

How to stop sparks flying

When engineers talk about devices being blown up by static, the expression does not usually refer to anything more cataclysmic than a dead piece of c-mos. However, given the increase in the use of flammable fluids for cleaning and degreasing, a more serious hazard could be lurking around.

A symposium on electrostatic hazards held at a meeting of the American Institute of Chemical Engineers considered amongst other things what can happen when a flammable liquid is carried in a partially-filled plastic bottle. One speaker described an incident in which a lab technician began to pour methanol into a metal can from a plastic bottle that had been carried in a plastic bag. Movement between the bag and the bottle had created a static charge which had in turn induced an opposite charge on the methanol. As the methanol flowed into the metal can a spark occured igniting the liquid.

Methanol is particularly dangerous in this respect because it is electrically conductive *and* highly volatile. The AICE warns, however, that any liquid can become charged up either by being transferred from one container to another or indirectly through the walls of a non-conducting container. Even passing through a filter of critical pore size can effect a significant transfer of charge.

Care is necessary not only with volatile liquids that are obviously flammable, but even when transferring chemical powders in and out of metal bins or drums. Because of the friction between individual particles, powders are more likely to acquire a charge than liquids. In finely-divided form they can also be just as explosive. Serious damage has resulted in the past from spontaneous ignition of such unlikely substances as custard powder.

Experiments conducted by Union Carbide using granular polyethylene have shown that when such material is poured into a silo there is nearly always widespread discharge as the powder settles down. This occurs because of charge concentration and results in thousands of microscopic sparks. The finer the powder, the worse the effect. What can also happen, often with catastrophic results, is one big spark instead of harmless microsparks. Why this happens is not precisely known, though it does depend on the type of material and the size of the particles.

Until more is understood about the precise mechanisms of static build-up, the most obvious advice must be: think before you pour.

Stable resistors for gallium i.cs

One of the many problems in the fabrication of gallium arsenide microwave integrated circuits is the design of the humble resistor. Ion-implanted or mesa-etched GaAs resistors might seem the easiest in terms of the manufacturing technology, but suffer from non-linear behaviour at high electric fields. They also have an unacceptably high positive temperature coefficient. Currently used alternatives include nichrome, tantalum nitride and cermet, but none of these is entirely free from problems of stability of manufacture.

A team working for British Telecom's research laboratories at Martlesham Heath (*Electronics Letters* vol.23 no.23) reports promising results from tungsten silicide, a material usually employed in mesfet technology. Tungsten silicide resistors have been fabricated on a GaAs substrate using r.f. sputtering. A ratio of 1.6 parts of tungsten to one part of silicon was chosen to give a resistance of 50-300Ω/square and from this material resistors were etched using a sulphur hexafluoride plasma. Values of up to 9kΩ were obtained, with high reproducibility and good temperature stability. As for long term stability, a newly-constructed resistor decreased in value by 1.25% after 1000 hours at 125°C. A pre-aged one that had been encapsulated by a layer of silicon nitride changed in value by less than 0.1% under the same conditions.

The BT team claims that its tungsten silicide resistors are completely compatible with GaAs i.c. fabrication technology and superior to alternative forms of resistor.

Medical effects of power lines

Two recent studies have added to the tantalisingly inconclusive evidence on this emotive subject. Each of them in different ways has unearthed what seems like compelling anecdotal evidence that low frequency electric and magnetic fields do indeed have a harmful effect. The problem faced by all studies of this sort is that of establishing a true causal connection from what, at best, are barely significant statistics. Another difficulty in this particular case is reconciling the epidemiological evidence with laboratory work showing that fields much higher than those associated with power lines have little or no effect on biological tissue.

So what is one to make of evidence from a British medical practice that migraine sufferers tend to be clustered near power lines? Obviously there *could* be some direct effect of the lines on the blood vessels in the patients' brains. But why then does it affect only a tiny minority of the people living near power lines? Could it be that the mere sight of nasty great pylons is enough to induce migraine in those who are susceptible to stress? Several other possibilities suggest themselves, including pure chance association. As with similar epidemiological problems such as the speculative link between radioactive discharges and leukaemia, most of us incline to an opinion based more on emotion than on scientific evidence.

For that reason another study in the USA costing $5 million was undertaken to try and establish the true facts. Financed by the US government, the New York electricity companies and various charities, it reviewed all the existing evidence and also funded a number of major new studies. The New York Power Lines Project, now published as a 153-page report, makes interesting reading, covering not only the 765kV overhead lines that were the prime objects of the study, but also electric and magnetic fields in the home and work place. Diseases looked at include cancer, mental illness, strokes, infertility and problems associated with fetal and child development. Studies on isolated biological cells were likewise included.

To summarize such a study in a few words is difficult. Most of the individual research projects reported no effects of concern. No effects were found on reproduction, growth or development. Several attempts to demonstrate genetic or chromosome damage that might lead to inherited defects or cancer also failed completely. Brain studies showed no effects of power lines except a hint of a small but consistent effect on body rhythms that might interfere with sleep patterns. Experiments on rats showed changes in their response to pain and in their ability to learn.

One effect of power lines that the authors of the New York study *do* believe warrants further investigation is a possible link between leukaemia and elevated 60Hz or 50Hz magnetic fields. Although they admit that more research is necessary before a causal link is properly established, they claim that only two of four studies showed any connection at all and that the two in question are from the same geographical region. Perhaps it has something to do with the birds that sit (*sic*) on the lines?

Research Notes is written by John Wilson.

Speech transposer for radio hearing aids

For some types of deafness, adding a frequency shifter to a classroom hearing aid brings a marked performance improvement.

B.J. SOKOL AND MAX VELMANS

Many people with sensory-neural deafness receive some benefit from conventional amplifying aids. But they may find it difficult or impossible to hear certain high-frequency speech and other sounds. Such patients usually have residual hearing in the low frequencies but little or none in the high frequencies, producing what is known as a 'ski-slope' hearing loss. Since vowel information is concentrated in the lower speech frequencies and consonant information in the higher speech frequencies, hearing loss of this kind tends to impair selectively the perception of consonants – in particular, fricative and stop consonants which have major energy components in the higher speech frequencies (e.g. from 4kHz to 8kHz). In addition, the perception of many environmental sounds, including important ones such as water running, gas hissing and the ringing of door bells and telephones may be greatly impaired. Patients in this group often complain that their aids amplify but do not clarify speech.

Over recent years, therefore, various attempts have been made to modify the response of conventional hearing aids so as to improve intelligibility for patients with sloping losses. Evaluation studies have been carried out with various configurations of low-pass and high-pass filtering, with extended low frequency and extended high frequency response, with selective amplification (typically of the higher frequencies) and with various forms of amplitude compression.

Although a number of studies have suggested modifications that may be of benefit[1,2], in general the effects of such manipulations have been found to be complex and the findings inconclusive[3,4,5]. Moreover, none of these techniques can be expected to restore missing high frequency information in cases where its loss is very severe or profound – for instance, where the average loss at 4kHz, 6kHz and 8kHz exceeds 80dB[6]. Furthermore, in cases where no measurable hearing in the higher frequencies exists, such techniques become inadequate in principle. For these patients, therefore, frequency transposition (i.e. converting the non-detectable high frequency signals to some detectable low frequency form) may be an appropriate alternative.

There have been many attempts over the last 20 years to produce devices which accomplish such conversions[7] but few of these have proved to be superior to conventional amplifiers. In some ways this is hardly surprising as the vast majority of these devices produce versions of speech which sound grossly distorted both to those with normal hearing and to the hearing impaired. Furthermore, the recoded high frequency information provided in the low frequencies may in fact be treated by the ear/brain system as noise and may also interfere with low frequency information already available in the residual hearing range[8,9,10].

During the last decade, however, a frequency recoding device (Fred) has been developed whose output is highly speechlike in character[11]. The Fred system subtracts a constant 4kHz from signals in the 4-8kHz region, thereby mapping them on to the 0-4kHz range. This transposed information is then combined with conventionally amplified speech in a second, non-transposing channel. One realization of the Fred system in the form of a radio hearing aid is outlined below. Before turning to this, however, it is worth noting the effects of the recoding operation on both speech and environmental sounds.

EFFECTS OF FRED

In *speech*, very little energy related to vowel sounds occurs in the region above 4kHz. Vowels, therefore, remain largely unaffected by the transposition process. But fricatives and stop consonants do have significant energy components in this region, and Fred transposes these in such a way that they blend with consonant cues that already exist in the low frequency range (transmitted by a conventional amplifying channel).

Recoded speech sounds much like normal speech. To a normal hearing person, however, transposed speech cues are redundant and phonemes affected by such cues are unnecessarily emphasized. For those with high-frequency hearing loss, the subjective effects vary. Where the loss is severe, recoded cues may improve the identifiability of connected speech. If the high frequency loss is profound, this improvement may be considerable, because the recoded cues may fill what would otherwise seem to be gaps in the speech stream. On the other hand, a patient with a relatively flat hearing loss may receive little or no advantage from transposition, since high-frequency cues can, in general, be made audible for such patients by the use of a conventional amplification technique.

Transposition also affects a range of *environmental sounds*, i.e. sounds with significant energy in the region above 4kHz. These include natural sounds such as rain, birdsong, wind in the trees, etc., sounds around the house, baby cries, doorbells, telephones and so forth. These not only provide increased contact with the environment but may also be important for safety or for communication. By and large, transposed environmental signals sound very similar to the originals (to a normal hearing person) although their lowered frequency may, in some cases, give them the appearance of coming from a larger object – keys jangling may, for example, sound more like cowbells and water running into a glass may appear to be running into a bath. With a little practice, such sounds are easily identified.

In principle, transposition may improve the discrimination, identification and articulation of various phonemes and it may therefore help in the speech training of sensory-neural deaf children. For example, transposed information may improve their ability to discriminate between sounds which are otherwise commonly confused, e.g. z/v, t/k. To test such claims, however, it is necessary to compare the effects of conventional amplification on learning to discriminate such sounds with the effects of adding transposition to conventional amplification. Furthermore, the children involved in the present study were already equipped with radio hearing aids for classroom use. It was necessary, therefore, to construct an adapter for these aids so that they could be used either as a conventional amplifier or as a frequency transposing device.

DEVISING A TRANSPOSING ADAPTER

The engineering difficulties in making a transposing adapter for radio hearing aids resulted from physical and economic constraints. The children were already required to carry radio receivers and so there was a restriction on size and weight. Sixty units had to be produced in little time and within a limited budget.

At the two schools designated for the trials, the partially-hearing units were provided with different types of very expensive radio hearing aids. It was uneconomic to replace or even retrofit these units, and so an early decision was made to find a means to add to the existing apparatus without modifying it.

It would have been easier and cheaper to apply transposition to the transmitted signals rather than the received signals because teaching is often a one-to-many communication and so fewer transposers would have been needed. Transposition before transmission is advantageous because it reduces bandwidth and enables the narrow-band f.m. channel to carry a wider effective speech range. Furthermore, the placing of prototype equipment in the care of adult teachers rather than children might have increased reliability.

This desirable solution ran into problems, however. Inputs to the children's hearing aids could come from a local microphone as well as from the radio channel, and this 'environmental' signal could not of course be transposed at the teacher's transmitter. In addition, the design of the experiment required students to have identical apparatus, yet half of them at any time had to be a control group without transposition. If teachers were to transmit transposed signals, the need for a control group would require them also to transmit non-transposed signals simultaneously on another channel. That would have meant the unacceptable use of different-coloured receiving crystals which would have identified the control and test groups, and it would also have required more frequency channels than were available.

Thus it was necessary to overcome the problems of providing identical transposers for each student and to fit these with invisible on/off control.

The transposer connection had to be at the output terminal of the radio receiver hearing aids to achieve transposition by means of a non-invasive jack-socket connection. This arrangement also allowed transposition of both radio and environmental signals. However then the transposers had to match or duplicate the output impedance and levels of the radio receiving hearing aids.

Both types of radio receivers were designed to drive multi-turn inductive loops, to be worn like necklaces, that could couple their outputs magnetically to normal post-aural hearing aids. These loops require 2V peak drive and have impedances of about 100 ohms.

From the block diagram (Fig.1), it is clear that the transposer output must be added to the non-transposed audio output. This non-transposed output was already provided at sufficient power level by the radio receiver hearing aid, so an ideal solution in energy terms would be to place the transposed power in series with the receiver output and provide extra output only for transposed signals. To achieve this the transposer output stage would need four active elements in a full bridge configuration (Fig.2). With this arrangement, even when the main channel had large signal currents flowing, only base drive currents would be needed to drive the transposer output to zero, if there was no transposed signal.

In the event a compromise circuit (Fig.3) was used instead. This was due to constraints on space within the transposer units and to the greater importance of quiescent currents than running currents because of the variable level and intermittent nature of speech.

The energy budget was saved by the very low quiescent current of the audio output stage. This is a crude current-dumping circuit: an op-amp delivers small outputs itself, but for higher outputs it supplies drive and difference signals to control and correct the transistors. The output transistors remain cut off for signals whose peaks do not turn on their base-emitter junctions. Even with larger signals the transistors have a dead zone between the drive levels of ±0.7V. This dead zone of course allows this output stage to operate with no more quiescent current than the op-amp alone, but on the other hand guarantees crossover distortion. The problem in this case was effectively eliminated because the entire output stage was used as part of a low pass filter.

Low power op-amps, a high quality monolithic multiplier, nine poles of filtering (some to compensate deficiencies of the radio channel), and the special output stage completed the design of the adapters.

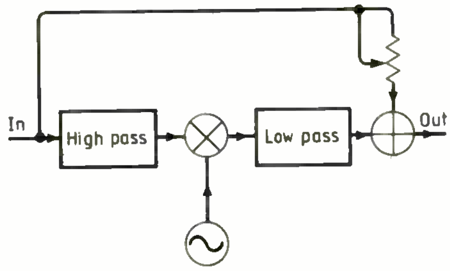


Fig.1. Transposer-type hearing aid. Sound components above 4kHz are superimposed on the 0-4kHz components. This treatment improves intelligibility by adding emphasis to speech consonants and other sounds.

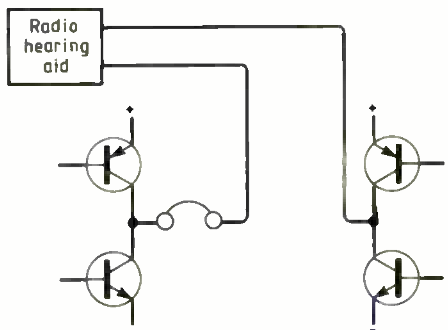


Fig.2. Modifying a radio hearing aid using a full bridge transposer output stage.

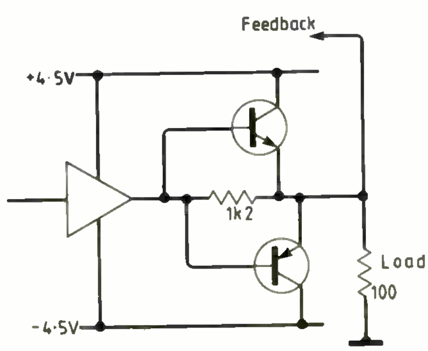


Fig.3. Final version of the combiner. The op-amp alone supplies the load current for outputs of less than 700mV.

RESULTS OF THE STUDY

At the time of writing the results of the study are still being analysed. But the initial finding is that Fred transposition may indeed improve children's ability to discriminate amongst and to produce transposed sounds. Whether it does so, however, depends, at least in part, on the nature of the child's hearing loss and, in particular, that at high frequencies. Children with a severe or profound loss in the high frequencies (an average loss of 71dB or more averaged over 4, 6 and 8kHz) are likely to benefit from transposition. But children with mild or moderate losses at these frequencies cope just as well (or better) with conventional amplification.

It is clear, furthermore, that requiring children to wear a module additional to their body-worn receivers causes considerable practical difficulties. This was particularly true of the school where a binaural system was used and therefore two additional modules were required. For everyday use it would be necessary to incorporate the Fred circuitry within the receiver of the radio hearing aid.

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Multiprocessor systems

In this illustration of a multiprocessor system, two 8080 processors running synchronously produce economical hardware with high performance.

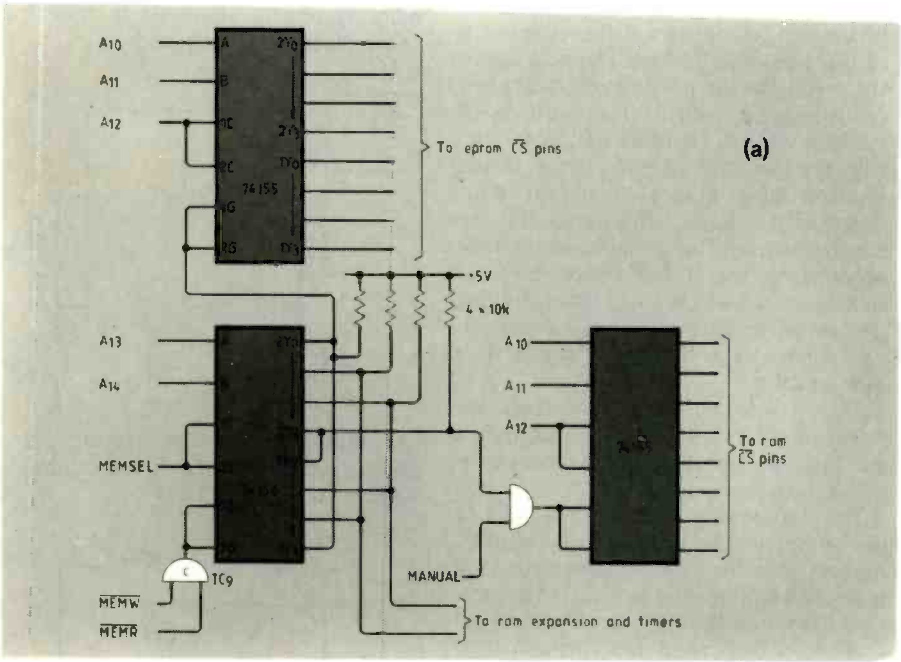
G.A.M. LABIB

Some microprocessors are not fast or powerful enough to keep up with demanding real-time applications. 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 slow processing speed.

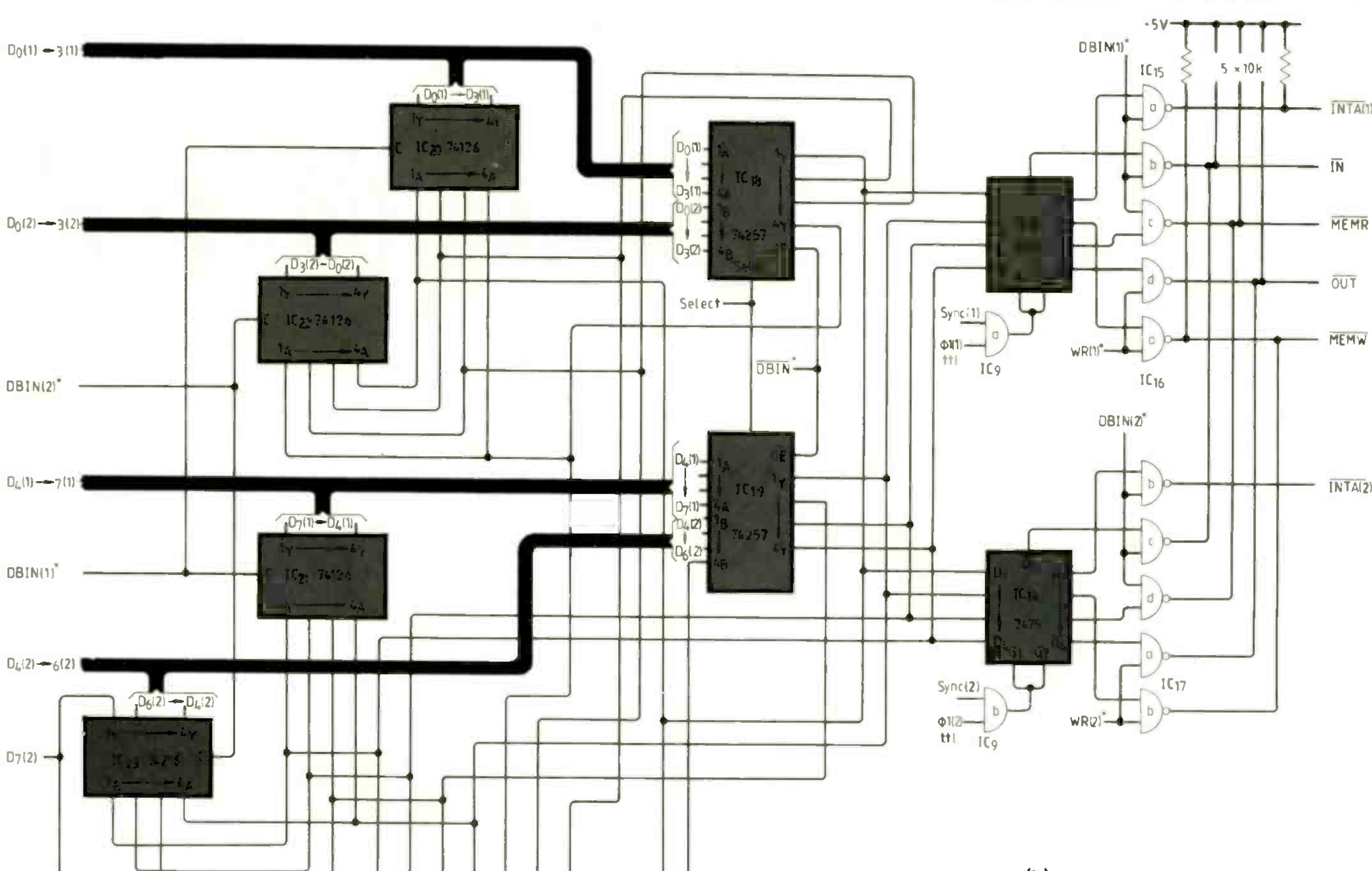
In a synchronous multiprocessor system, each processor takes control of the common bus whenever it requires it, independently of the other processors. Synchronous bus control is achieved by dividing the bus-control cycle into equal time slots, each of which is permanently assigned to one processor.

Last month's article outlined various ways of connecting microprocessors in a multiprocessor system. This article is a specific example of how two economical eight-bit processors can work together efficiently over a common synchronous bus.

A block diagram of this system was shown last month. Output of the 18.432MHz central clock generator (CK) synchronizes the



(a)



(b)

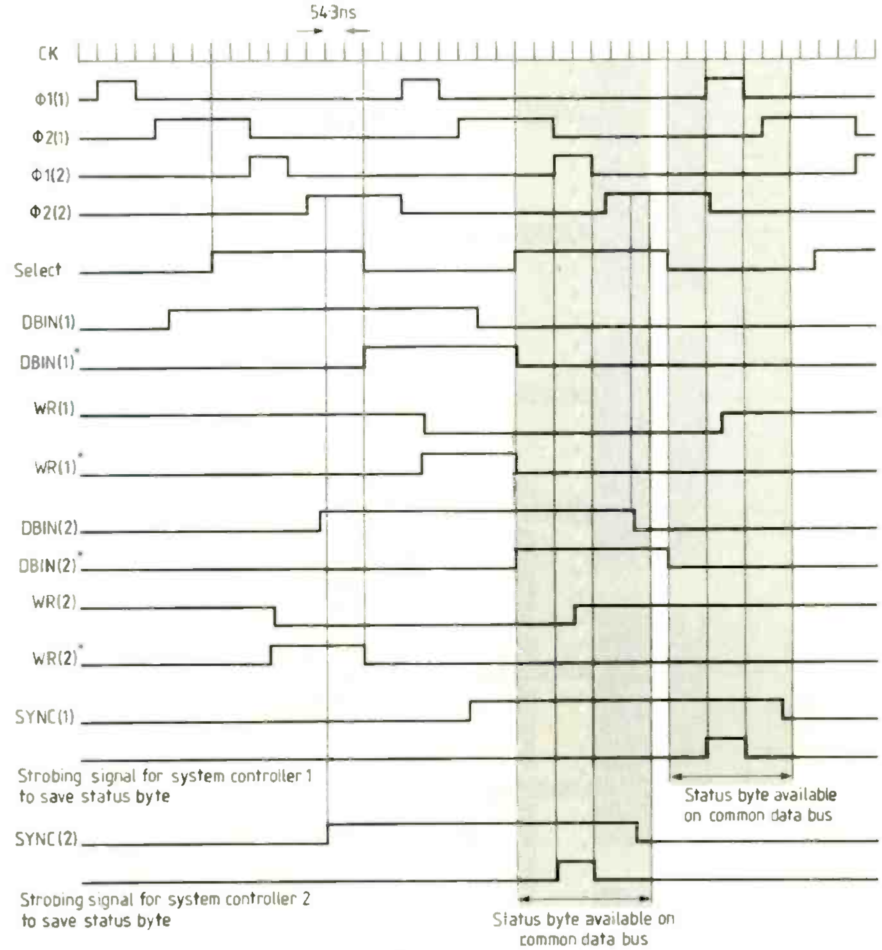


Fig.1. Processor control signals modified to allow two processors to operate together. In this synchronous system, ϕ1 and ϕ2 clocks of each microprocessor are shifted in relation to each other so that the processors access the bus alternately.

clocks of both processors with the multiplexing operation of their buses over the common bus. It feeds the circuit producing phase-shifted clocks ϕ1(1,2) and ϕ2(1,2), and control signal SELECT.

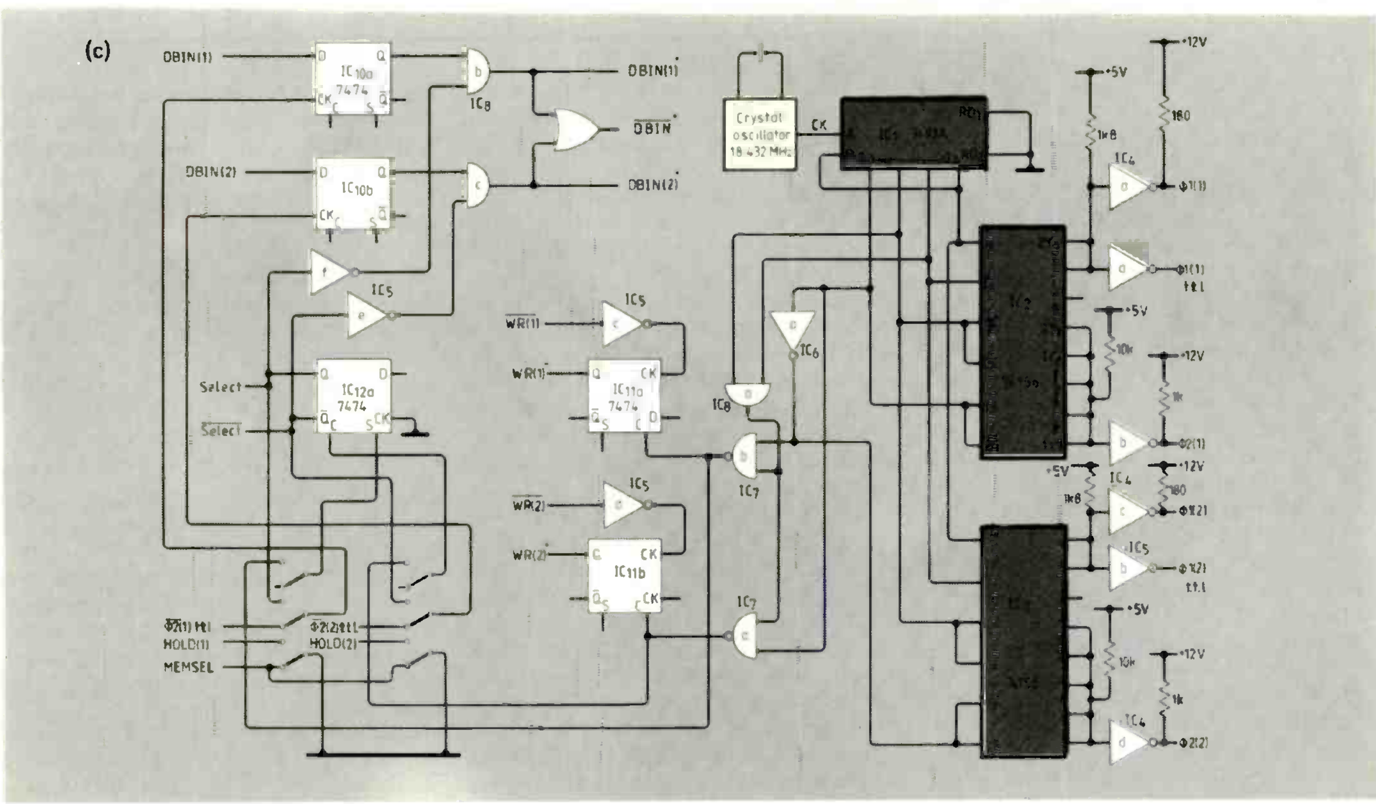
Figure 1 is the system timing diagram showing that each machine state takes 16 CK pulses i.e. 868ns. Within each machine state, ϕ1 is generated during the first two central-clock pulses, resulting in a pulse width of 108ns, and ϕ2 is generated from the fourth CK pulse until the eighth, resulting in a pulse width of 271ns. Remaining central-clock pulses in each machine state are used to produce ϕ1 and ϕ2 clocks for the other processor in the same manner.

Signal SELECT determines which processor is to gain the control of the common bus. When it is low, the first processor controls the bus, and when it is high, the second processor controls the bus. Each processor is allowed to control the bus during the first two CK pulses ahead of its machine state, and during the first six CK pulses of its machine state. This timing allows each processor to control the common bus for about 108ns ahead of the rising edge of its ϕ1 clock pulse, and for about 325ns following that edge.

Like single-processor systems, each microprocessor in this multiprocessor system has an associated circuit for producing memory and i/o control signals. The multiprocessor system controller combines these control signals to produce common bus-control signals. Overlapping of combined signals can cause disturbed system operation. To prevent this, signals from each system controller are activated only during the time slot of the bus-control cycle of the appropriate processor.

Each processor's system controller decodes the status byte together with data-bus input signal DBIN and data-write signal $\overline{WR}$ from each c.p.u. Controlling the period during which DBIN and $\overline{WR}$ signals are active

Fig.2(a). Chip-select decoders for the common memory, opposite page top, (b) data-bus multiplexers, opposite page bottom, and (c) clock drivers.



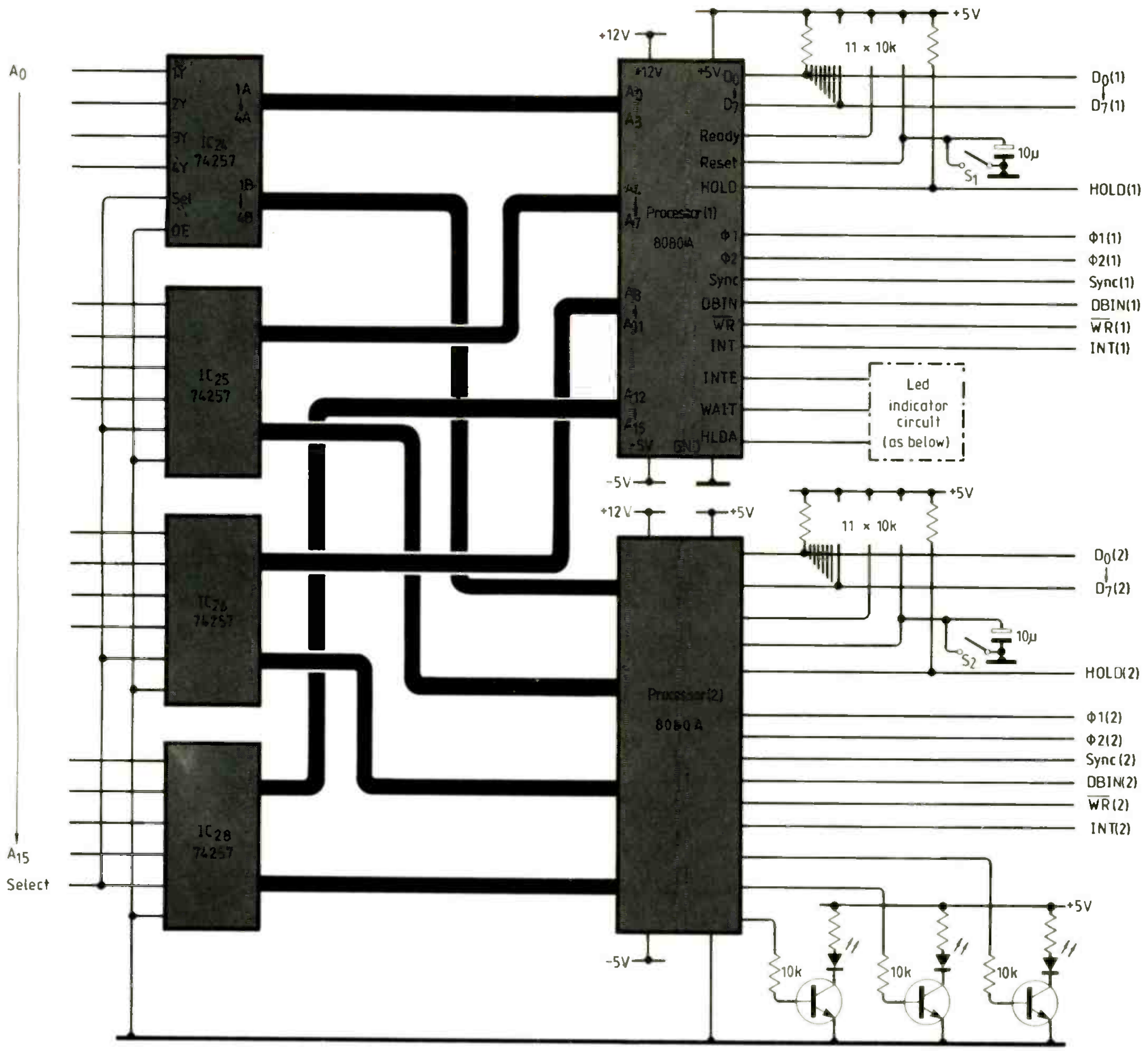


Fig.3. Address buses from the two microprocessors are multiplexed together and applied to the shared memory alternately using the SELECT signal. Simple circuits for keying in and reading data are also shown opposite.

affects the duration of activation of the output signals from both system controllers. This is achieved in this design by control-signal alignment modules which act upon DBIN and $\overline{WR}$ signals of each processor, and product DBIN* and WR* modified signals. These signals are activated only during the bus time slot of their associated processor.

Central clock CK is a crystal oscillator running at 18.432MHz whose output feeds phase-shift generator IC_{1-5}. Four-bit binary counter IC_1 produces the 16 states of each bus-control cycle from clock CK. Output of IC_1 is fed to open-collector decoders $IC_{2,3}$ to produce the clocks of both processors, Fig.2(c). During the first eight states of the bus-control cycle, IC_2 is activated to produce the first processor's $\phi 1$ clock during the first two states by wiring together $2Y_0$ and $2Y_1$ outputs of IC_2, and the $\phi 2$ clock of the same processor between the fourth and eighth states by wiring $2Y_3$ and $1Y_{0-3}$ of IC_2.

Decoder IC_3 is activated during the next eight states of the bus-control cycle by feeding the inverted most-significant bit (Q_d) of IC_1 to its 1G and 2G inputs. During these eight states, the clocks of the second processor are generated in a similar way to those of the first. Pull-up resistors are connected to the wired outputs of $IC_{2,3}$ resulting in t.t.l. compatible signals. Outputs of $IC_{2,3}$ feed open-collector inverters $IC_{4,5}$ which produce processor clocks $\phi 1(1,2)$ and $\phi 2(1,2)$ at mos levels, and $\phi 1(1,2)$ at t.t.l. levels.

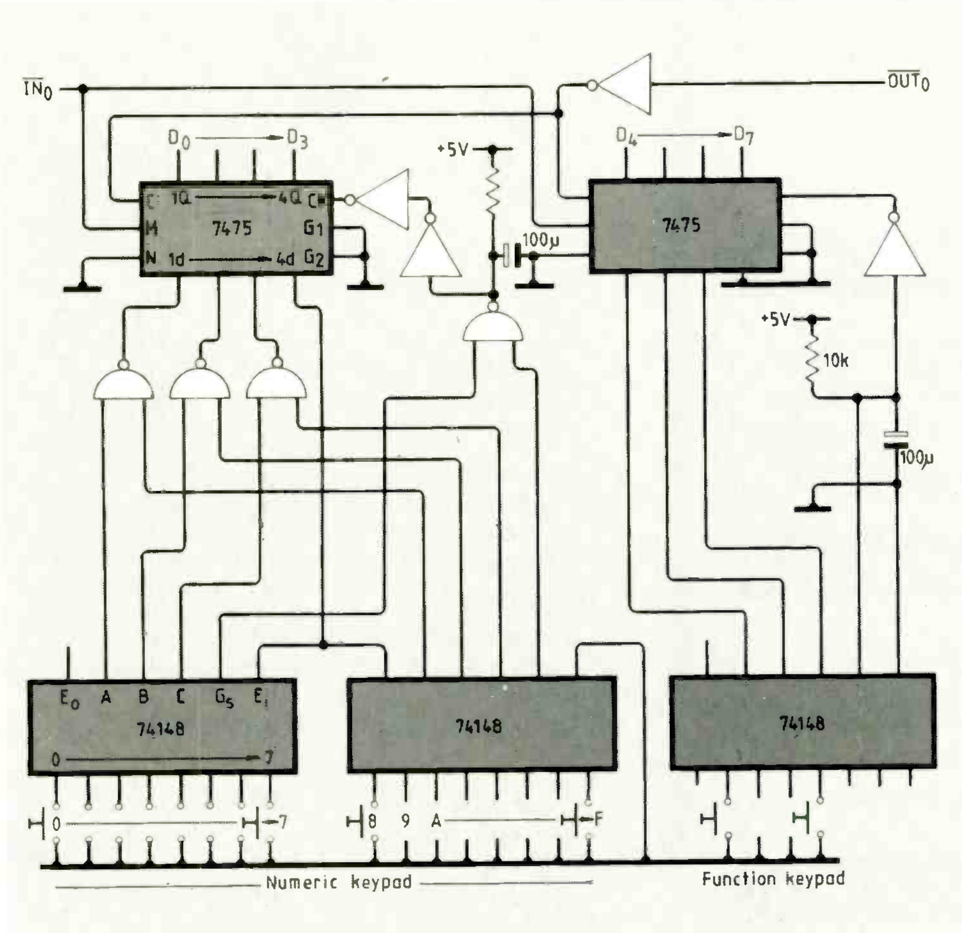
Signal SELECT, which is responsible for switching both processors on to the common bus, is produced during the seventh state of the bus-control cycle until the fourteenth. This is achieved by decoding the three most-significant bits of counter IC_1 using Nand gates $IC_{7a,b}$, And gate IC_{8a}, and inverter IC_{6a}.

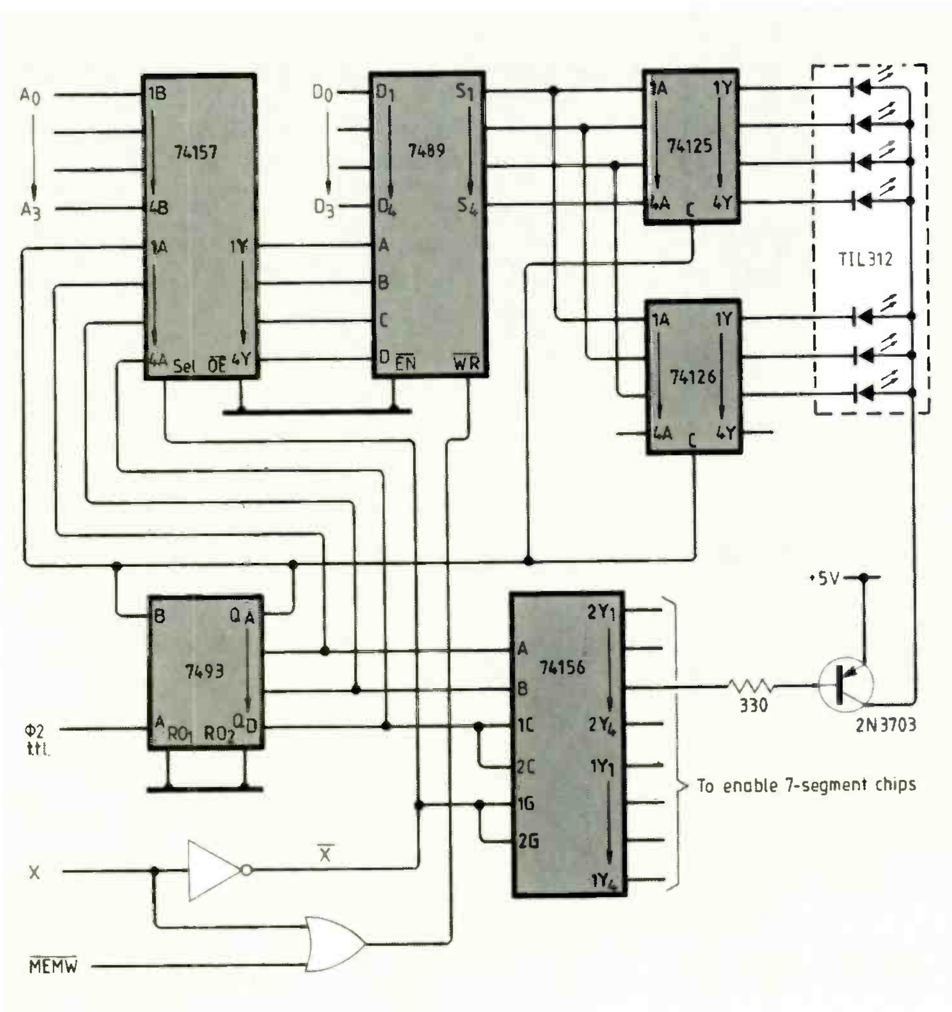
The SET input of D-type bistable device IC_{12a} is low at the seventh state, while the CLEAR input is high causing SELECT to be set high. At the fourteenth state, the SET input is high while the CLEAR input is low, causing the SELECT signal to be set to low. When SELECT is low, the first processor controls the bus and when it is high, the second processor controls the bus.

Signal-alignment modules of both processors are composed of D-type bistable devices $IC_{10a,b}$, And gates $IC_{8b,c}$ and inverters $IC_{5e,f}$. These modules modify DBIN and $\overline{WR}$ signals of both processors to fit in each time slot of the associated processor. Signal DBIN is normally produced by the processor during the $\phi 2$ clock pulse and lasts until the next $\phi 2$ pulse. For the first processor DBIN(1) is fed to D input of IC_{10a} and the bistable device is clocked by $\phi 2(1)$ at t.t.l. level causing signal DBIN(1) to be latched at the falling edge of the $\phi 2(1)$ pulse.

Output Q of IC_{8b} is Anded with the inverted SELECT signal at IC_{5f} output, generating the aligned DBIN(1)*, Fig.2(b). At the negative edge of the following $\phi 2(1)$ pulse, DBIN(1) will be low causing bistable IC_{10a} to be reset, and thus DBIN(1)* goes low.

The same method is applied to DBIN(2) of the second processor but in this case $\overline{SELECT}$ is applied as a clock to IC_{10b}. Note that in spite





of the availability of $\overline{\text{SELECT}}$ at the $\overline{Q}$ output of IC_{12a}, the inverter IC_{5f} is used to invert the SELECT signal prior to Anding it to the latched DBIN(1) signal. This is because the SELECT signal is used for latching DBIN(1) and there must be a delay before it is reapplied to align the latched state of DBIN(1). Inverter IC_{5f} provides this time lag. The same applies to both processors.

Signal $\overline{\text{WR}}$ is normally generated from the processor during φ1's clock pulse, and lasts until the next pulse. For the first processor $\overline{\text{WR(1)}}$ is inverted by IC_{5c} and then fed to D-type bistable IC_{11a} as clock input. At the negative edge of $\overline{\text{WR(1)}}$, a binary one is latched at the Q output of this bistable device. Whenever the second processor is controlling the common bus, output of IC_{7b} goes low for the duration of the seventh state of the bus-control cycle, causing IC_{11a} to be cleared. Thus aligned signal WR(1)* is activated only during the time slot of the first processor whenever $\overline{\text{WR(1)}}$ is active.

The same applies to $\overline{\text{WR(2)}}$ of the second processor but in this case, the output of IC_{7a} is used to clear bistable IC_{11b} whenever the first processor is controlling the bus.

System controllers for the first and second sections are composed of $IC_{9,13\text{-}17}$. For the first processor, IC_{13} is a four-bit latch which saves part of the status byte generated by the first processor when it is connected to the common bus. At the first machine state of each machine cycle of the first processor, SYNC(1) goes high and feeds And gate IC_{9a} together with φ(1)t.t.l.; output of this gate latches the status byte of the first processor.

Only bits $D_{0,4,6,7}$ of the status byte are used to produce the necessary control signals $\overline{\text{INTA(1)}}$, $\overline{\text{IN(1)}}$, $\overline{\text{MEMR(1)}}$, $\overline{\text{MEMW(1)}}$ and $\overline{\text{OUT(1)}}$. The first three signals are produced by Anding the latched least-significant bits of the status byte with the aligned DBIN (1)* signal. The last two signals are produced by adding the second and fourth latched status bits with the aligned WR(1)* signal. The system controller of the second processor is similar to that of the first.

In the multiprocessor system controller, control signals of both processors are aligned with their associated c.p.u. time slots so Oring the corresponding control signals of both system controllers results in common bus-control signals $\overline{\text{IN}}$, $\overline{\text{MEMR}}$, $\overline{\text{OUT}}$ and $\overline{\text{MEMW}}$. Open-collector Nand gates of $IC_{15\text{-}17}$ perform these Or functions.

Data bus multiplexing is done by $IC_{18\text{-}23}$. The multiplexer is bidirectional in that it switches the data buses of both processors in the outward direction to the common bus whenever the time slot of the corresponding c.p.u. is due. Multiplexers $IC_{18,19}$ perform this function whenever $\overline{\text{DBIN}}$* is active, and the switching process is controlled by SELECT which feeds the select inputs of both i.cs.

Also in the inward direction, the multiplexer switches the common bus to either processor data bus depending on the current time slot. Drivers $IC_{20\text{-}23}$ perform this function according to DBIN(1,2)* states.

Components $IC_{24\text{-}27}$ form the address-bus multiplexer. It is a unidirectional multiplexer which switches the address buses of both processors at the corresponding time slots under control of the SELECT signal. Fig.3.

SATELLITE SYSTEMS

Uplink station for UK's d.b.s.

Programmes and spacecraft control signals will be transmitted to Britain's direct broadcasting satellite from an earth station at Chilworth, Hampshire, about four miles north of Southampton. The IBA is responsible for designing, building and operating this uplink station. Construction work is now going ahead on the site, which lies near the M27 motorway, and the installation is expected to be completed in October 1988.

Brian Salkeld, the IBA's Head of Satellite Engineering, gave an outline of the uplink arrangements at a recent IEE lecture on the forthcoming d.b.s. service. Sited in fairly open country, the station is being landscaped so that it will not be an environmental eyesore. Like all IBA transmitters it will operate unattended, though office accommodation is being provided.

Four parabolic antennas will be installed. A pair of these, with eight-metre reflectors, will be used for transmitting programme signals to the satellite in the 17.3 – 18.1GHz uplink band, one acting as the main antenna and the other as a redundant spare. Step-tracking will automatically keep the antenna beam pointed at the satellite in its 31°W geosynchronous slot.

The third antenna will be for tracking, telemetry and command (t.t.c.) and will operate in the 14 – 14.5GHz band. Finally, the fourth antenna will be used for testing and t.t.c. of BSB's second spacecraft held in an inclined storage orbit as a spare d.b. satellite. Having this fourth antenna available means that the spare satellite can be tested at the same time as the main one is operating.

As already reported, the transmission standard to be used is encrypted D-MAC/packets (see September 1987 issue, p.928). Incoming baseband video signals will be in component form to give compatibility with the CCIR world digital coding standard for studio equipment and to allow flexibility for future developments. Each baseband signal in the three programme channels (4, 8 and 12 in the WARC-77 plan) passes through a D-MAC encoder and subsequently the D-MAC multiplex frequency-modulates the appropriate carrier. Details of the carrier frequencies and digital audio system were given in the September 1987 issue. Finally, each modulated carrier passes through a high-power r.f. amplifier and into a combiner, which sends all three signals via waveguides to the two 8m uplink antennas.

The specified uplink e.i.r.p. is 84dBW. On being questioned whether he didn't consider an 8m antenna something of an overkill for the task required, Mr Salkeld replied that this size was required in order to give the necessary power flux density over the whole of the geostationary slot area, allowing for the permitted satellite movement within it. An additional safety measure to ensure reliability of service will be a transportable uplink terminal available to the station.

During 1988 the IBA hopes to be able to provide some D-MAC test transmissions, both from a terrestrial source in the London area and from a satellite.

Further details of the satellite itself were given in this lecture. The Hughes HS376 was chosen by BSB mainly because of this manufacturer's ability to deliver, in orbit, in the required time of two years (by August 1989). Other spacecraft considered at the time included designs by British Aerospace, Eurosatellite (manufacturer of Germany's TV-Sat 1 and France's TDF-1) and RCA Astro-Electronics.

The HS376 is required to provide three operational transponders but will carry six separate chains of equipment through which any of the three channels can be switched, thus giving a 6-for-3 level of redundancy. As shown by earlier experience, the most critical part of the high-power d.b.s. transponder is the travelling-wave tube amplifier. Each 110W r.f. amplifier will in fact be formed by two 55W t.w.ts running in parallel from a common power supply.

These tubes are made by Hughes themselves and were chosen by BSB because of their current reliability record both in space and in simulated space conditions on the ground. Some 40 are operating in space at the moment; 32 of these have been running for 1½ years; and 198 have been ordered for various satellites including the new Intelsat VI, Anik E (Canada) and Eutelsat II spacecraft.

After launch on a Delta rocket from Cape Kennedy, USA, in August 1989 the first HS376 satellite is expected to be ready for broadcasting by Christmas of the same year. Mr Salkeld said that the e.i.r.p. should be about 61 – 62dBW in the London area and about 59dBW at the periphery of the UK coverage. With the resulting power flux density, small receiving dishes of 30 – 40cm diameter should be adequate to obtain good signal strength.

Bert Horlock, an engineering consultant to BSB, was questioned about methods to be used for collecting subscription payments for use of the d.b.s. service. (Initially it will be financed in a 7:1 ratio of subscriptions to advertising.) He said that the pay-per-view method would be extremely difficult to put into practice and that technical solutions were very much dependent on business decisions which had to be made first. Discussions on whether local authority planning permission would be required for installing the small receiving dishes were speculative and inconclusive.

Digital sound for Hong Kong

BBC External Services recently opened a new sound broadcast relay station at Hong Kong. Like other relay stations in the world network, it now receives a digital programme feed via satellite. This gives much better sound quality than the old method of re-broadcasting short-wave multi-hop transmissions from the UK and is cheaper than air-freighting tapes of non-topical programme material.

From London the programme feed signals are sent to BTI's earth station at Madley and thence to Hong Kong via an Intelsat V comsat at 63°E above the Indian Ocean. Analogue speech and music waveforms are sampled at a rate of 14.2kHz, then encoded into 11-bit numbers and companded down to 9-bit numbers. The resulting 128kbit/s stream digits modulates a 70MHz carrier by quaternary phase shift keying and this signal is upconverted to the 6GHz satellite uplink frequency. The downlink to the Hong Kong earth terminal is at 4GHz. In a 36MHz comsat transponder, which will carry 800 telephony channels, one BBC high bit-rate programme feed takes up the bandwidth normally required for two 64kbit/s s.c.p.c. telephony channels.

Overall, the low-noise satellite circuit to Hong Kong has an audio bandwidth of 50Hz to 6.4kHz. Distortion is 1.2% at 1kHz zero level.

Kicked upstairs

When geostationary satellites become defunct or obsolete their owners remove them elsewhere, if possible, to make more positions available in the precious orbit. This has now happened to the last of the Intelsat IV spacecraft. Comsat F-1 of that generation has been taken out of service by the international co-operative and propelled from its slot at 50°W to a higher altitude, some 280km above the geostationary orbit. It had been in operation for 12 years.

Such a process depends, of course, on there being enough fuel left for the reaction-propulsion thrusters. It's a tribute to the manufacturer and operator that sufficient fuel remained in the comsat after such a long period of service.

OU video for schools

Communications and remote sensing satellites are among the topics included in a video cassette lecture produced by the Open University for use in schools. Called "Space at Work", its purpose is to give children some idea of what it would be like to work in this sector of industry. Other subjects dealt with are equipment testing at the European Space Technology Centre, Netherlands, and the space exhibition gallery at the London Science Museum.

Supplied with support notes and priced £28.75, the video cassette is available from the OU at the following address: ASCO, PO Box 76, Milton Keynes, Buckinghamshire MK7 6AN.

Satellite Systems is written by Tom Ivall.

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BC338	0.09
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BCY34	7.50
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BD237	0.35
BD238	0.35
BDX10	0.91
BDX32	2.00
BDY10	2.40
BDY20	1.50
BDY60	1.50
BF115	0.30
BF152	0.16
BF153	0.19
BF154	0.17
BF159	0.20
BF160	0.20
BF166	0.35
BF167	0.30
BF173	0.45
BF177	0.30
BF178	0.30
BF179	0.30
BF180	0.30
BF181	0.25
BF182	0.30
BF183	0.30
BF184	0.30
BF185	0.30
BF194	0.15
BF195	0.15
BF196	0.15
BF197	0.15
BF200	0.33
BF224	0.12
BF241	0.12
BF244	0.35
BF257	0.30
BF258	0.30
BF259	0.30
BF336	0.30
BF337	0.30
BF338	3.00
BFS21	4.00
BFS28	2.50
BFS61	0.30

BFS98	0.30
BFW10	1.04
BFW11	1.01
BFX84	0.28
BFX85	0.28
BFX87	0.28
BFX88	0.28
BFY50	0.28
BFY51	0.28
BFY52	0.28
BFY64	0.36
BFY90	0.65
BSX19	0.27
BSX20	0.27
BSX21	0.27
BT106	1.65
BTY79 400R	3.00
BU205	1.20
BU206	1.20
BU208	2.00
BY100	0.42
BY126	0.15
BY127	0.15
BZX61	0.17
Series	
BZY88	0.10
Series	
BZY91	8.00
Series	
BZY93	1.80
Series	
BZY95	1.64
Series	
BZY96	2.00
Series	
CRS1 40	0.60
CRS3 40	0.75
CRS3 60	0.90
GEX66	3.00
GEX541	6.50
GJ3M	3.00
GM0378A	1.75
KS100A	0.45

MJE340	0.79
MJE370	0.73
MJE371	1.05
MJE520	0.75
MJ521	0.73
MJE2955	2.25
MJE3055	2.00
MPF103	0.55
MPF104	0.55
MPF105	0.55
MPSA06	0.17
MPSA56	0.17
MPSU01	1.11
MPSU06	1.33
MPSU56	1.71
NE555	0.45
NKT401	4.00
NKT403	3.50
NKT404	4.00
OA5	1.75
OA7	0.75
OA10	0.55
OA47	0.15
OA70	0.22
OA79	0.21
OA81	0.21
OA85	0.21
OA90	0.08
OA91	0.08
OA95	0.08
OA200	0.15
OA202	0.15
OA211	1.00
OAZ200	1.50
OAZ201	1.50
OAZ206	1.50
OAZ207	1.50
OC16	5.00
OC20	6.00
OC22	4.50
OC23	10.00
OC24	3.00
OC25	1.75

OC26	1.50
OC28	5.50
OC29	4.40
OC35	4.00
OC36	4.00
OC41	1.20
OC42	1.50
OC43	1.50
OC44	1.25
OC45	0.85
OC71	0.65
OC72	2.20
OC73	1.45
OC74	1.40
OC75	1.40
OC76	1.60
OC77	2.75
OC81	0.90
OC81Z	4.00
OC82	0.95
OC83	1.40
OC84	1.40
OC122	6.50
OC123	6.50
OC139	12.00
OC140	18.00
OC141	18.00
OC170	4.40
OC171	4.40
OC200	4.00
OC201	5.50
OC202	5.50
OC203	5.50
OC204	7.00
OC205	10.00
OC206	8.50
OC207	18.00
OCP71	2.50
ORP12	2.40
R2008B	1.95
R2009	2.25
R2010B	2.00
TIC44	0.48

TIC226D	1.20
TIL209	0.29
TIP29A	0.35
TIP30A	0.36
TIP31A	0.25
TIP32A	0.25
TIP33A	0.53
TIP34A	0.60
TIP41A	0.38
TIP42A	0.42
TIP110	0.10
TIP117	0.45
TIP125	0.35
TIP130	0.45
TIP131	0.45
TIP132	0.48
TIP135	0.45
TIP137	0.48
TIP140	0.85
TIP141	0.85
TIP142	0.85
TIP2955	0.60
TIP2955T	0.45
TIP3055	0.60
TIP3055T	0.45
ZS140	0.25
ZS170	0.21
ZS178	0.54
ZS272	0.23
ZS278	0.57
ZTX107	0.12
ZTX108	0.12
ZTX109	0.12
ZTX300	0.13
ZTX301	0.14
ZTX302	0.14
ZTX303	0.14
ZTX304	0.14
ZTX311	0.13
ZTX314	0.25
ZTX500	0.14
ZTX501	0.14
ZTX502	0.14

ZTX503	0.14
ZTX504	0.20
ZTX531	0.20
ZTX550	0.25
IN914	0.03
IN916	0.03
IN4001	0.04
IN4002	0.04
IN4003	0.04
IN4004	0.04
IN4005	0.04
IN4006	0.04
IN4007	0.05
IN4009	0.06
IN4148	0.03
IN5400	0.10
IN5401	0.11
IS44	0.04
IS920	0.10
IS921	0.12
2G301	1.00
2G302	1.20
2G306	1.50
2N404	1.50
2N696	0.30
2N697	0.36
2N698	0.38
2N705	2.50
2N706	0.20
2N708	0.22
2N930	0.25
2N1131	0.35
2N1132	0.35
2N1302	1.80
2N1303	0.90
2N1304	3.00
2N1305	1.00
2N1306	3.00
2N1307	1.20
2N1308	4.00
2N1309	1.50
2N1613	0.30
2N1671	5.00

2N1893	0.30
2N2147	8.00
2N2148	2.75
2N2218	0.32
2N2219	0.32
2N2220	0.22
2N2221	0.22
2N2222	0.20
2N2223	7.50
2N2368	0.23
2N2369	0.23
2N2384	0.24
2N2646	0.75
2N2904	0.30
2N2905	0.30
2N2906	0.22
2N2907	0.22
2N2924	0.12
2N2925	0.22
2N2926	0.12
2N3053	0.30
2N3054	0.55
2N3055	0.70
2N3440	0.60
2N3441	0.75
2N3442	1.00
2N3614	5.00
2N3702	0.11
2N3703	0.11
2N3704	0.11
2N3705	0.11
2N3706	0.11
2N3707	0.11
2N3708	0.11
2N3709	0.11
2N3710	0.11
2N3711	0.10
2N3771	1.20
2N3772	1.20
2N3773	1.60
2N3819	0.50
2N3820	0.60
2N3823	0.80

2N3866	1.00
2N3904	0.10
2N3905	0.10
2N3906	0.10
2N4058	0.12
2N4059	0.20
2N4060	0.12
2N4061	0.12
2N4062	0.15
2N4124	0.13
2N4126	0.13
2N4248	0.25
2N4288	0.15
2N4289	0.12
2N4400	0.12
2N4401	0.12
2N4402	0.12
2N5457	0.45
2N5458	0.40
2N5459	0.40
2S017	16.00
2S019	25.00
2S024	35.00
2S025	35.00
2S026	40.00
2S103	2.50
2S302	5.50
2S303	5.50
2S322	5.00
2S324	4.00
2S701	12.50
2S745A	1.75
2S746A	1.75

VALVES

A1834	9.00
A2087	13.50
A2134	17.50
A2293	16.00
A2426	35.00
A2521	25.00
A2900	15.00
A3343	45.00
AZ31	2.75
AZ41	2.60
BK448	114.90
BK484	165.00
BS90	58.00
BS810	60.00
BT5	58.95
BT17	185.00
BT19	44.05
BT29	349.15
BT69	354.80
BT95	129.90
CBL31	4.00
CL33	4.00
CY31	3.00
C1K	20.00
C3A	22.00
C3JA	22.00
DA41	25.00
DA42	18.70
DAF91	1.75
DAF96	1.75
DET22	35.00
DET24	49.00
DF91	1.75
DF96	1.75
DK91	1.75
DK92	2.00
DK96	1.75
DL92	2.00
DL94	1.75
DL96	1.75
DLS10	14.00
DLS15	12.50
DLS16	12.50
DLS19	12.50
DM70	2.00
DM71	2.00
DM160	4.75
DY87	1.50
DY802	1.50
E55L	50.00
E80CC	15.00
E80CF	11.27
E80F	14.19
E80L	27.50
E81CC	8.00
E81L	13.27
E82CC	8.10
E83CC	8.40
E86C	8.25
E88C	8.25
E88CC	10.33
E90CC	9.47
E90F	9.90
E91H	6.25
E92CC	8.75
E99F	9.10
E130L	18.50

E180CC	10.50
E180F	12.05
E182CC	13.25
E186F	11.50
E188CC	8.91
E280F	22.51
E283CC	12.00
E288CC	17.50
E810F	35.48
EA52	110.00
EA76	2.50
EABC80	1.25
EAC91	3.50
EAF42	2.50
EAF801	2.00
EB41	4.00
EB91	1.50
EBC33	2.50
EBC41	2.50
EBC81	1.50
EBC90	1.25
EBF80	1.50
EBF83	1.75
EBF89	1.50
EBL31	10.00
EC86	2.75
EC90	3.25
EC91	8.00
EC92	1.75
EC157	462.00
ECC33	4.50
ECC35	4.50
ECC40	5.50
ECC81	1.75
ECC82	1.75
ECC83	1.75
ECC84	1.75
ECC85	1.75
ECC86	2.50
ECC88	3.50
ECC89	2.75
ECC91	8.93
ECC189	2.10
ECC807	1.75
ECC808	5.00
ECF80	1.50
ECF82	1.50
ECF86	2.50
ECH35	3.00
ECH42	3.50
ECH81	3.00
ECH83	2.50
ECH84	2.50
ECL80	1.50
ECL81	1.75
ECL82	1.50
ECL83	3.00
ECL84	1.50
ECL85	1.50
ECL86	1.75
EF37A	5.00
EF39	2.75
EF40	5.00
EF41	3.50
EF42	4.50
EF50	2.50
EF54	5.00
EF55	3.50
EF80	1.75
EF83	4.00

EF85	1.75
EF86	3.50
EF89	2.50
EF91	2.95
EF92	6.37
EF93	1.50
EF94	2.50
EF95	5.99
EF98	2.00
EF183	2.00
EF184	2.00
EF804S	12.00
EF805S	15.00
EH90	1.75
EK90	1.50
EL32	2.50
EL33	4.00
EL34MUL	4.00
EL36	2.50
EL41	2.80
EL42	2.50
EL81	5.25
EL83	6.00
EL84	2.25
EL86	2.75
EL90	3.25
EL91	7.39
EL95	2.00
EL156	30.00
EL360	18.50
EL500	3.00
EL509	10.00
EL821	13.00
EL822	13.97
ELL80	25.00
EM34	8.00
EM80	2.50
EM81	2.50
EM84	2.00
EM85	2.75
EM87	2.50
EN32	25.00
EN91	6.50
EN92	6.96
EY51	2.75
EY81	2.50
EY83	2.50
EY84	9.24
EY86	1.75
EY88	1.75
EY500A	3.00
EY802	1.75
EZ35	1.75
EZ40	2.50
EZ41	2.50
EZ80	1.50
EZ81	1.50
EZ90	3.00
FW4-500	3.50
FW4-800	3.50
G1.371K	35.00
G551K	12.00
G180.2M	17.50
G240.2D	12.00
G400.1K	17.50
GN4	9.00
GN4A	9.00
GS16	16.00
GT1C	25.00

GU50	20.00
GU51	20.00
GXU1	15.35
GXU2	30.00
GXU3	40.00
GXU4	44.50
GXU50	20.00
GY501	3.00
GZ32	4.00
GZ33	4.75
GZ34	4.00
GZ37	4.75
KT61	5.00
KT66	15.00
KT77 Gold Lion	12.00
KT88	15.00
KTW61	2.50
KTW62	2.50
KTW63	2.50
M8079	12.34
M8080	8.25
M8081	9.82
M8082	9.69
M8083	10.25
M8091	10.43
M8096	6.80
M8097	8.10
M8098	8.15
M8099	8.00
M8100	10.30
M8136	11.75
M8137	12.25
M8140	6.00
M8141	6.50
M8142	8.75
M8144	7.50
M8149	6.50
M8161	9.35
M8162	11.75
M8163	8.25
M8190	5.00
M8195	10.85
M8196	7.50
M8204	7.05
M8212	11.37
M8223	6.00
M8224	6.30
M8225	4.50
M8248	14.03
MD2901	115.00
MU14	2.50
MX119	55.00
MX123	86.00
MX145	61.50
MX151	18.30
MX152	150.00
MX161	175.00
MX163	19.50
MX164	26.40
MX166	164.00
MX168	78.50
N78	15.00
OA2	3.25
OA3	2.50
OA4	6.00
OB3	2.50
OC2	4.35

OC3	2.50
OD3	2.50
OZ4	3.50
PC86	2.50
PC88	2.50
PC95	1.75
PC97	1.75
PC900	1.75
PCC84	1.75
PCC85	1.50
PCC88	2.00
PCC89	1.75
PCC189	2.50
PCC805	1.60
PCC806	1.60
PCE82	2.00
PCF80	2.00
PCF82	1.50
PCF86	2.50
PCF87	2.00
PCF200	3.25
PCF201	3.25
PCF801	2.50
PCF802	2.50
PCF805	1.70
PCF806	1.70
PCF808	1.70
PCL82	2.00
PCL83	3.00
PCL84	2.00
PCL85	2.50
PCL86	2.50
PCL805/85	2.50
PD500	6.00
PE06-40N	45.00
PFL200	2.50
PL36	2.50
PL81	1.75
PL81A	2.00
PL82	1.50
PL83	2.50
PL84	2.00
PL504 5	2.50
PL508	5.50
PL509	6.00
PL519	6.00
PL801	1.50
PL802	6.00
PY33	2.50
PY81	1.50
PY82	1.50
PY83	1.25
PY88	2.00
PY500A	4.00
PY800	1.50
PY801	1.50
QF451	82.50
QQV02-6	38.00
QQV03-10	26.25
QQV03-20A	48.38
QQV06-40A	46.00
QQV07-50	76.65
QQZ06-40A	62.20
QU37	12.50
QV03-12	6.80

QV04-7	3.50
QV08-100	197.40
QY3-65	63.24
QY3-125	78.48
QY4-250	74.00
QY4-400	87.20
QY5-500	208.00
QY5-3000A	566.80
QZ06-20	46.00
R10	6.00
R17	3.00
R18	3.00
R19	9.24
R20	2.50
RG3-1250	59.50
RG3-250A	32.68
RG4-1250	61.60
RG4-3000	99.45
RR3-250	40.00
RR3-1250	45.75
S130	6.00
S130P	6.00
S11E12	65.00
STV280-40	14.00
STV280-80	21.00
SU2150A	5.00
SU42	10.00
TD03-10	35.00
TD03-10F	35.00
TT15	50.00
TT21	37.50
TT22	37.50
TT100	60.00
TY2-125	78.75
TY4-400	88.20
TY4-500	124.26
TY5-500	272.50
TY6-800	231.00
TY6-5000A	632.20
TY6-5000B	395.00
TY6-5000W	523.20
TY7-6000A	632.20
TY7-6000W	579.00
TZ40	25.00
U18 20	3.50
U19	13.75
U25	2.50
U26	2.50
U37	12.00
UABC80	1.25
UAF42	2.50
UB41	3.00
UBC41	2.50
UBF89	1.50
UCC84	1.75
UCC85	1.85
UCF80	2.00
UCH42	2.50
UCH81	2.50
UCL82	1.75
UCL83	2.75
UF41	2.00

UF42	2.10
UF80	1.75
UF85	1.75
UF89	2.00
UL41	5.00
UL84	1.75
UM80	2.00
UY41	4.00
UY85	2.25
VLS631	15.00
XG1-2500	100.00
XG5-500	30.00
XG2-6400	185.00
XR1-1600A	53.75
XR1-3200	81.97
XR1-3200A	
XR1-6400	165.00
YD1120	395.00
YD1240	588.60
Z803U	25.00
Z759	25.00
ZM1001	8.00
ZM1020	9.00
ZM1021	9.00
ZM1022	9.00
ZM1023	9.00
ZM1040	19.36
ZM1041	16.66
ZM1042	17.77
1B3GT	3.00
1B24	25.00
1B35A	48.00
1B63	64.00
1R5	1.75
1S5	1.75
1T4	1.75
2A515	11.50
2C39A	60.00
2C43	70.00
2021	3.25
2E26	8.25
2J42	98.00
2J55	265.00
2J70A	383.00
2J70B	336.00
2K25	125.00
3400Z	115.00
3500Z	100.00
3A5	3.00
3B24	11.00
3B28	15.35
3B29	20.05
3B240M	17.50
3B241M	17.50
3C23	25.00
3C24	12.00
3CX100A5	47.00
3E29	45.00
3S4	2.00
3V4	1.75
4-65A	60.00
4-125A	60.00
4-250A	80.00
4-400A	87.00

4B32	20.00
4C35	120.00
4CX250B	58.00
4CX350A	105.00
4X150A	60.00
4X150D	56.00
5B254M	35.00
5B255M	35.00
5C22	160.00
5J180E	2500.00
5R4GY	5.50
5U4G	3.00
5U4GB	2.50
5V4G	2.50
5Y3GT	2.50
5Z3	4.00
5Z4G	2.50
5Z4GT	2.50
6-30L2	1.75
6AB4	1.75
6AB7	3.00
6AC7	3.00
6AF4A	4.25
6AG7	3.00
6AH6	5.00
6AK5	5.99
6AK6	2.50
6AL5	1.50
6AM4	4.00
6AM5	9.69
6AM6	6.02
6AN5	4.75
6AN8A	3.50
6AQ5	3.25
6AS6	8.66
6AS7G	8.75
6AT6	1.25
6AU5GT	5.00
6AU6	2.50
6AV5GA	4.50
6AV6	1.50
6AX5GT	3.00
6B7	3.25
6B8	3.25
6BA6	1.50
6BA7	5.00
6BA8A	4.00
6BC4	4.00
6BE6	1.50
6BH6	2.50
6BJ6	2.25
6BK4	4.50
6BL6	125.00
6BL7GT	4.50
6BM6	115.00
6BN6	2.00
6BQ7A	3.50
6BR7	6.00
6BR8A	3.50
6BS7	6.00
6BW6	6.00
6BW7	1.50
6BX7GT	5.00
6BZ6	2.75
6C4	1.25
6CB6A	2.50
6CD6GA	5.00
6CG7	2.50
6CH6	13.00

6CL6	£3.75
6CW4	8.00
6D2	1.50
6DK6	3.00
6DQ6B	4.75
6EA8	3.00
6EB8	2.50
6EW6	2.25
6F6	3.00
6F23	1.60
6F28	1.60
6F33	33.50
6H1	14.00
6H3N	2.75
6H6	3.00
6J4	5.50
6J6	8.93
6J7	4.75
6JE6C	7.50
6K6GT	2.75
6K7	3.00
6K8	3.00
6KD6	8.00
6L6G	5.00
6L6GA	3.50
6L6GC (GE)	5.75
6L6GT	3.00
6L7	2.50
6N2P	2.50
6N3P	2.50
6N7	3.00
6P25	4.00
6Q7	3.75
6R7	3.25
6RHH8 6KN8	10.00
6SA7	3.00
6SC7	2.75
6SF7	2.50
6SH7	3.00
6SJ7	3.25
6SK7	3.50
6SL7GT	3.00
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6SR7	4.00
6SS7	2.75
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6U8A	2.25
6V6GT	4.25
6X4	3.00
6X5GT	1.75
7B7	2.50
7C5	4.00
7C6	2.50
7H7	4.00
7R7	4.25
7S7	3.50
7Y4	2.25
7Z4	2.00
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12AT6	1.50
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12AU6	2.50
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12AV6	2.50
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12AX7	1.75

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6005	2.25
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6064	10.25
6067	11.75
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7410	0.36
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7417	0.48
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74154	1.40
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TELECOMMS TOPICS

GEC Plessey Telecoms

The combined GEC Plessey telecommunications company is planned to begin operations early this year. Study groups are already finalizing the market and product strategy. While GEC Private Systems Group (PSG), a division of GEC Telecommunications, has just announced major additions to its iSLX integrated services p.a.b.x. product range, it does not appear that these will form part of this international strategy – especially as Plessey's ISDX is already achieving export success.

PSG has extended the switch range downwards to provide 80 to 600 extensions whilst still, it claims, matching the performance of the larger systems. "We now have switches to suit any user" says Mike Bateson, the division's marketing manager. Larger switches in the family have been significantly upgraded so that the biggest in the range can now support over 5000 extensions and 35 000 busy-hour call attempts.

The iSLX is based on SL-1 technology licensed by GEC from Northern Telecom. According to Brian Meade, PSG's managing director, the Group does not have "specific rights to Europe" but exports mainly on a specific project basis. He pointed out that around £1M is required for territorial software as well as an infrastructure being needed to support operations. As these are all up-front costs there is a major disincentive to export.

While agreement would have to be reached with NT prior to exporting the iSLX, there is no such constraint with respect to Plessey's ISDX which uses in-house technology. Possibly 10% of its sales go to export.

First pocketable telephone

Libera Developments Ltd, formed to develop products based on the recently published UK CT2 standard for second-generation cordless telephones, has announced its Zonephone personal portable telephone together with associated base stations for both private and pub-

lic access. Ferranti will manufacture the Zonephone equipment under a UK exclusive licence. In addition, agreements covering the same equipment have been signed with two French companies, Secre and Alcatel Thomson Radiophone.

In the home or office, Zonephones will operate (in conjunction with a book-sized single-line base station) as a direct replacement for the conventional handset, with a range of around 200 metres.

On the move, the same handset can access multi-channel base terminals situated at airports, railway stations and other locations used by the public.

These base stations, which are to be linked into the p.s.t.n., create a radio microcell called a Phonezone in which anyone with a Zonephone will be able to make an outgoing telephone call. The call charge, expected to be set at about the same unit cost as for a public payphone, is billed to the subscriber's Zonephone account so that the user is spared the need for coins and queuing.

Global e-mail

The first around-the-world, continuously available electronic mail demonstration, linking the world's leading computer companies in the USA, Australia and Europe was held at the Compec show in London. It offered X.400 messaging and file transfer, access and management.

EurOSInet, the European Open Systems Interconnection (OSI) association, has forged links with similar organisations in the USA (OSINET) and Australia (OSICOM) and has carried out inter-operability testing over several months to ensure that participants adhere to the same standards – and not differing interpretations of the standards as is frequently encountered at present. It is intended that this will be a permanent demonstration, continuing 24 hours a day, as a resource to be accessed anywhere in the world to show what is practical in the real world of multi-vendor communications using OSI products.

C&W getting into Japan

The Japanese Minister of Posts and Telecommunications, Masaaki Nakayama, has said that licences to operate an international telecommunications business will be issued to the consortium in which Cable and Wireless is a major partner. Its members have been campaigning for this for the past two years. When formal approval, expected before the end of the year, is granted, C&W will be able to participate in the potentially lucrative Japanese market.

BICC opto cable factory

BICC Cables has opened a £15M plant which it claims is the first factory in Europe purpose-built for the production of fibre optic cables. At the opening ceremony, Sir William Barlow, chairman of the BICC Group, said that the company's manufacturing capacity in fibre optic cables was currently half a million kilometres per year but that it could be expanded greatly when needed.

Mercury to carry Vodafone traffic

Mercury Communications and Racal-Vodafone have signed an agreement for the former to deliver both national and international calls from customers of the latter's cellular radio network. By using Mercury's network, Vodafone will benefit from having, for the first time, a choice of carrier to deliver calls. This also means that an increasing number of calls by Vodafone customers will be carried from end to end on digital networks.

European travel networks

Multi-carrier travel reservation systems Amadeus and Galileo are setting up their operations centres in Germany and UK respectively.

The former, founded by Air France, Iberia, Lufthansa and Scandinavian Airlines System to develop, market and operate an independent and neutral European-based, global travel distribution system will have its operating centre in Munich, West Germany while Galileo, consisting of Aer Lingus, Alitalia, British Airways, British Caledonian, KLM, Swissair, TAP Air Portugal and Covia, the United Airlines subsidiary, is to establish its world headquarters in Swindon, Wiltshire.

Terminological inexactitudes

"TMA Preferred Terms for Telephone Systems Facilities" is the title of a booklet prepared by the independent consultancy Interconnect Communications. Endorsed by the Telecommunications Managers' Association, members of which are the major UK users, and sponsored by a number of suppliers, the booklet is primarily addressed to telephone or telecommunication managers and other purchasers of business systems.

Significant confusion exists because there is no commonly accepted terminology to describe the facilities which may be offered by modern p.a.b.xs. Indeed, different suppliers may use the same term for incompatible features. The booklet will enable users and those within the industry to compare and contrast the TMA-preferred terms with the features on actual products.

The booklet may be obtained free of charge from: Interconnect Communications (Consultants) Ltd, Merlin House, Lower Church Street, Chepstow, Gwent, NP6 5HJ, tel. 02912-70425.

Telecom Topics is compiled by Adrian Morant.

Pioneers

14. Alan Dower Blumlein (1903-1942): the Edison of electronics

W.A. ATHERTON

During his working life he accumulated 128 patents, roughly one every seven weeks. M. G. Scroggie has called him the greatest circuit designer and originator ever. Sir Bernard Lovell saw him as one of the best electronics engineers Britain has produced. To a few electronics enthusiasts Blumlein is a legend, to most and to the general public he is unknown.

Hardly any of his inventions (some of which were team work) bear his name. They covered telephony, measurements, audio, television, time-division multiplex and radar. Many of them, alone, would have granted him renown.

Alan Dower Blumlein was born on 29 June, 1903 at Hampstead in London, the son of Semmy Joseph Blumlein, a French mining engineer, and Jessie Dower, the daughter of a Scottish missionary. His parents met in South Africa but had settled in London where Blumlein spent most of his childhood. A year after Alan's birth his father became a British subject.

At five Alan Blumlein began prep school which, years later, he still liked to visit. It was on one of these visits that he met his future wife Doreen. They were married in 1933 and had two sons, Simon and David.

At primary school he was allowed considerable freedom in his choice of studies and it has been said that at the age of twelve he "could not read, but knew a lot about quadratics"[1].

Subsequent schooling improved his reading but perhaps there was a legacy. In 1924 one of his few published papers was returned with the request that the authors "go carefully through it, to rectify errors and improve the English".

A year earlier he had graduated with a first-class honours degree in heavy electrical engineering from the City and Guilds College, part of the Imperial College, London. He remained at the College as a demonstrator working with Professor Edward Mallett who was running a telephone engineering course. Together they devised a method of high-frequency resistance measurement. It was the publication of this work that led the IEE to demand that they "improve the English". They must have done so, for the final version was awarded a premium. Blumlein was just 21 years old.

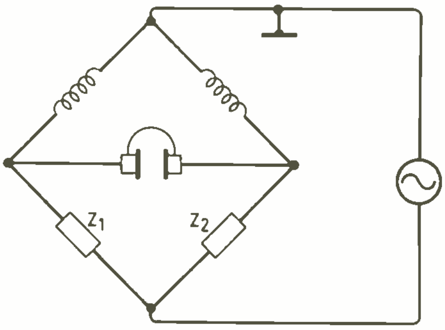
TELEPHONE ENGINEERING

In September 1924 Blumlein's industrial career began when he joined International Western Electric (now part of STC). Telephone networks were growing nationally and internationally and his first task was to look at interference caused by electric power lines. His boss, John Collard, "at first found him somewhat raw and "a difficult person to take to meetings". He could also be very rude, having little patience with anyone less brilliant than himself and being intolerant to those who would not work all hours as he did. Time mellowed him, however, and according to Collard, "he acquired a certain amount of tact"[1].

Thorn-EMI Central Research Laboratories

Philip Vanderlyn remembers the same man at EMI, but twenty years on, quite differently. "He would keep in daily touch with all the work in the laboratories, and he would talk with the most junior of us as equals without ever making us conscious of our lack of status, which was good for our egos and even better for our technical education. In this task of training his staff he had unbounded patience."[2]

Two years after joining International Western Electric Blumlein was asked to solve the problem of crosstalk in telephone loading coils. His success brought him a bonus of £250, which was £25 more than his starting salary. The work also led to his first patent (with J.P. Johns) and to the first of his many inventions: the tightly-coupled inductive ratio-arm a.c. bridge (above). One of the its uses was for measuring small capacitances in the presence of much bigger capacitances to earth, but Blumlein was



Tightly-coupled inductive ratio-arm bridge circuit, 1928: Blumlein's first invention. The coils were bifilar-wound.

forever finding other applications. During the war he used it as an aircraft altimeter.

AUDIO RECORDING

Blumlein was soon looking for wider horizons and so he moved to the Columbia Gramophone Company in March 1929. According to Benzimra[1] Blumlein told Isaac Shoenberg, the general manager, that he might not still want him when he heard the salary he was asking. Shoenberg's reply was to offer him even more!

By that time the knowledge and skills slowly acquired by telephone engineers had been applied to make a new audio disc recording method which made mechanical systems obsolete. Any record company that stuck with the old techniques would soon be obsolete too. The patents for the new method were held by the Bell System (Western Electric) in America to which a royalty was paid for every record pressed. Blumlein was given the task of inventing an alternative electrical method which would not violate the American patents.

To do this he adopted the moving-coil principle which the Americans had not used. He and his colleagues are known to have been working on the design in October 1929 and a prototype was tested the following February[2]. Electrical damping replaced mechanical damping to control the resonance of the cutting head and, with electrical filters, a wide frequency range was achieved with excellent linearity. A complete system was designed and built in-house, from new moving-coil microphones through the intermediate electronic circuitry to the final moving-coil recording head.

The first recordings were made in 1930 and they set a new standard for fidelity. Blumlein received a £200 bonus. But his thoughts had by now ranged beyond others' horizons to consider how a spatial impression of the artists' performance could be achieved using only two loudspeakers. He took out an incredible patent in 1931 with seventy claims relating to 'binaural' recording – in other words, stereophony. He was 25 years ahead of his time. When stereo records became a commercial reality in the 1950s EMI received nothing from this patent. Even after an extension, the patent had expired.

Blumlein's system was intended primarily for cinema use, but it also included records and was essentially that used for stereo records from the mid-1950s. The only widespread use that Blumlein lived to see was one of the few applications not covered by the patent. In World War Two a couple of thousand stereo sound locators were made for assisting in aircraft detection. With previous systems nearby gunfire could deafen the operators. Blumlein electronically limited the sound and used a cathode-ray tube (instead of earphones) for indicating the results.

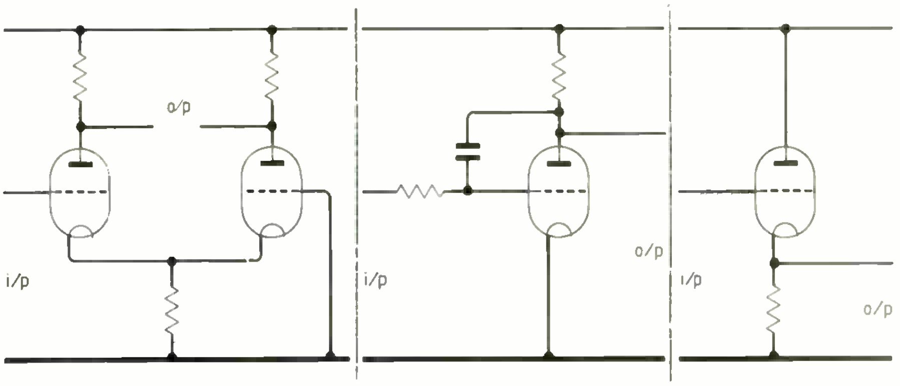
TELEVISION

In 1931 Columbia merged with The Gramophone Company (HMV) to form Electrical and Musical Industries Ltd, now Thorn-EMI. It was this new company that developed the 405-line electronic television system which became the standard British format and which remained in use until 1985. The format for the picture signal became a world standard, altered only to include colour and stereo sound. Blumlein was the principal architect of the waveform and some people call it the Blumlein signal.

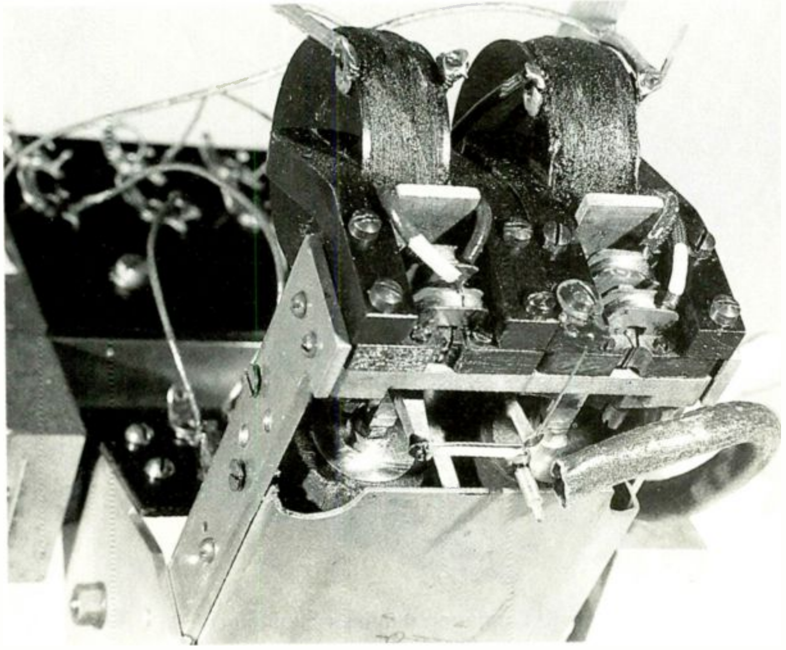
The development of television at EMI was a team effort and involved names which have become legendary in British television: Isaac Shoenberg, J.D. McGee, E.L.C. White and others with of course Blumlein. Blumlein was a major contributor to the circuit design and he had a hand in other areas including the Emitron camera tube, transmission cables and aerials. Among the circuits he invented or developed were a novel sawtooth generator for scanning, negative feedback circuits and the cathode-follower. He also invented and named the long-tailed pair circuit which was devised to reduce interference at the receiving end of a new video cable laid to Alexandra Palace.

RADAR

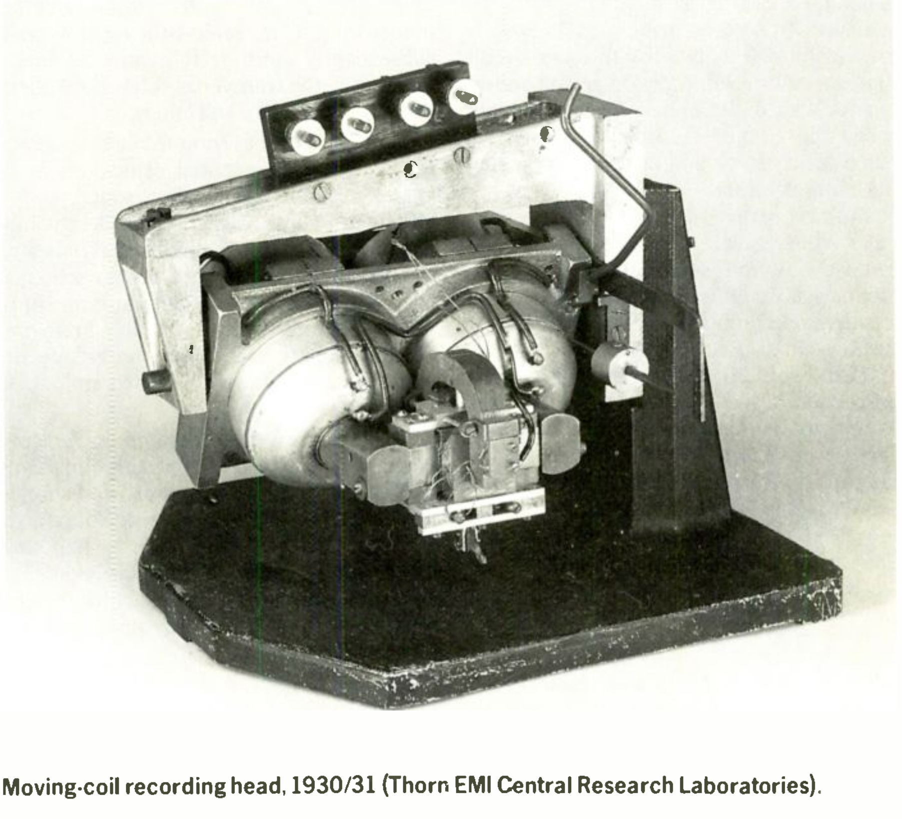
When the second world war began engineers in Britain already had considerable experience of radar development, all of it conducted in secret. EMI had barely touched radar work but the television team had the expertise for dealing with pulse techniques. So it was that the team which developed television turned to radar. Blumlein, White and others were soon at work on a 200MHz airborne-interception radar. This was followed by a model which searched for and locked on to an echo, thus allowing a fighter pilot to operate without a radar operator. The radar work involved a range of activities including frequency-shift keying, klystrons and magnetrons, anti-jamming circuits and so on.



Some circuits invented by Blumlein: from left to right, the long-tailed pair, Miller integrator and cathode follower.



Above: Blumlein's stereo disc cutter, 1933 (Thorn-EMI): decades ahead of its time.



Moving-coil recording head, 1930/31 (Thorn EMI Central Research Laboratories).

Previous articles in this series by Dr Tony Atherton dealt with the following:

1. Stephen Gray, who discovered electrical conduction.
2. H.C. Oersted, who found the link between electricity and magnetism.
3. A.M. Ampère, father of electrodynamics.
4. Charles Wheatstone, inventor of the first practical telegraph.
5. Samuel Morse, pioneer of long-distance telegraphy.
6. Lord Kelvin, who persuaded the transatlantic cable to work.
7. A.G. Bell, who conceived the idea of 'speech-shaped current'.
8. Oliver Heaviside, who rewrote the theory of telecommunications.
9. Guglielmo Marconi, who bridged the Atlantic by radio.
10. V.K. Zworykin, whose charge-storage principle has been used by every tv camera tube.
11. Edwin Armstrong, inventor of the superhet and of workable f.m. radio.
12. Jack S. Kilby, inventor of the integrated circuit and the electronic calculator.
13. Heinrich Hertz and the discovery of radio waves.

H_2S radar display: success for the RAF, untimely death for Blumlein.

It was during this radar work that Blumlein designed a ramp waveform or timebase generator more linear than any previously achieved. To do it he made use of a usually unwelcome effect in a triode valve circuit first noticed by John M. Miller and subsequently called the Miller effect. Blumlein called the circuit the Miller integrator, a name which stuck and kept his own name out of the electronics text books.

The next major work was a plan-position radar which gave a picture of the ground below the aircraft, so permitting very accurate navigation. It was code-named H_2S and was developed jointly by EMI and TRE (later the Royal Radar Establishment).

With two EMI colleagues and a good proportion of the TRE team, Blumlein was testing the equipment on board a Halifax bomber on 7 June, 1942 when an engine caught fire. The plane crashed, killing all on board. Despite this catastophe H_2S was completed and produced for Pathfinder and Coastal Command aircraft.

BLUMLEIN'S REPUTATION

Blumlein's name is not as well known as it should be. Most of his publications are in the form of patents, rarely easy reading, and his circuit inventions do not bear his name. But his work is all round us in stereo recordings, bridge measurements, television signals, plan-position radar, and the many circuits we use without realising they are his, solely or jointly with others: the closely-coupled inductor ratio arm bridge, the cathode (and subsequently emitter) follower, the long-tailed pair, the transversal filter, the Miller/Blumlein integrator and others.

M.G. Scroggie has summed up his character: "a grasp of essential principles, foresight, versatility, originality, soundness of engineering and insistence on 'designability' ". Others have remarked on his honesty, integrity and humour, and his conviction of the importance of understanding fundamentals. "He would repeatedly – I remember it as clearly as if it were yesterday – be going back to Thévenin's theorem", J.D. McGee has recalled[5].

This fondness for Thévenin is remembered by several who worked with him. "One of his favourite devices was to bring a discussion to its close by quoting Thévenin's theorem, and he would often be half way down the corridor, puffing his pipe and shouting 'Thévenin' over his shoulder before we were able to gather our wits together," says Vanderlyn[2].

Once he forgot this ritual. The team duly presented him with a "Thévenin Medal" made from the lid of a cocoa tin. As far as I know it was the only medal ever presented to him by engineers.

His achievements would be a fitting memorial if better known. Despite one attempt, no full-length biography of him exists. The profession he served so well should put that right. Perhaps through the Institution of Electrical Engineers, whose meetings he graced, this omission could be corrected.

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3. M.G. Scroggie, "The genius of A.D. Blumlein", *Wireless World* September 1960, 2-7.
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The author acknowledges the help given by Thorn-EMI Central Research Laboratories during the preparation of this article.

Next: Shockley, Bardeen and Brattain – inventors of the transistor.

Tony Atherton works for the IBA and is author of a book "From Compass to Computer, a history of electrical and electronic engineering."

Sinewave oscillator using c-mos inverters

This twin-RC oscillator gives stable performance over a wide range of audio and sub-audio frequencies

DRAGOLJUB DAMLJANOVIĆ

Oscillators with two RC circuits are employed mainly when a sinewave signal having widely variable frequency is needed. The most simple oscillator of this kind contains only one operational amplifier. More complex circuits with two or more amplifiers and other components can give a more stable output level and lower distortion [1-3].

This article describes a simple and inexpensive circuit using inverters instead of amplifiers (Fig.1). It easily covers the whole range of audio frequencies from 20Hz to 20kHz and can produce far lower sinewaves as well. Frequency is determined almost entirely by the RC constants and it can be very stable if stable resistors and capacitors are used. The influence of the inverters is negligible thanks to their high input resistance.

CIRCUIT DESCRIPTION

In the analysis which follows, resistors R_a' and R_a'' are treated together as R_a. An equivalent diagram of the circuit is shown in Fig.2. With the link closed, the inverters are assumed to have infinite gain; without it, the gains more realistically assumed to be finite and equal.

Referring to Fig.1, we can express all values in Laplace transform as follows:

$$\mathcal{L}(i(t)) = I(S) \quad (1)$$
$$\mathcal{L}(v_1(t)) = V_1(S) \quad (2)$$
$$\mathcal{L}(v_1(t)) = V_2(S) \quad (3)$$
$$\mathcal{L}(v_3(t)) = V_3(S) \quad (4)$$
$$\mathcal{L}(v_4(t)) = V_4(S) \quad (5)$$

$$Z_1(S)=\frac{R_1 \cdot \frac{1}{C_1S}}{R_1+\frac{1}{C_1S}} \quad (6)$$

$$Z_2(S)=R_2+\frac{1}{C_2S} \quad (7)$$

$$A=-\frac{R_b}{R_a} \quad (8)$$

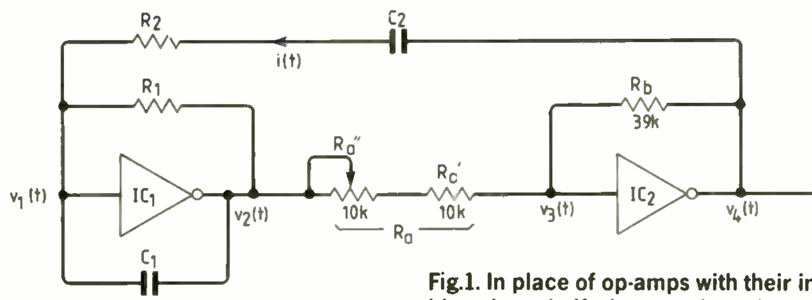

Fig.1. In place of op-amps with their inputs biased at half the supply voltage, the circuit uses c-mos inverters.

For Fig.2, $V_4(S) = AV_2(S)$ and thus

$$Z_2(S)I(S) = AV_2(S)$$
$$-Z_1(S)I(S) = V_2(S)$$

From this we get

$$R_1R_2C_1C_2S^2+(AR_1C_1+R_1C_1+R_2C_2)S+1=0 \quad (9)$$

To have an imaginary S it is necessary that the second factor is zero, i.e.

$$AR_1C_1+R_1C_1+R_2C_2 = 0$$

From this we get the necessary amplification A,

$$A=-\frac{R_1C_1+R_2C_2}{R_1C_2} \quad (10)$$

The frequency is

$$\frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

Expression (10) shows that the RC components should not be varied independently because this would require an adjustment of A. Thus, it is necessary to fulfil conditions $R_1 = R_2 = R$ and $C_1 = C_2 = C$. Gain is independent of the values of the resistors and capacitors and has a fixed value of −20. The frequency is $1/2\pi RC$ and the period $2\pi RC$.

Let us analyse now the more real case of Fig.2 with the link broken. According to Fig.1 and expressions 1 to 5, we may write

$$V_2(S) = aV_1(S)$$
$$V_4(S) = aV_3(S)$$

$$\frac{V_2(S)-V_3(S)}{R_a}=\frac{V_3(S)-V_4(S)}{R_b}$$

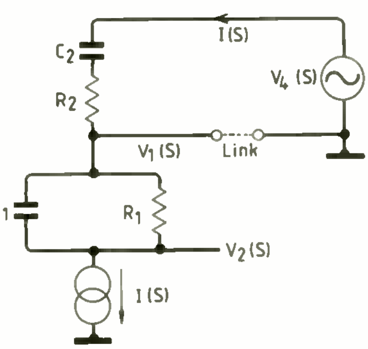

Fig.2. Equivalent circuit of the sine-wave oscillator of Fig.1. With the link closed, the circuit assumes inverters having infinite gain: practical devices have a finite gain (link open).

From this we have

$$V_4(S)=\frac{aV_2(S)R_b}{R_a+R_b-aR_a} \quad (11)$$

To test the result let a tend to infinity. This yields $V_4(S)/V_2(S)=-R_b/R_a=A$, as at the simplified analysis of equation 8.

To find the necessary amplification A, let us rearrange equation 11,

$$V_4(S)=\frac{a^2V_1(S)}{1-\frac{1}{A}+\frac{a}{A}}$$

Continued on page 191

Quality in a.m. broadcast radio

A method of providing variable selectivity while maintaining a level i.f. frequency response, in an attempt to regain the quality of a.m. reception that was common in the pre-War years.

R. KEARSLEY-BROWN

The author of the article in the October, 1986 issue of *EWW* entitled "Putting the quality back into a.m. radio", J.L. Linsley Hood, is to be congratulated on producing such an interesting design. There is, however, some room for improvement if the standard he set is to be met.

It is profitable to examine the reasons for the high standard of performance achieved by the better 1937-1939 broadcast receivers, re-discover their underlying circuit principles and to utilize the best of those principles in today's receivers.

The majority of commercial receivers and of those designed by *Wireless World* staff in the immediate pre-War period included an r.f. stage and two tuned circuits at signal frequency. The provision of an r.f. stage was considered essential to reduce cross-modulation and to eliminate superheterodyne whistles. To meet today's conditions, this scheme seems to be just as essential and to eliminate i.f. breakthrough an i.f. rejector should also be included in the aerial circuit.

I.F. BANDWIDTH

Good quality broadcast receivers of this era incorporated variable selectivity to ensure a level i.f. frequency response up to the selected bandwidth. Linsley Hood claims a modest overall i.f. response which is −6dB at ±6kHz, but this bandwidth seems to be unattainable with the specified transformers.

Wireless World Radio Data Chart No 19 (5th edition) is one of the easiest methods of determining bandpass curves. The i.f.ts described by Linsley Hood have a working Q of 100 and are critically coupled. The chart shows that the i.f. response of three such transformers will not be −6dB, but −33dB at ±6kHz.

Greater accuracy is obtained by using the following formula, which gives the frequency response, in dB of one i.f.t.

$$\text{loss} = 20\log_{10}\frac{Qk}{\sqrt{[1-(Qy)^2+(Qk)^2]^2+4(Qy)^2}}$$

where $y = \frac{2\Delta f}{f_0}$

f_0=centre frequency
Δf=semi-bandwidth
k=coupling factor
Qk=1 for critical coupling

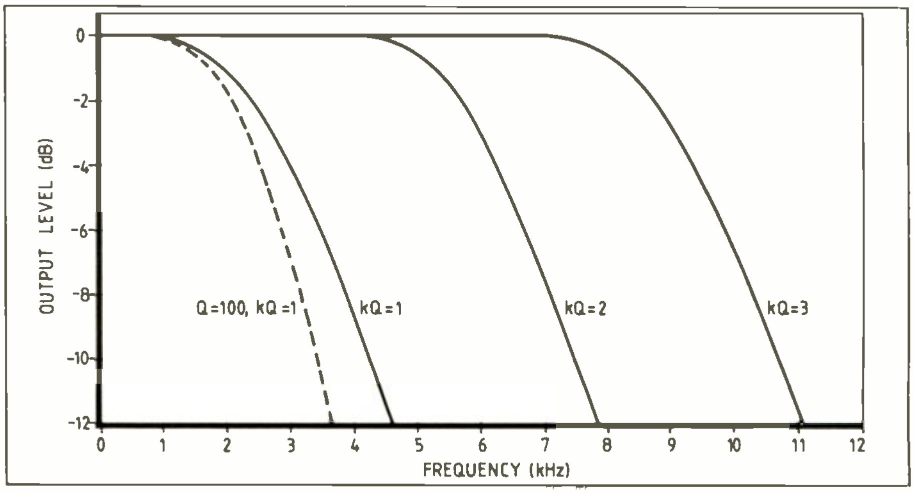

Fig.1. Semi-bandwidths of variable-selectivity, two-stage i.f. amplifier. IFT 1 and 2 have Q = 80 and switched Qk values as shown. IFT 2 has a Q of 49 with Qk = 0.5. Dotted curve is for three i.f.ts having Q = 100 and Qk = 1.

Substituting gives a loss of 10.8 dB, relative to that at f_0, at ±6kHz. For three i.f.ts, the response will be −32.5 dB at ±6kHz, which agrees well with the chart.

To this must be added the response of the r.f. tuned circuit. If this is a normal ferrite rod, the Q will be about 200 and the overall r.f. plus i.f. response at ± 6kHz is as shown in the table.

signal frequency	r.f. plus i.f. response at 6kHz
1500kHz	−38db
550kHz	−45.5dB
200kHz	−54dB

The reduction in high-frequency response is clearly unacceptable.

P.K. Turner[1] showed that one could obtain a r.f. or i.f. response flat to within ±0.01dB over the required bandwidth: an overcoupled bandpass circuit adjusted to 1.1 times the required bandwidth was used, producing the usual double hump. Turner showed that by adding a single tuned circuit of half the bandpass circuit Q the dip was eliminated and an almost perfectly level response obtained. The two circuits were, of course, separated by a stage of amplification. Wheeler and Kelly Johnson[2] showed that the level response given by Turner was maintained even when the bandpass coupling coefficient was altered to vary the bandwidth.

To apply Turner's principles to Linsley Hood's design, the first and third i.f.ts should be overcoupled using tertiary coils to couple the secondary to the primary. Tappings on the tertiary coils should be provided and switched in to give, say, three degrees of variable selectivity; in-circuit coupling factors could usefully be Qk=1, 2 and 3. The use of tertiary coils for mutual-inductance coupling has the merit of switching at low r.f. voltages with negligible displacement of the centre frequency and the facility of simple alignment. Capacitor coupling to obtain variable selectivity usually results in the centre frequency being displaced by several kilohertz.

To remove the dip in the response caused by IFTs one and three, one could add two separate 465kHz single-tuned circuits of half the Q. Alternatively, the second i.f.t could be used to provide suitable correction with almost as good results. Calculation shows that an overall i.f. amplifier response, level to within 0.15db up to 7.5kHz can be obtained with i.f.ts having the characteristics shown in the table.

i.f.t.	Q	overall bandwidth at ±0.15dB	−3dB	coupling factor
1 and 3	80	–	±2.75kHz	Qk=1 variable
		±4.7kHz	±6kHz	Qk=2 coupling
		±7.5kHz	±9kHz	Qk=3 coupling
2	49	–	–	Qk=0.5 fixed

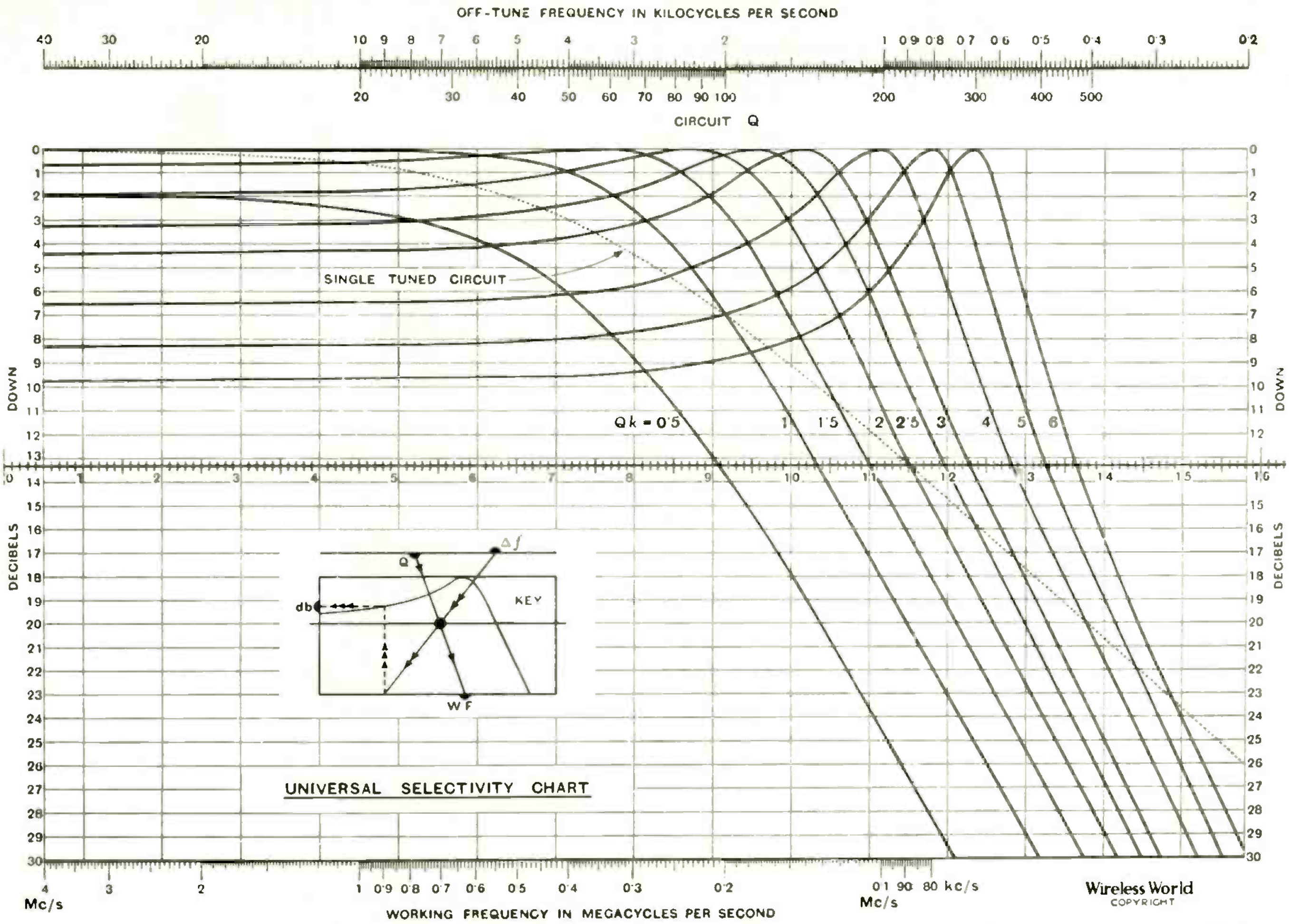

Chart No 19 from the collection of Wireless World Radio Data Charts, published many years ago and now, unfortunately, no longer available.

The increase in Q of IFT2 from 40 to 49 is needed because its tuned circuits are not isolated.

Figure 1 shows three bandwidths which are obtainable by switching the coupling factors of IFTS 1 and 3; the dotted curve shows the response of Linsley Hood's circuit for comparison.

Wider bandwidths may be obtained by dividing the Qs of all i.f.ts by the same factor. For example, a Q of 60 for IFTs 1 and 3 and 37 for IFT2 will provide a practically level response up to ±10kHz, with Qk=3. The coupling factors, measured in terms of critical coupling, should remain the same. If Q is reduced, then k must be increased so that Qk remains equal to the chosen values of 1, 2 and 3.

R.F. BANDWIDTH

To widen the r.f. circuit pass band when a wide i.f. bandwidth is selected, series resistors can be switched into the inductive arms of the r.f. signal tuned circuits: a series resistor reduces the Q of a variable tuned circuit mainly at the low-frequency end of the band, so widening the bandwidth where it is most needed – about 10 ohms is sufficient. The r.f. bandwidth should be wider than the i.f. by about ±3kHz to allow for oscillator tracking errors.

I.F. STABILITY

An i.f. amplifier should be designed with a stability factor of at least 4 to allow for a worst-case component tolerance building-up: a factor of less than 4 causes the i.f. response to become misshapen and difficult to align. Unfortunately, the L.H. design does not seem to meet this requirement.

Two i.f. stages with bandpass couplings of similar Q will be "just stable" when

$$(g_m \cdot B_{gd})/G_D^2 < 1.5 \text{ mho} \qquad (2)$$

where g_m = maximum fet transconductance (mho)

B_{gd} = maximum gate-to-drain susceptance (mho)
G_D = working dynamic conductance of the tuned circuit (mho)

To provide the required stability factor of 4,

$$(g_m \cdot B_{gd})/G_D^2 < 0.375 \qquad (3)$$

For a 3N201, the maximum g_m is 0.02mho. Gate-to-drain internal capacitance is 0.03pF and to this must be added external stray capacitance, say 0.02pF, which gives a total C_{gd} of 0.05pF. Hence

$$B_{gd} = \omega C_{gd} = 146/10^9 \text{mho}$$

Given that the i.f.ts have a working Q of 180, f_0=0.465MHz and the tuning capacitors are 0.001 μF, then

$$G_D = \frac{\omega C_T}{Q} = 29.22/10^6 \text{mho}$$

$$\frac{g_m B_{gd}}{G_D^2} = 3.423$$

Because $(g_m \cdot B_{gd}/G_d^2)$ exceeds 1.5, the i.f. amplifier will be unstable. Even when fets with the average g_m of 0.014mho are substituted, the amplifier will remain unstable. Many fets are better than average, so the design must be based on 0.02mho. It will be necessary to increase G_D by a factor of $(3.423/0.375)^{0.5}$ or about 3 to provide a minimum stability of 4. In other words, the dynamic resistance of the i.f.ts should be reduced to 11 300 ohms.

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Harmonics and intermodulation in the long-tailed pair

Using a simple empirical equation to describe the current-voltage characteristic, closed-form expressions are obtained for the harmonic and intermodulation performance of the long-tailed pair.

MUHAMMAD TAHER ABUELMA'ATTI

The long-tailed pair, shown in Fig.1, is the basic building block of many analogue electronic circuits; for example, the input stage of operational amplifiers, full four-quadrant multiplers and high-frequency, voltage-controlled amplifiers. Recently, Lidgey [1,2] obtained the expression of equation (1) to represent the current-voltage characteristic of the long-tailed pair.

$$\frac{V_{in}}{V_T}=\log_e\left(\frac{I_i}{I_0}\right)/\left(1-\left(\frac{I_i}{I_0}\right)\right)+\left(\left(\frac{I_i}{I_o}\right)-\frac{1}{2}\right)\frac{I_oR}{V_T} \qquad (1)$$

where $V_{in}=V_1-V_2$ and V_T= thermal voltage.

Equation (1) in its present form cannot be used to quantify the nonlinearity in the long-tailed pair, since this requires an expression for the output current as a function of the input voltage. By rewriting (1) as

$$V_n=\alpha i_n+\log_e\left(\frac{1+i_n}{1-i_n}\right) \qquad (2)$$

where $V_n=V_{in}/V_T$ is the normalized input voltage, $i_n=i/I_L$ is the normalized output current, $I_L=I_o/2$ and $\alpha=I_LR/V_T$. Expanding (2) as a power series, Irvine obtained, by using power series inversion, the expression of (3) to represent the output current as a function of the input voltage.

$$i_n=\frac{1}{2+\alpha}V_n-\frac{2/3}{(2+\alpha)^4}V_n^{\,3} \qquad (3)$$

Equation (3) is valid only for a limited range of input voltage, where $V_n \ll \alpha+2$, and therefore cannot be used for predicting the harmonic and intermodulation performance of the long-tailed pair under large values of input voltage.

It is the purpose of this paper to present an alternative expression for the output current in terms of the input voltage. The expression can be used to predict the harmonics and intermodulation performance of long-tailed pair under large signal conditions.

PROPOSED FORMULA

The development of this formula proceeded along empirical lines by comparing the truncated Fourier-series model of (4) with the normalized input-output characteristic of (2) for each α.

$$i_n=\sum_{n=1,3,5}\gamma_n\sin\left(\frac{n\pi}{B}V_n\right),\ -9\leq V_n\leq 9 \qquad (4)$$

The parameters B and γ_n were obtained by using the twelve-point method, which resulted in a family of parameters γ_n which depend on α. The parameters, γ_n were then fitted to simple, closed-form analytical expressions, giving

$$\gamma_1=-0.05036\alpha+1.208 \qquad (5)$$
$$\gamma_3=-0.0777\alpha+1.27332 \qquad (6)$$
$$\gamma_5=-0.0283\alpha+0.0651 \qquad (7)$$

and $B=18$.

To establish the accuracy of (4), calculations were made using (4-7), shown in Fig.2, from which it is obvious that the proposed model accurately represents the normalized input-output characteristic of the long-tailed pair.

HARMONIC AND INTERMODULATION ANALYSIS

Consider the case of a long-tailed pair excited by a multi-sinusoidal signal of the form.

$$V_i=\sum_{k=1}^{K}V_k\sin\omega_k t$$

where

$$\sum_{k=1}^{K}|V_k/V_T|\leq 9$$

Substituting (8) into (4), the output current can be expressed by

$$i_n=\sum_{n=1,3,5}\gamma_n\ \sin\left(\frac{n\pi}{B}\frac{V_k}{V_T}\right)\sin\omega_k t. \qquad (9)$$

Using the identity

$$\sin(x\sin\omega t)=2\sum_{m=0}^{\infty}J_{2m+1}(x)\sin(2m+1)\omega t,$$

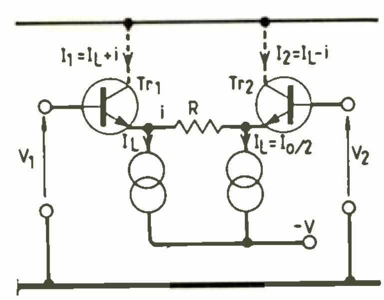

Fig.1. The basic circuit of the long-tailed pair.

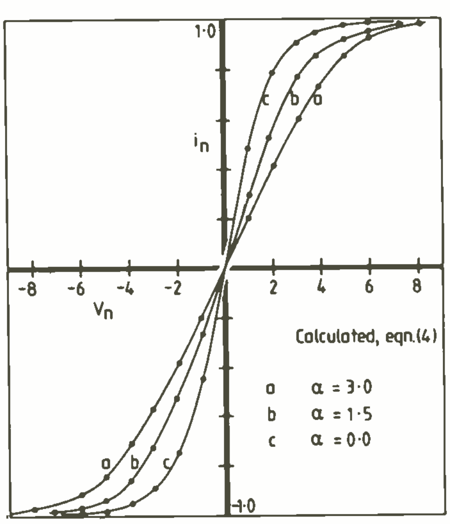

Fig.2. Graphs resulting from the application of equations (4) to (7).

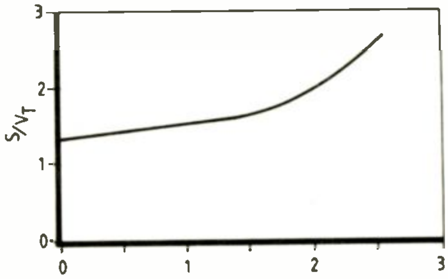

Fig.3. Variation of the third-order intercept with varying α.

the normalized output current can be expressed as

$$2\sum_{n=1,3,5}\gamma_n \sum_{m=0}^{\infty} J_{2m+1}\left(\frac{n\pi}{B}\frac{V_k}{V_T}\right)\sin(2m+1)\omega_k t. \quad (10)$$

By noting that

$$J_{-m}(x)=(-1)^m J_m(x),$$

it can easily be shown that the amplitude of the output current component, of frequency

$$\sum_{k=1}^{K} m_k\omega_k$$

and order

$$\sum_{k=1}^{K} |m_k| = \text{odd integer},$$

where m_k is a positive or negative integer or zero, will be given by

$$I_{m1,m2,\ldots,m_k}=2\sum_{n=1,3,5}\gamma_n \prod_{k=1}^{K} J_{m_k}\left(\frac{n\pi}{B}\frac{V_k}{V_T}\right) \quad (11)$$

Special case. To illustrate the use of equation (11), consider a two-tone, equal-amplitude input signal of the form

$$V_i(t)=S(\sin\omega_1 t+\sin\omega_2 t). \quad (12)$$

Using (11), the amplitude of the fundamental output current component of frequency ω_1 (or ω_2) will be

$$I_1=2\sum_{n=1,3,5}\gamma_n J_1\left(\frac{n\pi S}{BV_T}\right)J_0\left(\frac{n\pi S}{BV_T}\right). \quad (13)$$

and the amplitude of the third-order intermodulation output current component of frequency $2\omega_2\pm\omega_1$ (or $2\omega_1\pm\omega_2$) will be

$$I_{21}=2\sum_{n=1,3,5}\gamma_n J_2\left(\frac{n\pi S}{BV_T}\right)J_1\left(\frac{n\pi S}{BV_T}\right). \quad (14)$$

For $5\pi S/18V_T \ll 1$, the Bessel function can be approximated by

$$J_n(x)=(x/2)^n/n!$$

and (13), (14) reduce to

$$I_1=\frac{\pi S}{BV_T}\sum_{n=1,3,5} n\gamma_n \quad (15)$$

$$I_{21}=\frac{1}{8}\left(\frac{\pi S}{BV_T}\right)^3\sum_{n=1,3,5} n^3\gamma_n \quad (16)$$

Using (15), (16) the ratio of the unwanted third-order intermodulation product to the fundamental will be

$$R=\frac{I_{21}}{I_1}=\frac{1}{8}\left(\frac{\pi S}{BV_T}\right)^2\left[\frac{\sum_{n=1,3,5} n^3\gamma_n}{\sum_{n=1,3,5} n\gamma_n}\right] \quad (17)$$

Using (5-7), (17) reduces to

$$R=\frac{1}{8}\left(\frac{\pi S}{BV_T}\right)^2\frac{16.72514-5.68576\alpha}{2.35346-0.42496\alpha} \quad (18)$$

The third-order two-tone input intercept can be obtained by equating (17) to unity, giving

$$\frac{S}{V_T}=\frac{12}{\pi}\left[\frac{2.35346-0.42496\alpha}{16.72514-5.68576\alpha}\right]^{1/2} \quad (19)$$

A plot for (19) is shown in Fig.3, from which it is evident that, as α increases, the intercept level increases. Qualitatively, this result is in agreement with the observations of Irvine.

In this paper an empirical formula has been presented for the current-voltage characteristic of the long-tailed pair. Using this formula, closed-form expressions have been obtained for the amplitudes of the harmonics and intermodulation current components resulting from exciting the long-tailed pair by multisinusoidal large-amplitude signal. The results obtained using the present analysis are, qualitatively, in good agreement with results published previously and can be used to study the performance of analogue circuits using long-tailed pairs.

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Sinewave oscillator using c-mos inverters

Continued from page 187

Since the inputs of the inverters sink hardly any current, according to equations 6 and 7 we have

$$\frac{V_4(S)-V_1(S)}{Z_2(S)}=\frac{V_1(S)-V_2(S)}{Z_1(S)}$$

With both resistors and capacitors equal, we get a new expression corresponding to equation 9,

$$(RCS)^2+\left[2-\left(\frac{a^2}{1-\frac{1}{A}+\frac{a}{A}}-1\right)\frac{1}{1-a}\right]RCS+1=0 \quad (12)$$

From this we have the new formula for A

$$A=-\frac{2a^2-5a+3}{a^2+2a-3}$$

We see now that the gain A should not be −2 but a little higher. For example, when a = −20 the gain should be adjusted to −2.53. Referring to Fig.1 we find that R_a'' = 5.4kΩ, near the middle of the potentiometer.

EXPERIMENTAL RESULTS

The circuit has been tested over the whole supply voltage range of 4049 inverters and it works well if A is appropriately adjusted: inverter gain varies a little with supply voltage. Thus to fulfil condition 12 (with an imaginary S) we must fit A. This problem is not serious if we use a stable supply. A more important problem arises from the fact that is not easy to ensure that $R_1=R_2$ and $C_1=C_2$ over the whole frequency range. The sinewave amplitude depends on the active component's (here, the inverter's) non-linearity. This problem is present in all RC sinewave oscillators and it can be tackled in several ways. Here the amplitude was adjusted by adjusting A manually (with potentiometer R_a''). The adjustment was only 2-3% with randomly chosen components in the ranges 39kΩ–1MΩ and 200pF–1μF.

The temperature of the inverters was changed independently of the temperature of the resistors and capacitors, and it was found that the frequency was practically independent of it over a wide temperature range.

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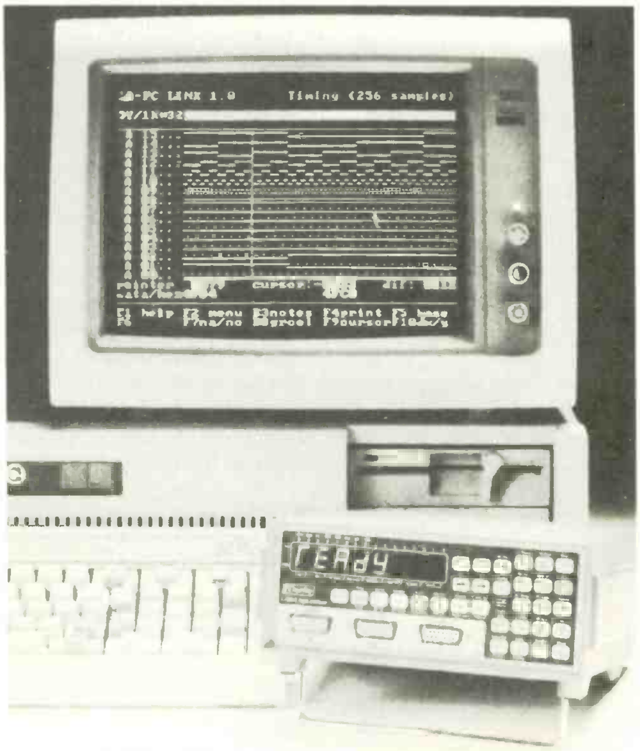

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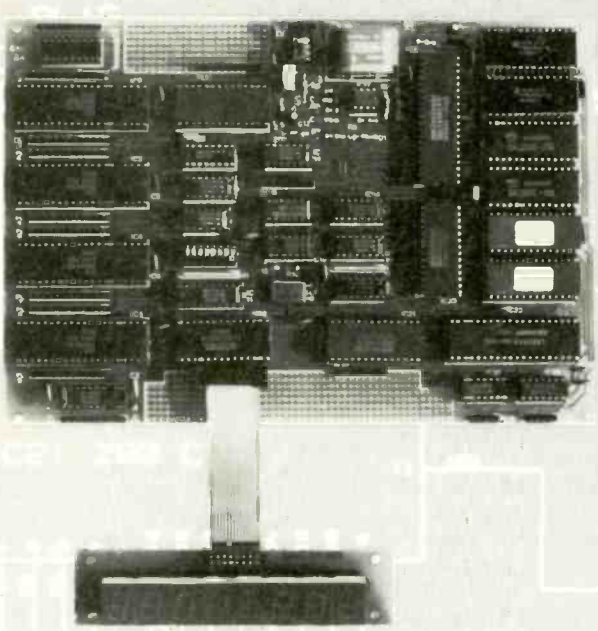

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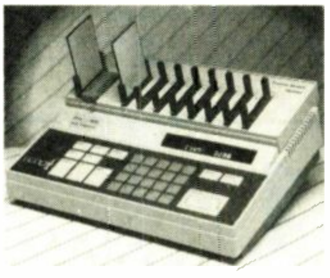
NEW PRODUCTS

Smart card programmer

Gang programming of 'intelligent' credit-card-sized memory banks is possible with a Stag 41M900 module. This adaptation of the PP41 programmer is used to download data from a master card or eprom, or from a host computer memory through the RS232 interface. The stored data can be listed, edited and deleted to update price lists, look-up tables, and similar information. The cards have found use in providing plug-in font designs for use with computer printouts. Stag Electronics Designs Ltd, Tewin Court, Welwyn Garden City, Herts AL7 1AU. Tel: 0707 332184.

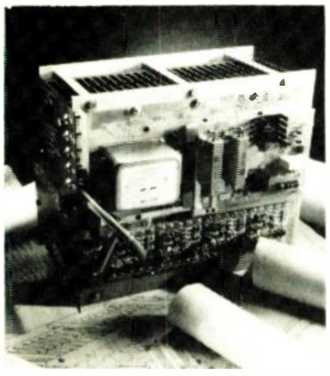


Building-block power supply

Power supplies to almost any specification can be designed and built using the InPower power converters and booster modules, which can be used as individual units or as basic building blocks to construct a p.s.u. for a specific application. Converter modules have a switching frequency of up to 1MHz, and are supplied in 30 to 150W models with 10 to 400V inputs and 2 to 90V outputs. Booster modules are connected to the converters in parallel to extend the output to more than 1kW.

Multi-output, fault redundant and distribution power systems can all be configured. Modules can be changed easily if the specification is altered.

InPower supplies offers an efficiency of around 80% and a high m.b.t.f; low standby power and low noise figures are also claimed. Small and light, the modules fit onto p.c.bs. InPower, Ballysimon Road, Limerick, Eire. Tel: +353 61 49677.



Eprom emulator runs through RS232

Any computer with an RS232 port can be used as an eprom development system. An eprom emulator, the DCA-EM08 from D.C. Allen, accepts all the regular eprom formats and also permits access to allow bytes to be entered individually. Command sequences enable the user to configure and control the unit. 28-pin eproms from 8K to 64K are emulated with access time down to 150ns. Target systems can be reset automatically by a probe when the unit has been loaded.

The main control unit is supplemented by a high-speed pod with a 28-pin header plug. Power is provided through a mains supply to avoid overloading the target. D.C. Allen (Engineering) Ltd. 27 Nuffield Road, Poole, Dorset BH17 7RA. Tel: 0202 671666.

Optical source and meter

Two hand-held instruments are intended for field-testing of optical fibres. Wandel & Goltermann's OLP-2 is an optical power meter for use with the 850, 1300 and 1550nm wavelengths. It has a high sensitivity and is capable of both absolute and relative measurements. The reference setting is controlled by a potentiometer and is therefore retained when the instrument is switched off. Adaptors enable the instrument to be matched to all the commonly used optical systems.

OSL-2 is a compact light source which can be switched between 850 and 1300nm. A method of thermal compensation allows the instrument to produce a stable output level without any warm-up period. Nominal output levels are achieved within a temperature range of −10°C to +50°C. Such an ability is claimed to have been possible only in laboratory equipment but is now available for precision field use. Wandel & Goltermann Ltd, Progress House, 412 Greenford Road, Greenford, Middlesex UB6 9AH. Tel: 01-575 3020.

Protection varistors

The protection offered by connector-pin varistors guards equipment from physical damage and improves reliability in components that may be upset by low-amplitude voltage surges and transients. A range of CP varistors from GE offers different sizes and a wide selection of voltage ranges for both direct and alternating currents. Maximum ratings are 25 to 130V r.m.s. or 31 to 150V direct. Energy dissipation is 1.5 to 5 joules at peak currents of 250 to 500A. Available through Gothic Crellon Ltd, 3 The Business Centre, Molly Millars Lane, Workingham, Berks RG11 2EY. Tel: 0734 788878.

Flash a-to-d for space video signals

A fast, low-cost analogue-to-digital converter is manufactured by ITT. Tv scramblers, digital teletext decoders, video memory applications and D2-MAC satellites are amongst the uses of the 20MHz device. It mainly consists of 127 comparators and operates as a seven-bit converter, or by toggling the l.s.b. it is possible to create a pseudo 8-bit mode with higher video resolution. It is designed to be compatible with ITT's Digit 2000 tv system. ITT Semiconductors, 145 Ewell Road, Surbiton, Surrey KT6 6AW. Tel: 01-390 6577.

Analogue data radio link

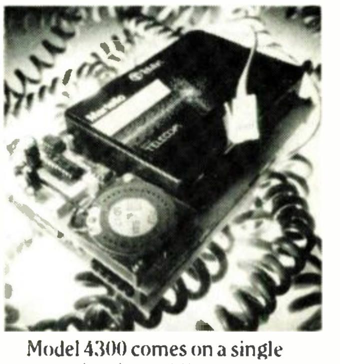
Radio data links in the u.h.f. band are available with a range of analogue inputs, thought to be of particular use in process control. ADL800 transmitters from Micromake are primarily intended as extensions to the p.s.t.n. telemetry systems and make possible the use of remote outstations or for temporary monitoring.

The single-channel version converts the incoming analogue signal to a stream of ASCII characters which are transmitted and can be received and then decoded on almost any desktop computer or terminal. Each sensor package includes signal conditioning circuits, a-to-d converters and a c-mos processor to give 15-bit measurement resolution and eight samples/s. A half-duplex version to be released soon will allow the user to interrogate the remote sensors and adjust or re-program the conversion process. The outstations will be addressable and will therefore offer random access by the central process control computer.

All links are type-approved for use in the UK. They operate in the 485MHz band with a maximum r.f. power output of 500mW. Micromake Electronics, 1 The Holt, Hare Hatch, Upper Wargrave, Reading, Berks RG10 9TG. Tel: 073 522 3522.

Modem for STE-bus

British Telecom claims to have made the first STE-bus compatible modem. System designers are thus provided with a means of building a system for remote control and data gathering through the telephone network. Operation to V21 (300/300baud) or V23 (75/1500baud) standards and built-in processing allow control by a high-level command protocol.



Model 4300 comes on a single Eurocard and, in addition to the usual modem functions, includes a loudspeaker for line monitoring. High speed bidirectional data transmission can be achieved by the inclusion of a 1500/75baud configuration. British Telecom, Microprocessor Systems, Martlesham Heath, Ipswich IP5 7RE. Tel: 0473 643101.

NEW PRODUCTS

Audio distortion analyser and level meter

An auto-tuning rejection filter stage is a feature of the Crotech 2017 distortion analyser and level meter, enabling it to eliminate the fundamental from a signal and then measure the remainder; presenting the result as signal distortion. The instrument functions between 30Hz and 300kHz.

Distortion measurements have a resolution of 0.3% of f.s.d. and an accuracy of >−2dB between 30Hz and 100Hz, and >−3dB above that to 300kHz. The residual within the instrument is <0.05%.

Signal voltage levels can be measured between 1mV and 300V, equivalent to +50dBm to −60dBm. Levels are displayed by the meter to an accuracy of ±5%. Residual noise is <200μV r.m.s. and an output of the level signal gives about 150mV into an open circuit.

Crotech also makes a low-distortion signal generator and a power meter and the three instruments can be rack-mounted for a comprehensive audio test system. Crotech Instruments Ltd, 2 Stephenson Road, St. Ives, Huntingdon, Cambs PE17 4WJ. Tel: 0480 30181.

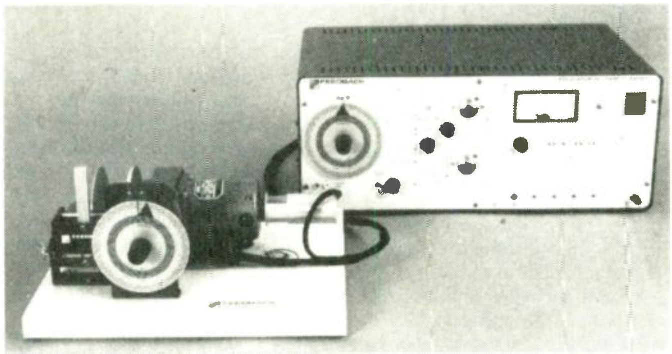
Pin-grid zif sockets

A lever is used to close the contacts on the Robinson Nugent PGZ range of pin-grid array sockets. This is intended for test and burn-in purposes and reduces the contact-wiping action which causes wear within test sockets and can reduce electrical contact. Tests have shown that the sockets can withstand 10,000 open/close action with no adverse effect on the beryllium-copper contacts. Available through Hunter Electronic Components Ltd, Unit 3, Central Estate, Denmark Street, Maidenhead, Berks SL6 7BN. Tel: 0628 75911.

Any-mains power supply

Fitting an Onan Spec II power supply to electronic equipment will allow it to be used anywhere in the world, claims Gresham Powerdyne. Inputs from 90 to 264V with frequencies from 47 to 63Hz can be accepted without the need for transformer taps, range switching or jumpers and regulated outputs of ±5, 12, 15 and +24 are provided with ratings of 50W and 140W.

An additional advantage of the system is that it is suitable for use in areas where the voltage may drop through excessive cable length or where the mains voltage/frequency is highly variable. Gresham Powerdyne Ltd, Osborn Way, Hook, Hants RG27 9XH. Tel: 025 672 3939.



Demonstration servo

An instructional d.c. servo has been specifically designed to be an introduction to the principles of d.c. control. The high engineering standard adopted permits advanced levels of study where quantitative measurements are needed.

The system includes a control unit with power supplies. A detailed mimic diagram on the front panel shows how the system is working.

The servo motor, with an integral tachometer, drives a potentiometer through a gearbox. Variable loading is provided, acting directly on the motor shaft. Two manuals, introductory and advanced, are provided. Feedback Instruments Ltd, Park Road, Crowborough, East Sussex TN6 2QR. Tel: 08926 3322.

Video studio on a PC

Plug-in cards for an IBM AT computer combine 8-bit frame stores with 8-bit video input channels. Images can be grabbed in real-time directly from a video camera or recorder.

Colour look-up tables allow up to 256 levels of grey scale or 256 colours to be displayed simultaneously, selected from a palette of 16 million. By installing three cards in the computer, the user can generate a full colour system which will grab and display 24-bit true colour images in real time.

Display resolutions conform to European or US broadcasting standards. In addition to the standard image display, a separate overlay plane is provided for keying text or other computer-generated images. It is possible to view the active frame through windows in the overlay plane.

Primagraphics' Virtuoso PC system is to be supplemented by a number of software packages which will include an MS-DOS version of the VCS image processing program from Vision Dynamics. Primagraphics Ltd, Melbourn Science Park, Melbourn, Royston, Herts SG8 6EJ. Tel: 0763 62041.

Redesigned accelerometers

Miniature accelerometers have been made by Entran which use a new sensor design which have fewer moving parts and are machined to a high precision by spark erosion.

Egasy transducers are small but robust; the mechanical stop arrangement allows them to withstand an overrange of up to 10,000G. Measuring ranges vary from ±5G up to ±2500G. Having a mass of only one gram, the device is especially suitable for vibration testing of small components and the overrange allows leeway for accidental impact or mishandling. Entran Ltd, 5 Albert Road, Crowthorne, Berks RG11 7LT. Tel: 0344 778848.

Board-mounted heat sinks

A comprehensive range of board-mounted heat sinks is available from Marston Palmer. Three profiles and four lengths can be specified, with or without solderable pins or spring clips, and with a number of standard hole patterns. Depending on the length, thermal resistance is isn the range 7 to 12°C/W. The company produces over 100 different heat sink profiles. Marston Palmer Ltd, Wobaston Road, Fordhouses, Wolverhampton WV10 6QJ. Tel: 0902 78361.

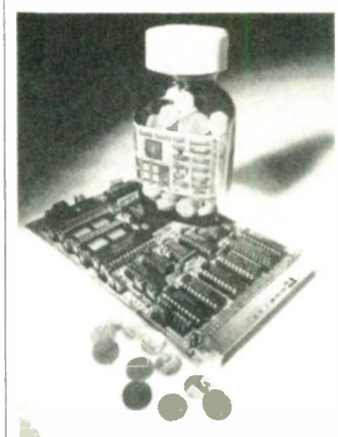
Inspection tool for drilling

The integrity and accuracy of c.n.c. drilling in p.c.bs can be checked by using Chek-Rite. This is a stable, colour-contrasting, translucent film which is cut and drilled in the same way as a prototype board. Placing the film over subsequent production boards makes it easy to spot incorrect hole locations and tolerances, missed or extra holes, or misorientation. Because the film is dimensionally stable, it can also be used to produce solder mask patterns. Two colours, bright green or darkroom-neutral orange are available. Intertronics, Allvalve House, 159 Brookwood Road, Southfields, London SW18 5BD. Tel: 01-871 2735.

STE-bus card runs CP/M+

A single-board computer combines the 64180 processor with an STE-bus interface and is thought to be ideally suited to running CP/M+ banked applications.

The single-chip c.p.u. incorporates a Z80-like 8-bit processor with memory management, two uart channels and a two-channel direct-memory-access controller. Its 1Mbyte addressing space is similar to that used in the STE-bus. This allows the CP/M+ operating system to run directly without the need for switched



memory banks and give immediate access to the STE-bus extension modules such as hard and floppy disc drivers, memory and i/o cards.

All these features are combined in Arcom's SC180 computer board which includes four 28-pin memory sockets and interrupt handling with controlled priorities. It can be used for both data processing and real-time systems applications for software development or as a target control board. Arcom Control Systems Ltd, Unit 8, Clifton Road, Cambridge CB1 5WH. Tel: 0223 411200.

Low-noise filtered D-connectors

Built-in filtering and steel shells on the 'Silent-D' range of D connectors make them suitable for 90% of all applications that need to meet standards of electromagnetic noise elimination. Online, the distributor of the ITT Cannon range, claims that the 10 to 15dB attenuation offered meets most requirements, whereas the 40dB designed into many filter connectors is only needed for military applications.

Plugs and sockets come in 9, 15, 25, and 37-way, right-angle p.c.b.-mounting versions. They feature gold-over-nickel contacts. Online Distribution Ltd, Melbourne House, Kingsway, Bedford MK42 9AZ. Tel: 0234 217915.

NEW PRODUCTS

Space-saving i.c. designer

Layout of v.l.s.i. circuits usually involves much manual work, but a new system from Caeco can produce results automatically that are similar to those crafted manually. Layout Synthesis generator uses a new technique that requires no preset libraries of components. The system creates functional blocks of design using an input logic diagram or a text file describing the logical function of the device. The user specifies the desired block shape, pin locations and design rules and the program will return a completed i.c. layout with detailed circuit and electrical parameters. The format of the output is standardized so that the user can easily edit a block and connect it with other blocks.

A further program, Caeco Blocks, can automatically place and interconnect blocks prepared by the layout system, designed by hand, imported from previous designs, standard cells or even blocks designed by other automatic tools.

The layout program follows the conventions used by most c-mos designers. N and p transistors are grouped in separate regions. Transistors are lined up in rows to allow efficient power and signal connections and long source/drain diffusion chains are formed for transistors having common connections. This optimizes the diffusion areas and reduces space.

The system is claimed to offer similar tools to the fully custom i.c. designer as are available to those making application-specific i.cs, while offering speed and space-efficiency. Caeco Inc, PO Box 240, Beaconsfield, Bucks HP9 2QN. Tel: 04946 77706.

Mixed analogue and digital simulator

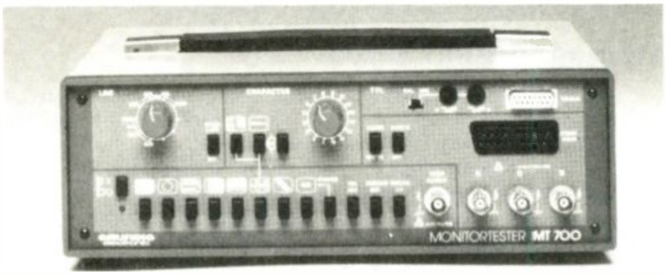
Simultaneous running of an analogue and digital simulator is now possible through the co-operation of Viewlogic and MicroSim. Each of their simulation programmes, Viewsim and PSpice, have been linked by an interface which transfers information between the simulators and synchronizes their operation. Accurate simulation is assured for circuits with feedback loops or circuits with different time constants between the sections.

The system was developed by Viewlogic and the resultant waveforms, both analogue and digital, can be displayed by their ViewWave waveform processor. These simulators run on a standard VAX/VMX workstation. Available through Instrumatic UK Ltd, First Avenue, Globe Park, Marlow, Bucks SL7 1YA. Tel: 06284 76741.

Testing video monitors

A range of signal outputs is available on the Grundig MT700 to make it suitable for the testing and adjustment of virtually any monochrome or colour tv monitor. All the standard European and US line and frame frequencies are catered for and it is possible to programme the tester to cope with non-standard formats.

In addition to the usual standard test patterns for setting up convergence, linearity, colour adjustment and frequency-response, there are a number of text tests which are particularly suitable for computer monitors. Outputs are in composite video signal form as well as RGB and RGB/t.t.l. Interlace can be switched out to reduce jitter on tests. Available through Electronic Brokers Ltd, 140 Camden Street, London NW1 9PB. Tel: 01-267 7070.



Three-phase energy analyser

A new version of the Microvip energy analyser can be used on a three-phase system with unbalanced loads. It includes integral phase and continuity indicators, and provides total current, power and power-factor measurements. Microprocessor controlled, the instrument is claimed to be easy to use and gives a print-out of data collection. Direct measurements include: true instantaneous voltage, current, power-factor and active power; reactive and active energy consumption since the last zero setting; leakage current to earth; voltage frequency and mean power factor. Alpha Electronics Ltd, Unit 5, Linstock Trading Estate, Wigan Road, Atherton, Manchester M29 0QA. Tel: 0942 873434.

Inverters increase display life

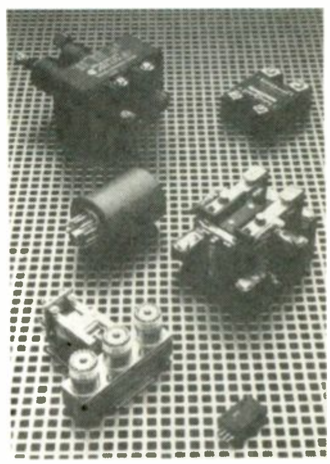
The Endicott range of d.c. to a.c. converters are designed for use with electroluminescent lamps. Applied voltage and frequency are automatically adjusted by the inverter to give the display a constant light level. And e.l. display acts like a lossy capacitor and brightness diminishes in time. This is often compensated for by stepping up the voltage and/or frequency. Smart Force inverters incorporate a tuned resonating circuit that adjusts automatically as the capacitance of the lamp changes. Versions of the inverters have input d.c. voltages ranging from 5V to 48V with nominal outputs of 60, 80, 100 and 120V. They can provide power for up to 375cm^2 as used for backlighting l.c.ds in portable computers. Gresham Powerdyne Ltd, Osborn Way, Hook, Hants RG29 9HX. Tel: 025 627 4246.

Miniature tantalum capacitors

A range of miniature moulded tantalum chip capacitors conforms to a new EIA world standard for sizes. It is particularly designed for surface mount applications. Four standard sizes are catered for by the Sprague 293D range, which covers capacitance values from 0.1µF to 100µF with working voltages between 4 and 50V. Sprague Electric UK Ltd, Airtech 2, Fleming Way, Crawley, West Sussex RH15 2YQ. Tel: 0293 517878.

Relays galore

Magnacraft makes relays in the United States. They are particularly strong in solid-state and high-power devices. Keyswitch Varley makes a complementary range, especially of cradle and octal-based relays and has now become the UK stockists for Magnacraft, thereby offering a very comprehensive range of relays. Keyswitch Varley Ltd, Tom Cribb Road, Thamesmead, London SW28 0BH. Tel: 01-317 1717.



Miniature 15W d.c. converters

The new d.c.-to-d.c. converters from Rifa are the size of a credit card and not much thicker. They are designed to be mounted on a p.c.b., when they have a height of 10.7mm, but may also be mounted with the base fitting into a cutout on a p.c.b., then protruding only 8.5mm.

PKC-series converters offer 500V d.c. isolation and one, two or three outputs. Input voltages can range from 24V to 48 or 60V and the outputs are 5, 12 or 15V within 2..5%. The design is particularly suited to parallel connection and, for example, has a negative temperature coefficient. Internally, they use 300kHz p.c.m. switching; the high frequency contributing to their small size. Rifa AB Power Products, Market Chambers, Shelton Square, Coventry CV1 1DJ. Tel: 0203 553647.

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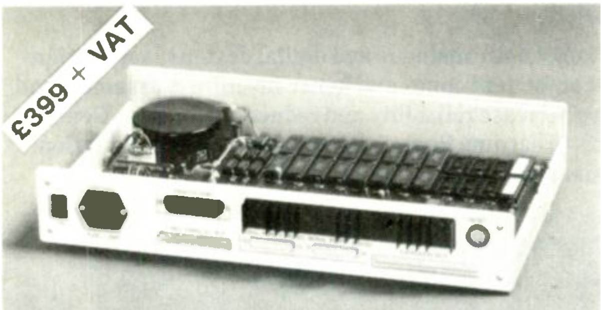

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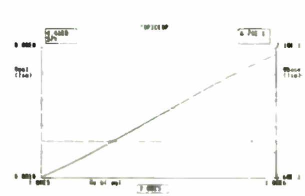

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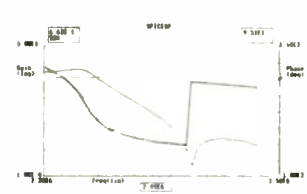

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BOOKS

Microwave Processing and Engineering, edited by R. V. Decareau and R. A. Peterson. Ellis Horwood series in food science and technology, 224 pages, hard covers, £37, ISBN 3-527-26210-5. Microwave here means 60kW pasta driers at 915MHz (which should certainly wipe out the managing director's cellular telephone) and steam processing lines for cut-up poultry parts on 2450MHz – in other words, mostly the large-scale industrial uses of microwave heating. Besides applications, the text covers microwave theory and techniques, magnetrons, klystrons and special waveguide components. Further chapters illustrate the design of microwave systems step-by-step and explain the regulatory requirements in both and US and Europe.

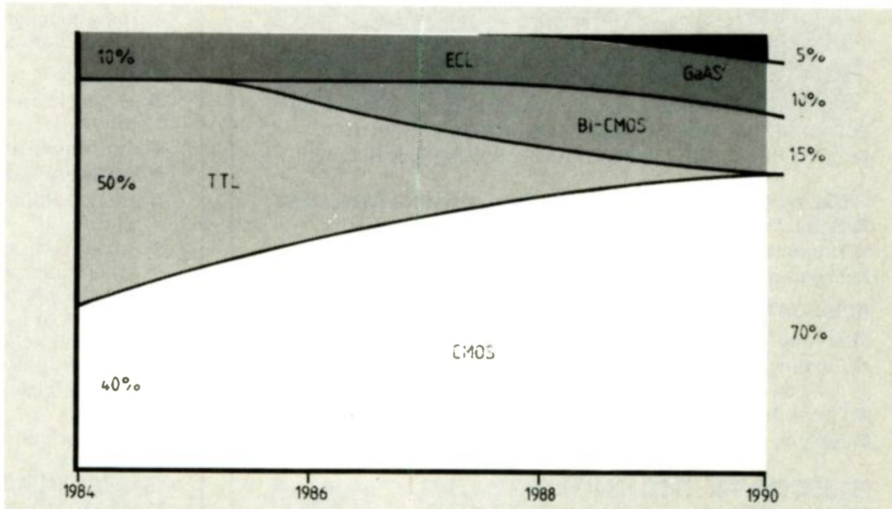
Waveforms: a history of early oscillography, by V. J. Phillips. Adam Hilger, 259 pages, hard covers, £35. Electronics is not so new a discipline as to lack a past, and works such as this and the splendid history of technology series from the IEE do a service by reminding us of it. The history of man's attempts to see electricity stretches back further than one might imagine and embodies devices more fantastical than now seems possible. But it is no part of Dr Phillips's purpose to make fun of early travellers along blind alleys. Instead, he provides an informative and extensively researched account, tracing out with the help of over 200 contemporary illustrations the tangle of threads which eventually came together in the cathode-ray oscilloscope. It is interesting to note how imaginative our 19th century forebears were at naming their apparatus: some of their efforts could well do with reviving, when we run out of three-letter abbreviations for new electronic devices. Rheotome, for example, (Charles Wheatstone's word for a current chopper) might have been an apt substitute for s.c.r.

Electronics & Electronic Systems by George H. Olsen. Butterworths, soft covers, 406 pages, £19.95. Text for first and second year undergraduates or for higher-level TEC course students. The analogue electronics section is noticeably larger than the digital, which will please those who think the emphasis has been going too far the other way.

Advanced Semiconductor Fundamentals by Robert F. Pierret (Purdue University). Addison-Wesley, soft covers, 228 pages, £17.95. Volume VI of a series on solid-state devices, with sections on semiconductor properties, quantum mechanics, energy band theory, equilibrium carrier statistics, recombination-generation processes and carrier transport. The author intends the book as a supplement to the graduate-level text **Physics of Semiconductor Devices** by S.M. Sze (Wiley-Interscience, New York) and as a reference work for engineers and scientists.

Application-specific integrated circuits

In volume production of both analogue and digital designs, application-specific i.cs reduce component count and hence inventory, assembly and testing costs; they also increase reliability and reduce p.c.b. area. Generally, using an asic starts to become financially attractive when production quantities reach a thousand or more.



NEC's asic production output trends show c-mos replacing t.t.l. by 1990.

Five years ago, the scope of asics was limited. Most asic devices were based on uncommitted logic arrays, resulting in wasted silicon and a relatively high degree of inflexibility. But now asics are available in many configurations – even microprocessor macros – and in semiconductor technologies ranging from t.t.l. to bipolar/c-mos combinations.

Software for asic simulation is so advanced now that breadboarding can be unnecessary. Nevertheless, the full requirements of the final asic must be defined before the design work starts to minimize costs. Changes in an asic design become more expensive as the design work progresses, reaching very high proportions once the first iteration (samples) is produced.

Most manufacturers can supply a range of asics with various numbers of gates. Of course the functional requirements of the final device mainly determine which asic is chosen but the number of i/o pins needed also has to be taken into account. It can be necessary to choose an asic with more gates than are needed in order to satisfy i/o requirements. Good design reduces the number of gates required.

Asic semiconductor technologies available from NEC

Type	Process	Speed/ geometry	Gates
C-mos gate arrays	CMOS-3	2μm	800-11 000
	CMOS-4/4A/4R	1.5μm	300-20 000
	CMOS-5	1.2μm	2000-45 000
BiCmos gate arrays	BICMOS 4/4A	1.2μm	600-10 000
Bipolar gate arrays	ECL-2	500MHz	300-2000
	ECL-3	200MHz	1200-3000
	ECL-3A	450MHz	600-1200
Cmos standard-cell arrays up to 25 000 gates	64K ram		
	256K rom		
	Mega macros		

Choosing a technology is quite easy, being decided by cost, performance, power consumption and output current. Now that c-mos devices out-perform t.t.l., the choice is mainly between c-mos and e.c.l.

Total design time is a major consideration. Time scales for most of the design stages are difficult to determine, depending on the capacity and efficiency of both the design centre and buyer as well as the complexity of the device. During the initial stage, designers have access to their paperwork logic design and can make alterations. At this stage also, the designer needs to consider which tests are required for the final asic. Subsequently, the program for a test tape will be produced.

Generally, only the time between completing the design and producing the first test devices is fixed; a few weeks is usual. At one time, buyers relied solely on the speed of design centres but now that asic-design workstations and software are becoming reasonably priced, asic buyers can have much more control over design time.

Packaging also has to be considered. Power dissipation and chip layout can restrict the types of packaging available and using a high proportion of gates can affect pin out. In such complex i.cs, power-supply and ground pins can be important. With c-mos technology for example, the number of outputs that can switch state simultaneously is limited by the number of ground pins.

Nowadays, selling asics is a service industry. Success of an asic supplier depends as much on support as on the range of devices.

Advanced f.s.k. modem i.c.

A high degree of integration offers the prospect of intelligent auto-dialling modems with an unprecedentedly low component count.

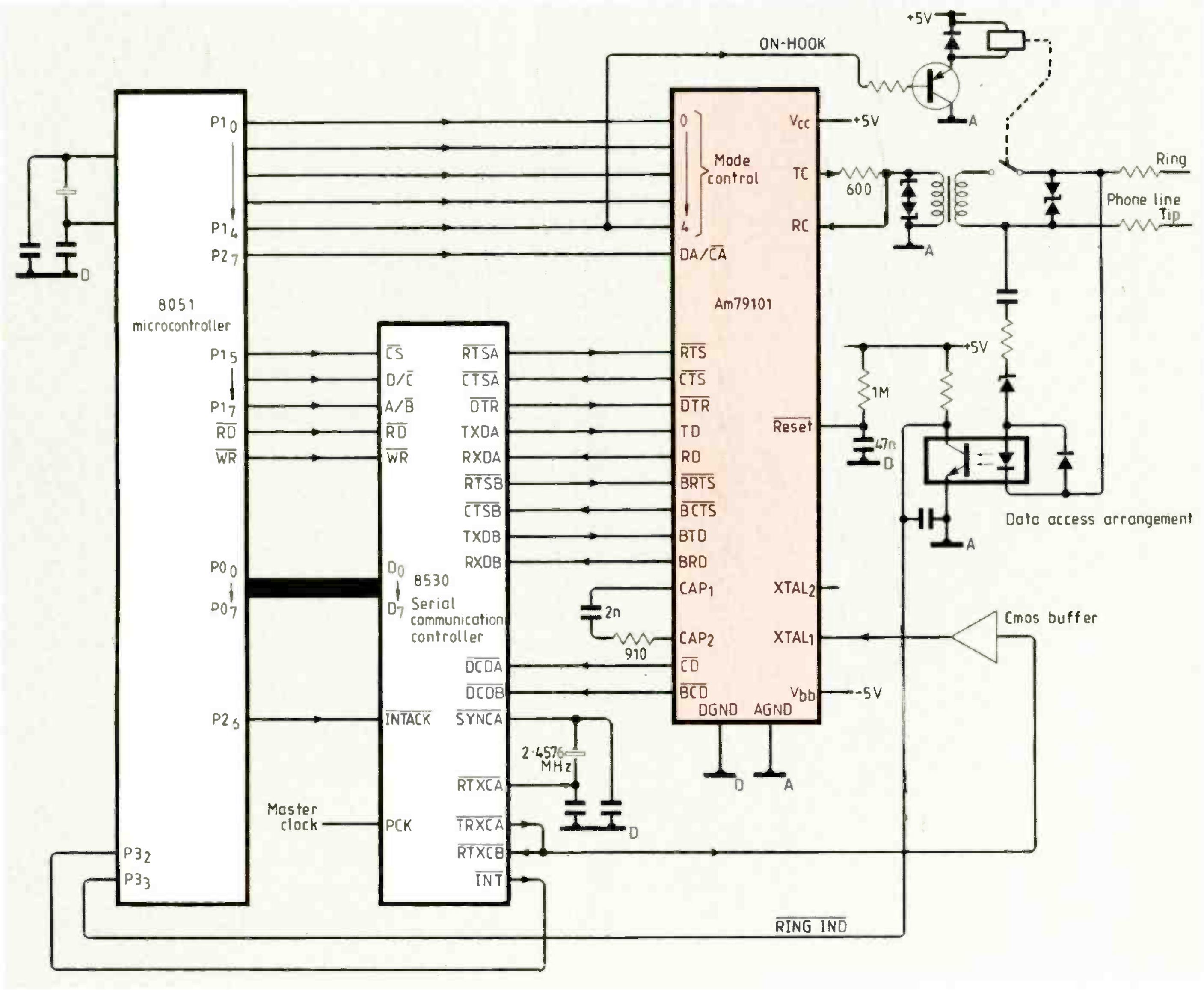
Advanced Micro Devices has announced an enhanced version of its Am7910 f.s.k. modem chip, the device which in the last couple of years has become virtually standard in low-speed asynchronous data modems.

Like its predecessor, the new Am79101 provides transmission and reception at rates of up to 1200 bits per second, both in the CCITT V.21 and V.23 standards and on Bell standards 103,113, 108 and 202. In Bell 202 and CCITT V.23 half-duplex modes a back channel of up to 150 bit/s is possible, making the device suitable for split rates such as the 1200/75 commonly used by viewdata systems such as Prestel. But in addition, the Am79101 includes full support for autodialling and auto-answer: it has a built-in d.t.m.f generator and call progress tone detection, which can identify dial tones and number-engaged signals.

Modulation, demodulation, filtering, digital-to-analogue and analogue-to-digital conversion are all implemented within the chip using digital signal processing techniques. Transmit signals are digitally-generated sine-waves: when the modulator switches from one frequency to the other during phase-shift keying, it does so in a phase-continuous manner. Data inputs and outputs are serial signals at t.t.l.-compatible 5V levels, which can easily be converted to RS-232 levels.

Connection to the telephone network may be either via an acoustic coupler or via an external data access arrangement, which provides the necessary isolation. But a two-wire to four-wire hybrid is provided within the chip, simplifying the design of the interface. The Am79101's high degree of integration will make it possible to design full-featured modems with a very low component count. Very compact arrangements for portable use should be easy to achieve.

As a design illustration, AMD suggests the 1200/75 modem shown below. For this split data rate, a second uart is needed in the form of an 8530; at non-split rates such as 300/300 V.21, the Am79101 can be driven by the 8051 on its own, using its built-in uart. Automatic answering of incoming calls is handled by an interrupt routine in the 8051. If d.t.m.f. dialling is not available on the telephone network, the 8051 can pulse the relay to generate loop-disconnect dialling pulses. Power supplies are +5V at up to 170mA and −5V at up to 25mA. Sample quantities of the Am79101 "World-Chip" are already available; production quantities will be ready in February. The device is to be produced in 28-pin d.i.l. and p.l.c.c. versions. Details, and a preliminary data sheet, can be supplied by AMD at Woking on 04862-22121.



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4CX250K EIMAC	115.00
4CX250R AMPEREX	125.00
4CX350A	100.00
4CX350F	95.00
4CX1000A	425.00
4CX1500B	398.00
4CX5000A	1000.00
4D21/4-125A	85.00
4D32	125.00
4GS7	2.25
4GV7	2.25
4J6A	2.95
4KT6	1.50
4X150A	35.00
4X500A	350.00
5A/102D	9.50
5A152M	9.00
5A163K	10.00
5A170K	6.25
5A-180M	9.00
5A-206K	10.00
5AMB	2.15
5ANB	1.20
5B 110M	10.00
5B-254M	14.50
5B-255M	19.50
5B 256M	15.00
5B 257M	15.00
5B258M	14.50
5C22	125.00
5CL8A	2.50
5J180E	2950.00
5JL8	2.95
5R4GB	5.50
5R4GY	4.95
5T4	5.95
5TBA	1.95
5U4G	2.95
5U4GB	4.50
5V4G	2.50
5X4	4.95
5Y3GT	1.95
5Z3	4.50
5Z4GT	2.50
6/30L2	0.70
6A/203K	9.00
6A7	4.95
6A8	1.50
6AB4	3.50
6AC7WA	2.00
6AG5	2.50
6AG7	1.95
6AH6	3.50
6AJ4	3.50
6AJ7	2.00
6AK5	1.95
6AK6	2.50
6AL5	0.60
6AM4	3.25
6AM5	6.00
6AM6	1.95
6AN5	4.50
6AN8A	4.50
6AQ5	1.75
6AQ8	1.00
6AR5	5.95
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	0.90
6AT8	1.75
6AU4GT	2.00
6AU5GT	4.50
6AU6	0.95
6AV6	0.90
6AWBA	3.50
6AX4GT	1.95
6AY3B	1.95
6AZ8	4.50
6B4G	5.50

6B8G	1.50
6B10	1.95
6BA6	1.50
6BA7	4.50
6BA8A	3.50
6BC8	0.85
6BE6	1.50
6BG6G	3.00
6BH6	1.95
6BH8	1.50
6BJ6	1.50
6BK4	4.00
6BL6	85.00
6BL8	1.15
6BM6	115.00
6BN6	1.65
6BN8	3.95
6BQ5	0.95
6BQ7A	1.50
6BR7	4.95
6BS7	5.50
6BW6	5.35
6BW7	1.50
6BZ6	2.50
6BZ7	2.95
6C4	1.50
6C5	1.95
6C6	3.50
6C8G	1.50
6C9	4.95
6CA4	4.95
6CA7	3.50
6CB5	3.95
6CB6	1.95
6CD6GA	4.50
6CF6	1.95
6CG7	3.50
6CH6	6.95
6CL6	3.25
6CL8A	1.50
6CM7	2.95
6CS6	0.75
6CS7	0.95
6CW4	8.00
6DC6	2.35
6DJ8	1.00
6DJ8 SPECIAL	3.50
6DK6	1.50
6DQ5	8.50
6DQ6B	2.50
6DT6A	1.50
6DW4B	21.5
6E5	3.95
6EA7	2.50
6EA8	2.50
6EB8	1.75
6EJ7	0.85
6EM5	2.50
6EM7	2.50
6EU8	1.75
6EV7	2.95
6EW6	1.50
6EW7	4.50
6F1	2.00
6F5	5.50
6F7	5.50
6F13	3.00
6F14	1.00
6F17	2.75
6F23	0.60
6F24	1.25
6F25	1.25
6F28	1.25
6F32	1.25
6F33	12.50
6FH5	6.50
6FH8	5.95
6FL2	4.50
6FQ7	3.50
6GE5	3.95
6GH8A	2.50
6GJ7	0.85
6GM6	2.65
6GS7	21.5
6GV8	0.95
6GW8	2.50
6GY5	3.95
6GY6	2.50
6H1	9.50
6H6GT	1.50
6HB7	1.95
6HF5	5.50
6HF8	2.50
6HM5	2.50
6HQ5	3.50
6HS6	4.95
6HS8	2.95
6HZ6	3.50
6J4	2.15
6J5GT	2.50
6J6	2.00
6J7	4.15
6J7G	4.15
6JB6A	5.50
6JE6C	7.50
6JM6	7.50
6JU8A	2.50
6JS6C	7.50
6K7G	2.00
6K8G	3.00
6KD6	7.50
6KG6A	6.95
6L1	2.50
6L6GC	2.95
6L6GC(G.E)	5.75
6L6GC PHILIPS	6.50
6L6GAY	5.50
6L6GT	2.50
6L6WGC	5.50
6L7	3.50

6L15	3.15
6L19	3.95
6LJ8	2.50
6LD20	1.15
6LF6	7.50
6LQ6	7.50
6P28	2.00
6Q7GT	1.50
6R7	3.15
6RHH8	10.00
6S4A	1.50
6SA7	1.35
6SC7	1.50
6SG7	2.50
6SH7	1.35
6SJ7GT	1.20
6SK7	1.35
6SL7GT	1.95
6SN7GT	1.95
6SQ7G	1.50
6SS7	1.95
6T8	1.50
6U6GT	3.50
6U7G	3.50
6U8A	1.50
6V6G	1.25
6V6GT	1.95
6W4GT	1.95
6Y6G	3.95
6X2N	1.00
6X4	1.50
6X5GT	1.00
6X5GTY	1.00
6X8A	2.25
7A6	4.50
7AU7	1.50
7B6	3.50
7B7	2.50
7D8	4.50
7J7	5.50
7K7	7.50
7L	1.50
7Q7	4.50
7Y4	2.50
8B8	2.50
8B10	2.50
8BQ5	1.95
8CW5	1.50
8EB8	1.50
8FQ7	1.95
10CW5	1.50
10D2	1.25
10DE7	2.50
10DX8	2.50
10EB8	1.95
10EW7	2.95
10F1	0.75
10GK6	1.95
10P4	2.50
11E3	55.00
11R3	5.50
12A6	3.95
12AE6	5.50
12AH7GT	4.95
12AL5	1.00
12AT6	1.25
12AT7	1.15
12AT7WA	2.50
12AU6	1.50
12AU7	0.85
12AV6	1.95
12AV7	2.50
12AX4GTB	1.50
12AX7	0.95
12AX7WA	2.50
12AX7S	7.95
12AY7	3.95
12B4A	4.50
12BA6	1.50
12BE6	1.95
12BH7A	2.95
12BL6	1.75
12BR3	1.95
12BY7A	2.75
12C8	2.50
12CA5	1.95
12CX6	1.20
12DQ6B	3.50
12DW4A	3.50
12DZ6	3.95
12E1	19.50
12E14	38.00
12FX5	1.95
12GN7	3.95
12GH7	3.95
12J5GT	3.95
12J7GT	3.50
12JZ8	2.95
12K7GT	1.50
12K8Y	1.95
12KU7	1.95
12S7GT	1.50
12SA7GT	1.95
12SG7	4.75
12SK7	1.95
12SJ7	1.50
12SN7GT	1.85
12SW7	3.50
12SY7	4.50
12X4	1.95
13D3	3.20
13D7	3.20
13D8	3.20
13DE7	2.50
13DR7	2.95
13E1	145.00
13EM7	3.50
14B6	4.50
14R7	3.50
15E	5.50
16AQ3	1.35

16GY5	2.95
16H	0.40
16L	0.40
17A8	3.50
17AX4GTA	1.95
17BE3	2.50
17DW4A	2.95
17EW8	0.95
17JZ8	4.50
18D3	6.00
18GB5	3.50
19AQ5	3.50
19AU4GT	2.50
19BG6	3.50
19G3	19.50
19G6	9.00
19H4	35.00
19H5	33.50
20CV	9.50
20D1	0.70
20LF56	7.95
20L1	0.95
20P1	0.55
20P4	1.95
20P5	1.15
21JZ6	4.95
21KQ6	4.95
21LU8	3.75
24B1	39.50
24B9	39.50
25BQ6	1.75
25DQ6B	2.95
25L6GT	1.75
29C1	19.50
29KQ6	6.50
30C15	0.50
30C17	0.40
30C18	1.48
30FL2	1.35
30FL12	0.95
30FL13	1.10
30FL14	1.25
30L1	0.45
30L15	0.60
30L17	0.60
30P4MR	1.00
30P12	1.00
30P18	0.60
30P19	1.00
30P1	2.50
30PL13	0.60
30PL14	1.75
31JS6C	5.50
33A/158M	19.50
35A3	3.95
35A5	4.50
35C5	4.50
35L6GT	2.00
35Z3	1.95
35Z5GT	3.50
38HE7	5.95
40KD6	5.50
42	6.95
47	6.00
50A5	1.50
50B5	1.95
50C5	0.95
50CD6G	1.95
50EH5	1.50
50JY6	2.95
53KU	4.50
75B1	3.50
75C1	4.50
80	4.50
83	8.50
82A1	7.50
85A1	6.50
85A2	2.95
90AV	15.00
90C1	3.50
90CG	13.50
90CV	12.50
91AG	9.00
92AG	19.50
92AV	15.00
95A1	6.50
100E1	10.00
108C1	2.50
150B2	6.50
150C1K	9.00
150D2	2.50
150C4	2.50
185BT	1.50
211	25.00
230D	15.00
231D	15.00
250TH	150.00
307	5.00
328A	15.00

572B	59.50
723A/B	75.00
724A	275.00
725A	275.00
726A	75.00
801A	15.00
802	25.00
803	14.95
805	59.00
807	5.50
811	15.00
812A	35.00
813 Philips	35.00
813	27.50
829B	14.50
833A	95.00
845	45.00
866A	6.50
872A	20.00
873	60.00
954	1.00
955	1.00
1768	95.00
1849	315.00
1927	25.00
2040	25.00
2050A	5.95
2050W	6.50
4212H	250.00
4471	35.00
4687A	9.50
5544	79.50
5559	55.00
5636	5.50
5642	9.50
5651	2.50
5654	1.95
5670	3.25
5675	28.00
5678	7.50
5687	4.50
5696	4.50
5702	3.50
5704	3.50
5718	6.15
5725	2.50
5726	2.50
5727	2.50
5749	2.50
5750	1.85
5763	5.75
5772	4.50
5814A	3.25
5823	9.50
5829WA	6.50
5840	3.50
5842	11.00
5863	95.00
5886	13.95
5894	39.50
5899	4.50
5963	1.75
5965	2.15
6057	3.75
6060	2.25
6072	6.95
6080	8.50
6080WA	9.50
6132	10.50
6136	2.50
6146B	7.50
6148 GE	9.50
6155	72.00
6156	72.00
6157	2.50
6158	3.20
6201	6.45
6299	250.00
6350	3.50
6360	4.50
6386	14.50
6443	7.00
6463	7.50
6550	8.50
6550A GE	10.95
6550 RCA	15.00
6870	11.50
6883B	9.95
6973	7.95
7025	2.50
7025S	6.95
7027A	7.50
7119	9.00
7189	5.50
7193	7.50
7199	7.50
7247	4.95
7360	15.00

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TELEVISION BROADCAST

An industry wake?

An IEE discussion meeting, "What is happening to the UK broadcast manufacturing industry?" brought together a panel and audience of manufacturers and users, many at managing-director level. It was a pity that the overall attendance, like that at so many recent IEE professional group meetings, rather reflected an industry in decline, with the manufacturers' name plates on equipment in the television and radio studios of the UK now very different from those of only ten years ago and with a number of familiar names completely gone. Nevertheless, it is widely recognized that the UK is still a vigorous and successful competitor in transmission equipment and in the equipments developed and marketed by a number of small British specialist firms, many of them formed only recently.

But there is no denying that the final withdrawal a year ago of British industry from the design and manufacture of high-grade electronic cameras and other flagship products has had a sobering effect on both industry and broadcasters. It has also been a decade of mergers and acquisitions, sometimes with successful companies losing their own identities in the process; in other cases with a number of small production units grouped under the umbrella of a large group.

Some members of the large panel were keen to deny any illness, let alone demise or a wake. With Stuart Sansom as chairman and panellists Richard Ellis, John Jefferies, Peter Rainger, John Wills, John Jarvie, Jerry Ventham, Granville Cooper, Mike Cox, Richard Taylor and Ken Barrett, and contributions from Peter Wayne, Tom McGann and Bill Dennay, as well as telexed comments from Peter Mothersole there was no lack of diverse and often conflicting views on what has gone wrong, what has gone right and what the prospects are for the future.

Do British firms spend enough on r&d? Are they sufficiently marketing-led or technology-led? Have we lost the pioneering spirit in which engineering giants such as Alan Blumlein (see page 184) also possessed the ability to be first-rate administrators? Do the City and the increasingly influential accountants concentrate too much on short-term results? Can UK firms successfully co-ordinate their efforts while retaining their corporate independence? Has the EEC a diode in circuit that encourages European countries to sell into the UK while largely blocking exports into the more protected markets of France and Germany?

To almost all of such questions, except perhaps those on deficiencies in engineering training, almost directly contrary answers were given. Some, but perhaps insufficient, attention was given to the profound effects of Japanese marketing strategies that concentrated first on attacking the mass consumer and component sectors by offering improved reliability that significantly reduced the differences between consumer and professional equipment, then gaining and holding specific market sectors, if necessary by what John Wills (Varian-TVT) described as "kamikaze-pricing" that can still put their equipment 30 to 40 per cent below the competition despite dramatic changes in the value of the yen.

But it was depressing to hear one panelist trotting out the discredited idea that the Japanese broadcast industry is derivative rather than innovative. Were this really the case, more of those British name plates would still be seen in our studios!

Component video for film storage

It could be argued that the single most important current trend in television is the increasing use of component waveforms, with luminance and chrominance signals kept separate rather than the long-established composite picture waveforms with 'mixed highs'. Component techniques are being used in digital (CCIR 601) and analogue form, including MAC (multiplexed analogue components). Analogue component techniques have made practicable the use of half-inch metal-particle tape for studio as well as field operation in the form of the M.II and Betacam SP formats. Granada's Liverpool centre became one of the first to operate on a component basis and the BSB UK d.b.s. play-out centre being planned near Southampton will operate entirely with component video. Thames Television is already using its new M.II component editing suites at the Euston Road centre.

Thames is also using a novel from of 'Studio-Mac' in a new approach to long-term storage of archival material on 35mm (possibly later 16mm) black-and-white film with a technique it terms "Cinemac". This is based on telerecording a black-and-white display of time-compressed MAC colour pictures.

In support of this system, Thames engineers argue that some of their 20 000 massive reels of two-inch archival quadruplex recordings, although mostly less than 20 years old, have already begun to show serious signs of deterioration, including gradual disintegration of the cardboard packaging, leading to mould growth on the tape itself. Very long term storage of broadcast-quality colour tapes still remains to some degree an unknown quantity. Similarly, conventional telerecording of archival material on to colour film would not only be rather more costly and subject to processing flaws, but would also require careful temperature control to ensure that the film is stored at under 10°C. Black-and-white film can tolerate storage temperatures up to 25°C and a relatively wide humidity range. Furthermore film material, unlike video tape, is independent of television standards and can be played out for any system without standards conversion.

Thames are using the agreed S-MAC standard with the addition of line marker pulses and a digital time-code track that identifies individual frames. PAL composite signals from the archival tape are decoded with a high-quality comb-filter decoder and the analogue luminance and colour-difference components are sampled digitally (CCIR 601 digital standard). The stored 13.5MHz luminance and 6.75MHz colour-difference signals are read out at 27MHz to provide a MAC-type black-and-white display and then telerecorded, for later reproduction with the aid of a MAC-decoder as high-quality colour pictures.

Avoiding on-screen ovens

The second annual report of the Radiocommunications Division of the DTI provides an interesting example of the efforts of the division's Kenley radio technology laboratory to look ahead and anticipate potential electromagnetic compatibility (e.m.c.) problems rather than waiting until it is too late to do much about them.

The laboratory is already preparing to meet complaints about interference from the fifth harmonic of 2.3GHz microwave ovens to d.b.s. reception (reception of low-power distribution satellites by home viewers is not protected). The unstabilized magnetron power generators, despite the decreased leakage of signals through oven doors brought about by public concern at possible biological hazards, are still capable of interfering with weak incoming satellite signals, and this problem could be enhanced by the smaller dish antennas with poorer sidelobe performance, possibly located inside a house window only a few feet from an oven.

The DTI laboratory has developed an improved method of measuring the level of radiation from ovens and other microwave sources. To quote the DTI report: "A screened room is equipped with two or three paddle wheels. Rotation of the paddles produces a time-varying pattern of nodes and antinodes in the electromagnetic field generated by the equipment under test. By waiting 10 to 20 seconds a receiving antenna will give a maximum output which is related to the total power of the equipment under test. The technique is useful for frequencies above 1GHz and has now been accepted as an international standard method of measurement. Work is now continuing to determine what limits should be used with this method in order to protect the reception of satellite television."

Television Broadcast is compiled by Pat Hawker.

RADIO COMMUNICATIONS

Universities tackle e.m.c.

A number of UK university departments, where research in various aspects of electromagnetic compatibility (e.m.c.) is under investigation, have recently come together in an effort to form a grouping similar to that which has existed for a number of years in the field of mobile radio research. These include: Bradford (Dr P. Excell), Bristol (Dr. R. Burbridge), City University London (S. Wilkinson), Hull (Professor M. Darnell), Nottingham (Professor P.B. Johns) and York (Dr A.C. Marvin).

As an opening shot, Dr Andy Marvin sent out some 200 invitations to industry, Government departments, research establishments etc. for a meeting at City University. The organizers expected that about 20 people would show interest, but about 70 accepted the invitation. The meeting provided firm evidence that there is a growing recognition of the importance of e.m.c. and r.f.i. in many branches of industry – although this has not prevented many problems from remaining undiscovered until products are in use.

Surveys by Dr Peter Excell and Dr Andy Marvin, plus poster presentations, gave an overview of what is currently being achieved by university research in such areas as biological and r.f. ignition hazards; user-friendly software packages for the computation of pick-up on metallic structures; e.m.c. measurements; crosstalk and harmonic generation by the 'rusty bolt' effect; miniature and superconductive cavity resonators for filtering; parallel plate and Crawford cell technique for testing the degree of immunity of equipment; research into intermodulation products generated in materials and structures; h.f. systems with adaptive frequency selection; the application of transmission-line modelling to computer simulation of electromagnetic fields and couplings to circuits; the development of test methods enabling measurements to be carried out in screened rooms or with computer simulation; and investigation of radiation leakage from screened cables and the coupling between coaxial cables.

It was evident from the lively discussion period that there is a dichotomy in respect of industry and academic expectations. University research is increasingly having to wear the clothes of marketplace in attempting to sell its expertise in order to obtain funding support from industry. Industry looks on the universities primarily as academia from where it would like to receive graduates with a better basic knowledge of the increasingly important thermal and e.m.c. design factors.

When I drew attention to digital e.m.c. problems that have been exacerbated by the long delay in limiting, by regulation, the radiation from desk-top computers and other consumers digital equipment, Anthony Nieduszynski, divisional head of DTI's Radiocommunications Division, expressed confidence that the draft EEC directive on e.m.c. will be implemented within the next 18 months.

It was admitted that most universities still find it difficult, if not impossible, to squeeze the study of e.m.c. into degree courses in electronics engineering. Too many firms producing consumer or even professional products still show little awareness of the problems that they can give rise to, or conversely the problems imposed on others by basic lack of immunity to r.f. fields. Some unease was expressed that the merging of the IEE and IERE could result in a reduction of activities in the e.m.c. field, since the IEE, it was suggested, pays less attention to e.m.c. than the IERE.

City University drew attention to the keynote address by Rear Admiral R.J. Grick, USN, at a 1987 e.m.c. conference, when he said in conclusion: "There is a significant and growing problem of global proportions in the ability to employ new technology without paying undue performance penalties. Electromagnetic environment considerations need to be organized and systemized into an engineering discipline, taught in our engineering curricula and applied in design and production to help reduce the unexpected performance penalties."

The London meeting expressed the hope that the university researchers will agree to stay together on a more formal basis to encourage e.m.c. studies. But whether industry will agree to fund much university e.m.c. research remains to be seen.

One UK educational establishment where e.m.c. studies are already being encouraged is the Cambridgeshire College of Arts and Technology. John Worsnop, a senior lecturer and also radio amateur G2BAO, has been concerned with a project that involves the recording of v.h.f. meteor-burst signals using a BBC microcomputer. He encountered e.m.c. problems emanating not only from this computer but from several hundred other computers around the college campus. He has described methods of reducing r.f.i. by about 30dB by having the plastic case of the BBC micro plated with a conductive zinc compound and by decoupling and filtering the interface and mains leads. CCAT has two HND student projects in this area: one concerned with the suppression of r.f. pickup in public address systems, the other studying the use of fibre-optic cable to replace copper in RS232 computer terminal wiring.

In-car security

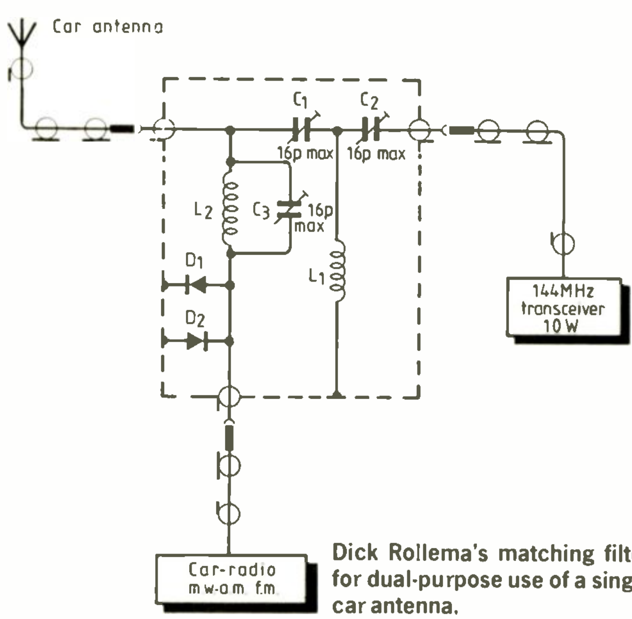
The vulnerability of in-car entertainment (i.c.e.) and two-way radio equipment to car thieves and/or vandals has led a number of manufacturers to incorporate security devices in models at the top end of their ranges. It has been claimed that, in the U.K. alone, one i.c.e. unit is stolen on average each minute of the day, often with damage to the vehicle.

Communications equipment, including cellular, p.m.r. and amateur radio, has proved as attractive to the thieves as entertainment systems. Some models have been designed to be removed from their housings when the car is left unattended, with the added bonus that they can then be used as hand-portable units.

Another useful step is not to have an attention-attracting antenna on the car. The back window heater antenna developed at Bangor (*E&WW* February 1985, pp64-67) and now fitted as standard on a number of cars is much less vulnerable to casual vandals than the usual external car antenna and has been shown to work reasonably effectively as a communications antenna with the aid of a matching unit.

The Dutch engineer amateur Dick Rollema, PA0SE, has found that a standard car radio antenna mounted on the front side of the roof immediately above the windscreen provides also an entirely acceptable antenna for his 144MHz, 10W transceiver, with the aid of a simple matching-filter. This provides adequate protection for the front-end of his car radio.

Radio Communications is compiled by Pat Hawker.



Dick Rollema's matching filter for dual-purpose use of a single car antenna.

MSC digital stereo at 256kbit/s

A decade ago, in the short-lived flurry of interest in the possibility of broadcasting 'surround sound' (quadraphony) based on Ambisonics technology, the IBA developed, field-tested and patented a '2½-channel' system called MSC, standing for mono stereo compatible.

Curiously, the same set of initials has emerged again, this time from Germany, and now standing for 'Multiple adaptive Spectral audio Coding' – using adaptive transform coding to provide Compact Disc digital quality over transmission channels at a data rate of 256kbit/s instead of the normal CD rate of 1.4Mbit/s.

MSC has come from the joint efforts of E.F. Schroeder and H.J. Plate of Thomson consumer r&d laboratories at Hanover and D. Krahe of the University of Duisburg (*IEEE Trans. on Consumer Electronics* November 1987, pages 512 to 519). It is pointed out that whereas coding methods based on delta modulation or differential p.c.m. seem incapable of preserving CD quality at data rates below about 300kbit/s, this is not the case with a form of adaptive transform coding described by R. Zelinski and P. Noll in 1977 for low bit-rate speech transmission.

Transform coding itself reduces redundancy of a signal and it is claimed that despite the large bit-rate reduction only about 15 per cent of the transmitted data, containing the side information on the global shape of the spectrum, needs to be error-protected. High quality audio is maintained with random errors of the order of 10^{-3} in the unprotected 85 per cent of data. For a 44.1kHz sampling rate, the signal representation is only about 2.9 bits per sample with, it is claimed, the overall annoyance of transmission errors much less than with straight p.c.m. encoding.

Detailed testing of the system on many different types of music and sounds has still to be carried out. Dedicated hardware is being constructed as the next step towards an l.s.i. solution.

On radio, on CD: classic 78s revived by Robert Parker.

Recordings restored

In his several *Jazz Classics in Stereo* series on BBC Radio 2, the Australian sound engineer Robert Parker has shown conclusively how effective can be the use of digital signal processing in removing the surface noise and clicks from the 78 r.p.m. disc recordings of the 1920s and 1930s – revealing in the process how much better some recording companies were than others in achieving good standards of acoustic and early electrical recordings – even though not everybody would agree that adding digital pseudo-stereo effects always offers significant advantage to playing out a mono channel on spaced loudspeakers.

It is thus widely recognized that digital signal processing offers many advantages in restoring archival material over analogue processing, particularly in terms of flexibility and the ease with which complex operations can be implemented. With analogue processing, it has been pointed out, separate equipment is required for operations such as filtering, spectrum analysis and the more specialized operations specific to restoration of recorded material; whereas, with digital processing, the system can be completely reconfigured under program control from a keyboard.

Likely to be marketed this year is the Cedar (computer enhanced digital audio restoration) equipment to a design developed by the National Sound Archive of Kensington, London (where a unit has been installed) in collaboration with Cambridge Electronic Designs. As shown at the 1987 BKSTS film and television exhibition at Brighton, this has been developed specifically for the restoration of damaged or imperfect archival recordings by eliminating thumps, bangs, scratch noise etc. from disc, cylinder, acetate or film recordings with the aid of software designed for IBM or compatible computer systems.

The effectiveness of digital signal processing was also demonstrated in conjunction with a presentation by S.V. Vaseghi, P.J.W. Rayner and L. Stickler at the 1987 Congress of FIAF at Berlin.

They emphasized that many of the more advanced processing techniques are virtually impossible to realise with analogue systems. Operations requiring signal delay, such as correlation, are difficult to achieve in analogue form, but straightforward in digital form since signal data can be stored in memory.

They demonstrated an example of a disc which had been broken and the two halves glued together, resulting in two different forms of click on each revolution as the stylus jerked upwards and dropped downwards. It was shown that scratch templates could be obtained and both these forms of large clicks virtually suppressed.

Digital processing also offers promise for removing periodic interference with slowly varying frequency, echo removal and possibly distortion correction.

Sailing under false colours

The tendency for American university authors to produce long, exhaustive studies, peppered with references to a multitude of publications, on ever more specialized topics was evident long before the growth of computerized library information-retrieval systems. But electronics will surely exacerbate the situation.

I have no idea whether Lawrence C. Soley and John S. Nichols plus five acknowledged "researchers" used computer retrieval in compiling 'Clandestine Radio Broadcasting – a study of revolutionary and counter-revolutionary electronic communication' (Praeger, 1987) but it includes some 270 publications in its 12-page list of references, rather than any reference to first-hand involvement. Even so, the information given on the British operation of 'black' broadcasting by the Political Warfare Executive from "Simpson's" recording centre in Wavendon (Milton Keynes) appears to have been drawn solely from Sefton Delmer's memoirs. The authors have apparently missed the more detailed and more objective book by Ellic Howe, 'The Black Game – British subversive operations against the Germans during the second world war' (Michael Joseph). They concentrate mainly on the many post-war 'black' and 'grey' radio stations that have broadcast highly political and subversive programmes in Central and South America, East Asia, Africa and the Middle East, including a number of operations funded by the CIA in the 25 years or so since the days of the CIA's anti-Castro station on Swan Island in the Caribbean.

Political broadcasting has spawned its own vocabulary and Soley and Nichols provide some useful definitions. 'White' stations are those that operate legally and openly identify themselves in their propaganda broadcasts (e.g. Radio Liberty, Radio Free Europe). 'Grey' stations are clandestine stations attributed to or purportedly operated by dissident groups within a country (e.g. Free Voice of Iran). 'Black' implies broadcasts by one side that are disguised as broadcasts by the other.

In practice there is a range of shades between white, grey and black. 'Snuggling' implies operating a station on the same or adjacent frequency as a legal broadcast station. 'Ghosting' consists of interruptions to a legal station on the same frequency.

In some useful appendices, the book lists well over 200 clandestine stations that have operated in the periods 1948 to 1967 and 1971 to 1985, identified by ideology or source. The number may seem large, until it is remembered that Howe identified no less than 48 different operations by the PWE between 1940-45 in the UK alone, mostly on h.f. but also using the 600kW 'Aspidistra' medium-wave transmitter at Crowborough, Sussex.

Radio Broadcast is written by Pat Hawker.

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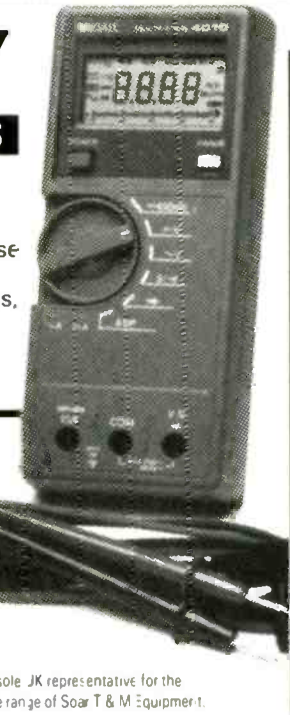

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ENTER 27 ON REPLY CARD

Power research

Joint investment by the Science and Engineering Research Council and the Central Electricity Generating Board will go to research in the power industry. £1.5M will be added to the £1M already invested. This will be used to extend research projects for three years in addition to the four years originally planned and will also increase the amount spent on each project.

The grants are going to universities throughout the country undertaking academic research relevant to the work of the CEGB. Particular areas earmarked as priority projects are:

- electrical systems and control engineering to take advantage of the latest developments in computer software and electronics to plan the refurbishment and eventual replacement of the national grid.
- computational fluid dynamics; the use of supercomputers to model the complex movement of fluids in power plants and increase their performance.
- predictive techniques for materials failure; the scientific examination of materials to increase power station efficiency and extend their life.
- non-destructive testing; the development of techniques to monitor equipment under extreme stress.

Award-winning position sensor

An additional feature of the recent Testmex exhibition was the institution of the Testmex award for a project connected with test and measurement. The winner was a system for sensing the positions of the edges of objects, using a single linear-array charge-coupled device (c.c.d.).

The target is back-lit and the c.c.d. is focussed onto its image in a system very similar to a photographic camera. The charge accumulated on each element of the c.c.d. is sampled sequentially at a frequency of up to 33kHz. Sampling frequency can be varied by the user. The prototype device can identify the position of an edge to a resolution of one part in 256.

The advantage of the system is that it does not contact the material and does not depend on it having any electrical or magnetic properties. Intended to solve a specific problem in textile machines, the edge sensor is suitable for measurements on filaments, threads and wires and is likely to find applications in a number of different areas.

Receiving the award was Amir Rezaie, an electronics student at Bristol University where the sensor was developed as a joint project between the mechanical, and the electrical and electronics engineering departments.

Teletext for the city

News and prices from the international foreign exchanges, financial and futures markets are to be broadcast, like Oracle, using spare capacity on the IBA tv signals. Reuter's Citywatch service comes from its central database obtained directly from over 1000 financial institutions, nearly 2900 subscribers in 79 countries and from a network of 1100 journalists.

Improving airport radar

Two study contracts have been awarded to Marconi by the Civil Aviation Authority to investigate methods of improving the performance and operational effectiveness of primary and secondary radar systems.

The first study concerns the integration of primary and secondary surveillance radar on the display of an approach controller. At present the primary system uses the familiar analogue display with a rotary sweep on a circular screen. The s.s.r. receives, from an automatic transmitter on the aircraft, its identity and height.

The proposal is to use airfield surveillance radar plots in place of the analogue data, reinforced by the s.s.r. This could provide a clear clutter-free display and remove the need for the dark environment now needed for analogue displays. Additional advantages accrue from the variety of radar data sources that could then be used. The study will concentrate on making the display accurate, immediate and unambiguous.

Secondary surveillance radar is the specific area of the second study which will investigate the replacement of rotating antennas with electronically-scanned arrays (e.s.a.).

The advantage of an e.s.a. is that it can be programmed to take up any direction immediately, and so is not dependent on the intermittent sampling or dwell time (i.e. beamwidth) of a rotating antenna. This will be especially useful when the s.s.r. messages are expanded into the extended messages of 'Mode S'. The study will consider many aspects of antenna design and beamforming techniques

Torch rescued by Australians

Torch Computers, which now specializes in Unix workstations, has received a 'substantial' capital injection from Catsco, an Australian computer and communications group. Catsco has supplied a number of systems, based on Torch equipment, to the New South Wales and Victoria state telecom companies, so it has a vested interest in keeping Torch going. Its directors also see Torch as an entry into the European marketplace and the opportunity to launch "a number of new and exciting products from the development teams of both companies."

Changes at Nimbus records

Nimbus Records was the first UK company to build its own compact disc mastering and manufacture plant. Its first commercial CD-rom is a world atlas, commissioned for use by oil companies. Each CD stores 550Mbyte of mapping data and is run by a personal computer with output to a digital plotter. Three scales and two projections are built into the disc images but accompanying software from Clarinet Systems allows the user to zoom in and out with a choice of 26 projections. Colour display and plotting of specific features, boundaries, towns, landmarks is possible.

The largest information display in the world using liquid crystals is Racal's claim for the arrivals and departures board at London's Euston station. Eight thousand display modules are arranged in 20 lines. Each module uses a 12 by 6 dot matrix to allow upper and lower case characters. All is controlled from a desk-top computer.

UPDATE

The company's expansion plans include further manufacturing facilities in Wales and in the USA while the pilot plant in Monmouth will concentrate on laser mastering (for which the company won a Queen's Award) and other pre-production services. A new research and development centre is being provided for work on new products and improvements and a sound and vision studio for recording CDs and CD videos.

Maxwell Communications has acquired a majority share in the company for £24M. A particular thrust of the investment is the development of electronic publishing on CD-rom.

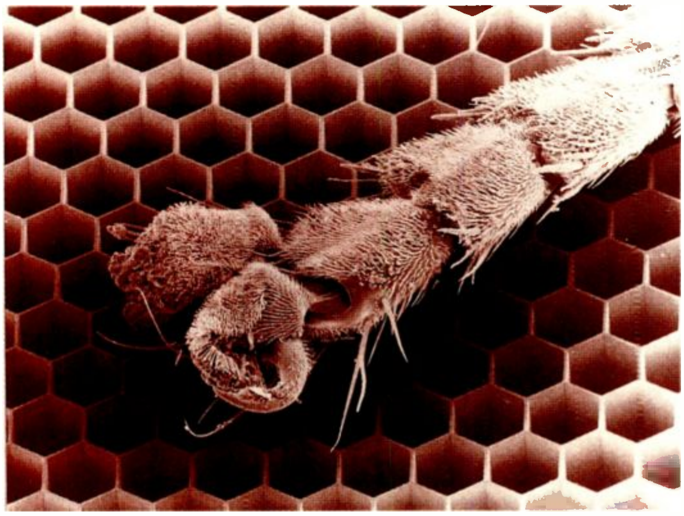
Hopping relay

Battlefield communications often use frequency-hopping radio systems which are resistant to jamming and eavesdropping. Now Ericsson has come up with a frequency-hopping radio relay to enable the use of flexible networks with anti-jamming performance. Pseudo-random switching across the full bandwidth is used to protect the network from high-power pulsed jamming as well as partial band jamming.

Prize for helping disabled

The third IEE prize for helping disabled people will be awarded in November, six months after 31st May which is the closing date for entries. Applications are welcomed from any part of the world for electrical or electronics devices or techniques which help overcome any type of disability.

Winners of the three-yearly competition include John Feaver, for a system to operate a car from a joystick manipulated by thalidomide victims and other severely handicapped people. In 1985 there were two winners: Andrew Downing of the University of Adelaide, for an eye-gaze operated computer; and Peter Donaldson of the MRC for an electronic bladder control device for paraplegics.



A fly's leg is used to demonstrate the size and precision of a microstructure produced by Degussa, Frankfurt. Such galvanoforming processes are used in the preparation of i.cs.

Only devices actually in use are eligible. Devices will have been developed or significantly improved since June 1985. Awards are made to individuals and not to companies or institutions: though the prize may be shared. Applicants need not be members of the Institution. Details from the Institution of Electrical Engineers, Savoy Place, London WC2R OBL.

Award for young designers

Electronics engineers under the age of 25 are invited to enter for the 1988 Young Electronics Designers Awards. To enter, students must produce an electronic device of their own which is original, effective and has a useful application in every day life. Trophies and cash prizes are presented to winners in each of three categories: junior (under 15), intermediate (15-18), and senior (19 to 25). Entrants should be students in UK educational establishments and the senior category has the increased incentive of the possibility of employment in electronics and course sponsorship.

Finalists will also receive prizes from the sponsoring companies, Cirkit and Texas Instruments. The awards are administered by a charity, The Yeda Trust, 24 London Road, Horsham, West Sussex RH12 1AY; the closing date for applications is 31st March.

Ferranti sells semiconductor business

Ferranti has sold its semiconductor division to Plessey for £30M. At the same time it has merged with, i.e. bought, the International Signal and Control Group. This marks a shift in emphasis for the company, away from components and towards further expansion into integrated systems. During the recession Ferranti has found it increasingly difficult to keep up with the growing demands for new devices. Rationalizing its priorities has resulted in the current moves. A Ferranti spokesman told us that similar moves have taken place between GEC and Plessey, with Plessey Telecommunications going to GEC and some of GEC's manufacturing facilities transferred to Plessey. Plessey and Marconi, followed closely by Inmos, will thus be the only remaining major semiconductor manufacturers in the UK.

In brief

IBM are to buy high-resolution colour c.r.ts from Mullard for display terminals. The contract is thought to be worth millions of pounds. Mullard's plant in Durham will supply the tubes to IBM in Greenock where terminals and personal computer systems are produced in large numbers for Europe, the Middle East and Africa.

The prestigious Fellowship of the Society of Motion Picture and Television Engineers, SMPTE, has been awarded to a BBC engineer. Michael Stickler is deputy head of BBC tv planning and installation and was awarded the fellowship for his work with remote control and digital video interface standards. Over recent years Mr Stickland has been chairman of the EBU committee which has investigated and agreed with the SMPTE international standards for such systems.

Those who forget to turn their tv off at night may be surprised to see scrambled pictures on their sets. The BBC is carrying out experiments for a closed user-group system which could transmit programmes overnight to, for example doctors, which could be recorded for subsequent viewing. The trials involve scrambling the pictures by pseudo-random line delays, while the sound is frequency inverted. There is no plan to institute such a system since it would need a new broadcasting act. A similar system, Discrét 12, is used in France.

Desktop weather maps are now available to subscribers of MicroLink, whose WeatherLink service receives images from the geosynchronous Meteosat which transmits true-colour pictures rather than the infra-red images available from NOAA in polar orbit. The images are distributed through the telephone line and can be received by most desktop computers with a modem.

Power transistors from Silicon Transistor Corporation are to be tested and packaged in the UK by Semiconductor Supplies International. This joint venture provides an alternative European source for 2N, Jedec, MJ and SDT devices under the trade name Silicon Transistor Europe. It also makes possible custom packaging and special selection of power devices for up to 100A.

Two PDP11 computers have been bought by the BBC for use with Radio Data Services. Initially, channel identification will be broadcast, with traffic flashes on some local stations.

PINEAPPLE SOFTWARE

Programs for the BBC model 'B', B+, Master and Master Compact with disc drive

DIAGRAM II

Diagram II is a completely new version of Pineapples popular 'Diagram' drawing software. The new version has a whole host of additional features which make it into the most powerful and yet quick to use drawing program available for the BBC micro. The new features mean that 'Diagram II' can now be used for all types of drawings, not just circuit diagrams. Scale drawings are possible and the facilities for producing circles and rubber banded lines together with the pixel drawing routines make any type of drawing possible. This advert has been produced completly using Diagram II.

Summary of Diagram II features:

1. Works on all model BBC computers and makes use of Shadow memory if poss.
2. Rapid line drawing routines with automatic joins for circuit diagrams.
3. Rubber band line and circle drawing modes.
4. Makes use of the Acorn GXR rom to produce ellipses, arcs, sectors, chords and flood filling.
5. Pixel drawing mode allows very fine detail to be added.
6. Defined areas of screen may be moved, copied, deleted or saved to disc.
7. On-screen cursor position indication allows scale drawings to be made.
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9. Wordprocessor files may be loaded and formatted into defined areas.
10. Up to 880 UDC's if shadow memory available, 381 without shadow.
11. Compatible with Marconi Trackerball and most makes of 'mouse'.
12. All 'Diagram Utilities' are included.
13. Completly scaleable print routines allow any area of the diagram to be printed either horizontally or through 90deg. in scales that may be varied in 1% steps allowing up to 18 mode 0 screens to be printed on an A4 sheet (still with readable text).
14. Smooth scrolling over the whole area of the diagram.

Diagram II consists of a set of disc files and a 16k Eprom. The disc is formatted 40T side 0 and 80T side 2. Please state if this is unsuitable for your system, or if you require a 3.5" Compact disc

DIAGRAM II – £55 + VAT p&p free

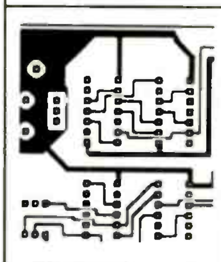
PCB

Pineapple's now famous PCB drafting aid produces complex double sided PCB's very rapidly using any model BBC micro and any FX compatible dot-matrix printer.

The program is supplied on Eprom and uses a mode 1 screen to display the two sides of the board in red and blue either separately or superimposed. Component layout screens are also produced for a silk screen mask.

The print routines allow a seperate printout of each side of the board in an expanded definition high contrast 1:1 or 2:1 scale. The print time is typically about 5 minutes, for a 1:1 print of a 7" ★ 5" board. This program has too many superb features to adequatly describe here, so please write or 'phone for more details and sample printouts.

Price £85.00 + VAT



PCB PLOTTER DRIVER

A new addition to the PCB software is the PCB plotter driver programe. This enables files produced by PCB to be used in conjunction with most types of plotter to produce plotted output rather than the normal dot-matrix printer output. The program is suitable for use with most makes of plotter including Hewlett Packard, Hitachi and Plotmate M. The program can also be configured to work other plotters by entering suitable plotter instructions.

All the features of the printer driver are included, such as the automatic thinning down of tracks between roundels. Mirror image plots are also available.

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AR8	1.15	EF86	1.25	PCL805/85	0.95	1A3	2.75	6CW4	7.40	12AT6	0.75
ARP3	1.15	EF89	1.60	PD500/510	4.30	1L4	0.65	6CX8	4.60	12AT7	0.95
ARP35	0.70	EF91	1.60	PFL200	1.10	1R5	0.80	6CY5	1.15	12AU7	0.95
ATP4	0.90	EF92	2.15	PFL200'	2.80	1S4	0.65	6D6	2.50	12AX7	0.75
B12H	6.90	EF95	0.95	PL36	1.10	1S5	0.75	6F6G	1.95	12BA6	1.40
CY31	1.40	EF96	0.60	PL81	0.85	1T4	0.75	6F6GB	1.10	12BE6	1.90
DAF70	1.75	EF183	0.75	PL82	0.70	1U4	0.80	6F7	2.80	12BH7	2.85
DAF96	0.90	EF184	0.75	PL83	0.60	2X2A	3.80	6F8G	0.85	12E1	19.95
DET22	32.80	EF812	0.75	PL84	0.90	3A4	0.70	6F12	1.50	12J5GT	0.55
DF92	0.65	EFL200	1.85	PL504	1.25	3A12	3.40	6F14	1.15	12K7GT	1.15
DF96	0.85	EH90	0.85	PL508	2.00	3B28	12.00	6F15	1.30	12K8GT	1.25
DH76	0.75	EL32	0.85	PL509	5.65	3B28'	19.50	6F17	3.10	12Q7GT	0.75
DL92	1.85	EL34	2.10	PL519	5.85	3D6	0.60	6F23	0.65	12SC7	0.80
DY86/87	0.65	EL34'	5.15	PL802SE	3.45	3E29	21.85	6F24	1.15	12SH7	1.25
DY802	0.70	EL82	0.70	PY80	0.70	3S4	1.85	6F33	10.50	12SJ7	1.40
E92CC	2.80	EL84	0.95	PY81/800	0.85	4B32	18.25	6FH8	18.80	12SK7	1.45
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E1148	0.58	EL90	1.75	PY88	0.60	5U4G	1.85	6GH8A	0.90	12Y4	0.70
EA76	1.60	EL91	6.50	PY500A	2.10	5V4G	0.75	6H6	1.60	13D3	2.80
EB34	0.70	EL95	1.25	QQV03/10	5.95	5Y3GT	0.95	6J4	1.95	13D6	0.90
EB91	0.60	EL504	2.70	QQV03/10'	7.50	5Z3	2.80	6J4WA	3.10	19AQ5	1.35
EBC33	1.85	EL509	5.85	QQV03/20A	27.50	5Z4G	1.25	6J5	2.30	19G3	11.50
EBC90	0.90	EL519	7.70	QQV06/40A	28.50	5Z4GT	1.15	6J5GT	0.90	19G6	10.35
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EBF89	0.80	ELL80SE	4.50	SP61	1.80	6AC7	1.15	6JE6C	8.10	20E1	1.30
EC52	0.65	EM80	0.80	TT21	37.50	6AG5	0.60	6JS6C	8.10	20P1	0.60
EC91	4.40	EM87	3.00	TT22	37.50	6AK5	0.95	6JU6	6.35	25L6GT	1.60
EC92	1.85	EY51	0.90	UABC80	0.75	6AK6	2.85	6K7	1.45	25Z4G	0.75
ECC81	0.95	EY81	0.75	UBF80	0.70	6AL5	0.60	6KD6	7.40	85A2	1.40
ECC82	0.95	EY86/87	0.60	UBF89	0.70	6AL5W	0.85	6L6	4.60	85A2'	2.55
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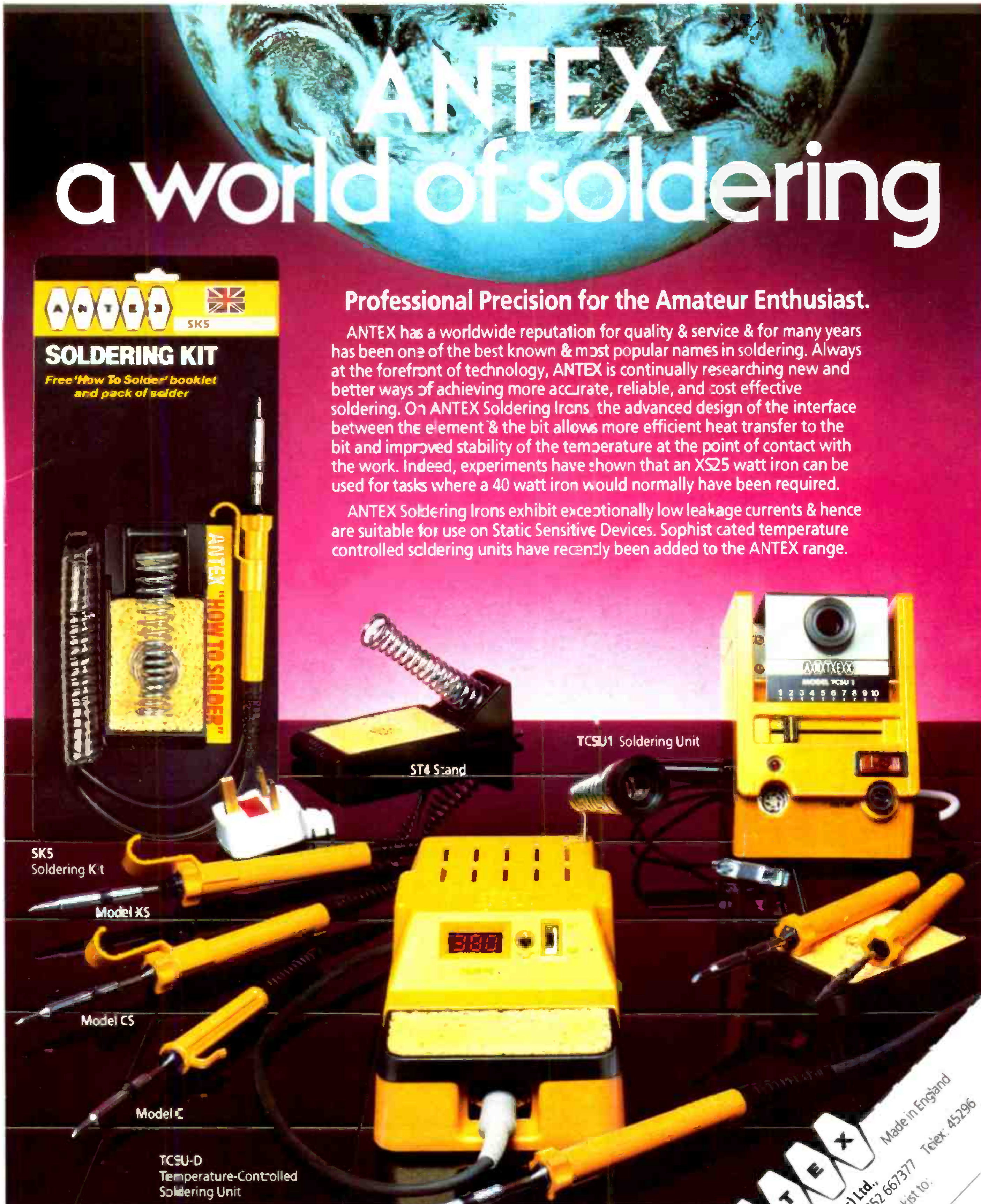

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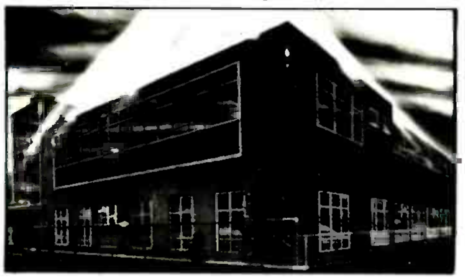

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