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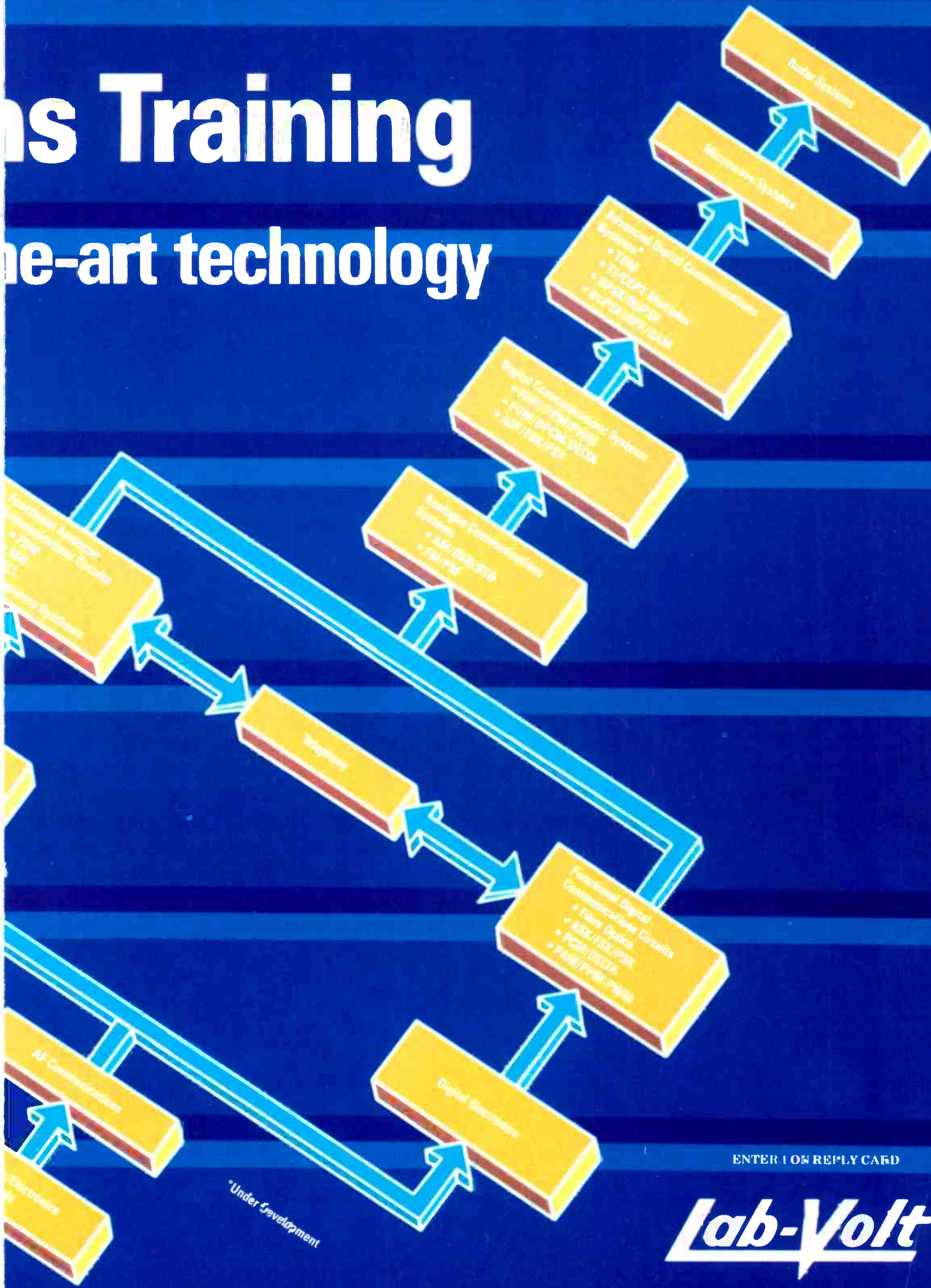

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January 26, 1989

AN OPEN LETTER FROM THE EDITOR

In the January issue of Electronics & Wireless World, my first as editor of our magazine, I wrote of changes in our magazine. They are starting to happen.

I intend that Electronics & Wireless World will cater fully for the new methods of design engineering by regularly reporting on industrial computer systems, software and the working environment. We also have in hand reviews of engineering software. We have made a start by considering the PC for datacomms and interface applications.

I also plan increased coverage of technology and research science. We bring you the definitive account of Wafer Scale Integration written by its British founding father, Ivor Catt. Future topics will include an alternative view of electromagnetics and a fundamental rethink of plasma science.

Our readers have always looked to us in the past for the broader view denied to controlled circulation journals. We won't disappoint them. In a word our philosophy adds up to entertainment.

Our bimonthly Industry Insight supplements which focus on established industry sectors have met with enthusiasm from both the industry and readers. We now intend to target areas of strategic development with in depth coverage on an alternate, bimonthly basis. We will also look at the personnel demands of new business through a series of regular employment features.

We have reported on the electronics industry since 1911. I look forward to combining our best traditions with the fullest acknowledgement of the changing world.

Yours sincerely

Frank Ogden
Editor

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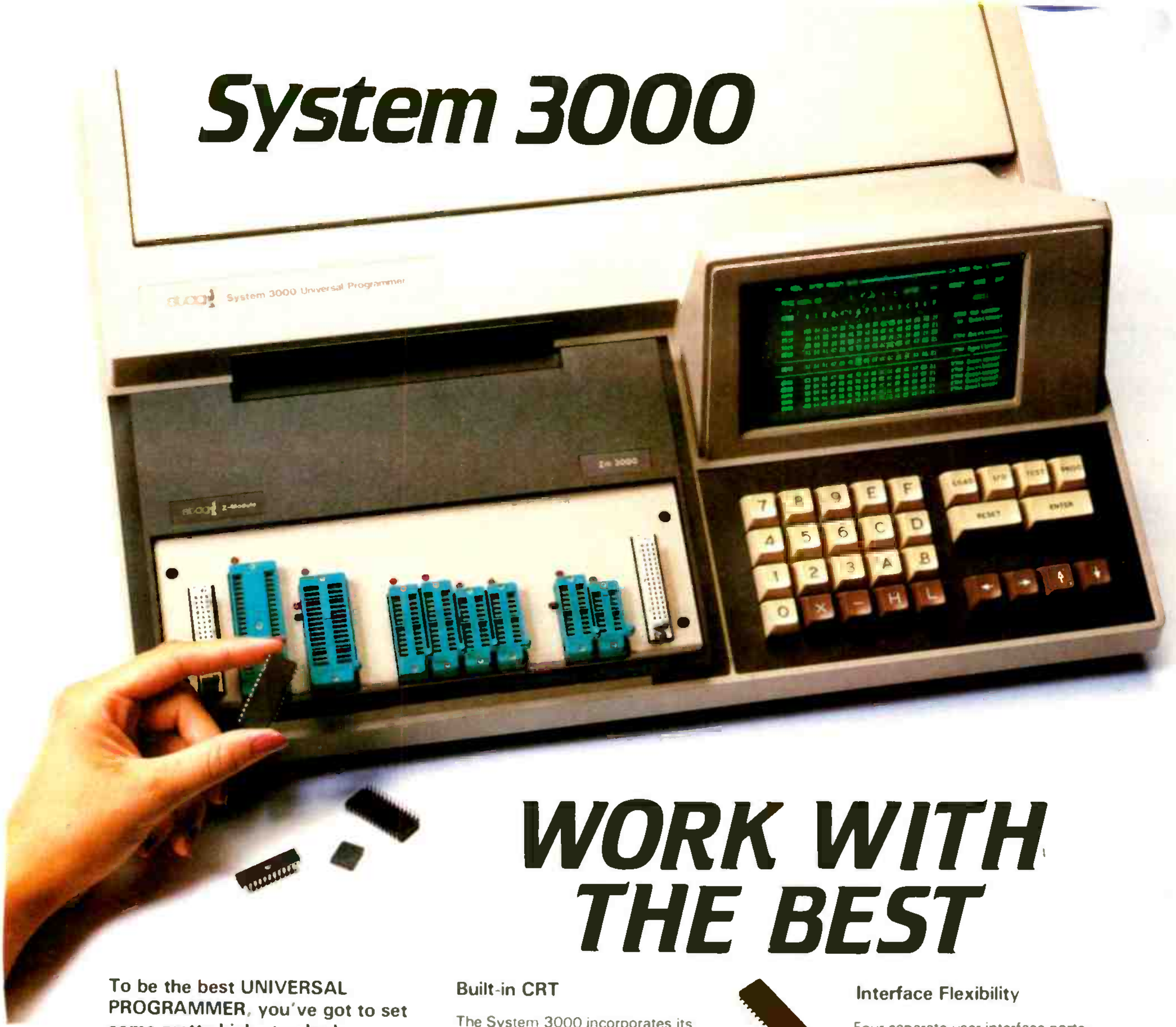
System 3000



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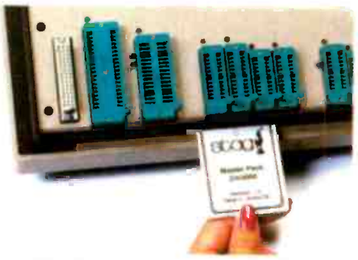

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COMMENT

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A cordless euphoria

The current euphoria over CT2 cordless telephones and telepoints (where these phones may be used to make to make calls away from one's home base) indicates that a revolution in personal communications is just around the corner. There is a danger, however, that the revolution may not turn out as the marketeers are predicting, leaving the marketplace (and the airwaves) in a state of confusion.

Telepoints are to be established as rapidly as possible, before a common air interface (CAI) is established and agreed. Initially, handsets will employ proprietary communications protocols and will work with only a single operator's base station network. Thus these early purchasers may find their CT2 phones are incompatible – *read* useless – if in future they change allegiance to another operator's network of telepoints.

It is assumed (but nowhere promised) that the cost of phoning from a telepoint will be little more than a normal payphone call, though how such charges will fund the cost of providing the base stations is not stated. Telepoint users with CT2 handsets will not be able receive incoming calls and the initial provision of telepoints will not meet user expectations, leading to frustration all round.

The target end-user price for a home system is £200-300, which means that manufacture may well be shifted to the Far East on cost grounds; indeed talks are already in progress. Costing the same as a video recorder, this price will look pretty poor value to private customers. On the other hand businessmen always rate convenience over price: they will continue to buy poserphones, which are already on sale at prices scarcely more than this.

On all counts, the vision of a CT2 and telepoint revolution starts to cloud. Even for cordless telephones for the home, the cost of CT2 is too high (compared with existing offerings), and the specifications do not match the proposed pan-European digital CT3 cordless telephone.

Meanwhile, cellular radio manufacturers are not going to allow a potential market to slip through their fingers. They will exploit the shortcomings of the telepoint concept and target a new 'bottom edge' market with cheaper phones. The only problem is that this will put even more pressure on the spectrum available to cellphone users, which is already operating at capacity in metropolitan areas. Final score: Users 0, Industry 0.

Electronics & Wireless World is published monthly USPS687540 By post, current issue £2 25, back issues (if available) £2 50 Order and payments to 301 *Electronics and Wireless World*, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS Cheques should be payable to Reed Business Publishing Ltd. **Editorial & Advertising offices:** *EWW* Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS **Telephones:** Editorial 01-661 3614. Advertising 01-661 3130 01-661 8469 **Telex:** 892084 REED BP G (EEP) **Facsimile:** 01-661 3948 (Groups II & III) **Beeline:** 01-661 8978 or 01-661 8986 300 baud, 7 data bits, even parity, one stop-bit. Send ctrl-Q, then EWW to start, NNNN to sign off **Newstrade** – Quadrant Publishing Services No 01-661 3240 **Subscription rates:** 1 year (normal rate) £23 40 UK and £28 50 outside UK **Subscriptions:** Quadrant Subscription Services, Oakfield House, Perrymount Road, Haywards Heath, Sussex RH16 3DH Telephone 0444 441212 Please notify a change of address **USA: $116 00** airmail Reed Business Publishing (USA) Subscriptions Office, 205 E 42nd Street, NY 10117 **Overseas advertising agents: France and Belgium:** Pierre Mussard, 18-20 Place de la Madeleine, Paris 75008 **United States of America:** Jay Feinman, Reed Business Publishing Ltd, 205 East 42nd Street, New York, NY 10017 Telephone (212) 867-2080 Telex 23827 **USA mailing agents:** Mercury Airfreight International Ltd, Inc., 10(b) Englehard Ave, Avenel N J 07001 2nd class postage paid at Rahway NJ Postmaster – send address to the above

 ISSN 0266-3244

Chip repair by laser

The use of a 20W argon ion laser to repair a fully packaged c-mos prototype chip is reported by a team at University College London and at King's College London (*Electronics Letters* Vol.24 No 24). Prior to this work such experiments have only been undertaken on partially fabricated circuits at strategic points during manufacture.

The chip to be repaired in this instance was an application-specific VLSI prototype that contained a superfluous aluminium link. This link, the result of a design error, prevented the operation of the chip's clock and hence made it impossible to troubleshoot the remainder of the circuit. Normally it would have been necessary to fabricate a new chip before proceeding with the functional checking procedure, so each error discovered would have meant a re-design.

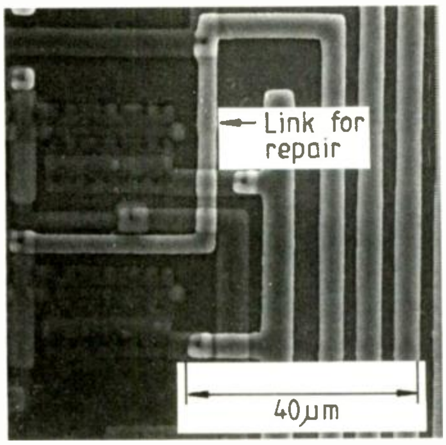
To remove the spurious aluminium link the protective plastic packaging was first removed using an unfocussed laser beam of around 2mm diameter, with the chip immersed in 98% sulphuric acid. In the presence of the laser beam, the acid slowly etched away the plastic, exposing the active surface of the chip. Then the chip was removed from the acid and the laser focussed through a microscope objective lens to produce a 10μm spot of blue/green light on the aluminium link to be removed.

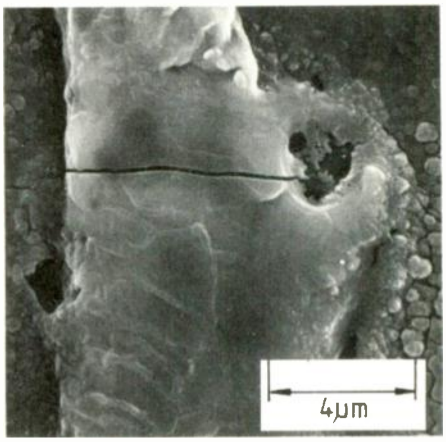
In the presence of this high-intensity laser illumination the aluminium loses its protective layer and reacts readily with oxygen in the silicon dioxide of the chip's surface. The London group found moreover that the reaction automatically stops when all the aluminium has been oxidized.

When the chip had been washed and examined, micro-cracks were found across the width of the oxide left behind by the aluminium. As yet it's not known whether it's these cracks or the oxidation *per se* that leads to the electrical open circuiting of the link. Either way an effective open circuit had been achieved and the chip's clock mechanism made to function.

Research is now in progress to optimize the process and to develop a complementary technique for depositing links where they've inadvertently been omitted during the design stage. When both techniques have been perfected they should find wide application, not only in prototyping, but in deliberate procedures such as gate array interconnection or the development of wafer-scale ics.

Aluminium link before (left) and after (right) laser treatment: note the oxidation and micro-cracking.





Safer in-circuit IC testing

In establishing the validity or safety of test procedures it is often necessary to stress components in ways that would not be encountered during normal operation. This is especially true when components are tested *in situ* on a printed circuit board. By means of a so-called 'bed of nails' spring-loaded multi-contact test probe it is easy to test a digital IC in every possible input and output configuration. The only problem is that an applied logic level which is safe for the device under test may be damaging to another chip connected to it elsewhere on the board.

In the absence of manufacturers' data on the effects of backdriving, as it is called, ICL have sponsored a number of different studies on a variety of IC families, mostly TTL. Their latest one [*ICL Technical Journal* vol.6 No 2], undertaken jointly with Loughborough University of Technology, investigated the effects of backdriving surface-mounted high-speed devices. Accelerated life tests were conducted on 74LS245, 74F245, and 74AS245 chips (bi-directional transceivers from low power Schottky, fast TTL and advanced Schottky families respectively).

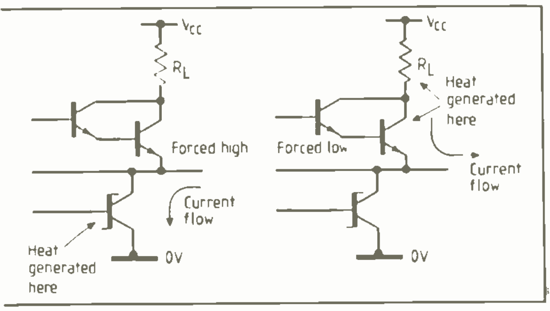
The principal aim of the study was to discover if permanent damage was likely to be caused by localized heating when a logic '0' or logic '1' level was fed back into the output pins of a particular chip. Obviously in certain configurations the heat generated is likely to be intense, especially as in the cases illustrated on the left.

The localized temperatures of the critical junctions were measured in an ingenious way making use of closely associated diodes. Although these diodes are primarily designed to prevent reverse bias or device saturation they make ideal temperature sensors because their forward voltage is linearly proportional to junction temperature.

Obviously, in the case of the configuration shown here, it is not possible to apply a continuous backdrive without burning out the lower transistor. The tests therefore employed 4.5V pulses of 20ms spaced by 2s, i.e. a 100:1 duty cycle.

95 devices were subject to 25 such pulses and later compared to 95 control devices in a 2000 hour accelerated life test at 125°C.

The failure rate in the backdriven group was shown, if anything, to be marginally lower than in the non-backdriven group. ICL conclude therefore that even small surface-mounted TTL packages can be safely tested in-circuit as long as the mark/space ratio of the testing pulses is kept at a suitable value around 100:1. Of the three logic families they found that the fast (74F245) devices heated up most and hence took longer to cool after a test pulse.



Left: normally low output driven high; right, normally high output driven low.

RESEARCH NOTES

R.I.P. fifth and sixth forces

Evidence has previously been presented in these pages (June, 1988) for the existence of the so-called fifth and sixth forces in Nature. Hitherto every interaction had been ascribed to one of four well known forces: the electromagnetic force, the weak nuclear force, the strong nuclear force and gravity.

Belief in the existence of further elusive natural forces emerged when certain experiments showed what appeared to be anomalies in highly sensitive measurements of gravity. In 1986, Ephraim Fischbach of Purdue University analysed some old experimental results and concluded that there must be a fifth force, intermediate in nature and operating over a range of between 10 and 1000 metres. Such a force appeared in the the calculations as a sort of negative form of gravity.

Later experiments down a drill hole in Greenland pack ice, up a TV tower in North Carolina and down a mine in Australia seemed to add weight to the evidence for a fifth force and also suggest the existence of a sixth force. This latter appeared to boost gravitational attraction by up to 4% over a range of 500 to 1700 metres.

Now it seems that the fifth and sixth force theories are being debunked by some of the very scientists who invented them. In a new analysis presented to a meeting of the American Geophysical Union, a team from the Los Alamos Laboratory, the Scripps Institute of Oceanography and AT&T Bell Laboratories in New Jersey claim that the Greenland experiment was flawed because it failed to take into account variations in the density of the rock beneath the ice. They add that, in their opinion, there is still no convincing evidence for any more than four natural forces.

AT&T workers now plan to repeat some of the gravity measurements within the homogeneous environment of the sea, which should circumvent the present objections and settle once and for all the question of whether or not there are more than four forces in Nature. If there are, then it will change our understanding of what went on in those first few microseconds of time in which all the processes of physics emerged from a single primaeval force. If, on the other hand, the fifth and sixth forces don't exist, then physicists will have a much harder time in their search for a grand unified theory, a mathematical process that will elegantly link together everything from the behaviour of an electron to the immensity of gravitational attraction across whole galaxies.

Sun on the boil

Solar activity is likely to reach an all-time high sometime late this year. According to Kenneth Schatten, a research astrophysicist at the NASA Goddard Space Flight Centre, solar cycle No 22 will probably be the most active in terms of sunspots and flares since the time of Galileo nearly 400 years ago.

Schatten and his co-workers who've been monitoring the latest of the 11-year cycles of solar activity, say that since it began in September 1986 this cycle has so far exceeded cycle 19, the most active previously recorded.

Although sunspots and flares are only observable using special viewing devices (DON'T use a telescope even with a dark filter – it probably won't be opaque to harmful UV), they can nevertheless have a dramatic effect on satellites, on HF communications and even on the weather.

Most radio enthusiasts are all too familiar with the ways in which enhanced solar activity can temporarily destroy the ability of the ionosphere to refract HF signals. The result can often be a complete radio blackout for several hours or days at a time. Even at VHF, line-of-sight transmissions may be affected by the considerable increase in solar noise emission at these frequencies.

Enhanced solar activity may be a nuisance for radio enthusiasts but it can be of critical importance to the operators of military surveillance satellites. Such satellites, which operate in the lowest possible orbits in order to get a clear view of the Earth's surface, are peculiarly vulnerable to the effects of the Sun's radiation on the atmosphere. When this exceeds its baseline value, it causes the atmosphere to expand and hence extend to a greater height above the ground. As a result, a satellite that was previously orbiting in a good vacuum is now subject to a dangerous amount of atmosphere drag that could cause it to re-enter. Satellite operators, when they can, therefore have to boost their craft into a higher orbit until such time as the Sun's activity subsides. (During solar cycle 21 it was unexpected flares that caused Skylab to re-enter the atmosphere prematurely over Western Australia.)

For most of us, however, falling satellites are likely to present no great hazard. The most we're likely to see on a dark night is a more than usually spectacular aurora.

Good vibrations

'Anti-sound' is now a recognised technique for creating a bit of hush in certain industrial environments. The idea is to pick up the sound emitted by a piece of machinery, invert the phase and then use a loudspeaker to create an equal and opposite sound. If the compressions and rarefactions in the air cancel each other out, then theoretically at least there should be silence.

The fact that anti-sound techniques get more efficient as the frequency is lowered has led the Japanese Kajima Corporation to develop a system to counteract some of the world's most powerful infra-sonic vibrations, namely earthquakes.

Kajima's anti-quake system works on much the same principle as anti-sound. The only real difference is the output device is not some mega-loudspeaker but a system of massive weights on wheels, running on tracks along the top of a building. These weights, of a ton or more, can be moved back and forth rapidly by hydraulic actuators driven by computers linked to vibration sensors elsewhere in the building. The idea is that, if an earthquake should set the building wobbling, the sensors will pick up the motion and instruct the system to set the huge roof-top weights vibrating in the opposite phase.

The company, which plans to install an anti-quake system in an 11-storey building in Tokyo early this year claims that it should reduce the severity of a magnitude-4 earthquake by up to 75%. Similar reductions are also expected in movements induced by the buffeting effects of high winds.

In answer to the obvious question of what happens if the system gets out of control, Kajima admit that a small error of system timing could indeed turn a minor quake into a major disaster by amplifying the vibrations! For that reason they've built into the software a fail-safe program that will kill the power if things get out of hand. . . .

Research Notes is written by John Wilson of the BBC World Service's science unit.

High temperature IR optics

By reducing the bulk resistivity of germanium used in the manufacture of infra red optical systems, the temperature at which the optics may be successfully used has been extended to the 50 to 100°C range.

According to the manufacturer Pilkington normal germanium becomes IR opaque at elevated temperatures because, being a semiconductor, the number of free carriers increases rapidly with temperature. The electrons hanging about the lattice interfere with transmission. Introducing a dopant to the germanium reduces the resistivity, sweeping up the free carriers.

Transatlantic optical cable

The world's first transatlantic optical fibre cable, capable of carrying 40 000 simultaneous telephone conversations has now been placed in service.

The result of a joint venture between BT, AT&T and France Telecomm, the TAT-8 cable will transmit data, voice and video.

The main cable consists of six strands of fibre; two pairs carry the traffic with the third pair provided for back-up. It uses repeaters placed at 55km intervals along the ocean floor. The cable is actually buried one metre under the sea bed at depths of up to 3200ft. It relies purely on its steel armour at greater depths: it will resist biting sharks at depths down to 8500ft below sea level.

There are many interesting facts and figures associated with the cable. Each fibre pair has a data rate of 280Mbit/s. The power line to the 120 repeaters runs at 15kV with a corresponding line current of 1.6A, the operating wavelength is 1.3μm and the branching unit for the England/France junction is located some 400km from the European coast in 7000ft of water. The British branch comes ashore at Widemouth Bay, North Cornwall (pictured in *E&WW*, April 1988, p.406).

Millimetric transistor

An HEMT device specified for use up to 60GHz is now offered by Toshiba. Designed for satellite communications systems, the JS8903-AS high electron mobility GaAsfet has a gate length of 0.25μm and a gate width reduced from 100 to 120μm. The effect is to reduce capacitance and increase inductance making the device easier to match at high frequencies. The transistor returns a claimed noise performance of 1.2dB at 18GHz with an associated gain of 8.5dB.

An HEMT is a lattice matched heterojunction formed between GaAs and AlGaAs semiconductors. Electrons move from the donor AlGaAs forming a thin two-dimensional electron gas at the heterojunction interface. The spatial separation of the conduction electrons from their parent donor impurities produces their high mobility. Normally a thin layer of AlGaAs adjacent to the heterojunction interface is left undoped to separate further the ionized centres.

VLSI chip plant

NEC plans to spend $282 million on a new 4Mbyte dram wafer fab in Higashi, Hiroshima. The plant is designed to turn round 30 000 6in wafers per month with submicron process geometry. 1Mbyte static rams will also feature in the product portfolio. It expects first production in 1990.

Balloon amateur fined £2500

A radio amateur who worked for the Ministry of Defence admitted breaking into police frequencies and helping another radio ham interfere with United States Navy signals.

Michael Holland, of Pollards Hill North, Norbury, was also said at Croydon Magistrates' Court to have attached a radio transmitter to a balloon.

Holland, a 24-year old electronics engineer, pleaded guilty to seven charges under the Wireless Telegraphy Act.

Mr Jonathan Davies, prosecuting, said that Holland, who had worked for a weapons research establishment, was the subject of a massive investigation mounted by the police and the MoD which had cost £48 000.

He had used frequencies of an extremely sensitive nature, including some that were not published. He had frequencies for many police stations. He had also failed to give and acknowledge a call sign, and had not logged his conversations.

Holland also admitted attaching a transmitter to a helium balloon, obtaining and giving information, and aiding and abetting a member of his radio group to interfere with United States Navy signals.

Many of the frequencies had now had to be changed, said the prosecution. When spoken to in the course of the investigation, Holland said "I have tuned around".

Miss Debra Gold, defending, said that Holland did have a licence for using his radio equipment. He was an amateur radio enthusiast, in fact his social life revolved around short wave radio.

"He had no ulterior motives, and failed to see the harm his actions could have caused", she said.

He started off keeping to all the rules, but became lax as time went by. He was in a group of about five people who communicated with each other through the airwaves.

They did not use a call sign amongst themselves, which they should have done, and they failed to log conversations.

Regarding the balloon attached to the transmitter, this was for "meteorological research." This idea was to monitor atmospheric temperature changes for the group's own interest.

The information received and given was purely of social interest. They did listen to police calls and discussed them amongst themselves.

continued on page 223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Maxwell's equations and the Crossed-field Antenna

Reversing the form of Maxwell's equations has led to the realisation and development of a revolutionary new antenna system.

F.M. KABBARY, M.C. HATELY and B.G. STEWART

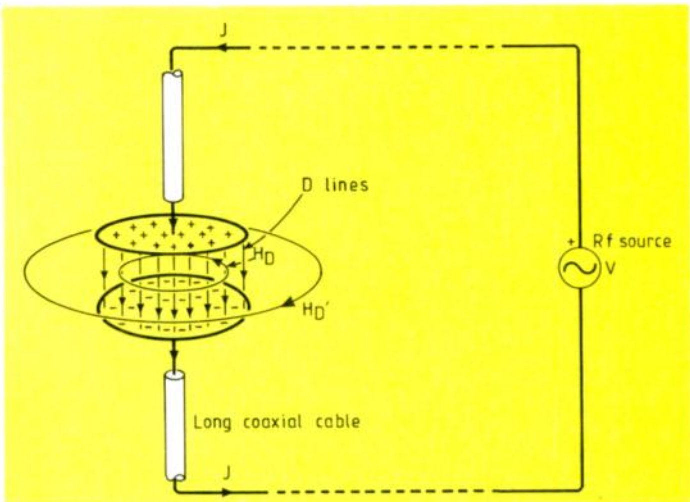

Fig.1. Circular capacitor plates showing the surrounding magnetic fields when applied with a sinusoidal voltage V.

All electrical and communications engineers are in some way acquainted with Heaviside's differential form of the third and fourth Maxwell equations, viz

$$\nabla \times \mathbf{E} = -\mathbf{B}' \quad (1)$$
$$\nabla \times \mathbf{H} = \mathbf{J} + \mathbf{D}' \quad (2)$$

In these equations ' is the derivative with respect to time, **E** represents the electric field strength, **H** magnetic field strength, **J** current density, **B** magnetic flux density = μ**H**, and **D** electric displacement = ϵ **E**. **D**' is called the displacement current. Equation (1) is Faraday's Law, while equation (2) is credited to Maxwell for adding **D**' to Ampere's Law, $\nabla \times \mathbf{H} = \mathbf{J}$, to maintain charge conservation or charge continuity and thus obtain **J** + **D**' as the true or total current[1].

Unfortunately, the understanding of these equations still poses many conceptual difficulties for many people which inevitably lead to shortcomings in the basic understanding of their engineering applications. One reason for this lack of insight is perhaps the inability to appreciate the physical meaning of the vector operations curl, div and grad. Many texts and research papers often detail the mathematical intricacies of these vector operations but few describe in simple practical terms their physical interpretation[2].

In addition to the above, it is often not realised that contained in equations (1) and (2) is the following extremely valuable information: (a) a time-varying magnetic field creates an electric field (or back EMF) and, importantly, (b) a current *or* a time-varying electric field *or* both will create a magnetic field.

The essence of Maxwell's equations, conveyed through points (a) and (b), is that fundamentally they are reaction or field-production equations. The physical, mathematical and engineering importance of the field-production nature may be more readily relayed and understood if the forms of equations (1) and (2) are reversed(

$$\mathbf{B}' \Rightarrow -\nabla \times \mathbf{E} \quad (3)$$
$$\mathbf{J} + \mathbf{D}' \Rightarrow \nabla \times \mathbf{H} \quad (4)$$

The reversal leads not only to a greater understanding of Maxwell's equations (which is hidden in the non-reversed form) but to a greater appreciation of the nature of time-varying electromagnetics and their associated engineering applications.

One significant engineering application, only fully realised through the reversed form of Maxwell's 4th equation, has been the recent development of revolutionary antenna systems called crossed-field-anntennas[3] (CFA) which synthesize directly the Poynting vector **S** = **E** × **H** from separately stimulated **E** and **H** fields. A fundamental feature of these antennas is that the physical size of the structure is small and also independent of the radiated wavelength, a truly remarkable concept in relation to present antenna theory and design techniques.

REVERSING THE MAXWELL EQUATIONS

The principle of Faraday's Law, equation (1) as detailed by most textbooks, is that an electric field can be related to the rate of change of a magnetic field. This electromagnetic feature can be expressed in a more elegant and informative way by reversing equation (1) to give

$$\mathbf{B}' \Rightarrow -\nabla \times \mathbf{E}$$

which is interpreted as a time varying magnetic flux, **B**', creating an electric field **E** such that the negative of the curl of the induced **E** field distribution is equal to the source **B**'. The directive arrow is present in the relationship to indicate that the left-hand-side causes or creates the right-hand-side. The negative sign is the manifestation of Lenz's law. In fact the application of the reversed form of Faraday's law is fully deployed in transformer theory, where a time-varying magnetic flux creates, i.e. induces, a back EMF. Note that the **E** field in the reversed form of Faraday's Law is the induced **E** field from **B**' and is not in any way related to the independent electric field created from free charge through Gauss's Law.

Consider now equation (2). In magnetostatics, it has always been accepted that current produces a magnetic field through the phenomenon called Ampère's Law. To get across the importance of this statement in a more meaningful physical and mathematical form, Ampere's Law should be expressed as

$$\mathbf{J} \Rightarrow \nabla \times \mathbf{H} \quad (5)$$

i.e. **J** creates a magnetic field **H**, such that the curl of H is equal to the source J. It is also known (though often ignored) that a magnetic field may be related to either a current as above, *or* a time-varying electric field[1]. The latter source of magnetic field is sometimes referred to as the Maxwell Law[4], and may be expressed in the more informative reversed form as

$$\mathbf{D}' \doteq \nabla \times \mathbf{H} \qquad (6)$$

i.e. displacement current D′ (a time-varying D field) creates a magnetic field H such that the curl of the H field distribution is equal to the source D′. We see now the importance of reversing equation (2) to give equation (4), i.e. $\mathbf{J} + \mathbf{D}' \doteq \nabla \times \mathbf{H}$ which should now be interpreted as J or D′ or both can create a magnetic field H such that the curl of the H field distribution is equal to the source J + D′. The plus sign can, and should, be interpreted as analogous to the digital-logic OR symbol.

Unfortunately, many people fail to realise that an H field may at any time be the combination of two separately induced fields from independent types of sources, i.e. charge motion *and* displacement current.

THE MAGNETIC FIELD ASSOCIATED WITH A SIMPLE CAPACITOR

To illustrate the importance of the reversed form of Maxwell's 4th equation and, in particular, the feature of D′ creating an independent magnetic field from J, consider the practical illustration of circular capacitor plates. Consider circular capacitor plates (**Fig.1**) with an applied sinusoidal voltage V. Free charges flowing into and out of the capacitor, and also within the capacitor plates themselves, are a source of J. Also, due to the build up of free charge in the capacitor, E lines and therefore D lines exist between the capacitor plates. The waveforms of V, J and D are shown in **Fig.2.** Note that D follows V, while J is 90° phase-advanced from V. As the D lines vary in strength due to sinusoidal charge variation on the plates, D′ will create a sinusoidal magnetic field through $\mathbf{D}' \doteq \nabla \times \mathbf{H}_{D'}$. Since $H_{D'}$ is in time-phase with D′ then $H_{D'}$ is 90° phase-advanced from D. Also, since J flowing into and out of the plates is sinusoidal then $\mathbf{J} \doteq \nabla \times \mathbf{H}_J$ produces a sinusoidal magnetic field H_J which is in-phase with J. It is easy to show that in the vicinity surrounding the capacitor gap the magnetic field lines from J into and out of the plates and the magnetic field lines from D′ will be concentric circles surrounding the gap and in-phase.

Now, J flowing within the plates themselves will create a magnetic field H_P. Applying the rules of Biot-Savart to the geometry of the plates, many components of magnetic field produced from individual J contributions within the plates will cancel, resulting in reduced-strength circular field lines surrounding the plates. We should expect the created field H_P to be in phase with H_J, but taking into account the geometry and the current motion within the plates, then H_P is directed in the opposite direction to H_J. This is equivalent to a 180° phase change between H_P and H_J. The waveforms of H_J, $H_{D'}$ and H_P surrounding the capacitor gap are given in Fig.2.

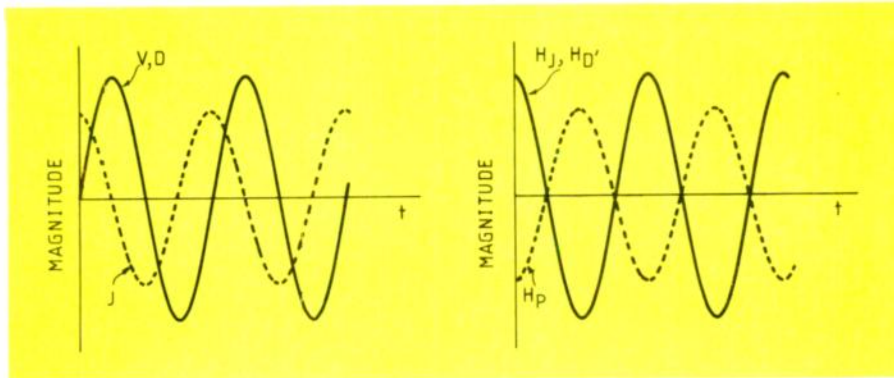

Fig.2. The waveforms of V, D, J and H_J $H_{D'}$, and H_P.

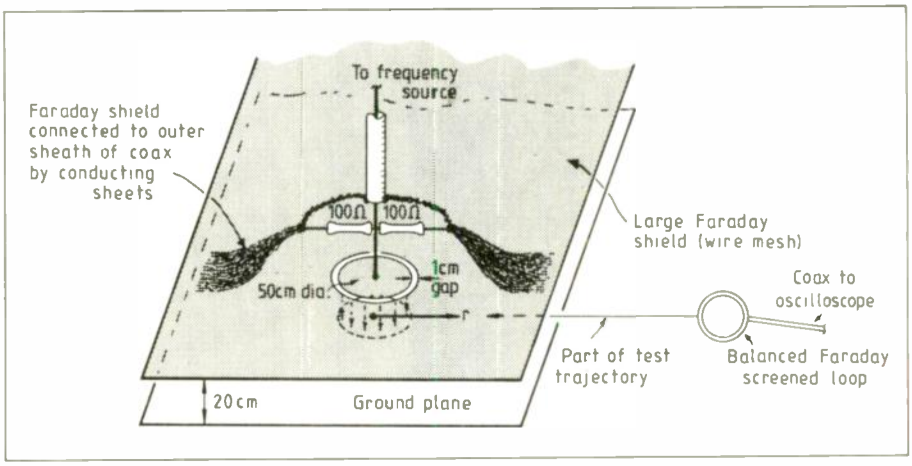

Fig.3. Experimental set-up to measure the magnetic field surrounding "large circular capacitor plates.

A simple experiment may be carried out to verify that $H_{D'}$ does exist surrounding circular capacitor plates. The main equipment required is an RF signal source capable of supplying a frequency range of 10 MHz – 100 MHz with an output voltage up to 20 V and an output current up to 3A, and secondly a triggered, dual-beam oscilloscope.

EXPERIMENTAL SET UP

As shown in **Fig. 3**, two circular, flat-plate conductors (made from wire mesh) of radius 25 cm were positioned as a capacitor with an air gap of approximately 20 cm. The capacitor was placed on top of a large conducting ground sheet. The top plate was then connected to a signal coax. cable terminated by two 100Ω resistors paralleled between the live inner-core and the outer sheath. The entire volume surrounding the capacitor gap was then Faraday shielded using a second large conducting sheet such that no H_J contributions from the connecting coax. cable could extend into the region around the capacitor gap. The Faraday shield is also connected to the outer-sheath of the coax. The magnetic fields within and surrounding the capacitor were measured using a circular, balanced, Faraday-screened coax. loop of radius 6 cm (**Fig. 4**), which was connected and matched to one of the inputs of the oscilloscope, thus eliminating standing wave problems on the leads. To provide a reference phase signal for the measured magnetic fields from the Faraday loop, a small resistor, 4.7Ω, was placed in the live coax. lead at the signal source, and the voltage monitored across the resistor using the second input to the osciloscope. This signal also gives phase information of H_J.

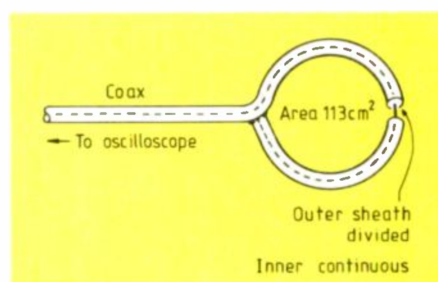

Fig.4. Balanced Faraday screened loop.

Results. A pk-pk voltage of 15 V was chosen, at a frequency of 40 MHz (λ = 7.5m). The voltage across the plates was approximately 8V. Positioning the Faraday loop in the middle between the plates, the measured voltage and phase from the loop as a function of distance r from the centre of the plates is shown in **Fig.5**. Referenced to H_J (taking into account path length, etc.) then between the plates H_P is strongest even though mutual effects will always exist between the loop and the plates. Moving outwards, H_P decreases and H_D takes over, hence the 180 phase change. The cross-over takes place near the edge of the plates. Outside the capacitor plates the magnetic field is therefore due mainly to D′ between the plates.

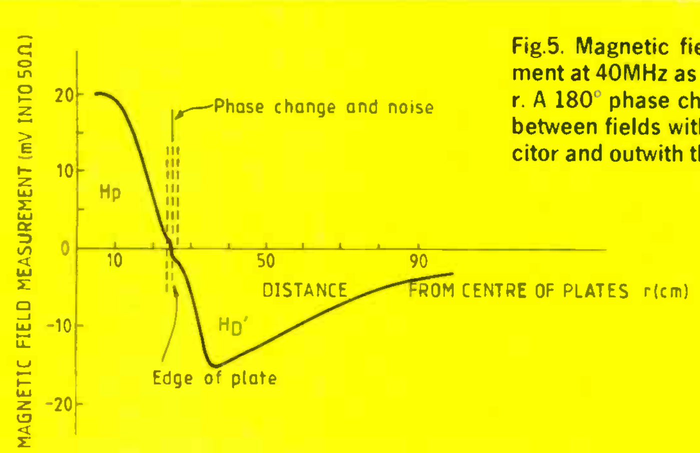

Fig.5. Magnetic field measurement at 40MHz as a function of r. A 180° phase change is seen between fields within the capacitor and outwith the capacitor.

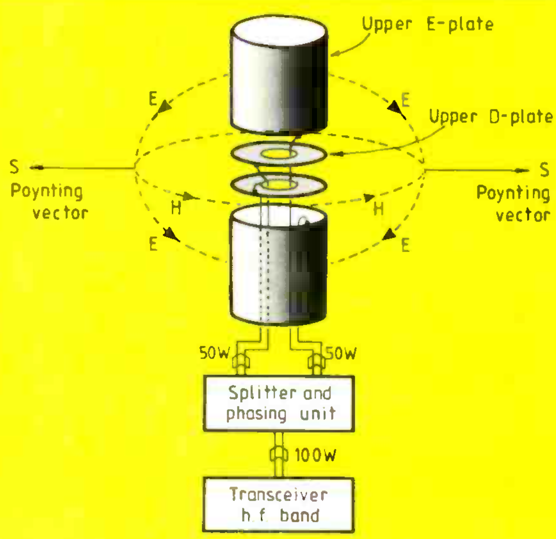

Fig.6. The "barrel-shaped" crossed-field-antenna (CFA).

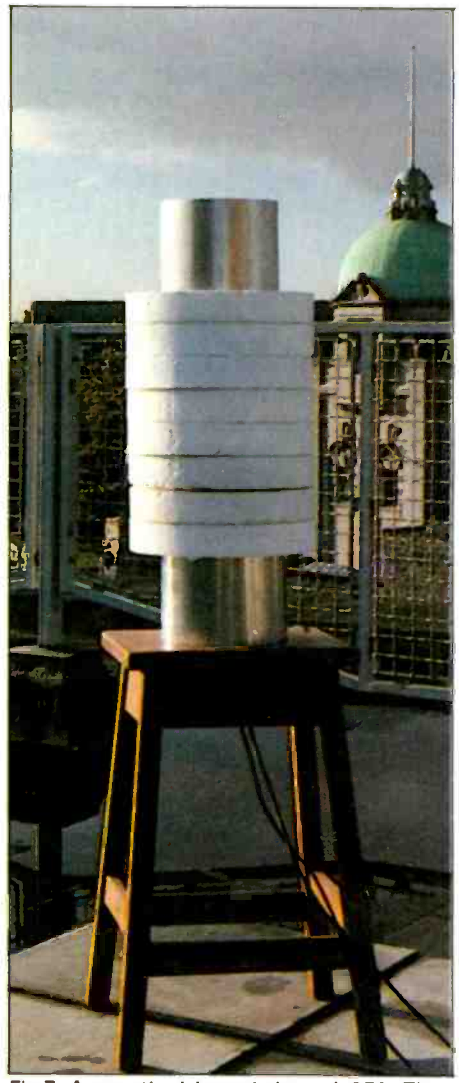

Fig.7. A practical barrel-shaped CFA. The length of this particular structure is 70cm.

This simple experiment provides proof not only that the Maxwell law $\mathbf{D}' = \nabla \times \mathbf{H}_D$ is functioning between the capacitor plates, but that **D'** is an additional and significant source of magnetic field surrounding circular capacitor plates at high frequency. Though some textbooks comment on the existence of **D'** within capacitor plates, the authors fail to realise that it creates its own magnetic field which can extend well outside the capacitor plates.

CROSSED-FIELD-ANTENNAS

From the experimental verification of **D'** within large circular capacitor plates, producing a surrounding magnetic field distribution, a revolutionary engineering design of antennas has now been developed in which the Poynting vector $\mathbf{S} = \mathbf{E} \times \mathbf{H}$ is directly synthesized by separate **E** and **H** field stimulus within a very small volume. These antennas are called crossed-field antennas[3] (CFAs). Success with the CFA systems can be said to be a direct consequence of the perception of reversing in particular the 4th Maxwell equation to gain a full understanding of the physical reaction or field production nature. A brief description of the operation of one particular CFA design, the "barrel-shaped CFA", **(Fig.6)** is given below (see also photograph **Fig.7**).

"Large" circular capacitor plates when supplied with high voltage will produce *strong circular* magnetic fields around the plates through $\mathbf{D}' = \nabla \times \mathbf{H}$. In the antenna these capacitor plates are referred to as the **D**-plates. Two large cylindrical plates of short length but the same radius as the capacitor plates are positioned one above and one below the **D**-plates. When the cylinders are driven by an RF power source they produce high-frequency **E** lines (due to voltage difference) between the plates. These cylindrical plates are therefore called the **E**-plates. (Note that they are analogous to the arms of a dipole antenna but *much smaller* in length than in any practical dipole, sometimes $< \lambda/200$.) The power from the transmitter is split roughly in half between the **E**-plates and the **D**-plates. Through suitable design considerations and delay arrangements between the **E** and **D** plate voltages, a toroidal volume surrounding the **D**-plates is crossed-stressed with in-phase **E** and **H** field components such that $|\mathbf{E}|/|\mathbf{H}|$ matches space impedance. Radiation is then produced through $\mathbf{S} = \mathbf{E} \times \mathbf{H}$ and power flows out to space as vertically polarized radio waves of intense power density.

The important features of these antennas are (i) that they are extremely small, excellent receivers, powerful, efficient radiators, and (ii) that their physical size is independent of the radiated wavelength – an *unprecedented* concept in antenna theory and design. All textbooks on antenna theory suggest that radiation is initiated solely by conduction current flow **J**. In the CFA, the radiation is not produced from fields related to **J** but from space electric fields created from voltage build up. In addition, though the CFA is small, it is not restricted to the limitations of narrow bandwidth, a critical feature of all other inductively or capacitively shortened antennas; the measured operating bandwidth on transmitting and receiving in most CFA systems is greater than 30%. In fact there also appears to be no restriction in the physical size of CFAs and they can be made as small as desired.

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3. M.C. Hately & F.M. Kabbary "Twin-Feeder Crossed-Field-Antenna Systems", UK patent application 8802204 February 1988.
4. G.B. Walker, "The axioms underlying Maxwell's electromagnetic equations", *Am.J.Phys*. 53, 1985.

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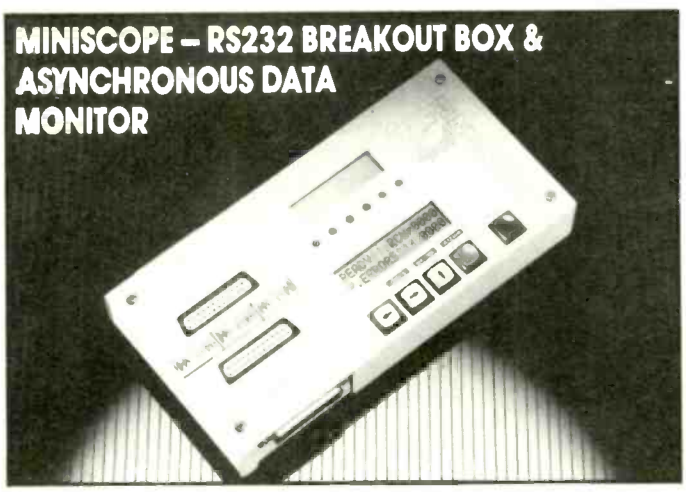

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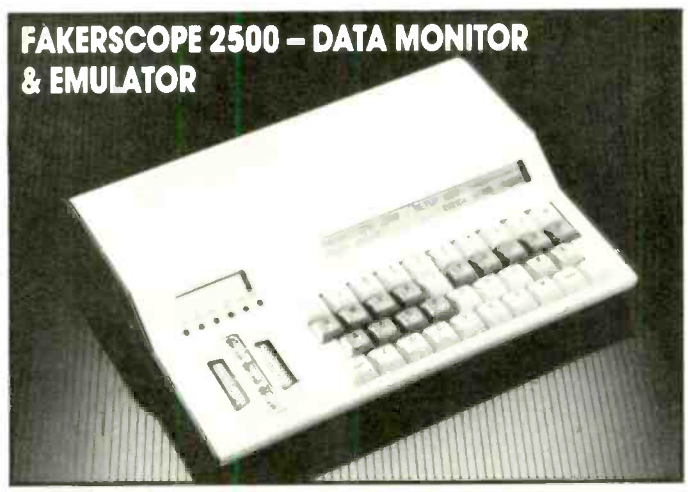

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PIONEERS

27. Harry Nyquist (1889-1976) and Hendrik Bode (1905-1982): from networks and noise to NASA.

The names of Nyquist and Bode go together like peaches and cream and are often paired in textbooks dealing with the theory of stability in linear networks. Unlike some other paired names (such as Thévenin and Norton, for example, who lived in different continents and at different times) Nyquist and Bode knew each other and worked in the same company laboratories on the same types of problem.

The laboratories were those of Bell Telephone in America and the pair's best known contributions, on amplifier stabilization, were the mathematical completion of the breakthrough begun in 1927 by their colleague Harry Black with his invention of the negative-feedback amplifier, described last month.

But both Nyquist and Bode did far more than their epic work on stability criteria and the mathematical design of feedback amplifiers. They worked through a period which might well be regarded as the classical period of network analysis and synthesis in telecommunications design and they worked with other giants of the period: George Campbell, John Carson, R. V. L. Hartley, E. H. Colpitts, Claude Shannon, and many more.

HARRY NYQUIST

Harry Nyquist was born at Nilsby in Sweden, a hundred years ago on 7 February 1889; his family name was originally Nykvist. When he died in 1976, at the age of 87, he was survived in Sweden by two sisters and a brother, the brother still living at Nilsby.

Emigration to the United States beckoned and at the age of eighteen he settled in Minnesota, west of the Great Lakes, where he worked for a time as a school teacher. He entered university education late, graduating from the University of North Dakota at the age of 26 with a degree in electrical engineering. He followed that with a Master's degree the next year and transferred to Yale University, where he received his Ph.D. in 1917.

The American Telegraph & Telephone Co. (AT&T) offered him a position at their Engineering Headquarters in 1917, some seven or eight years before the Bell Telephone Labs were formed. There he stayed until his transfer to Bell Labs in 1934.

In all, he spent 37 years in the Bell System until his retirement in 1954 and received 138 American patents, averaging nearly one every three months and gaining a reputation for providing inventions almost to order. "Harry, why don't you invent this?" his colleagues are said to have asked when they faced a problem, whereupon Nyquist (at least according to legend) would do just that over the next few days, weeks or months. At least one former Bell colleague has suggested that those 138 patents only "suggest his contributions to the field of communications."

Those contributions include the first quantitative description of thermal (Johnson) noise, signal-transmission studies which helped lay the foundations for information theory and data communications, the invention of vestigial-sideband transmission and the famous Nyquist stability criterion, which has been used outside electronics as well as within it – to describe the way in which someone drives a car, for example.

Nyquist's first major contribution to transmission techniques was a series of theoretical studies of the behaviour of analogue and digital signals in transmission systems, beginning in 1924. This appears to have been part of a whole series of work at AT&T which stemmed from the 1915 invention of the wave filter by George Campbell. Campbell's filter gave an inexpensive method of separating signals of different frequencies on a wire line to allow dual use for telegraph and telephone communications.

Digital signals were used in telegraph systems and, in the 1920s, AT&T did considerable work on developing start-stop teletypewriters, multiplex telegraphs and carrier telegraph systems. Previously, in telegraphy, distortion measurements had been very elementary but, with this new and more critical work, distortion began to acquire greater importance. Nyquist and others carried out theoretical studies and laboratory experiments and designed distortion-measuring instruments for use by maintenance engineers. Nyquist also provided definitions for three types of distortion.

4kT. It was also in 1928 that the *Physical Review* published, on consecutive pages, papers by John B. Johnson and Nyquist on thermal or Johnson noise. Noise has been described as "the ubiquitous, unwanted, insistent, unwelcome gate-crasher" of electronic systems[1]. Walter Schottky of the German Siemens and Halske firm published the classic paper on noise in 1918, suggesting two fundamental types of noise which he named thermal and shot noise. Of the two, Schottky suggested that shot noise would be the more troublesome.

In 1925, Johnson published an important paper on noise. Studying his data later, he discovered evidence of a type of noise which was proportional to the amplification of the valves and which masked the shot noise. This was the experimental discovery of thermal noise, now also known as Johnson noise, made in 1926. Subsequent experimental work led to Johnson's 1928 paper. Meanwhile Nyquist, working alongside Johnson, analysed thermal noise mathematically using thermodynamic principles and produced the famous formula of 4kT watts per unit of bandwidth, where k is Boltzmann's constant and T is the absolute temperature. Years later, Johnson himself described Nyquist's work as "based essentially on the thermodynamics of a telephone line, and covering almost all one needs to know about thermal noise"[3]. The next major contributions did not come until the 1940s (S. O. Rice).

Stability criteria. Nyquist and Bode are however, best known for their work on stability criteria. Harry Black's 1927 invention of the negative-feedback amplifier solved the enormous problem of how to reduce the distortion within an amplifier almost to the point of elimination. As we saw last month, Black more or less ignored stability and assumed the amplifiers would not oscillate or "sing".

Black's success raised other problems for, despite his desires, the amplifiers did have a tendency to become unstable and oscillate. As mathematical physicists, Nyquist and Bode were two of the men chiefly responsible for the derivation of the mathematical theory that enabled the systematic design of stable feedback amplifiers to take place. This success took time: for some years, whilst the potential was recognised, a really good design proved very hard to achieve. A few even regarded it as verging on being a pipe dream, hence the comment that Black's invention

Harry Nyquist.

"had all the initial impact of a blow with a wet noodle."

Nyquist's Criterion (or the Nyquist Diagram) showed what conditions were needed if feedback amplifiers were to be prevented from oscillating once the feedback loop was closed; in other words, it provided a means of evaluating the stability of feedback amplifiers. That was published in 1932. What it did not tell circuit designers, however, was how to achieve it. This problem was tackled by many people, but Hendrik Bode's book "Network Analysis and Feedback Amplifier Design", published in New York in 1945, provided the classic solution to the problem. As a result of the work of these three men in particular (and that of many others) the valve amplifier (and subsequently the transistor amplifier) when properly designed became "a high-precision instrument" as one volume of a history of the Bell System has proudly expressed it.

Harry Nyquist (right) discussing the travelling wave tube with its inventor Rudolf Kompfner (centre) and John R. Pierce. Picture from AT&T Bell Laboratories.

HENDRIK WADE BODE

Bode was born in Madison, Wisconsin, on Christmas Eve 1905. Presumably he suffered the usual childhood problem of dual-purpose Christmas and birthday presents.

After schooling in Illinois and Arizona he attended Ohio State University and graduated with a degree in 1924 and a Master's degree in 1926, whereupon he joined the year-old Bell Laboratories. He was soon at work on the design of electrical filters, but in 1929 he transferred to the Mathematical Research Group where he specialized in electrical network theory and its application to the problems of long-distance communications. Twenty-three years later he became Director of Mathematical Research, subsequently becoming Director of the Physical Sciences and, in 1958, a vice president of Bell Labs overseeing military systems engineering. On the way he received a Ph.D. from Columbia University in 1935.

Bode's contribution to feedback-amplifier design began, according to his own recollections, with a study of equalizing circuits whose function was to provide automatic compensation for temperature and other variations in transmission lines. The big problem came when the equalizers had to be inserted into the feedback loop without causing instability. "In desperation," Bode recalled, "I began modifying the amplifier proper rather than trying to tinker further with my equalizer. . . . Finally, after I had in effect redesigned the complete feedback loop, I found I could obtain a solution[1]". The idea of the mathematical physicist whose book became a standard reference on electronic network analysis modestly expressing his own electronic design work as "tinkering" has a certain appeal.

Hendrik Bode.

It is also an example of Bode's apparent belief that "specialists" should not restrict themselves to a narrow specialism. "Dig deep for good answers" may have been a Bell Labs motto but there was also a strong belief in the need for the horizontal flow of information within a project through all stages of development, design, manufacture and installation. This information flow requires feedback, of course, and one wonders to what extent these pioneers of the mathematical understanding of feedback applied their knowledge to optimizing the human side of project management.

Because of the continuing need to make improvements in equipment the flow of information down through the lifetime of a project or system was also recognised as important. "Continuity in time," Bode wrote in 1971, "from project to project, building on the experience and techniques and skills acquired in the development of the preceding technology, is as vital as collaboration horizontally between development and manufacturing engineers." Both, he added, were used in meeting Bell System objectives.

During World War II, Bode applied electronics (in place of or in conjunction with mechanics) to the problems of anti-aircraft gunfire control. This resulted in a model T-15 gun director which, though it appeared superior to existing equipment in trials, was not placed in production. Later Bode and W. A. MacNair directed research and development of anti-aircraft missiles. In 1946 Bode received a Presidential Certificate of Merit for his wartime contributions.

In February 1945 Bode was one of five men asked to form a team to study the possibilities for a guided missile capable of shooting down future aircraft flying at heights and speeds beyond the capabilities of conventional gunfire. In just five months, the group produced a report which was later to be regarded as a classic for its thoroughness and insight. The project itself developed into a major defence contract and established a working partnership with the Douglas Aircraft Company (later McDonnell-Douglas) which lasted 30 years. The missile was the famous Nike missile, named after a mythological Greek winged goddess of victory. The first test firing at an aircraft was in 1951 when a token flash detonation, representing the warhead, exploded only 16 feet from the bomber. In another test, the missile "drilled through the entire length of the aircraft".

Bode completed his career with Bell as special adviser and member of the Board of Bellcomm, a company formed by Bell as a small part of the NASA effort for "landing a man on the Moon and returning him safely to Earth," as President Kennedy expressed it in 1961. Then in October 1967, aged 61, Hendrik Bode retired from Bell Labs after 41 years service to take up a second career as the Professor of Systems Engineering at Harvard University. There he directed graduate research and taught a course on the planning and implementation of engineering and development programmes. He finally retired, for the second time, as professor emeritus in 1974.

HONOURS

As with most pioneers of their calibre, both Nyquist and Bode deserved and received honours. Nyquist was awarded medals by the Franklin Institute and the Institute of Radio Engineers, Bode the Edison Medal of the IEEE. Nyquist died in Texas, aged 87, on 4 April 1976, five years after his wife Antonie. He was survived by a son, two daughters and seven grandchildren. Bode died at his home in Cambridge, Massachusetts, on 21 June 1982, aged 76 and was survived by his wife, Barbara, and two daughters.

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2. J. B. Johnson, *IEEE Spectrum*, vol. 8, no 2, 42-46, February 1971.

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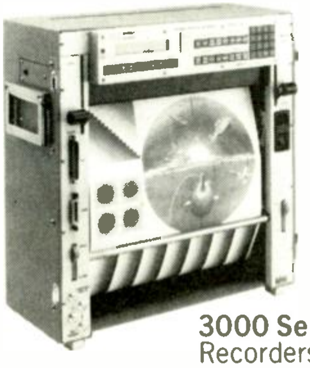

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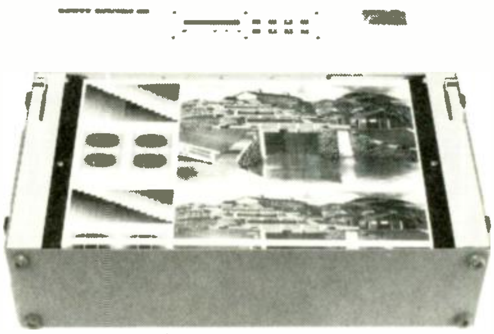

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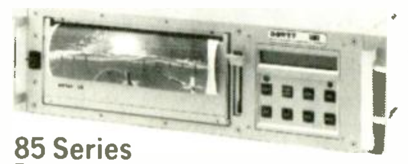

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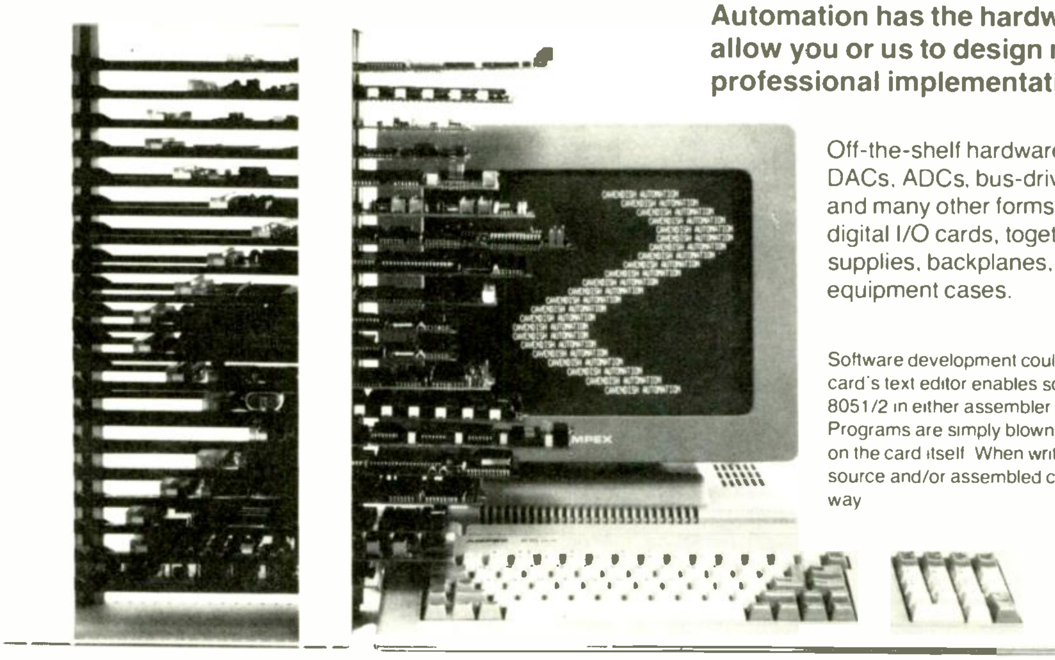

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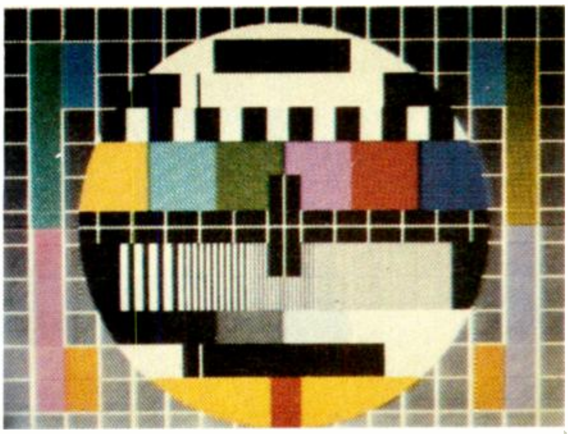
European flat-screen tv nearing production

MARTIN ECCLES

Colour liquid-crystal TVs that are much flatter, thinner and more robust than CRT based sets should be in production this year. General Electric is already producing flat screens for cockpit applications but Philips and Japanese companies including Matsushita, Toshiba and Sharp are working on liquid crystal displays for domestic TV.

The only non-Japanese company competing for the flat-screen TV market is Philips. Together with Warner, Philips is already producing small liquid-crystal screens for seat-back entertainment experiments in 'planes and by the end of this year the company hopes to be manufacturing 6in flat-screen televisions for domestic use.

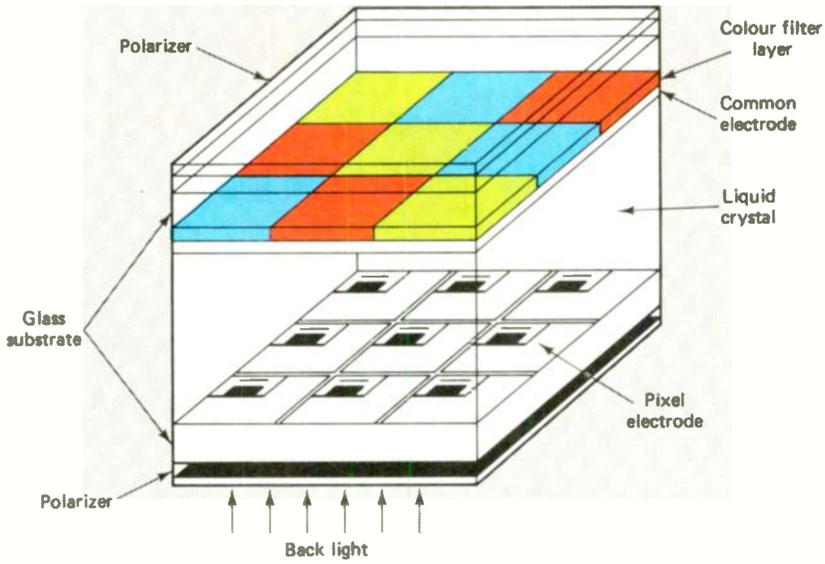


Two criticisms of this prototype display are its dullness and its diagonal lines. In practice, dullness is certainly not a problem and the diagonal lines disappear at about 1m.

In display terms, domestic TV is one of the most stringent applications. Television pictures contain fast moving images and TV displays require high resolution, high contrast and high brightness. To obtain fast switching of all picture elements, especially those at the centre of the display, the Philips liquid-crystal display uses an 'active matrix': there is one transistor switching each picture element.

Subjectively, the picture from the prototype display compares with that obtained from a good domestic video recorder. One of the main problems with liquid-crystal tv displays has been response speed; on the selected programme material that we viewed, some of which contained fast-moving images, there was no detectable image blurring at all. Viewing the display close up, the most noticeable effect is diagonal striping caused by the one-and-a-half dot staggering of the RGB elements. These diagonals disappear at about 1m though.

Unlike front-lit liquid-crystal displays the back-lit active matrix appears at least as bright as a CRT. In fact within reason its brightness is only limited by the intensity of the backlighting, but unlike a CRT the active-matrix display does not lose intensity as it ages (Philips says that a life of 10 000 hours is feasible for the new display).

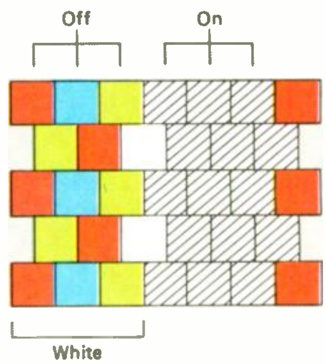


Flat-screen full-colour televisions should be available this year – this prototype was made by Philips researchers at Redhill.

Liquid-crystal displays do not like DC. Asymmetrical LCD drive (field inversion) would solve this problem, but it would also cause an unacceptable 25Hz flicker. Instead, the active matrix uses inversion on alternate lines. As a result, flicker is reduced to about 1/30th of the total amplitude which is less than that produced by a conventional CRT.

You might think that power consumption of such a liquid-crystal would be lower than that of an equivalent CRT, even taking into account backlighting requirements, but the current 6in active-matrix takes about 10W as opposed to about 6W for the same size CRT.

Colour pixels in the prototype display, and probably in the final product, are staggered by one-and-a-half dots to give a better picture. The polarizer absorbs about 50% of light and there are other losses, hence the need for backlighting.



Connection of the matrix is currently much more difficult than plugging in a CRT; each line and row in the matrix needs a driver and a connection. Future displays will have multiplexers and drivers built in but until then, connecting the flexible PCB material leading from the matrix edges must be quite a labour-intensive task.

Although there is no theoretical limit to the display size, there are currently technological limits. According to Dr Alan Knapp, leader of Philips Information Display group at Redhill, there is no particular

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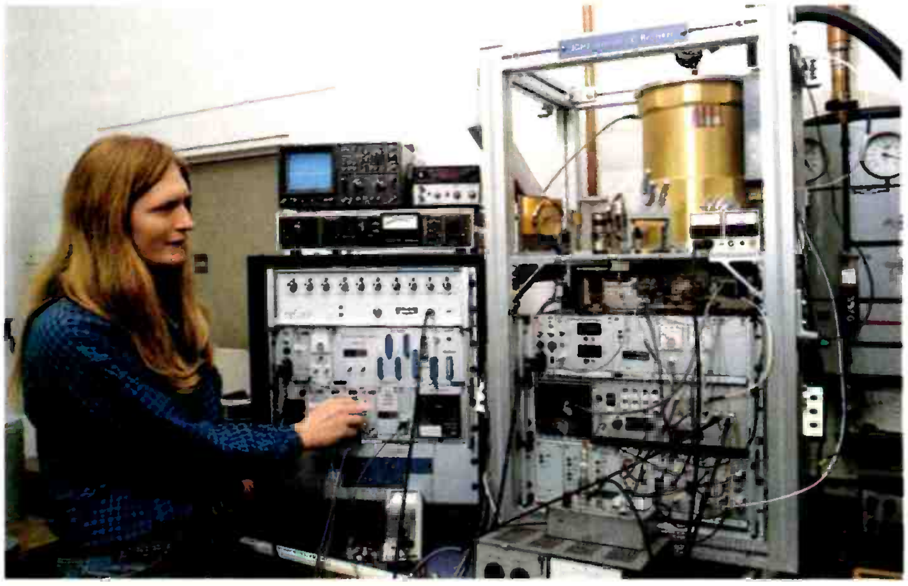
UPDATE

At one of Britain's largest university physics departments — Cambridge — major research work is carried out at three locations. These include the Mullard Radio Astronomy Observatory and the Microelectronics Research Laboratory, but the most significant site for electronics engineers is probably the Cavendish laboratory, having been established more than a century ago under the direction of professors Maxwell, Rayleigh, Thomson, Rutherford and Bragg.

In this month's research profile, which is devoted to the more electronics-oriented aspects of Cavendish Laboratory's work, it is interesting to note that 'cold electronics' are as evident at Cambridge as they are at Oxford (see our Research Profile of last month and Dr Gregg's article in this issue).

MARTIN ECCLES



460-490GHz radio-astronomical receiver (above) being assembled and tested. When completed it will be installed in the 15m diameter James Clerk Maxwell telescope on top of the 4260m high Mauna Kea, Hawaii.

The framework on the right houses the actual detector elements, as well as the local oscillator and associated microwave electronics and the IF stages. Control electronics, the microprocessor, and the synthesiser generating the reference frequency for the phase-lock system are housed in the left-hand rack.

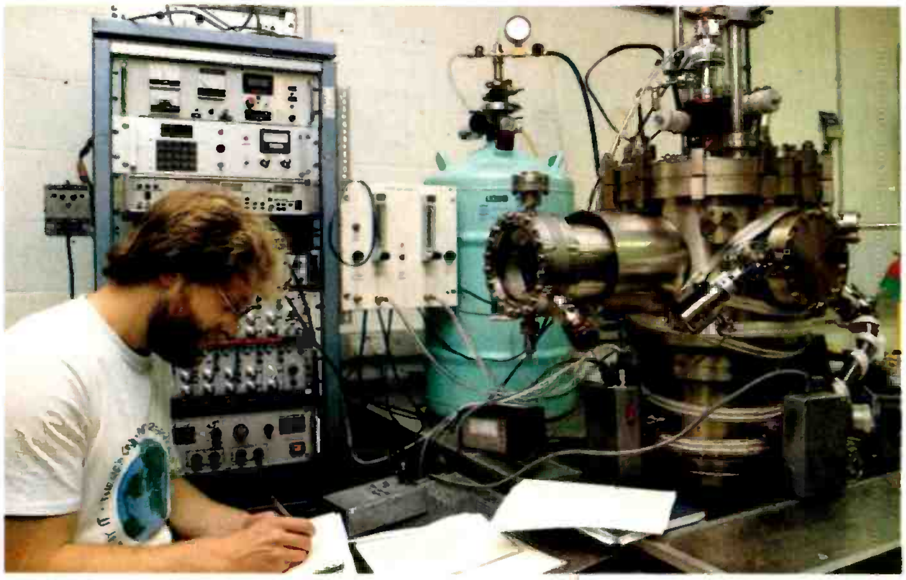
Both the framework and rack are mounted in the telescope receiver cabin, and move about with the dish. The receiver system will be used to make observations of star-forming regions with very-high frequency resolution (e.g. 1 part in 10^6).

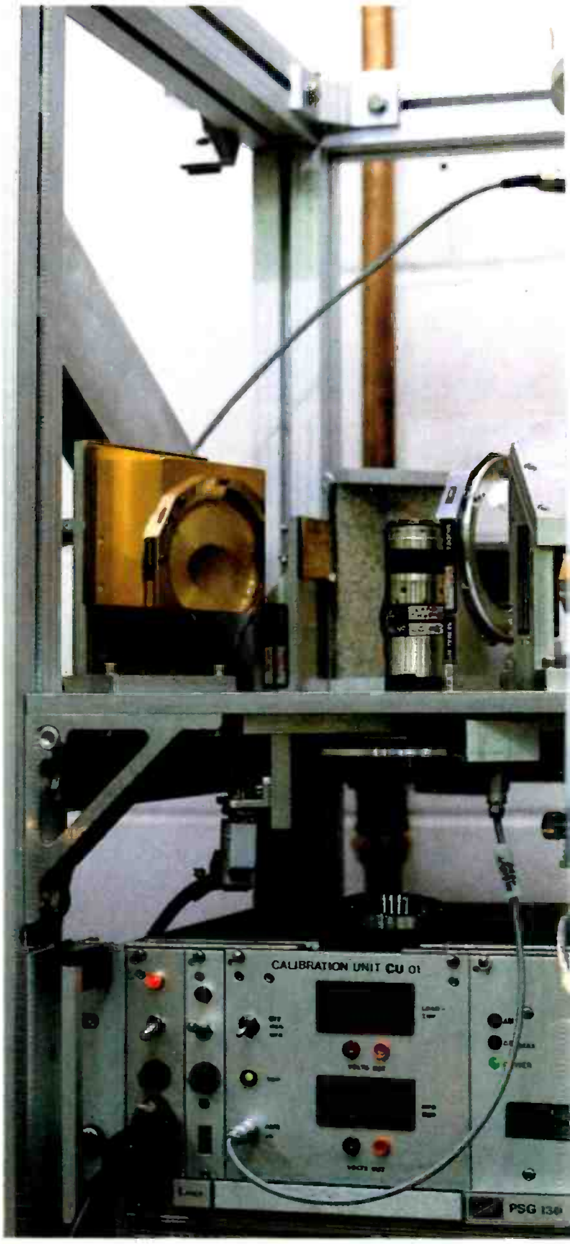
Clouds of gas and dust which are collapsing under the force of gravity to form new stars, contain small amounts of trace gases such as CO and isolated carbon atoms. These emit radiation at certain well-defined frequencies. By comparing the frequency of the radiation we observe with that expected we can tell how fast the gas clouds are moving away from or towards us. Thus we can study the kinematics of the gas clouds and learn more about the star formation process.
Dr Rachel Padman

Electron energy-loss spectroscopy Surface physics is a sub-discipline of solid state physics and is concerned with effects which occur at solid surfaces (below). All of the interesting gas/solid, liquid/solid chemical reactions necessarily occur at a surface – a seemingly obvious statement, but the ability to do proper studies of surface phenomena has only been possible since the late 1960s and is still a rapidly growing area of fundamental technological interest.

In order to prepare atomically clean surfaces, all experiments must be performed inside an ultra-high vacuum chamber (pressure 1mP) so that background gases do not contaminate the surface being studied. Cavendish's Surface Physics Group is particularly interested in studying the absorption of monolayer films of simple molecules (O, CO) on a surface and studying their interaction with the surface.

Eventual understanding of the mechanisms of molecular-surface interactions will help in improving catalysts, in understanding oxidation processes and in the fabrication of semiconductor devices (VLSI technology involves growing layers of material on a substrate surface by the reaction of gases at the surface).
Erik Jensen





Close up of the 460-490GHz receiver. The gold-coloured vacuum vessel (above) houses two InSb homodyne detectors for two polarizations of the incoming signal. They are cooled to 0.2K above absolute zero using liquid-helium refrigerant.

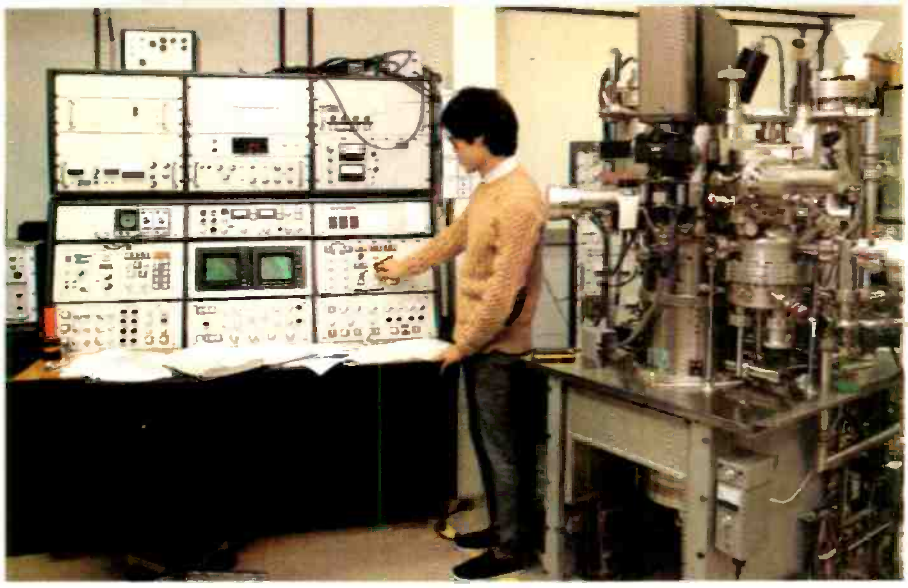
Although the detectors themselves are mounted in a waveguide (about 0.5mm diameter) most of the signal processing at the observing frequency is done using quasi-optical components. The signal propagates as a nearly parallel beam, and is collimated and focussed using optical components such as mirrors and lenses.

The local oscillator (just seen underneath the plate supporting the vacuum vessel) consists of a Gunn-diode oscillator for 115GHz or 123GHz, which is then frequency quadrupled and radiated from a small horn. This is focussed by a lens and mirror, and a small amount of power is injected into the path by a 20% reflection off the 98%-transmitting mylar beam-splitter and combiner.

The plane input mirror is used to align the direction of the beam into the receiver with that arriving from the telescope. An image of the window in the side of the Dewar vessel can just be seen.

VG Scientific HB501 scanning transmission electron microscope. Specimens are mounted within the ultra-high vacuum stainless-steel column to the right of the control console (right). A coherent electron ray, the electrical equivalent of a laser beam, can be focussed onto a spot only half a millionth of a millimetre in diameter.

Transmitted electrons can be used to make atomic resolution images displayed on the two CRTs on the console. Electron energy loss spectroscopy, stable to ▼



within 0.5V in 100kV can be used to identify the atomic species of the thousand or so atoms illuminated by the beam. X-ray signals are also available.

The apparatus can also be used to manufacture extremely small structures — nanolithography. With this technique, it is possible to condense the words in all the books ever published in Britain into less than one square metre. One day, the technique may be used to create super-small electronic chips.

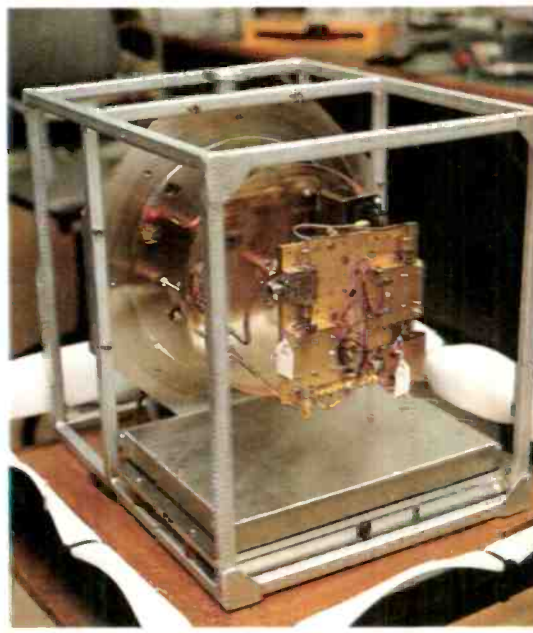
Dr J. Rodenburg

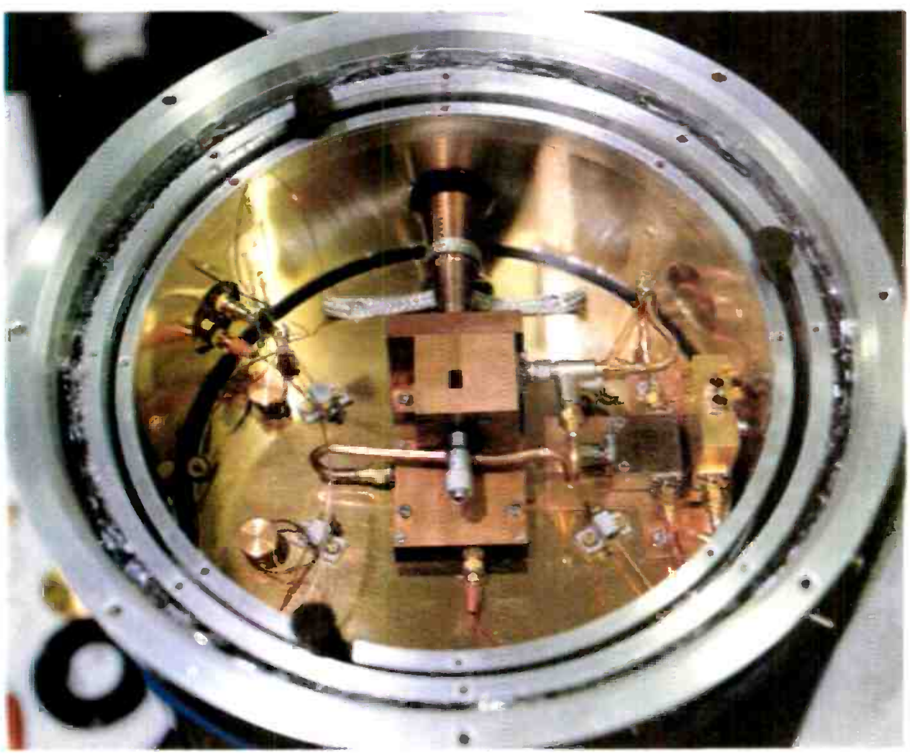
Mullard Radio Astronomy Observatory is a research facility operated by the Radio Astronomy group of Cavendish Laboratory. The principal instrument at the observatory is an eight-element, 5km-long microwave interferometer. This instrument is used for studying the nature of distant radio galaxies and the physics of the early universe.

The photograph on the right is an internal view of one of the very low-noise microwave receivers used on the 5km interferometer. To achieve the required sensitivity, high-electron-mobility transistors are cooled to a physical temperature of −260°C by means of closed-cycle helium refrigerators.

It is necessary to illuminate the transistors, by means of optical fibres, to prevent the semiconductor being frozen into an insulating state.

Dr S. Withington





Superconducting receivers. The Radio Astronomy group at the Cavendish Laboratory is developing, in collaboration with the Materials Science Department, superconducting receivers for use on the James Clerk Maxwell Telescope in Hawaii (right).

Shown above is a prototype 100GHz receiver. The receiver is based on an extraordinary device that consists of two superconducting niobium films separated by a dielectric layer only a few tens of angstroms thick.

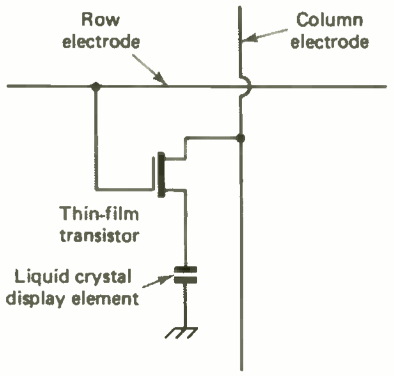
Photon assisted tunnelling of quasiparticles — entities which are very similar to electrons — across the barrier allows the detection of millimetre and submillimetre-wave radiation with a sensitivity approaching the quantum limit.

When used as a mixer, the device displays a number of curious quantum phenomena including classically forbidden conversion gain and quantum reactances.

Dr S. Withington

continued from page 223

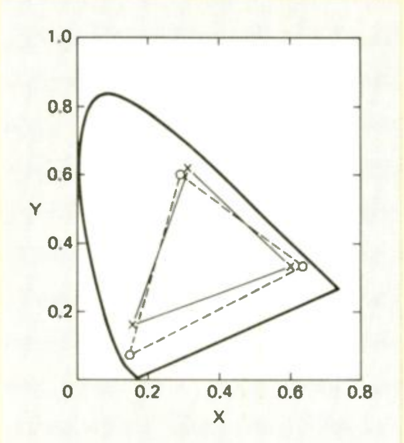
problem to be overcome before the 6in screen goes into production – it is just a question of getting all the processes right to give the necessary yield. "Display sizes will go up," says Knapp, "but only gradually."



Earlier thin-film transistors used to switch liquid-crystal picture elements in this way were leaky and required an extra capacitor across the liquid-crystal display.

Specifications of prototype 6in flat TV

Pixels	468×288mm
Pixel size	0.26×0.318mm
Aperture (colour filter)	68%
LC effect	twisted nematic
Contrast	>50:1 (max)
Viewing angle (contrast >20:1)	
horizontal	80°
vertical	35°
Response times	
black-to-white	19ms (10% to 90%)
white-to-black	11ms (90% to 10%)
Vertical resolution	half PAL (288 lines)
Horizontal resolution	>2.4MHz
Drive voltages	
row	18V
column	3V pk-pk white, 10V pk-pk black



Beyond CT-2

Quite apart from CT2, another UHF personal communication system is being proposed in government circles. Known as Short Range Radio (SRR) it is envisaged that handsets should be made to a pan-European system, using much of the digital technology of CT2. For a modest licence fee anyone would be able to communicate with anyone else over short distances: users would just key in the number of the person they wished to communicate with and would be connected automatically if the wanted set was within range and switched on. The system is intended to combine the accessibility of citizen's band radio with selective calling and privacy of conversation.

The UK Department of Trade and Industry has indicated that it hopes to introduce SRR in 1992, but will allow hand-portable sets only – not the mobiles or base stations described in the CEPT proposals. This is fascinating, since it would appear to limit the use of SRR to *extremely* short ranges. Certainly, for businessmen SRR would make a nice on-site paging system while enthusiasts might find it excellent for hikers' groups and marshals at sports events. Beyond this it seems fit for very little.

Although the specification provides for community repeaters these will not be permitted in Britain. Taken together with the ban on base stations and mobiles this will reduce the utility of SRR to virtually nil.

In the Government's original proposals for Open Channel radio, it was specifically stated that these frequencies would provide ideal low cost communication for small businesses, veterinary surgeons, farmers and the like. This dream was not realised, yet SRR could provide precisely this kind of facility. At least one industry source lays the insistence for a minimal SRR system at the door of the vested financial interests of the private mobile lobby.

IBM small, fast

In a paper presented to the International Electron Device meeting at San Francisco, a group of IBM scientists have published results on engineering IC test samples which demonstrate a clock rate of 30GHz.

Built using an experimental cmos process with 0.25μm geometry it holds out the prospect of producing commercial 256Mbit drams or processor chips with a million gates. This compares with a current tally of around 100 000.

The test chips were made in bulk silicon technology and advanced processing – some elements have a thickness of just 20 atom layers in places.

Silicon potato chips

You can now put electronic tomatoes, sugar beet and potatoes on your shopping list although they are unlikely to catch on as a high tech gourmet delight. They cost more than their weight in Beluga caviar – around £2000 each.

Designed by the Scottish Centre of Agricultural Engineering, the skins of these artificial vegetables have a texture and density similar to the real thing but exhibit piezo-electric effect. When the skin's output signal is coupled into a small internal transmitter, it becomes possible to analyse scientifically the brutality of the mechanical handling involved in gathering the crop. (Source: Daily Telegraph)

MCA on a chip

Helping along the new accord between IBM and clonemakers producing machines with the IBM proprietary micro channel architecture, the Californian chip design company PLX Technology has produced an MCA bus interface chip.

The MCA1200 24-pin device built from CMOS PLA provides all the protocol logic, drivers and input buffers needed to perform the micro channel interface function. It replaces up to 15 discrete logic packages which are normally required for the interface task.

Floppy control

Intel has brought out a single-chip floppy drive controller which is said to integrate all the system level functions.

The 82077, which supports 2.5in drives of up to 4Mbyte capacity, includes an analogue phase locked loop, data separator, a fifo for data transfer and support for the perpendicular recording mode which will feature in the next generation of drives.

INDUSTRIAL IMAGING

An industrial, vision-based inspection system, using a PC or equivalent

NICK HEWITSON

The basic elements for solid-state image acquisition have been available commercially since the mid 1970s. The charge-coupled device (CCD) was invented by Fairchild Semiconductor Corporation and was quickly taken up in the consumer market, where the first major application was the autofocus systems for 35mm SLR cameras. This was achieved by a line-scan array (a single line of photosites or pixels) of a few hundred pixels in length, used to work out the distance to the object and focus the camera. Later, a much higher growth in the consumer market came with the advent of the video camcorder, which is made up of an area array (a matrix of rows and columns of pixels) which gives a TV picture in real time. An important application is office equipment, where CCDs are used in fax machines, photocopiers and today in document scanners for PCs.

The applications described require very little image processing of the video information coming from the charge-coupled device and therefore use low-cost equipment. The other field in which CCDs found early application was the industrial/professional market, where they became a small part of major systems in equipment such as telecine, cheque readers and even satellites. Here, there is a requirement for very high-level processing of the video image coming from the charge coupled device. However, the systems themselves are highly expensive pieces of equipment and so the cost of this processing power did not inhibit sales.

CCDs have been used in industrial inspection for some time, but the slow adoption of solid-state imaging has been due to the high cost of processing the video stream.

HARDWARE

The hardware required for an industrial CCD imaging system consists of the image acquisition front end, made up of a CCD camera and the driver electronics, and an intelligent board including a microcontroller or a computer.

CCD cameras used two kinds of technology: an area-scan system to give a live TV picture; or a line-scan CCD array where the picture is made up by integrating the video against time.

Historically, systems have been made in the main with area-scan CCD cameras. There is a misconception that, because you can display the information readily on a TV-type monitor and this information can be readily understood by the human eye and brain it is therefore easier to process in an electronic system. The main fallacy with this argument concerns the amount of information presented. For example, 1024 by 1024 area picture would give you a million bits of information. If this were updated at a video frame rate of 50 frames per second, the downstream processing would have to handle 25 million bits of information (due to standard video being interline transfer) a second. This amount of information is obviously beyond the capabilities of anything but supercomputers. The other major problem with using an area-scan camera is that, if the object is moving, the laws of probability state that the object will not be moving at the video frame rate. This mean that the information in the top right-hand corner of the picture is out of sync., relative to the position of the object, with the information at the bottom left-hand corner of the picture. This gives the effect known as smearing and is a major drawback where dimensional analysis of object is required. If the object to be viewed is stationary relative to the camera or if the system works on a step and repeat basis, then an area camera is the only possible option.

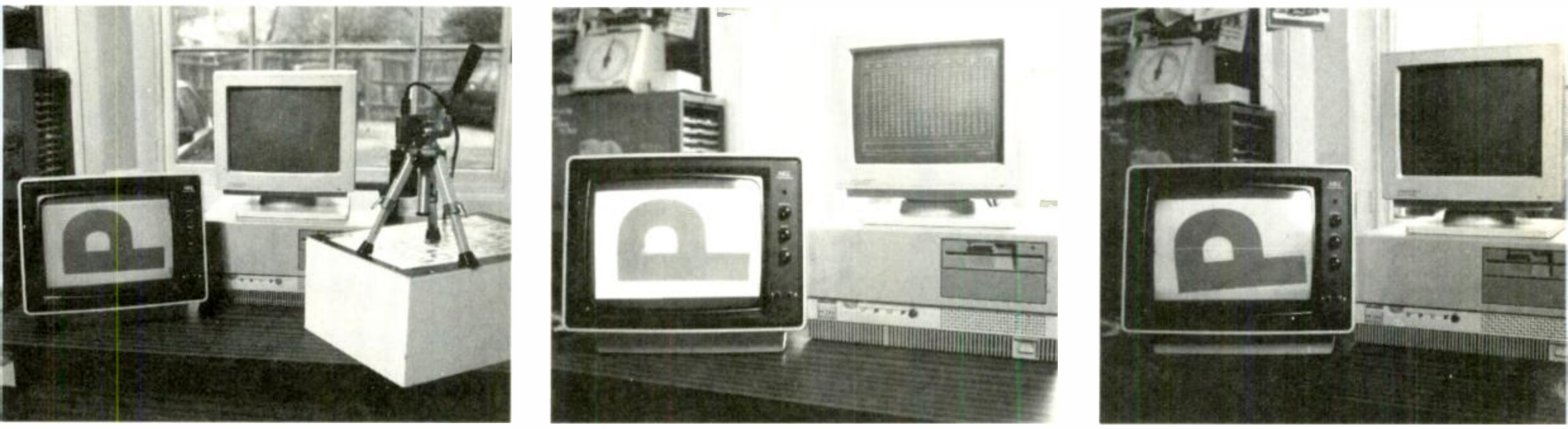
The problem of smearing can be overcome by using strobe lights or a mechanical shutter arrangement, which also has the effect of allowing time for the information to be processed during the period in which the CCD camera is not collecting information.

The most elegant solution is to use a line-scan array. In this method, a single line of pixels clocks out its information, which is fed to a frame store. The picture is then built up against time as the object moves under the camera or the camera moves over the object. An added advantage of line-scan is that resolution can be much higher than that of area-scan techniques.

With current technology a 1024 by 1024 pixel-area chip is the best that can be economically manufactured. However, line-scan arrays of six thousand pixels in length are commercially available from companies such as Fairchild Weston in California. By selecting enough clock periods, a picture made up of six thousand pixels read six thousand times can easily be built up, given sufficient computer memory. Because the amount of information processing needed at one time is much smaller, much less computing power can be used (the processor can be working on one line as the next line is collected). It is also very easy to vary the clock speed on a line-scan CCD array and to tailor this to the speed of movement of the object to be viewed. This overcomes the problems of smearing described earlier and, although it is harder to visualize the information from a line-scan CCD, as far as the computer is concerned it is much easier to process this information than from an area-scan camera (see **Fig. 1**).

Another major component of any electro-optical inspection system is the lighting and optics. This is the area in which most mistakes are made when systems are designed. The key requirements are to get an even field of light across the object, since the processing electronics are not able to differentiate between effects caused by unevenness of the light source and those due to the shape of the object. To overcome the problems of lens distortion the system must allow for programming to overcome these anomalies.

The system described in this article uses an IBM PC-compatible plug-in board manufactured by Sentel Messtechnik in Germany for the processing of the video stream from the CCD camera. In line-scan applications the analogue video signal produced by the camera is converted by a controller board into a standard video signal. This signal and some other digital signals are fed into the plug-in board (CCUM) inputs via a number



Left is a plot of light intensity against xy axis of image scanned through Fairchild Weston CCD camera and processed by CCUM board. Image on display screen is letter 'P' transfer. Middle picture is computer screen showing 8-bit numbers for each pixel built up against time. It is possible to measure edges to accuracy of 0.1 pixel (one micron). Computer screen in right-hand picture shows analogue information from line-scan camera. Intensity of light across P shown by cursor on computer monitor.

of cables, where the analogue video signal is initially digitized to an 8-bit resolution, resulting in 256 grey levels (see Fig.2). The grey-level value of each pixel is located at a certain address in the image memory of the board, which can be directly accessed by the use of the PC bus. The board has a colour look-up table which allows false colours to be allocated to the various half-tone levels, which can be programmed by the user as required. This means that the image output can be manipulated by either reverse-video imaging, emphasizing a certain half tone or image area, false-colour representation or binary representation, if required. Individual half-tone levels in this colour look-up table can be masked or labelled, allowing co-ordinate systems, crosswires, image windows or graphics to be integrated. A monitor may also be attached.

The board includes 256Kbytes of onboard ram, for the storage of the video image, as standard. By using other ram modules, the image memory may be expanded to 1 megabyte, which is sufficient for complete images of a maximum of 512 by 512 pixels each. A memory of this size cannot be simultaneously handled under the MS DOS operating system, so the image memory of the CCUM has been divided into a number of segments or windows, each of 32K bytes, through which the image memory can be viewed. Access to the entire image memory is provided by moving this window, allowing operations to be handled in real time. Several CCUM boards can simultaneously operate in a single PC by programming the respective ports to activate the memory of each board.

PROGRAMMING

Programming the CCUM takes place via registers, but the image memory can also be directly accessed. For this purpose, a structure of type "row" is defined, which contains for every image line the address of the first pixel in this line in the image memory and the respective page number. The CCUM board is normally programmed via a software library, which is included in the cost of the board. This library uses a high-level language and an easy-to-use software interface, allowing the user to operate the CCUM as required in the specific application. The design of the CCUM allows user programming to customize the system to various needs; a total of 10 registers are available to the user, sorted according to the subjects with indications being included as to whether the register is read or written on.

The universal counters of the CCUM allow special applications and can be used, for example, to display simultaneously several camera images onto the monitor. Another example is, when operating a line-scan camera, two of the registers are used in conjunction with the line-scan controller board to detect an edge or the width of an object via the hardware. Other registers available on the CCUM board control the A-to-D converter, the status register which gives information on the current status of the board, the camera modes register, which selects which camera is being used in multiple camera applications and the image memory segment register, which allows the user to state the image window he would like to access. The aim of the hardware for the CCUM board is to give a cost-effective flexible interface with the IBM PC/AT standard bus.

SOFTWARE

Any system which includes a complex camera-interface board should be assisted by hardware-orientated basic software products. Programmes of this type allow the programmer to use the CCUM as a 'black box' to solve his specific problem, without the necessity of detailed hardware knowledge, although he must have a flexible software interface so that long training periods to learn a new programming language or the re-writing of already existing software is unnecessary. The basic software for the CCUM board, CCUM.LIB, has been written in Microsoft C and is also available as the source code which allows the user a very flexible software interface. Programme written in Microsoft C, Microsoft Pascal, Fortran, to name just a few, can be linked with the CCUM.LIB without any difficulty. Various other software products are based on Microsoft standard and will thus be compatible. Apart from the CCUM.LIB a number of geometrical measurement, edge-detection and outline-recognition packages are available as standard with this board. These are also created using Microsoft compilers and are thus suited for adaption. Example programs are available from Optimum Vision (Tel 0730 64016).

Using CCUM, an IBM PC/AT compatible, a Fairchild Weston CCD camera and relevant application software, an industrial inspection system can be created for less than £10,000. This system works in real time, giving high-resolution industrial imaging with both static and fairly high-speed moving objects. For example, there are applications where people wish to study the surface of roads and rail tracks, while moving at up to 100 kilometres per hour, using CCD line-scan technology. Such a cost-effective system brings the world of industrial vision out of the realms of high cost and into the reach of small innovative companies and engineering groups.

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- **Interface card** – takes a 'short slot' in the PC and provides link in/out and control lines.
- **Cable** – links the interface card to the Transputer Module.
- **Transputer Module** – complete T414 based subsystem, supplied in its own sturdy case.
- **Power supply** – independant power to transputer if required.
- **Development Software** – folding editor, OCCAM compiler, downloader, terminal emulator and utilities, hosted on the PC.
- **Example programs** – no less than 28 fully worked examples.
- **On Screen Tutorials** – learn how to use the system 'on-screen'.
- **Hardware Manual** – full circuit diagrams, timing diagrams and circuit descriptions.
- **TDS User Guide** – self contained tutorial guide to using the development software.
- **TDS User Manual** – the reference manual for the development software.
- **Introduction to OCCAM** – a complete self-teach course in OCCAM.
- **OCCAM Programming Manual** – the definitive guide to OCCAM.
- **T414 Engineering Data** – full specifications for the Transputer.
- **C012 Engineering Data** – full specifications for the Link Adapter.

The Transputer Module houses a 15 MHz T414 with 256K RAM and is external to the PC, so that the hardware is fully accessable. The module includes a wealth of test points, 14 status LEDs, 16 I/O lines, EVENT input, independant power supply, prototyping area and four 15 way D connectors, which allow access to the 10 M bits/sec links and control signals.

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Cold electronics

Now that small 10K refrigerators are readily available, research into how cooled semiconductors operate is more than just a passing interest.

J. F. GREGG and I. D. MORRIS

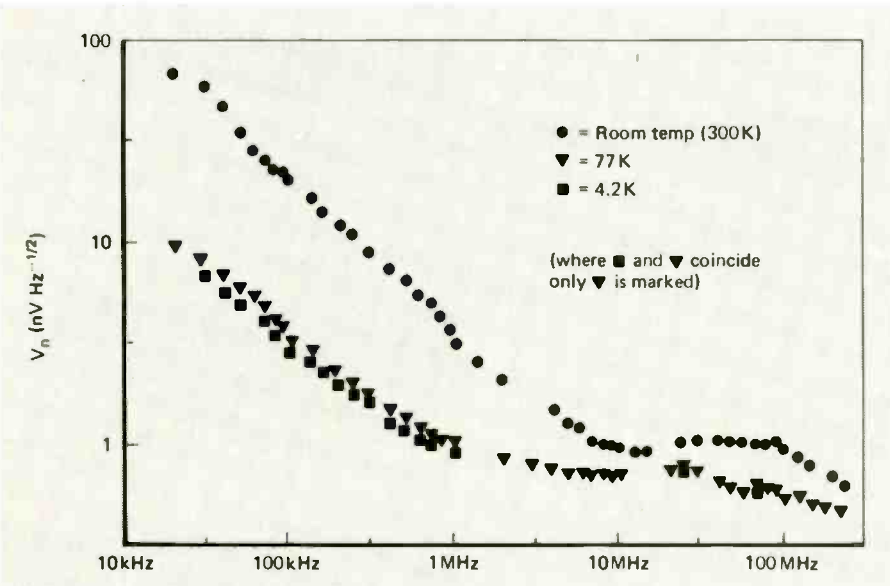
Solid state physicists researching into the magnetic properties of materials use liquid helium, ^4He, as a standard laboratory refrigerant for obtaining the low temperatures which are frequently necessary for investigating the physics of magnetic systems. Liquid helium boils at 4.2 kelvin (about −269°C). Some idea of the relative "coldness" of this liquid may be gained from **Fig. 1**, which shows various temperatures on the absolute (kelvin) temperature scale.

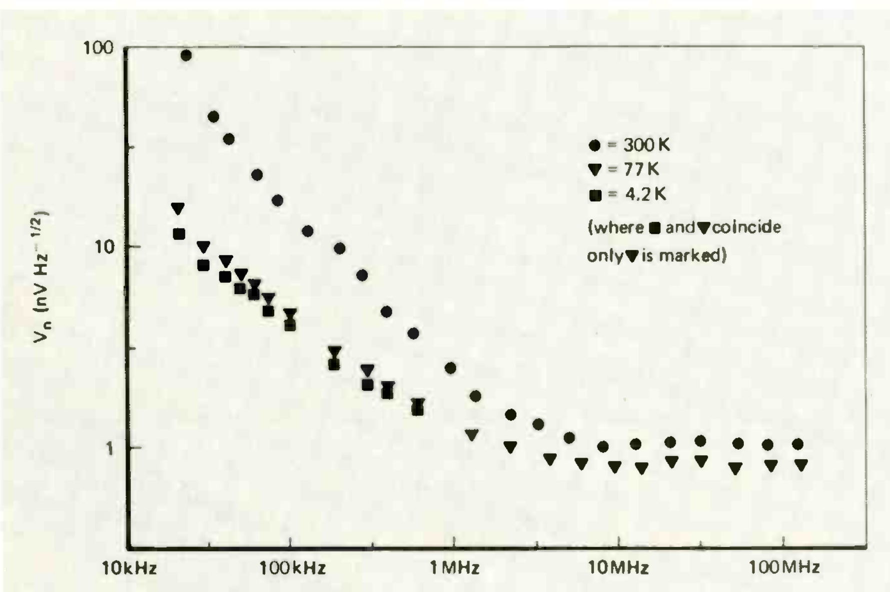
Low-temperature physics research frequently encounters technical problems which are solved by recourse to "cold" electronic instrumentation which itself operates at liquid helium temperatures. In this article we discuss the advantages of cooling electronic circuits and describe some of the possible applications of "cold" electronics to physics research and to other wider fields.

Descriptions of cryogenic (from the Greek "kryos" meaning "frost") circuits and the operation of semiconductor devices at low temperatures have been outlined in the technical literature since about 1964. However, the advantages of cold electronics have become rather more marked and its applications have proliferated with the recent advent of gallium arsenide (GaAs) devices. For reasons which we shall discuss below, the physics of this material makes it very suitable for low temperature working.

In the low-temperature laboratory environment there are two main incentives for cooling electronics. The first arises from the requirement with some physics instrumentation this it should be sited close to the sample of material under investigation. In practice, given the difficulty of maintaining large temperature differences over short distances, this often means that the instrumentation must be held at the same temperature as the sample. For example, in the case of self-oscillating magnetic resonance spectrometers such as those popularized by F. N. H. Robinson of this laboratory, the resonant circuit and the oscillator must be within a fraction of a wavelength of one another: at UHF and low microwave frequencies, this corresponds to a maximum separation of a few centimetres. Proximity of instrumentation to the experiment has the additional advantage that it minimizes the opportunities for stray pickup and RF interference.

The second and rather more important benefit which arises from cryogenic electronics derives from the physics of electrical noise and fluctuations. Broadly speaking, noise is any signal which is unwanted by the observer. Leaving aside electrical interference from such sources as domestic fridges or local radio stations which must be eliminated by careful design and electrical screening, and ignoring the frying, crackling and popping types of electrical noise which are characteristic of faulty components, there are three kinds of fundamental electronic noise which are describable in terms of basic physical processes. These are respectively known as Johnson noise, shot noise and flicker noise, **Fig. 2**.





Noise spectra of two different types of GaAs mesfet measured at room temperature, 77K and 4.2K. Diagram (a) is for an NE720 from NEC, while Figure (b) shows the data for an AT8110 marketed by Avantek. The 77K and 4.2K results coincide so closely in places that only the 77K points are marked. This strongly suggests that, despite the fact that the devices are in different refrigerants, the effective electron temperatures in their respective channels are very similar.

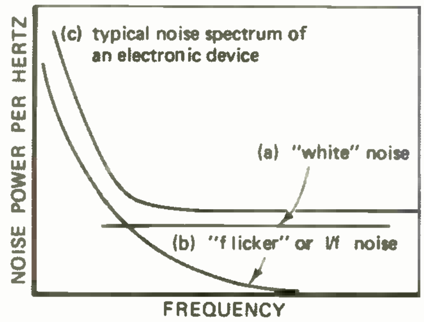
Fig. 2. There are three principal types of noise in electronics – Johnson noise, shot noise and flicker noise.

Johnson noise is associated with the resistive part of impedances and it arises from the same kind of thermal fluctuations as given rise to black-body radiation from, for example, the hot filament of a light bulb. Consequently, the frequency spectrum of this kind of noise is completely determined by thermodynamics and at all frequencies of interest in electronics, the noise is "white", i.e. the amount of noise power per unit bandwidth is a constant as in curve (a). The mean square Johnson noise voltage per unit bandwidth which appears across a resistor of value R which has temperature T is given by

$$v_n^2 = 4k_BRT$$

where k_B is Boltzmann's constant (1.38×10^{-23} J/degC).

Shot noise arises in circuits which contain a potential barrier such as that associated with a p-n junction in a bipolar transistor or with the gate-channel interface in a fet. The current is composed of those charge carriers which have enough thermal energy to surmount the potential barrier and it thus varies in a way that mirrors the thermal



fluctuations in the spatial and energy distributions of the charge carriers. Simple mathematical treatment suggests that shot noise is also white and that the mean square noise current per unit bandwidth associated with a current of mean value I is given by

$$i_n^2 = 2eI$$

where e is the electronic charge (1.60×10^{-19}C).

Flicker noise is characterised by the fact that the noise power increases at the lower frequencies as in curve (b); in the textbook case, the power spectrum is inversely proportional to the frequency and flicker noise is sometimes nicknamed "1/f noise". The processes which cause it are not well understood and are difficult to model mathematically, but it is thought to derive in many cases from device surface effects and microscopic details of the device structure over which the manufacturer has limited control. This has the consequence that, unlike Johnson and shot noise, two individual devices which are nominally identical may exhibit quite different degrees of flicker noise. The frequency below which flicker noise becomes comparable with the white noise present depends strongly on the type of device.

In bipolar transistors under optimum conditions this "elbow" frequency curve (c) may be of order 1Hz whereas in some point-contact microwave devices it may be as high as several hundred megahertz. As shown on page 232, the GaAs mesfet noise spectra which we measured had flicker noise elbows at frequencies of order a few megahertz and the flicker noise component reduced quite spectacularly on cooling.

For more detailed information on this subject the reader is referred to "Noise and fluctuations in electronic devices and circuits" by F. N. H. Robinson, Oxford University Press, 1974.

Lossy passive components (like resistors) will exhibit Johnson noise coloured with a certain amount of flicker noise, the latter dominating at very low frequencies. Johnson noise power has a linear temperature dependence, so, for example, if a resistor is cooled to half its temperature, its noise power is halved. One of the advantages of cooling to liquid helium temperatures is immediately clear — a resistor operating at 4.2 kelvin delivers roughly 100 times less noise power than at room temperature (300K). Of course, the low-frequency noise character will still be dominated by the flicker noise, but this too may reduce with cooling, albeit in a rather less predictable way.

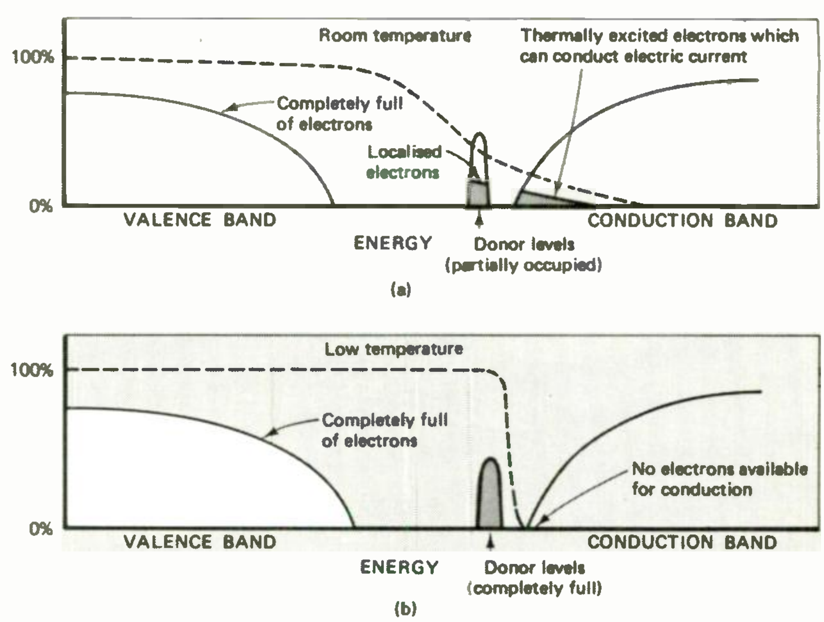
However, the major sources of noise in most circuits are the active devices and the mechanisms which cause this noise are a bit more complex. For example, in a FET, there will be a Johnson noise component from the channel, shot noise originating from the gate leakage current, flicker noise from the contact metallization strips and carrier recombination fluctuations in the bulk semiconductor, to name but a few. Fortunately, one or two of these noise sources usually dominate and, in general, the noise performance of semiconductor devices improves at low temperatures. We should stress at this juncture that this improvement is only significant for large temperature drops such as may be obtained using liquid nitrogen (77 kelvin) or liquid helium.

As you can see from **Fig. 1**, the sort of atmospheric temperature fluctuations which one experiences in the course of a year represent very small percentage temperature changes on the absolute (kelvin) temperature scale, so that, for example, immersing the front end of a radio receiver in iced water would afford a barely perceptible improvement in its noise performance (since the absolute temperature change is

Fig. 3. Electrical conduction in an n-type semiconductor occurs by virtue of electrons which derive from the so-called donor states which are just below the bottom of the conduction band. These donor states are formed by contaminating the semiconductor with a small number of impurity atoms which have more valence electrons than the atoms of the host semiconductor.

Provided that the impurity atoms are sufficiently dilute, their average separation is such that their wavefunctions do not overlap and their electrons are effectively localized. However, if the semiconductor is at a temperature comparable with the energy separation, in kelvin, of the donor levels from the conduction band edge, some of these donor electrons are thermally excited into the conduction band (a) where they are free to move around and so conduct electric current. If the semiconductor is cooled to a temperature much lower than the ionization energy in kelvin of impurities, then the electrons all return to the donor levels and the material becomes an insulator, as shown in diagram (b).

Diagrams (a) and (b) show electron population of the donor levels and valence and conduction bands for an n-type semiconductor at room and low temperature respectively. The dotted line shows the percentage of states at a particular energy which are occupied by electrons. This line becomes much squarer as temperature is lowered and there is less thermal fluctuation to kick electrons into higher energy states. Consequently, electrons flop into their lowest available states (the donor levels) leaving the conduction band empty.



only a factor of order 273/300), and might well have rather more spectacular and undesirable electrical consequences!

The main problem encountered in designing cryogenic circuits is that manufacturers don't build their devices for low temperature operation and one relies for suitable active components on the lucky accident that the materials and device structures which have been developed to meet some specialized room temperature needs just happen also to function at low temperatures. Most semiconductors just don't work when cold because the electrical carriers in the conduction band "freeze" out when the material is cooled, **Fig. 3**, leaving the material looking like a perfect insulator. Silicon is a case in point, and at liquid helium temperatures there is insufficent thermal energy to ionize electrons from the donor impurities into the conduction band.

There are three major factors determining how a particular semiconductor device will behave at low temperatures. The first is the method by which the charge carriers in the semiconductor are produced, and therefore the concentration of carriers at any particular temperature. The other factors are the mobility of the generated carriers as a function of temperature and the carrier lifetime.

The nature of the packaging of the device and the connections between the device and the outside world may also affect the performance quite considerably. Unfortunately, a particular construction technique which is ideal for room temperature operation may prove to be the opposite at liquid helium temperatures. For example, ceramic packaging is robust, reliable and inexpensive to manufacture. However, the thermal conductivity of such packages can reduce by an order of magnitude or more on cooling from room temperature to 10 kelvin, with the result that the semiconductor temperature is considerably higher than that of the

A spectrum analyser displaying the noise spectrum (between 20kHz and 350MHz) of a UHF amplifier constructed using GaAs mesfets. In the first photograph, the amplifier is operating at ambient temperature, while in the second it has been cooled by immersion in liquid nitrogen.

Cold front end of a Robinson magnetic resonance spectrometer constructed using three mesfets and chip-packaged metal-film resistors and capacitors. These are mounted on the circular printed circuit board which is visible to the right of the photograph. The sample under investigation is inside the NMR coil on the left of the picture. This coil, together with its air spaced tuning capacitor form the tank circuit of the Robinson oscillator whose RF amplitude is monitored by ambient temperature electronics. The spectrometer fits inside a cryostat of diameter 3.5 cms which sits between the polefaces of an iron-cored electromagnet capable of delivering magnetic fields between zero and 1.2 Tesla with a homogeneity of 1 part in 10^4 over a volume of 1 cubic centimetre. When the oscillator frequency coincides with the precession frequency (Larmor frequency) of the magnetic spin species under study, the spins absorb energy and the RF amplitude of the oscillator decreases. Our thanks to James Lord for allowing us to photograph his spectrometer.

surrounding liquid. The differential contraction rates of ceramic package and device may also cause problems and adversely affect device reliability.

The free carriers necessary for the operation of a semiconductor can be generated by a combination of three mechanisms; field effect, thermal ionization and impact ionization. Germanium and silicon bipolar devices rely on thermal ionization of carriers from donor and acceptor levels separated from the conduction or valence bands by energies of a few hundred kelvins. They are therefore very susceptible to carrier freezeout and cannot be used much below room temperature.

Some materials have been produced with very high doping levels which cause an impurity band to be formed just below the conduction band edge so that carriers are still available at low temperatures. However, these materials are in general too heavily doped for normal device use. Some Si and Ge mosfet devices with heavily doped channels do still operate at cryogenic temperatures, as the large field gradients in the gate/channel region are able to produce a conducting inversion layer due to field effect — just like enhancement mode devices at room temperature. These devices operate well at 4.2 kelvin, their performance aided by reduced noise figure and increased carrier mobility.

In most n-type III-V compounds the impurity levels for the popular dopants lie very close to the conduction band edge and, due to the very low effective mass of electrons in these materials, an impurity band can be formed at even quite moderate concentrations of donors (for example, about 10^{21} to 10^{22} per m^3 in GaAs). It has been shown that for n-type GaAs, the impurity band for certain types of dopant will start to overlap the conduction band edge at concentrations of about 6×10^{22} per m^3. Hence, n-type GaAs, InSb, InP and InAs devices are not susceptible to carrier freeze-out, and operating concentrations of carriers are still available at 1 kelvin and colder (p-type III-V materials do not show this effect in general, and behave in a way similar to Si and Ge devices.) This means that n-channel III-V devices should be usable at very low temperatures. At present, only GaAs devices are commercially available.

Once it has been established that the semiconductor material will have a sufficiently large concentration of carriers available at the temperature of interest, other factors must be considered. These mainly concern the mobility and lifetime of the carriers. The mobility of electrons in n-type InSb is relatively temperature independent, and at 4.2 kelvin is about $10^5 cm^2V^{-1}s^{-1}$ (for comparison, in n-type Ge at room temperature it is $3\times10^2 cm^2V^{-1}s^{-1}$).

Mobility in n-type GaAs has a strong temperature dependence: it is about $8\times10^2 cm^2V^{-1}s^{-1}$ at room temperature, rising to a maximum of $2\times10^4 cm^2V^{-1}s^{-1}$ at 100K, and then falling rapidly to $100 cm^2V^{-1}s^{-1}$ at 3K. Thus, InSb devices would have an edge over GaAs for use at cryogenic temperatures from the point of view of consistency of device characteristics. Moreover, given the peak in the temperature dependence of carrier mobility in GaAs, operation of GaAs devices at 77K would be preferable to using them at 4K. In fact, as is discussed later, it is probable that the active regions of devices such as GaAs mesfets do not get colder than about 50K even when the package is immersed in liquid helium.

Devices fabricated from InP are also very attractive. This material offers a mobility which is by a factor of ten greater than that of GaAs. Once again, these devices are not yet available in any form apparently owing to difficulty in obtaining material which is of sufficient quality to serve as the semi-insulating base for the devices, and to the problem of making ohmic contacts onto the material. Moreover, methods of making Schottky barriers to the material (a critical consideration for high-frequency devices such as mesfets) have yet to be perfected. However, assuming that these problems can be overcome, InAs and InP devices promise even better cryogenic operation than GaAs.

The higher mobility of electrons in GaAs and other III-V devices at low temperature comes from the reduced thermal scattering of the carriers. This improvement occurs mainly in cooling to liquid nitrogen temperatures; scattering at lower temperatures is dominated by impurity scattering. This non-thermal scattering can be reduced by removing the impurities (i.e. the donors responsible for the carriers!). Clever design of the device can separate the carriers from their donors, so that the carriers operate in regions of pure semiconductor, where mobility can be much improved. These devices (hemts or high electron-mobility transistors) have been developed for use at room temperature, but promise to be even more attractive as cryogenic devices.

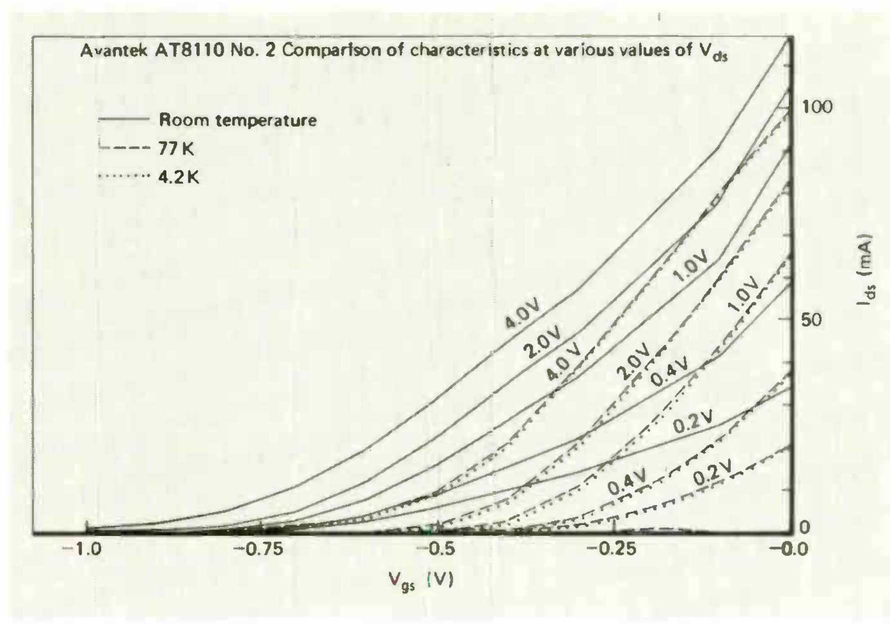
One other consideration which is of importance to microwave GaAs devices is the high-field behaviour of the carrier velocity. Most short-gate GaAs mesfets operate with a considerable proportion of the channel in the velocity saturated regime. Any increase in the saturation velocity of the carriers will not have a direct effect on the device performance, but the nature of the relaxation of carriers to that equilibrium high field velocity is important. If the relaxation is reduced, carriers in the very short channel will 'overshoot' their equilibrium velocity, shortening their transit times, and producing a much improved high-speed performance of the device. Hence, a long majority carrier lifetime in the channel is very desirable. Hence, increased carrier lifetimes from cooling provides more performance improvement.

The minority carrier recombination time in III-V materials is strongly affected by lowering the temperature. There can be a reduction of a factor of 100 (InSb, n-type, room temperature to 4.2K) in recombination rate for minority carriers, but the rate for majority carriers varies less; in some materials it may even increse slightly. Hence, again, the properties of minority carrier devices such as bipolar transistors will be strongly affected by cooling, but this variation will not appreciably alter the characteristics of majority carrier devices such as fets.

From the foregoing discussion it would seem that GaAs fets should be ideal candidates for cryogenic operation (providing that the channel is n-doped, to provide the all important impurity band for the carriers). These devices are available commercially, in the form of mesfets designed for GHz frequency operation. They are not cheap (about £10 to £20 per copy), but we have shown that the right brands do operate very presentably down to the lowest temperatures available, with significantly lower noise than at room temperature. However, there are a number of catches.

Firstly, these devices are optimized for operation in the gigahertz frequency regime, and their performance at frequencies of a few megahertz and below is dogged by large amounts of flicker noise. Particularly in circuit applications (such as Robinson

Fig. 4. Drain current versus gate voltage characteristics of a AT8110 mesfet for different values of drain voltage and different temperatures. Note how the mutual conductance of the device improves with cooling.



NQR spectrometers) where the signals take the form of small variations of a large amplitude RF carrier, device nonlinearities mix this low-frequency noise with the RF signal and it is this which sets the ultimate limit to the noise performance of high level circuitry.

Secondly, the effect of cooling the device, while sometimes increasing the mutual conductance (compare the room temperature and 4K curves in **Fig. 4**), also has the effect of reducing the effective output impedance of the device which, in simple terms, may be thought of as the resistance which shunts the ideal current generator in the fet output equivalent circuit. The consequence is that, despite any increase in the mutual conductance, the maximum available gain of the device is almost always reduced on cooling, and this in turn tends to moderate the improvement in the noise figure.

The change in the device characteristics also changes the small-signal scattering parameters of the mesfets, but we have found it well worthwhile to evaluate low temperature s-parameters for the various device types which we have studied. The low temperature characteristics and hence s-parameters are highly reproducible between individual devices of the same type and such variations as do occur may be accurately predicted from room temperature measurements of I_{DSS} and V_P, for the particular devices, **Fig. 5**.

The final catch concerns the power dissipation of GaAs mesfets. A typical specimen may require I_D~10mA at V_D~3V to operate satisfactorily and this corresponds to a power dissipation of 30mW. At room temperature this figure is tolerable, but at 4.2K it is sufficient to evaporate liquid helium at a rate of about 30cm^3 of liquid per hour. Given that a typical experiment would use a cryostat of a few litres capacity and that more than one mesfet would typically be used, this feature can set a decisive upper limit to the duration of an experiment. In addition, this power dissipation, coupled with the indifferent thermal conductivity of the ceramic package when cold, implies that the fet channel operates at a temperature of around 80K even when used in liquid helium. This is corroborated by the observation that the device characteristics and noise measurements taken at 77K agree closely with the corresponding data measured at 4K, **Fig. 6**. This higher temperature operation of the fet is however not wholly undesirable since, as mentioned above, GaAs offers optimum performance under these warmer conditions.

On applying power to a mesfet the thermal time constants are of the order of microseconds or less, and we have used this to effect a dramatic reduction in overall power dissipation into the refrigerant in some pulsed experiments in which the electronics need only be switched on when signal is present.

The photograph gives some indication of the kind of noise performance improvement which may be achieved by cooling a GaAs mesfet UHF amplifier in liquid nitrogen. The circuit was constructed on a double sided printed circuit board using surface mounted (metal film) resistors and capacitors. A similar construction style is evident in the cold front end of a Robinson magnetic resonance spectrometer for use between 30 and 300MHz. The unit shown comprises a PCB with active devices, the coil (containing the sample) and the tuning capacitor, and the whole assembly fits inside a cryostat of 3.5 cm diameter which in turn is inserted between the polefaces of a 1.2 Tesla iron-cored electromagnet.

In conclusion, we feel that the advantages of "cold" electronics, which have served us so usefully in the furtherance of fundamental physics research, will come to be more broadly recognised, particularly when alternative methods of generating low temperatures become more widely available.

Already, this is becoming more realistic with the advent of small closed-cycle refrigerators capable of providing "temperatures of around 10K from a 13A mains plug".

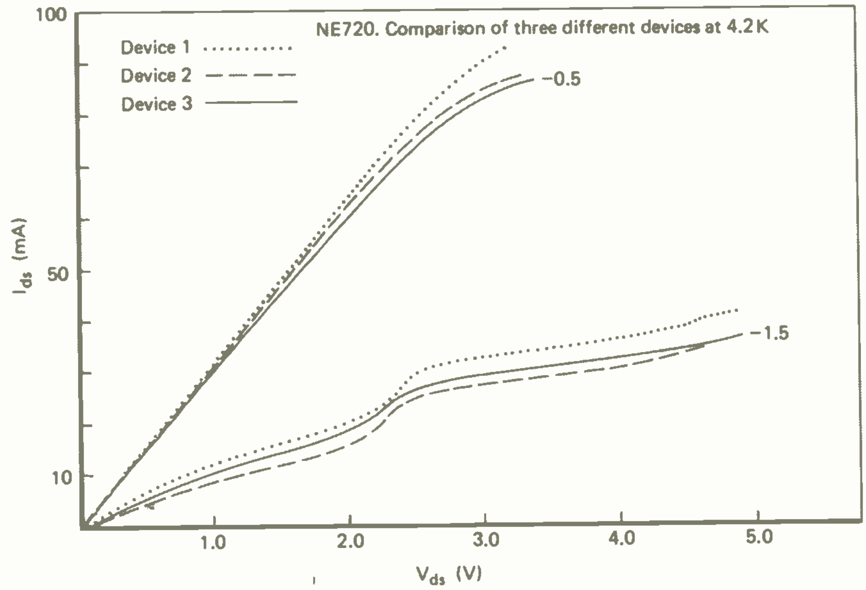


Fig. 5. Comparison of the characteristics at 4.2K of three individual devices of the same type (NE720) for two different values of gate bias. The dotted, dashed and full lines respectively represent the three devices.

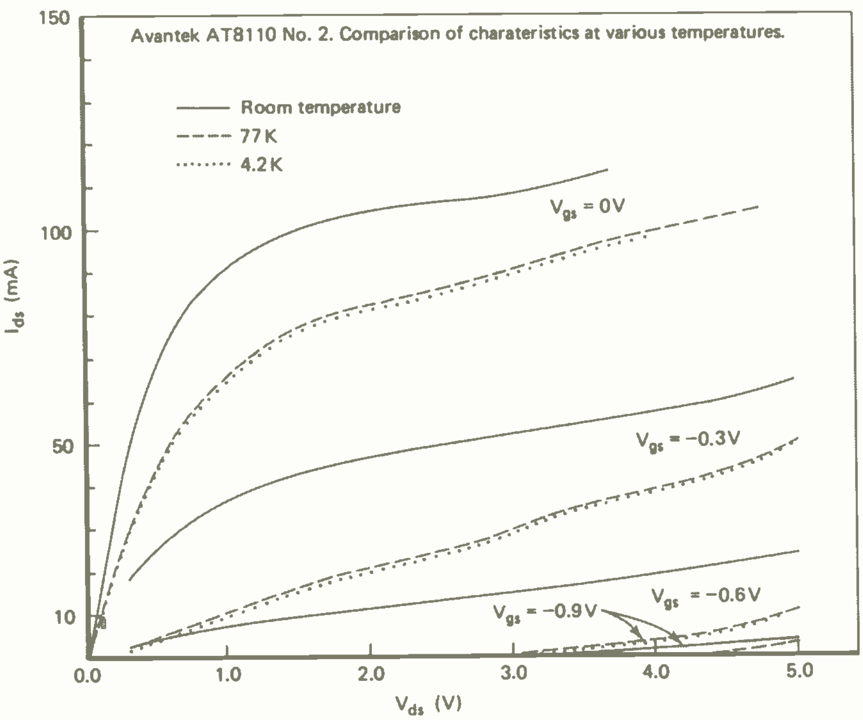


Fig. 6. Characteristics of a AT8110 at room temperature (full line), 77K (dashes) and 4.2K (dots). Note the remarkable agreement between the two sets of low temperature curves which suggests that even when the device is immersed in liquid helium, the effective channel temperature is probably of order 80K or above.

The authors are with Clarendon Laboratory at Oxford.

Microcontroller program development on a PC

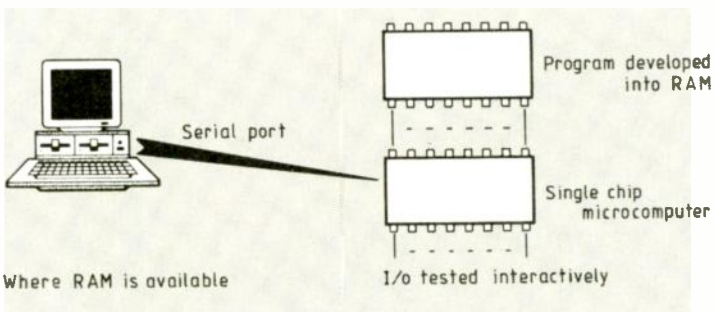
chipFORTH is a high level language for microcontroller program development. It combines the FORTH language with a PC based compiler and an interactive development environment. This allows the design, test and documentation of code in about one quarter of the time taken by other high level languages or one tenth that of assembler.

C. L. STEPHENS

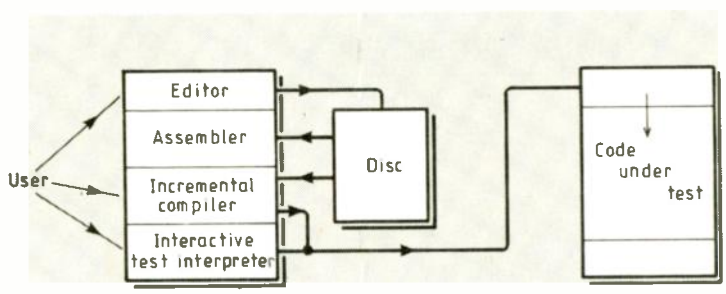
As more functions are integrated on to the chip of a microprocessor the cost and engineering advantages of selecting the right micro for the job over "using the one we always used" become significant. This can only be done cost-effectively if the engineer can isolate himself from the machine code details of the new processor by using a high level language and, at the same time, keep the cost of his development tools low.

With the aid of a grant from the Department of Trade and Industry's "Support for Innovation" scheme, Computer Solutions has developed a new way of working called chipFORTH which provides interactive development on the smallest eight bit microprocessors and microcontrollers without the need for an In Circuit Emulator (ICE). The hardware required for development (a PC and sometimes a low cost rom emulator) is independent of the project's target micro leaving the engineer free to choose the best micro for the job without having to budget for a new ICE.

Microprocessors are becoming highly integrated and sophisticated. They regularly include 16-bit operations, 64K address space, on-chip ram ranging between 128 and 512 bytes, and up to 16K bytes of on-chip rom, timers, a serial port, extra I/O lines and A/D converters. The applications themselves are also becoming more complicated, and it is becoming common to find an on-chip rom with 16K bytes of applications code. Users now favour high level programming languages. chipFORTH is based on FORTH and is ideally suited for I/O-intensive operations such as control, instrumentation and communications.



chipFORTH development environment



Software breakdown of a chipFORTH system

THE ENVIRONMENT

The development language requires an IBM-PC or compatible to act as the development system. A serial line connects the PC to the serial port of the single-chip micro. The code is compiled on the PC and passed down the serial line to the target system for storage. Interactive high-level debugging facilities are provided which require less than 256 bytes of eprom space on the target system. The PC appears to the engineer to be a VDU and keyboard attached to a full disc development system running on the CPU of the target.

Of course, this is not the real case. The PC is performing the compiling and interpreting functions, but all time and I/O critical actions are occurring on the target board. With this configuration it is possible to use high level commands to execute individual high-level or assembler modules, change variables and access I/O. New definitions (or modules) are added incrementally by the chipFORTH compiler. New high level code can either be loaded in from disc or quickly produced on-line at a keyboard.

Any target system serial output is displayed on the PC screen, while the keyboard can be used to provide test input to the target board. When more complex protocols (such as computer-to-computer links) are required, the software can be enhanced to carry out these tests, because all of the PC/target software is written in FORTH.

Alternatively, in the event that the application board does not provide a serial port then another hardware aid (called comROM, cost £195) is available. This device provides a processor-independent serial link to any computer board via an eprom socket.

THE CONSTRAINTS

Inevitably there are time critical parts of a program which cannot tolerate any overhead. To cope with this chipFORTH includes a full assembler for creating machine code (as opposed to high level) modules. These modules can be executed and tested using the same interactive facilities that are used in the testing of modules written in high level code. The package also contains sample application programs which show the engineer how to drive chip-specific hardware such as I/O ports, high-speed interrupts, A/D converters and pulse width modulated output. These provide valuable models on which other programs can be based.

Rom and ram locations are not restricted. For example, when testing hardware for the first time development can take place using only on-chip ram. To demonstrate further this flexibility it is worth noting that on the 8051 it is possible to operate either in single-chip mode or with any combination of separate or overlapping 64K program and data areas.

DEVELOPMENT HARDWARE REQUIREMENTS

The majority of applications require only a PC, but some also need a low-cost (£200) rom emulator. This is needed when the target board cannot be partially populated with ram, or when it has separate date and code spaces or when the micro is being used in single chip mode.

chipFORTH is available for the following generic family ranges: the Intel 8096 and 8051 series (including the 8031 and other derivatives such as Philips' 80552), the Motorola 68HC11 and 6801/6803 as well as the Hitachi 6301 family. It has also been implemented on the Motorola 6809, Intel 8080 and Zilog Z80, while a version running on the Hitachi 64180 (also the Zilog Z180) includes the ability to use its memory management system to develop programs as large as 512Kbytes.

USING chipFORTH – A PRACTICAL EXAMPLE

The Problem. A device is to be designed that will read an A/D converter attached to a thermocouple, linearize the value and generate an analogue output that corresponds to the temperature in degrees Celsius. In addition flexible facilities to calibrate the system and to compare the temperature to upper and lower alarm limits generating relay outputs are required. This unit is to go into high volume production with a number of different options being supported.

The Hardware. The 8031 chip was selected as it is low cost and has sufficient on chip ram for the designs requirements. An on-chip uart will be used to link to a hand held programmer for calibration and test purposes and one of the on-chip timers will be used to generate baud rates while the other functions as a general millisecond timer for the application. The on chip eprom version of the processor is too expensive for production purposes and while the volume is expected to be high this will be made up of a number of thermocouple types resulting in different versions which makes a masked rom version uneconomical. Because of these considerations the program will be held in low cost off-chip eprom. The product requires that calibration data be held in the system even when power is lost and this is done using an eprom. The A/D resolution required is better than can be obtained on chip with any of the single chip microprocessors currently available. An A/D convertor will be memory mapped into address C000 hex for the converter and C002 for the control and status register. A D/A converter is memory mapped to address C004.

THE DEVELOPMENT ENVIRONMENT

Rather than use an expensive In Circuit Emulator (ICE typical price £3000) we use a low cost rom emulator (fastROM which costs £195). This can be filled with code in less than one second and so no perceptible break in the interactive environment is noticed. A serial link is available for the PC to communicate with the board and so the standard chipFORTH configuration will operate without any modifications.

COMPONENT TESTS

The first thing to do when the application board is developed is to set about testing the hardware. The basic computer side of the system is simple (chip, eprom, crystal and RS232 connector) so after performing initial continuity and safety checks the next step is to try executing a program on the system. As this system uses a standard chipFORTH configuration it is straightforward to plug the eprom into the socket and use this as the system test environment rather than write special machine code routines. This is especially true if we are only just starting to learn how to use a new processor.

C>CF	(Load chipFORTH)
ok COMPILER LOAD	(Loads the cross compiler)
ok CPU LOAD EMU	(Loads typical chipFORTH set of words. EMU loads the resulting code into the fast-ROM emulator)
ok HEX RT	(Sets base and communications towards the target board)
ok .R	(Requests current CPU register contents)

A=E3 SP=FF R=0104 S=EFF0 U=EFF4

This is simply used to confirm communications and in the event that the stack pointers have not been set up correctly will provide diagnostic details. During the application development the content of registers is rarely needed: otherwise, why use a high level language?

What this has done is to test all the following:

i The emulator is connected correctly
ii The serial link between the PC and Applications cards is working
iii The chip and its internal ram are working.

ok 1 2 + .3

This puts values 1 and 2 on to the chipFORTH stack in the 8031's on-chip memory, commands that the values be added together (+) and then prints the total on the PC (.), which results in the 3. This has now checked out the ram, stack settings and basic micro and chipFORTH functionality.

ok C002 @ .0	(displays on the PC the contents of the A/D status register from the 8031)

@ is a chipFORTH word that reads a value from a memory location.

ok 1 C002 !	(! is a chipFORTH word that stores a value (1) into a location – the control register – this is assumed to perform a conversion).
ok C000 @ .3B	(so we have requested a conversion, assumed that the manual input time will be enough for it to have been completed and then read back a value)

Now we can change the voltage on the A/D and see what the value is by repeating the last two steps. A more useful thing to do is to write in a program to do this:

: A/D 1 C002 ! BEGIN C002 @ UNTIL C000 @ ;

: starts a definition – A/D is its name. We initiate a conversion and then wait in the BEGIN UNTIL structure until its status is non-zero, indicating completion, at which point we read the converter and leave its value on the stack for later use. Now we can build a second word for testing or to aid in calibration:

: ?A/D BEGIN A/D . CR 400 MS AGAIN;

This loops printing the contents of the A/D on a new line (CR) every 400 (hex) milliseconds (MS); we could have gone into decimal mode but 400 hex is close enough to one second for our purpose. This word will not get used for anything other than tests but a minor variant of A/D will clearly be of use in the application.

Now let us test the D/A just to check that we have wired up the high and low bytes the right way round!

ok 0 C004 !	(check volts)
ok FFFF C004 !	(check volts)
ok FF C004 !	(check volts)

So we can now write

: D/A C004 ! ;

and use the input to provide test data for the output:

: TEST BEGIN A/D D/A AGAIN;

Clearly we can now go on to check each of the relay outputs in the same way and also the eeprom.

WRITING THE APPLICATION

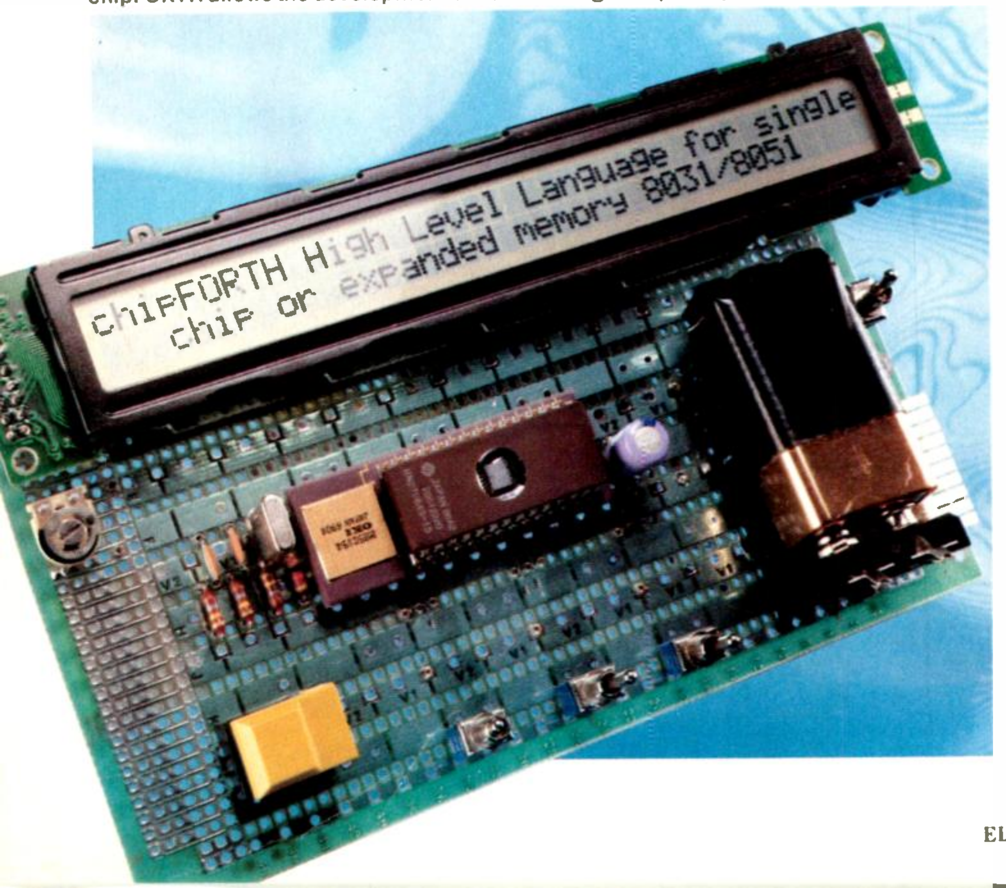
The application can now be written, probably using some of the words developed during the tests. For this project the top level program is

: GO BEGIN A/D NORMALISE ?LIMITS D/A AGAIN ;

We already have an A/D and D/A word, the normalization will depend on the type of thermocouple in use and may include switching in cold junction drift compensation. The word ?LIMITS will check whether the temperature is above the high or below the low limit (set up elsewhere), setting the relay outputs if necessary. Each word can be tested in isolation on the target system as was done for A/D before soak testing of the application takes place. The application is now running from a rom socket with on-chip ram used for variable and stack so it is only necessary to reorganize startup code to begin executing the word GO on power up and to burn a rom.

The example is a greatly simplified description of a recent application programmed in chipFORTH. In reality the normalization includes complex zero adjustments, converter gain changes, filtering and relay dead-banding. The resulting product is the Protech Sapphire Signal Processing Unit shown. Using another 8031-based hand held controller also programmed in chipFORTH, it is possible to perform either complex factory calibration procedures or on-site adjustments of the Sapphire unit with prompting from the micro to ensure operational simplicity. The flexibility of the high level chipFORTH code proved especially valuable when it was decided to modify and extend the calibration to take advantage of more effective procedures.

chipFORTH allows the development of code on single chip computers.



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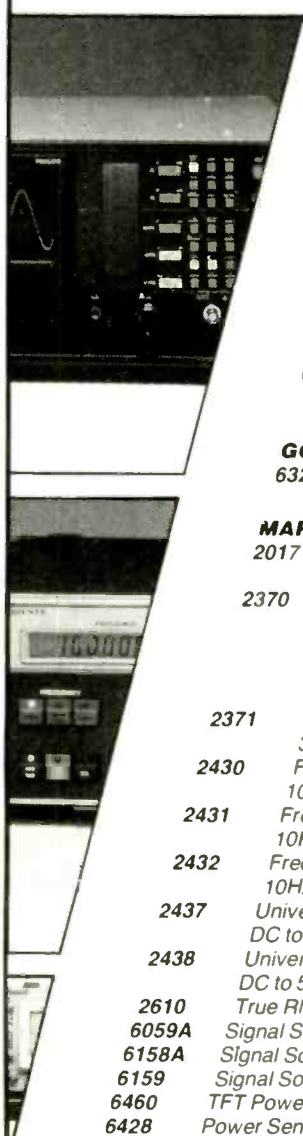

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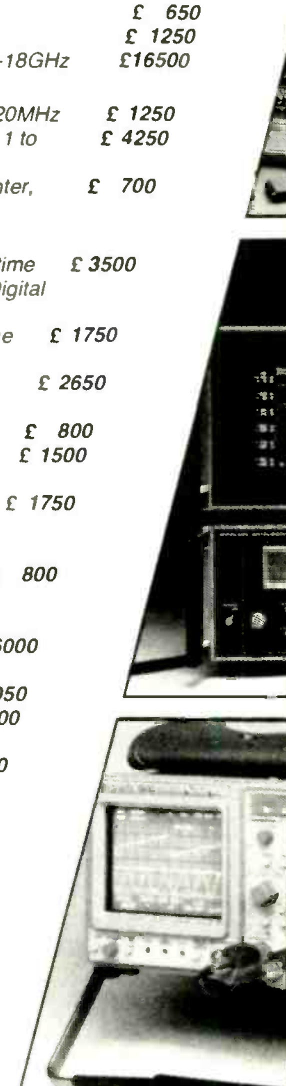

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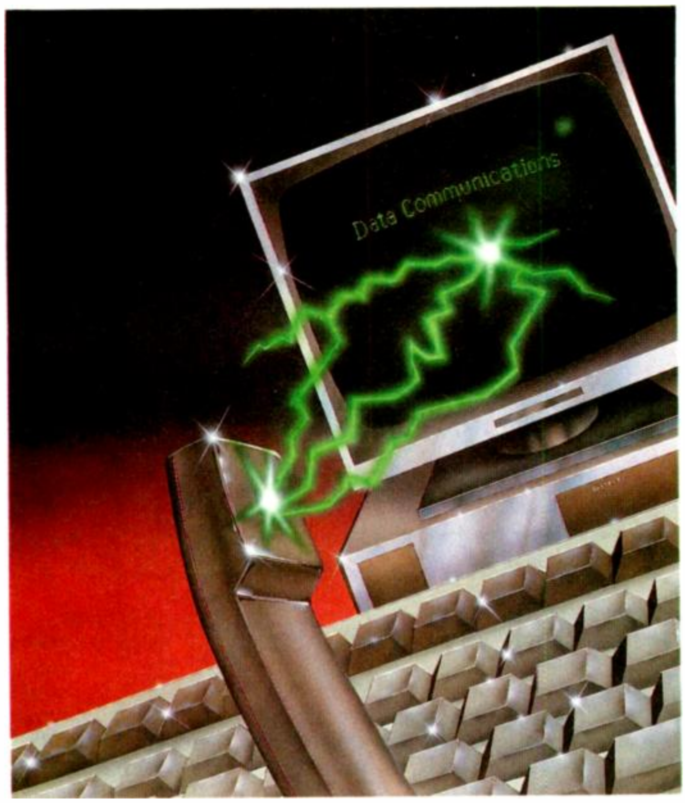


Putting AX25 to work

While the idea of sending data over radio is not new, the concept of an automatic adaptive network with minimal spectrum requirement looks particularly attractive for both military and commercial applications.

The transmission of digital data over a radio link is not a new idea. Commercial exploitation of packet radio or AX25 has many new facets. Much of the experimental work on the protocol and transmission techniques has been carried out by radio amateurs, who in many cases are professional engineers. We present the latest developments.

Packet radio originated in the USA and is based upon the well known X25 protocol. This derivation has become known as AX25 (Amateur X25). The use of the word amateur should not be taken to mean that the AX25 protocol is in anyway "amateurish"; it has been developed by well respected professional software engineers who just happen to be amateurs. An American amateur, Eric Scace, takes most of the credit for writing the original CCITT X25 protocol and is now a leading light in AX25.

THE UK AX25 PACKET NETWORK

Until approximately 1985, the terms "packet radio" and "AX25" were largely unknown in the UK, but following several technical articles outlining the uses and benefits of AX25, combined with the availability of reasonably priced equipment, interest grew.

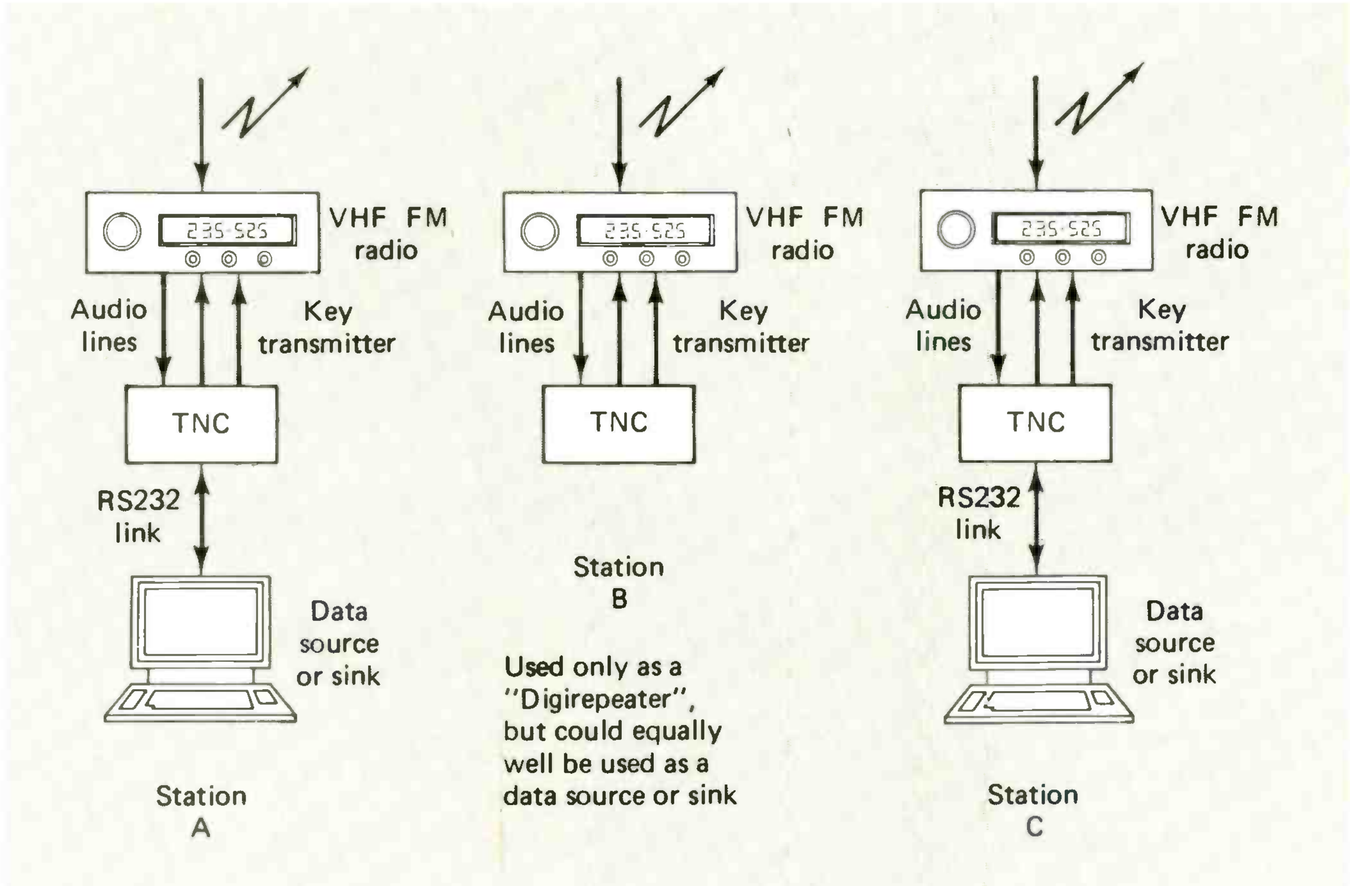
The AX25 packet network provides users with a unique set of benefits, the most important of which is error free exchange of data over HF radio.

The error free nature hinges on the initiating station getting an acknowledgement back from the distant station, and the error checking bits contained in each packet. The error checking is accomplished by the sending station calculating a certain number based upon the data being sent and a simple algorithm. This number is transmitted along with the data.

At the receiving end the number is recalculated using the same algorithm based upon the data received and if this number is the same as the number contained in the received packet of data, then an acknowledgement is sent to the originating station.

If the data has become corrupted, the received calculated number will not match the number contained in the packet. The receiving station will then transmit a reject message to the sending station causing the sender to retransmit that packet.

Due to the frequency time sharing nature of AX25, it is possible for several data links to operate on the same frequency without causing each other undue interference. This happens because each station automatically checks the frequency for other traffic before transmitting, thereby reducing the possibility of collisions. Simple low power FM transceivers are quite adequate for any



Packet radio on VHF: station B acts as an unattended relay point, making communication possible between A and C.

potential user to access the network, providing the set's bandwidth will pass 1200 baud data.

Other benefits include the ability to send and receive electronic mail from other users and the ability to address the whole packet community (in effect a computer circular letter): AX25 networks can handle traffic from BBSs similar to telephone bulletin boards.

There are four essential pieces of equipment required for the use of AX25:

1. A suitable transceiver.
2. A Terminal Node Controller, abbreviated to TNC.
3. A display terminal or VDU.

Item 1 provides the means of taking data transmissions off air. The frequencies presently in use on the amateur AX25 network are 50.67MHz, 70.4875MHz, 144.650MHz and 432.675MHz. There is also a fair amount of international AX25 traffic centred on 14.1MHz operating at 300 baud. This article is only concerned with the VHF network.

These frequencies all operate at a modest speed of 1200 baud. It is hoped that a network running at 9600 baud will be operational on 1299MHz in the very near future.

Item 2, the TNC, operates on the demodulated data, and handles all the AX25 protocol requirements of the radio link and passes the data to item 3. Usually, in amateur circles, the TNC feeds a VDU or home computer. The essential difference between AX25 and other digital communication systems over radio (such as RTTY or AMTOR etc), is the ability of each TNC to act as a simple "digipeater". This means that every user on the network has the means of relaying other users' traffic on the frequency to the next more distant station down the chain.

This digipeating occurs in the "background" of the TNC; it doesn't corrupt any traffic the host user may himself be passing. The only effect is a reduction of the throughput rate for his own data.

An example of digipeating is outlined in **Fig.1**. Station A wants to exchange data with station C, but due to the distance involved or some obstruction such as the hill, station A cannot directly communicate with station. He therefore instructs his TNC to connect to station C via station B. Hence station B is used as a digipeater.

While station B is being used as a digipeater it simply listens for any packets addressed to it. If it should receive a packet whose header contains its callsign, it then checks to see if it is intended for itself or is to be re-transmitted to the next station listed in the header.

For operation as an unattended fixed link, station A would have a list of routes programmed into the terminal enabling it to communicate with the desired distant station. Station B could be a very basic digipeater consisting of just a radio and TNC. It is possible, in theory at least, to digipeat through up to eight separate digipeaters, the figure of 8 being defined by the protocol.

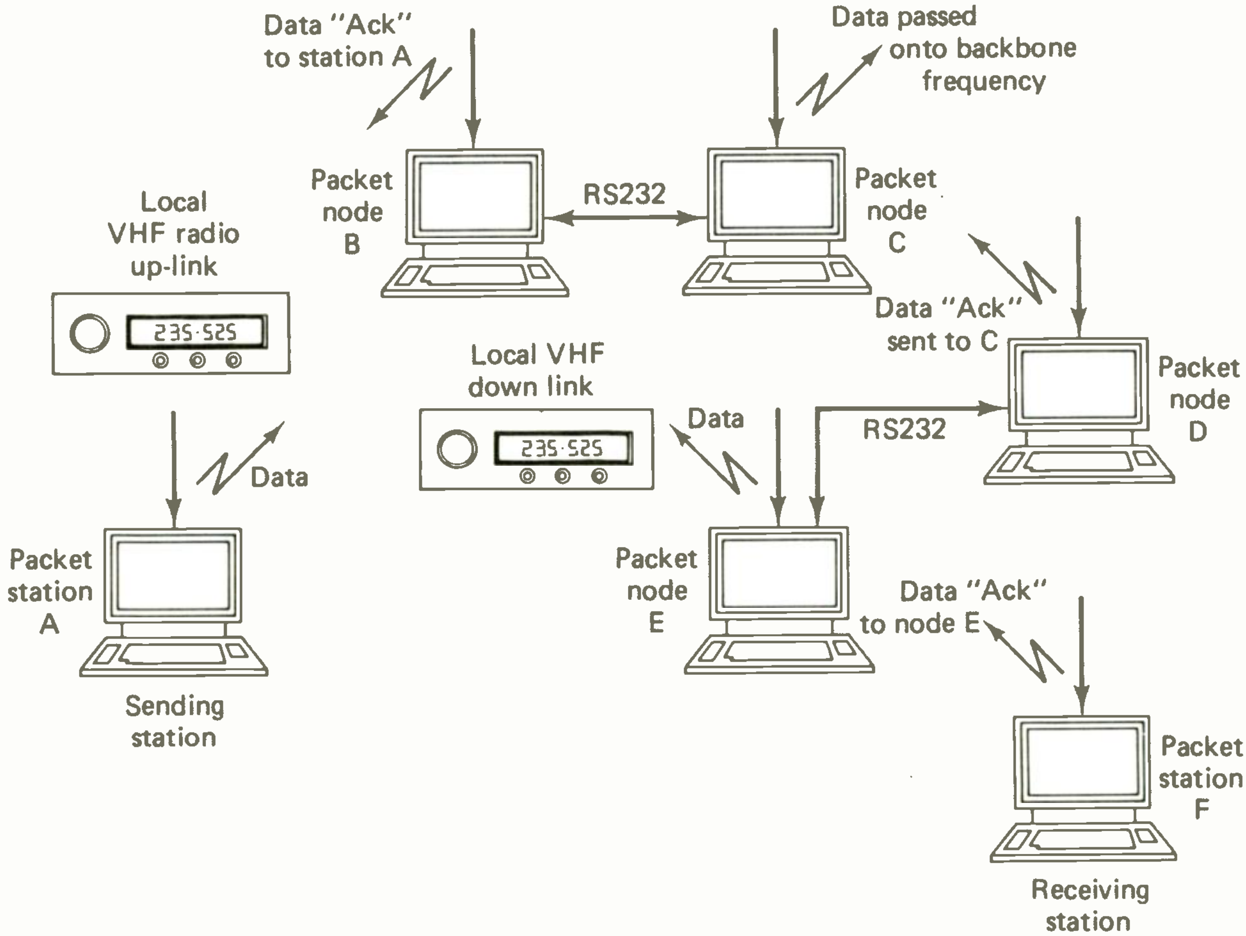
As there are no acknowledgements between adjacent digipeaters that the message has been successfully received, it is likely that at some point in the chain the message would become lost due to interference or a collision of packets caused by two or more transmitters operating at once. The initiating station would therefore have to try several times before getting a successful acknowledgement back from the distant receiving station.

In having to re-transmit the packet, the data throughput and consequently overall baud rate is dramatically reduced compared to a simple digipeating system.

In the early days of packet this simple digipeater worked fairly well, with many stations leaving their equipment turned on 24 hours a day to provide a digipeater network. Due to the rapidly increasing popularity of packet radio, it soon became unpractical to digipeat through more than two or three stations. This was due to the frequency becoming overloaded through sheer volume of traffic. A more sophisticated network had to be devised to handle the increased traffic flow.

An answer to the problem was provided by an American software house called *Software 2000*. It produced a program, held in eprom, which was compatible with the most popular types of TNC. It called this piece of software NETROM.

There are at the time of writing several



More complex packet networks are possible through the use of automatic message routeing.

other programs which offer similar facilities to NETROM; some of these other programs offer extra commands for the end user.

Instead of relying upon a digipeating network operating upon a single frequency, it enables cross links from one frequency to another, and to have inter-node acknowledgements. Referring to **Fig.2**, this means that the initiating station A has only to receive an acknowledgement from local node B. Local node B then takes over responsibility for getting the message passed successfully to the next node in the chain *en route* to the final destination. Local node B would usually pass the data via RS232 to another node physically co-sited but on a different frequency. This leaves the network input frequency clear for incoming traffic. Node C would usually operate at a higher data rate and form part of the backbone of the network. Packet node D would receive the data off the backbone network and acknowledge successful receipt to node C, before passing the data to node E via a local RS232 link. Node E would then downlink to the destination station F using a different frequency.

A feature of the network software is its ability to route the message automatically to the next node on a different frequency. It also maintains a list of other active nodes on the network and a record of which node is next in the chain *en route* to a more distant node. Using the auto routeing ability of the network, it is possible for a station to uplink to a local node, then connect to distant node before downlinking to the required distant station. All the routeing between nodes on various frequencies and bands is taken care of automatically.

As the routeing table is periodically updated by the program, it automatically incorporates new nodes and bypasses any nodes which are no longer active. For the UK network to communicate with other countries some network nodes have an HF port connected to a suitable radio for use on frequencies below 30MHz.

Another more innovative method of providing worldwide linking is via satellite. At present the University of Surrey is running a data communications experiment (known as the DCE), which involves the use of an orbiting satellite that has in effect a special type of TNC. This satellite can store up to 90k of data which can upload from the Surrey earth station and then down load at some distant earth station. Obviously this system cannot work in real time, but still provides a useful means of passing traffic.

APPLICATIONS

A packet radio network can be used in any situation where data has to be passed error-free between two points. An example might be the directing of an ambulance to the scene of an emergency, where any mistake in the passing of the exact location could waste valuable minutes. Some motoring organizations are already using a form of packet radio to pass information to their mobiles.

The US military have been quick to exploit the tactical advantages of a packet network. The adaptive nature of such a radio network allows for an individual station to go off air yet the system still remains functional. Also the relatively short duration of the data transmissions makes interception and jamming more difficult.

It also has other advantages over an open loop data transmission system. Some public utilities, such as the water authorities, have many fixed data links operating in the UHF band. If a packet type network were to be used, then it becomes possible to accommodate a larger data flow on each frequency in use, thereby releasing frequencies for other uses. The only penalty is the initial cost. It requires transceivers, TNCs and interfaces at each site.

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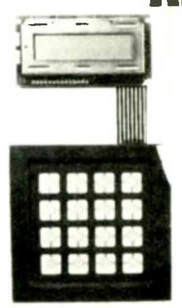

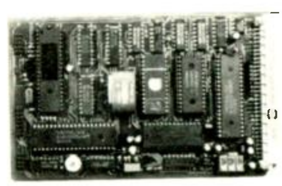

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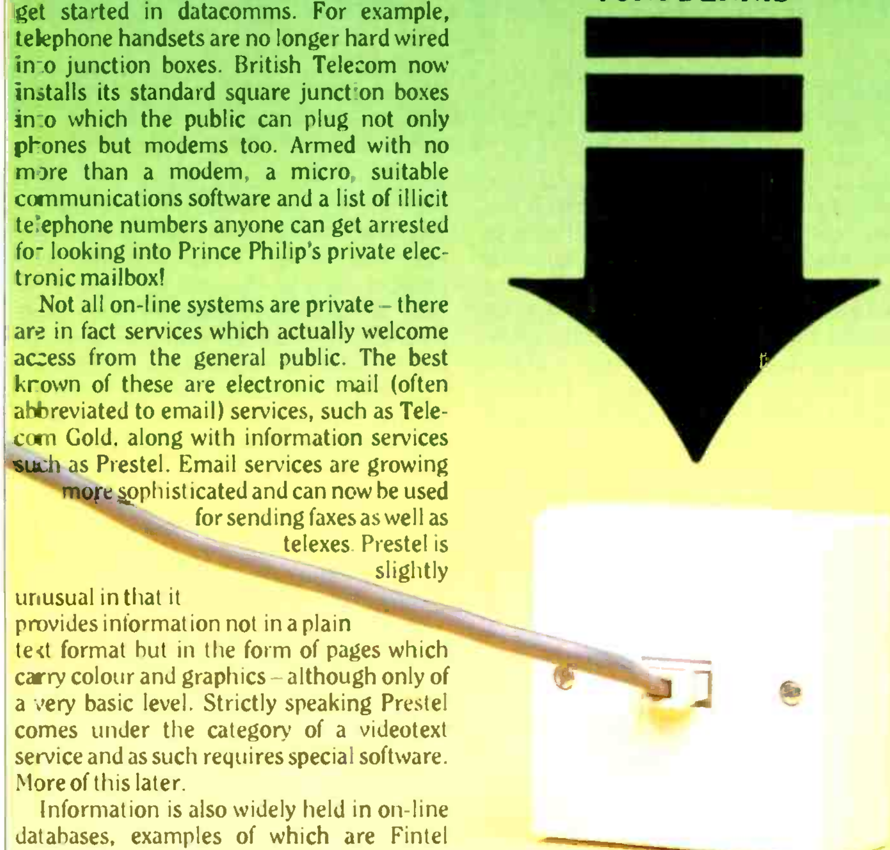
DATACOMMS New users start here

Plugging a computer into a telephone socket provides access to computer subculture of great diversity. Examination of the digital flora and fauna will even turn up a few useful species.

TONY DENNIS



The popular image of computer datacomms stems from films like Wargames depicting seventeen year old hackers blithely accessing Pentagon computers and accidentally starting World War III. The reality is much less romantic. Nevertheless, if the Pentagon *was* foolish enough to attach its computer systems to the other end of a telephone line then an ordinary PC plus a modem is all that the hacker would need to break in.

Recent technological changes have made it far easier for the average Harry Hacker to get started in datacomms. For example, telephone handsets are no longer hard wired into junction boxes. British Telecom now installs its standard square junction boxes into which the public can plug not only phones but modems too. Armed with no more than a modem, a micro, suitable communications software and a list of illicit telephone numbers anyone can get arrested for looking into Prince Philip's private electronic mailbox!

Not all on-line systems are private – there are in fact services which actually welcome access from the general public. The best known of these are electronic mail (often abbreviated to email) services, such as Telecom Gold, along with information services such as Prestel. Email services are growing more sophisticated and can now be used for sending faxes as well as telexes. Prestel is slightly unusual in that it provides information not in a plain text format but in the form of pages which carry colour and graphics – although only of a very basic level. Strictly speaking Prestel comes under the category of a videotext service and as such requires special software. More of this later.

Information is also widely held in on-line databases, examples of which are Fintel (financial information) and Profile (which carries the text of newspapers and other learned journals). However, amateurs weren't slow to get in on the act, and soon were using their own micros to act as 'hosts' for public messages. Such a service is now described as a bulletin board although most boards now carry out a range of services including distributing free or 'public domain' software. Boards have now evolved way beyond simple messaging systems.

BAUD RATE

In order to go 'on-line', however, a modem is a must. A modem is the physical device that has the job of taking digital output from a computer and transforming it into audio tones which travel easily down standard telephone lines. All that is happening is that the signal is modulated and then demodulated by a compatible device at the receiving end. [Hence the name is an abbreviation of MOdulator/DEModulator]. In the early days the method of operation employed by modems was known as Frequency Shift Keying (FSK) whereby each modulation represented one bit of data. With this type of modem its speed was expressed in numbers of modulations (measured by baud rate). Hence a 300 baud modem roughly translated into 300 bits per second (b/s).

The next move was to play games with the available bandwidth of the telephone line. When BT engineers were designing what eventually became Prestel, they came up with a modem which could receive at 1200 baud to give something approximating to an acceptable screen refresh time (ie 1200 b/s). This didn't leave much room for sending any information back but they just managed to squeeze 75 baud out of the remaining bandwidth. In fact 75 baud was fast enough for keying in at the speed of a competent typist. Thus the split baud rate 1200/75 modem was born.

As always a race to improve modems

developed and speed was the obvious target. An ordinary telephone line had sufficient bandwidth to cope with two 600 baud channels – one for receiving and one for sending. The next solution was to make each modulation carry two bits of information instead of one. This became known as DPSK (Differential phase shift keying). Likewise 2400 b/s modems are still using 600 baud but getting four bits with QAM (quadrature amplitude modulation). Further improvements followed with more bits being squashed into each modulation. It is currently possible to purchase modems which will carry 14 400 bits per second in both directions. Hence high speed modems are designated in terms of their bits per second rate while low speed modems are still measured by baud rate. Sadly this distinction has resulted in a great deal of confusion.

Clever technology is no good just on its own. The user must have some hope of being able to connect the modem to another bought from a different manufacturer. Naturally in Europe a body was formed to draw up relevant specifications and this is known as the CCITT (International Telegraph and Telephone Consultative Committee). Thus 300 baud became the CCITT's V21 standard and 1200/75 baud modems conformed to V23. Over in North America, modem manufacturers were following rival standards set by the Bell telephone company. Fortunately the Americans have subsequently decided to fall into line and now follow CCITT standards for 2400 b/s and above. Luckily the Bell and CCITT for 1200 b/s are virtually identical too!

	BOARD	STDCODE	NUMBER	AREA
1	PSYCHOBABBLE	0534	52086	CH
2	JETSET	0481	712597	CH
3	MASTER CONTROL	0534	58929	CH
4	HAWKS CASTLE	0344	411621	E
5	ICHTHUS	0734	484847	E
6	THE VILLAGE	01	4642516	L
7	DATA CONNEXION	01	4785464	L
8	SW10 WAREHOUSE	01	3765349	L
9	BODY MATTERS	01	6037581	L
10	CHARITY HOUSE	01	6737294	L
11	CRYSTAL TOWER	01	8862813	L
12	CO-OP BOARD	01	3166488	L
13	PARADIGM OPUS	01	2518255	L
14	TBBS ROVEREED	01	5424967	L
15	PD SIG B	01	8642633	L
16	DEC CATT HOUSE	01	2003033	L
17	CENTRAL OPUS	021	7111451	M
18	ACADEMICS	021	7059677	M
19	TUG II	021	4441484	M
20	STARGATE OPUS	0476	74616	M
21	MACTEL HQ	0602	817696	M
22	C-4-CHRIST	0926	28294	M
23	WELLAND VALLEY	0858	66594	M
24	THE GAS LAMP	0706	358331	M
25	ACCESS FIDO	0905	52536	M
26	MACTEL GREENBOX	0602	455444	M
27	POACHER OPUS	0476	62450	M
28	CORBY TOWN OPUS	0536	205113	M
29	NEPTUNE BBS	0274	573481	NE
30	LEEDS UNIVERSITY	0532	445276	NE
31	DEEP THOUGHT	0247	270199	NI
32	MCIS	061	7737739	NW
33	ULTIMATE SOURCE	061	6789580	NW
34	TEE PEE OPUS	061	4946938	NW
35	ARGUS PROJECT	091	4900327	NW
36	WEST END	041	3371519	S
37	JOCKS AWAY!	031	2255368	S
38	OPUS CLYDE	041	8807863	S
39	MACTEL PHEONIX	0473	610139	SE
40	AIRTEL	0342	717800	SE
41	SENTINEL	0628	781429	SE
42	GOSPORT APRICOT BBS	0705	524805	SE
43	BOB'S BIZARRE	0394	279644	SE
44	DATASOFT	0460	54615	SE
45	EXCHANGE TBBS	0767	50511	SE
46	STAINES	0784	65794	SE
47	SOFTNET B	0895	420164	SE
48	TRINITY 1	0392	410210	SW
49	WORLD OF CRYPTON	0458	47608	SW
50	ABSOLUTE ACCESS	0425	471370	SW

CH=Channel Islands - E=East of England - L=London - M=Midlands
NE=North East - NW=North West - NI=Northen Ireland - S=Scotland
SE=South East - SW=South West.

MODEMS

Obviously modems can be equipped with all kinds of bells and whistles so it would be best to outline some of their more useful features here. To save the user from having to plug a handset into the back of the modem and physically dial a number, most modems will now do the dialling automatically – hence they are 'autodial'. For those who want to set up their own remotely accessible system, a modem can be made to automatically answer incoming calls. This is called 'auto-answering'. Then rather than requiring the user to physically open up the modem's casing and mess around with jumpers and dip switches, manufacturers found life was much easier if the modem altered its own configuration through software commands. The company which set the standard in this area was Hayes Microcomputer Products based in Norcross, Georgia. The Hayes command set (which starts with the letters AT standing for attention) has now become a *de facto* standard and virtually all modems sold in this country for dial-up use are referred to as Hayes compatible.

The only other feature of a modem possibly worth worrying about is error correction. This has become almost indispensable with the rise of data throughput speeds. Error correction deals with the problems caused by line noise 'corrupting' data is it is being transmitted. The usual method is to check blocks of data and ask the originating modem to resend any which have become corrupted. The MNP series of protocols invented by Microcom are rapidly establishing themselves as an industry standard but watch out also for the CCITT's V42 standard which includes both MNP and a rival protocol – LAP-M.

The easiest way to go on-line with a micro is to run a program which allows it to pretend to be a popular terminal such as a DEC VT52. This is known as terminal emulation. But what is the point of using a micro as a 'dumb' terminal when it is quite capable of handling more intelligent tasks such as file transfer? It didn't take long for budding hackers to write their own communications software and in the process introduced a file transfer protocol known as Xmodem. The attraction of Xmodem is that it permits file transfer between totally incompatible systems even if the actual file contains machine code!

The good news is twofold. Firstly suitable communications software exists for virtually every kind of microcomputer in existence: even the Sinclair ZX-81! Secondly such programs can be obtained for little or no cost. The authors of many terminal programs have placed their work 'in the public domain' which means anyone can distribute it as long as no charge is made. There is a second category known as 'shareware'. Shareware originated in the USA where the idea is that the program can be freely copied. If, however, the user feels the program is worth something then the idea is to send off a registration fee to obtain a manual plus future program upgrades, etc.

Shareware is especially popular in the world of IBM PCs and compatibles. There are a number of extremely good comms packages available as shareware. Good examples are Procomm and PC-Talk. This kind of program is available from commercial companies like Shareware Marketing or from the PC Users' Group. In general, the user groups associated with individual machines or operating systems will be an excellent source of software. Commercially produced packages such as PMS' *Dialup* (£50) and Softklone's *Mirror II* are recommended (£70).

There are a number of features which make for an ideal comms package. The first is a viewdata capability which provides access to Prestel and its section specifically aimed at computer users – *Micronet*. Sadly software of US origin often lacks viewdata compatibility as the system isn't widely used over there. Incidentally French software will be compatible with Teletel, which is similar to, but still incompatible with, Prestel. Those which can boast viewdata emulation also need to have a 'Mailbox' editor. This feature enables text messages to be prepared off-line for subsequent transmission to Prestel's electronic mail system, *Mailbox*.

Apart from Prestel emulation, a communications package should also include support for text based systems. This is quite simple and basically involves emulating a standard TTY (teletype) terminal. Some programs just support DEC VT52 emulation which for all intents and purposes is the same. Originally it was necessary to instruct comms software to recognise a particular kind of modem. Nowadays virtually all modems will recognise Hayes commands so there is no need. As a by-product of this, most packages contain a dialling directory.

The next feature to look for in a comms package is support for what are known as 'auto-logins.' It is general practice with on-line systems that before providing anyone with access, a recognised user name or identity number along with a password has to be suplied by the caller. This process is known as 'logging on'. As these have to be keyed in exactly, it soon becomes a boring, repetitive process. Thus most packages allow the user to store identity numbers and passwords against an entry in the dialling directory for a specific service. As soon as the software detects that a connection has been made, this log-on string is then uploaded automatically.

The drawback with low-cost modems is that they tend to be difficult to operate, making life difficult for the beginner. For example, ex-GPO modems have been on sale for as little as £30. On the other hand, they were built like tanks and about as easy to handle. The next cheapest option is called an 'acoustic coupler'. These tend to suffer from data corruption caused by line noise more than the directly connected type of modem. Single standard modems start at around £70 but the best advice is to consider one which supports both V21 and V23. An example would be the Pace Linnet for around £130. Those with enough money should consider Amstrad *MC2400* which for £199 plus VAT provides four speeds including 2400 b/s. There is another good way of obtaining a modem cheaply. Paying Micronet's annual subscription of £79.95 brings with it a free GEC Datachat (V23 only) modem.

CABLE TANGLE

One of the greatest datacomms dangers comes from attempting to use a cable not specifically designed for modem connections. [Not for nothing did Spitting Image come out with the RS232 cable song!]. The required interface between the computer and the modem is always a serial port conforming to the RS232C or RS423 standards. This is frequently used for printers but the pin connections are *not* the same. For a modem configuration, pins 2 and 3 must not be cross connected. The best advice is therefore to obtain the cable from whoever supplied the modem, or buy a card modem which fits inside the computer's casing and therefore needs no cable.

Occasionally there are problems when trying to use a modem on a switchboard extension line. The normal method of signalling a number to the telephone exchange is called pulse dialling. This system has been supplanted by the more efficient DTMF tone dialling method as used by PABXs. However, not all modems support tone as well as pulse dialling so it is a point worth checking. Luckily, domestic subscribers who happen to be connected to System X exchanges can use tone dialling from the comfort of their homes.

Armed with comms software and a working modem, the next move is to find a system on which to test them. With Prestel it is quite simple. Dial 618 (or 01 618 1111). Then use fourteen number 4s when asked for an identity number and password. This will provide access to some demonstration pages supplied by Micronet. There are ways of doing something similar with Telecom Gold. It is at this point that some knowledge of modem speeds/standards becomes important. On-line services will have a number of ports supporting all the popular communications speeds. However, the telephone number may vary according to supported speed. Hence Telecom Gold's 300 baud/V21 port is 01 583 3000 whereas for V23 it is 01 583 1275.

Certain systems are sensitive to data protocol settings a really annoying trait. Put simply some still use a 'parity' bit whereas others have ceased this outdated practice. Thus for Prestel and Telecom Gold, users should select (with an option buried somewhere in the comms program) even parity along with seven data bits when calling these systems. For bulletin boards, however, select eight data bits along with no parity. It should be easy to tell if the setting is wrong. The screen will fill with a jumble of characters with the result that only the occasional word will be legible.

BULLETIN BOARDS

The best means of learning about datacoms is to call a bulletin board. The majority make no charge for accessing the service. The cost of the telephone call is the only expense. A firm word of warning here. Bulletin boards are addictive. It is very easy to forget the time and stay connected for half an hour at a time. The result is a quarterly bill of around £400, which is not uncommon. Software which displays the time spent on the current call is soon appreciated too! Another wise move is to call local boards.

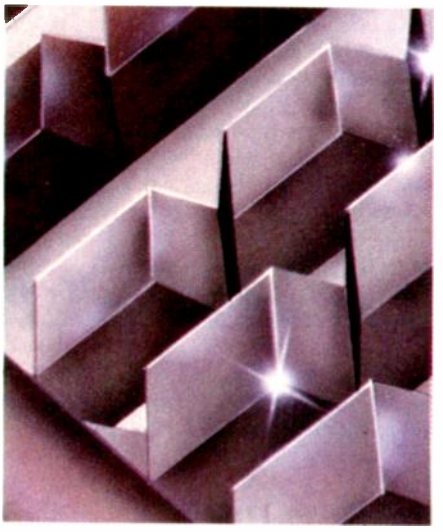
To go with this article is a list of boards supplied by Stephen Adams. He is the sysop (system operator) for the Sinclair London board. Stephen has broken down his list by geographical areas so that all readers should be able to find a board moderately close to where they live. Not all boards operate 24 hours a day like those included here, some are only run in the evenings and at weekends. Most boards can now support a range of data speeds but those which support 1200/75 only are almost undoubtedly viewdata only. Virtually every bulletin board (or BBS for short) carries a list of other systems which the caller can download. The UK is blessed with a substantial number – Stephen Adams' list is condensed from approximately 400 boards. Those unable to access his board [01 249 3238] can write to him at the address given below for a list.

To generalise somewhat, most bulletin boards tend to have one theme. This might be a type of micro – Sinclair, Acorn, Amstrad, etc – or it could be an operating system. CP/M, for example, is still relatively popular. Boards frequently offer sections for special interest groups such as radio amateurs or even hackers. Then there are boards which have been effectively turned into adventure games. Into this category fell the wonderfully named Mega Anchovy but sadly this type of board is somewhat ephemeral.

Out of all the on-line electronic mail services, Telecom Gold is by far the most popular. It carries a host of individually tailored services; MicroLink is aimed at computer users. Other electronic mail providers include One to One, and Mercury. Another email service worth a mention is CIX (Compulink Information eXchange) which is virtually a commercial bulletin board service but features 'conferences' on topics of virtually every hue and shade.

Experience has shown that most enquiring minds want to try their hand at hacking. Hugo Cornwall's Hackers' Handbook is required reading. It mentions such obscurities as PSS and JANET. These are data networks which can be accessed from an ordinary telephone line. Packet SwitchStream (PSS) is BT's public data network. It connects to all the major on-line database and electronic mail suppliers. It is necessary to have a password known as a NUI (network user identity) to use PSS. This can nearly always be obtained from the information provider and is much cheaper than joining individually. The Joint Academic Network (JANET) is intended as a network for universities to share computer resources. Students have a habit of using it for other purposes, however.

Useful address:
List of BBS – Stephen Adams, 1 Leswin Road, London N16 7NL.



Local area network technologies

We provide a summary of local area network technologies currently being incorporated into standards, particularly the Government Open Systems Interconnection Profile (GOSIP). Proprietary technologies outside the OSI standardisation sphere are not included; their importance will decline over the coming years as European procurement initiatives push the market down the OSI route.

ANDREW HARDIE

At the moment you cannot buy a lan system (i.e. hardware and software) that fully implements an OSI functional profile but you can buy the lower-level technology on which such future lan systems will be based. This article considers the only hardware of that available technology and makes no attempt to cover the large and complex subject of the software.

The physical transmission medium used in lans is either copper-based, using twisted pair or coaxial cable, or optical fibre based. Some individual lan technologies can support more than one type of media, usually depending on different speed options.

Two different data transmission techniques are used on the physical media: baseband and broadband. Baseband is the familiar voltage level signalling technique like TTL levels or RS-232 in which each bit value is signalled by a particular voltage level (or current in the case of a 20mA loop). Broadband employs the use of radio frequency modems to encode the bit values as frequencies. Use of multiple frequencies allows different signals to be multiplexed down a single cable.

TOPOLOGY

Topology refers to the way in which the transmission media are interconnected to form a complete system. There are three main types of network topology: star, bus and ring. In the star configuration, every node on the system has an individual connection to a central point where the routing is controlled. The obvious example of this is a telephone exchange. Star topology has not proved popular in lans.

In the bus configuration, every node on the system is connected via a tap of some sort to a single network cable. Obviously, this introduces the problem of deciding when each node should send or receive, this being the task of the access protocol which usually operates on the basis of time division – i.e. only one node sends at a time, determined by the protocol. Only a broadband system can support more than one node sending at a time by virtue of its frequency subdivision of the media bandwidth.

In a ring configuration, every node is connected to its two neighbours, usually on a one-way basis, i.e. it receives only from its neighbour on one side and transmits only to its neighbour on the other side, and so on until a complete ring is formed. Thus a message from one node to the adjacent node from which it receives must pass round almost the entire ring to reach its destination, passing through every node on its journey. Again, deciding which node speaks when (in originating a message, not in passing one on) is on the basis of time division.

ACCESS METHOD

The three access methods in widespread use, out of those currently defined are CSMA/CD, Token Ring and Token Bus. These three, together with the much less popular Slotted Ring, are defined in the fundamental 8802

series of international standards that form the physical layer standards upon which the OSI functional profiles rest.

CSMA/CD stands for Carrier Sense, Multiple Access/Collision Detect and has to be the worst mouthful of an acronym around; why didn't they call it CaSMACoD? At least you can say that! It is used in topologies such as Ethernet. It is based on the principle that each node with a message to send listens to the bus, waits for any messages in progress to finish, waits a short period, sends its message and listens while doing so to detect any collision caused by another node doing the same. If a collision is detected the node waits a further short, but random, period and tries again. The snag with this technique is that when the bus starts to get busy the collision rate rises and the throughput fails, both at an alarming rate.

Token Ring uses an electronic equivalent of the old railway token concept to determine which train has permission to use a length of single track. It is more complicated in that there are multiple levels of priority and other features but, essentially, a node with a message to send waits for an electronic token to arrive, accepts it, inserts its message into it and sends it on. Each message contains the address of the node for which it is intended and each node checks all incoming traffic for tokens, messages for passing on and messages intended for it. Tokens are passed on unless needed for outgoing messages as are messages for other nodes. Only messages for that particular node are copied to the host attached to that node; they are then sent on round the ring, marked to indicate their acceptance so providing the sending node with an acknowledgment.

Token Bus uses tokens in a similar way to a token ring but with those changes caused by the different underlying topology. Effectively, a logical ring is created on a physical bus with each node able to send directly to the intended recipient without the data passing through all the intervening nodes. The nodes' sequence is determined by a numbering scheme instead of a physical ring connection.

EMERGING TECHNOLOGIES

Although optical fibres are being included in the standards for CSMA/CD and Token Bus, they are really just physical layer replacements, an alternative to copper-based connections. Only one standardised network technology is specifically for optical fibres, FDDI (Fibre Distributed Data Interface).

This takes the form of a dual ring capable of up to 1000 nodes and a maximum data rate of 100Mbit/s. It doesn't yet form part of the OSI family and the few implementations that exist are large and expensive. If the cost comes down enough it could become the dominant high speed LAN technology. An enhanced FDDI II, able to carry digitised, live speech is on the way; try that on Ethernet!

The big sleeper – ISDN, the Integrated Services Digital Network, is nothing less than the ultimate replacement of the world analogue telephone system, the largest man-made network in existence. It is an all-digital system offering 64kbit/s point-to-point data transfer channels which can be used for speech, data, high-speed fax, slow-scan video or anything else that can be carried over a 64kbit/s "bit pipe". Standardisation is well under way and products are starting to emerge following pressure by the European Commission to keep things moving. When operating it will, essentially, provide a gigantic star topology network operating on a local, metropolitan, national and international scale.

At the lan level, the new generation of Integrated Services PBXs will route connections within a site and route data for remote destinations over the external public ISDN. The day of a digital telephone on your desk with a 64kbit/s port on the back offering you high speed X.25 links to anywhere on the network must appeal to all those who have used slow speed PADs. Provided that the standardisation problems of configuring OSI lans over an ISDN can be solved and existing building telephone wiring can be used (much claimed, but not yet conclusively proved) the ability to install a lan in a building without special wiring and the potential for instant wide area connectivity may be enough to offset the relatively low data transfer rate (compared to other lan technologies).

Ironically, the one lan technology you might encounter most often in the future, because it will be in your home, may be one you have probably never heard of. HES, the Home Electronics System, was regarded as a bit of a joke by some members of the standardisation community when it first surfaced about three years ago. It has come a long way since then and the sheer versatility offered by the overall system is impressive. Are you ready? It will work over a twisted pair, coaxial cable, optical fibres, power lines, air borne infra-red and radio links.

It is intended to carry everything from slow speed lighting control, security, white goods (the gadgets in your kitchen) and brown goods (the gadgets in every other room), through telephone, voice, hi-fi grade audio switching, and high speed data, to ISDN, fax and video routing. It will link many types of medium in a single installation through gateways and universal interfaces on the attached devices, making them independent of the transmission medium.

Network addressing could be a key issue though, to stop your TV remote control from inadvertently defrosting next door's freezer! If the low-level stuff is put into silicon chips and the far-East manufacturers start using them then it could all happen.

CONNECTORS USED IN LANs

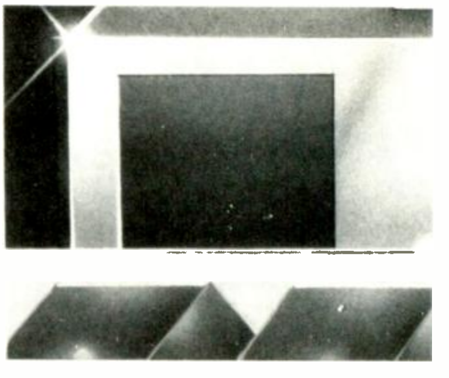
For the copper-based technologies the connectors used with twisted pairs are the 15 way D-type, the MIC Medium Interface

The table below shows which lan technology uses which connector.

Technology	Access	Media	Connector
CSMA/CD	Tap	TP	15 pole D-type
CSMA/CD	Bus	Coax	N type ("thick" Ethernet)
CSMA/CD	Bus	Coax	BNC ("thin" Ethernet)
	Bus	TP	8-pole modular
	Bus	Coax	F-type (broadband)
	Bus	Fibre	FSMA
Token Bus	Bus	TP	8-pole modular jack
	Bus	Coax	BNC
	Bus	Coax	F-type
	Bus	Fibre	Duplex
Token Ring	Ring	TP	4 pole MIC
Slotted Ring	Ring	TP	15 pole D-type
ISDN	Basic	TP	8-pole modular jack
ISDN	Primary	TP	8-pole modular jack
FDDI	Ring	Fibre	Duplex

(TP = Twisted Pair)

Connector and the eight-way modular jack (like the US telephone connector, but eight pole). For coaxial cable, many familiar connectors are used like BNC, N, F and some perhaps less familiar types like TNC and twinax. Optical fibres use either FSMA, the fibre version of the widespread SMA miniature RF coaxial connector, and Duplex, a special twin fibre connector developed for FDDI.



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Capacitors	Large Range	from 5p
Sil Tant's	Large Range	from 25p
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Item	Cost (1 off price)
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Z8420ABI	95p
Z8430ABI	95p
Z8440ABI	£1.50

Item (CMOS)	Cost
Z84C20AP	£1.00
Z84C40AP	£2.00

Item	Cost (1 off price)
SRAM 4K×1	30p
UPD42832C-150L	£2.20
MM65256PB-15	£3.00
MAB8031AH12P	90p
ICL7107CQH	£1.50

Item IC's	Cost (1 off price)
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Tea 1060	70p
S1240	25p
27256-15	£3.20
UPD6537GMC	£1.50
UPD8206GMC	£1.75
UPD449G-15NC	£1.00

Item	Cost (1 off price)
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Green LED Display 45mm	£1.66
Red LED Display 12.7mm	50p
2×20 LCD Module	£5.00
5.3 Digit A/D LED	£2.00

Item – Cable			Cost
Flat Twisted Pair	All prices per metre	26 way	50p
Flat		50 way	£1.00
Flat		40 way	80p
Flat		36 way	70p
Flat		25 way	55p
Flat		16 way	35p

Item	Cost (1 off price)
Large range of Papst Fans including: 45" dual voltage 120-240	from £7.00 to £12.00
PSU Power One 15V 1.35A	£20.00
Rockwell R5310-18	£5.00
Rockwell R5325-11	£5.00
Rockwell 10464-13	£5.00
B-B Sample Hold Amplifer SHC80KP	£10.00
B-B A/D Converter ADC84KG-10	£25.00
B-B Isolation Amplifier 3656BG	£25.00

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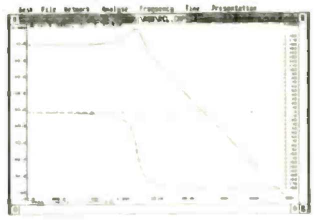
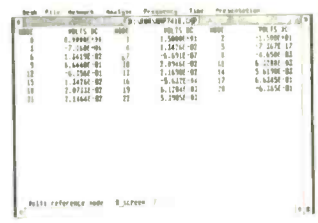


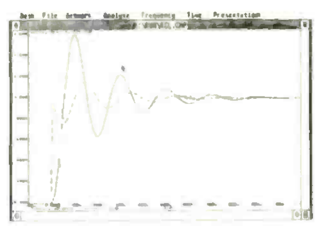
Frequency response of a low pass filter circuit

1 Frequency response
SPICE•AGE provides a clever hidden benefit. It first solves for circuit quiescence and only when the operating point is established does it release the correct small-signal results. This essential concept is featured in all Those Engineers' software. Numerical and graphical (log & lin) impedance, gain and phase results can be generated. A 'probe node' feature allows the output nodes to be changed. Output may be either dB or volts; the zero dB reference can be defined in six different ways.

2 DC Quiescent analysis
SPICE•AGE analyses DC voltages in any network and is useful, for example, for setting transistor bias. Non-linear components such as transistors and diodes are catered for (The disk library of network models contains many commonly-used components – see below). This type of analysis is ideal for confirming bias conditions and establishing clipping margin prior to performing a transient analysis. Tabular results are given for each node; the reference node is user-selectable.



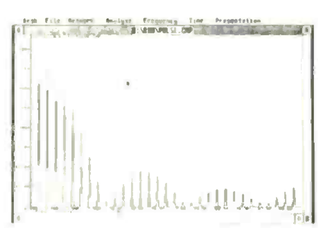
DC conditions within model of 741 circuit



Impulse response of low pass filter (transient analysis)

3 Transient analysis
The transient response arising from a wide range of inputs can be examined. 7 types of of excitation are offered (impulse, sine wave, step, triangle, ramp, square, and pulse train); the parameters of each are user-definable. Reactive components may be pre-charged to steady-state condition. Up to 13 voltage generators and current generators may be connected. Sweep time is adjustable. Up to 4 probe nodes are allowed, and simultaneous plots permit easy comparison of results.

4 Fourier analyses
SPICE•AGE performs Fourier transforms on transient analysis data. This allows users to examine transient analysis waveforms for the most prevalent frequency components (amplitude is plotted against frequency). Functions as a simple spectrum analyser for snapshot of transients. Automatically interpolates from transient analysis data and handles up to 512 data values. Allows examination of waveform through different windows. Powerful analytical function is extremely easy to use.



Spectrum of rectangular pulse train (Fourier analysis)

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The Kernel Logic Machine

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IVOR CATT

Occasionally, a number of technical advances come together to give a quantum leap forward. This occurred recently as a result of three factors – the increased density of components on an integrated circuit, the successful fabrication of fault-tolerant complete integrated circuit wafers at Anamartic Ltd, and a new approach to structuring these wafers called the Kernel Logic Invention. The result is that the latent, explosive power of semiconductor technology can be unleashed – one million complu-ters working together in an array to solve large, complex problems at high speed.

INTRODUCING KERNEL LOGIC

An improved approach to wafer-scale integration became possible back in 1972 because chips of reasonable yield contained, or would soon contain, as many as 10,000 components. Using an external piece of special test circuitry composed of 100 TTL packages, a single row (spiral) of perfect chips could be 'grown' into an imperfect wafer each time power was switched on to the machine (see panel). Burroughs Corp. (now Unisys) at Cumbernauld built three-inch working wafers which demonstrated the feasibility of the spiral approach. The same successful team of engineers later moved to Sinclair Research Ltd (renamed Anamartic), where in 1985 they successfully manufactured the first pre-production working wafers intended for the market. A four-inch wafer full of 16Kbit drams used the spiral algorithm to interconnect the good memory, bypassing the bad, to a total of 0.5Mbyte on the wafer. However, because of the slump in the ram market at the time, this product was never brought to market. In 1989, Anamartic will market a solid-state disc made up of a pack of six-inch wafers containing 1Mbit drams to a total of about 20Mbyte per wafer. Its size could be something like a six-inch cube.

In 1987, 15 years after the spiral algorithm was patented, the number of components in a chip of reasonable yield had risen to one million, an increase of one hundred times beyond the vintage of that invention. The Kernel Logic patent exploits the fact that much more 'fault tolerance' capability can be designed into today's dense chip.

To understand kernel logic, think in terms of the faults in a wafer. One model

HISTORY OF WAFER SCALE INTEGRATION

The first attempt to achieve WSI was at Texas Instruments in the USA in the 1960's. A wafer was made with an array of ordinary, identical chips with conventional bonding pads. These chips were then probed in the usual way, and a record of which were good and which were faulty was fed into a large computer. The computer designed a unique final layer of metallization which would interconnect the good chips on that particular wafer and avoid the bad. The major problem with this approach, and the reason why it failed, was that it was necessary to assume that this last layer of metallization would have 100% yield.

The other famous debacle in WSI was at Trilogy. Amdahl, the father of the IBM 360 series of computers, left IBM and succeeded in taking a share of their massive market with his company Amdahl Corp. He then ventured out to beat IBM's fastest computers for speed by cramming an IBM look-alike machine into five wafers, where signal lines and therefore signal delays would be less. Amdahl raised $250 millions on Wall Street in the biggest start-up in history. His wafers used a conventional approach to fault tolerance. A wafer was very complex, and had over one thousand wires bonded to it. The failure of his WSI and of his company in the early 1980's was the second major blow to the credibility of WSI. It is doubtful if the assertion in the Butcher article (see bibliography) that Trilogy made working wafers is true.

Other companies have approached the use of wafers in ways which would lead to their supplying only a niche market. Wafers have been used as a substitute for the PCB, with flipchips bonded onto them. Laser mending of faults has also been tried, but such expensive doctoring of wafers falls outside the mainstream of attempts to exploit the wafer for its potential low cost and high reliability. The Butcher article discusses other WSI projects at length.

suggests that tiny faults exist at random points across the wafer, so that if a wafer with 250 faults is cut up into 500 chips, half of them will contain a fault and so be scrapped. Now consider a tiny section at the south-west corner of each chip, which I call the kernel. If this kernel is small enough, its yield will be very large. It is easy to calculate the size of kernel required so that 80%, say, of the wafers manufactured will have a perfect kernel in the corner of every chip on the wafer. The other 20% of manufactured wafers – those with chips containing one or more faulty kernels – are scrapped.

When power is switched on to the wafer, the kernel logic spontaneously puts its chip through a test routine, and decides whether the chip it controls is perfect. If it isn't then the kernel logic cuts off communication with the outside, and the faulty chip disappears from the system.

Chips adjudged by their several kernels to be perfect are allowed to intercommunicate. There is then a simple procedure whereby control circuitry outside the wafer is informed as to which chips are perfect and which chips have been removed from the two-dimensional array. Perfect chips are instructed to link up into an array structured according to the needs of the external control circuitry. (Workers in artificial intelligence would restructure the machine to match the structure of their data).

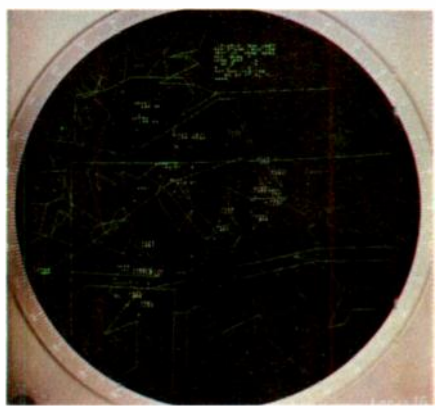
Communication into and out of the wafer is by means of signal lines at both ends of every column and also of every row of chips. The structure lends itself naturally to expansion into a Cartesian array of interlinked wafers, resulting in an array of 1000 by 1000 processing nodes, each with its own microprocessor and 1Mbit ram, at a cost of the order of one pound per processing node.

A DIGITAL ANALOGUE OF REALITY

The first signs of the new concept appeared in my own writing 20 years ago (*New Scientist*, 6 March 1969), later developed in "Computer Worship" (Pitman, 1973, page 128) in which I discuss 'situation analysis' and 'situation manipulation'. A clearer, more developed outline was published in this journal in my January 1984 article 'Advance into the past', (see The Nub of Computation, page 59). (The way in which an array processor composed of kernel logic nodes would tackle problems is more clearly stated in 1984 because at that point the appropriate hardware possibility existed, whereas it did not a decade earlier.) More recently, in the television series "The Mind Machine" on BBC 2 in September last year, the concept is clearly stated, usefully validating the approach.

* UK Patent 1377859, described in *Wireless World*, July 1981, p57

In a kernel logic parallel processing array for air traffic control over Europe new data would update the array in a ripple-through manner every second. Aircraft collision avoidance will...



...be achieved by transferring current data to an identical machine in the higher pages of the 1Mbit rams which will in effect be accelerated into the future by increasing the clock rate.

Parallel work in cognitive science has been done by Kenneth Craik and Phil Johnson-Laird, see bibliography.

The idea that I have nurtured is that future events should be predicted by speeding up the system clock and projecting a 'data cube' into the future. We do not have predictive algorithms. Rather, in the case of airline collision avoidance, for instance, we lift the current data state in our data cube into a second array, running at a faster clock rate. Two aircraft projected into the future (each occupying a larger and larger volume of space into the future to cover all possibilities) then collide, and the collision of the two over-size aircraft is reported back to the current data cube, pointing to a potential hazard in the near future. This forward projection is soon erased, to be replaced by a more recent valid current data cube, which in its turn will be accelerated into the future in search of possible hazards. This approach probably has a different conceptual base from the more conventional approach of calculating all kinds of possible hazards, and it seems to be more comprehensive and easier to effect. (This second data cube could conveniently reside in higher pages in the same 1Mbit ram as the original data cube.)

KERNEL LOGIC ARRAY PROCESSOR HARDWARE

To configure good chips (processors) in a wafer, the external controller can send in an instruction with a physical chip address. The address has two fields, an easting and a northing. This class of instruction has its address decremented each time it passes through a chip so that the address becomes 00 00 when it reaches its destination. A chip that is seven chips in and 13 up has a physical address 1307.

The interrogated chip then sends a reply, that it is good or faulty, rippling outwards, so that one or more replies are received by the external controller via a path of good chips. The controller then studies the pattern of good and bad chips and instructs most of the good ones on how to link together to make a perfect two-dimensional array.

The architectural constraints of this fault tolerance lead to the extremely powerful array processor machine described here. The standard kernel logic array processor contains a two-dimensional array of 1000 by 1000 processing nodes. Since each individual wafer contains an array of perhaps only 30 by 30 processing nodes, we have to use 1000 wafers in order to give the one million processing nodes in the standard machine. It is therefore necessary to interconnect the rows and ccolumns of an array of 30 by 30 wafers to give one million nodes interconnected in a two-dimensional array.

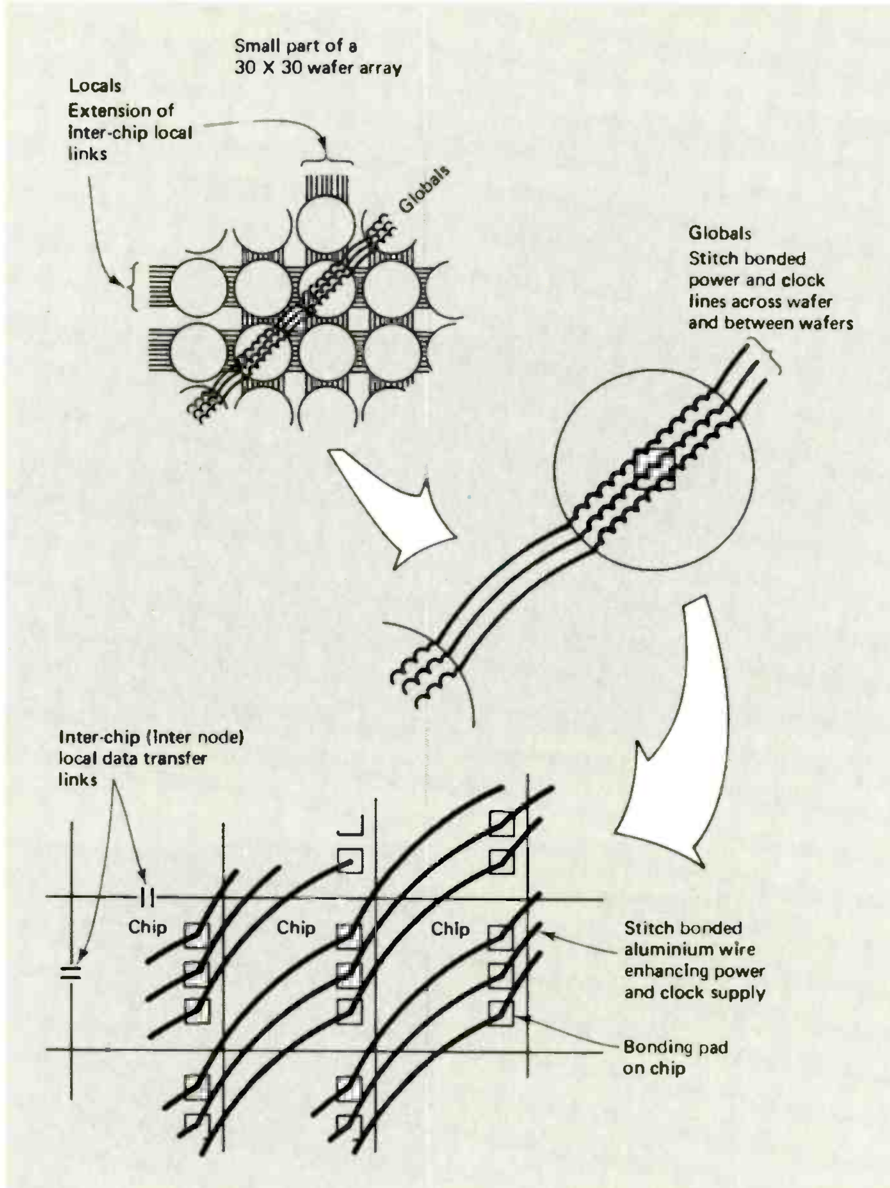
Four wires are stitch bonded down each column of chips (=nodes) on each wafer. These wires give lower resistance and faster links than is possible with the standard aluminium metallization on a chip. This means that a wafer will contain a set of about 100 vertical wires stitch bonded from top to bottom of the wafer. Each wire is connected to a pad on each chip that it passes over. These wires are then extended across to the two adjacent wafers, the wafer above and the wafer below. Each group of four wires comprises a ground line, a power line, a clock line and a data line. The transmission line represented by the pair of wires, ground and clock, is capable of delivering a 100MHz clock rate. Also, serial data can be clocked into each node at a 100Mbit/s rate. Such data includes 'global' instructions, broadcast to every processing node in parallel.

In practice, the number of wires will probably be reduced to three, and '0V' will be delivered instead through the wafer substrate. Various other deviations are possible in practice. For instance, to improve fault tolerance, the columns of stitch-bonded wires will probably be at an angle of 45° to the rows and columns of chips (nodes). Another possible variation will be for one set of four stitch-bonded wires to serve two columns of chips (processing nodes) rather than one, but discussion of such deviations here obscures the grand design.

Each chip (=node) will have the ability to communicate 100 Mbit serial data locally to its four neighbouring chips to the north, east, south and west. This will be via conventional aluminium surface metallization. In the case of chips on the border of a wafer however, local east-west inter-chip data lines will be bonding wires connecting the data lines from the right-hand edge of edge chips to the left-hand edge of chips in the next wafer to the right. Similarly, local north-south between-wafer inter-chip data lines will be bonding wires connecting the data lines from the bottom chips of one wafer to the top chips of the next wafer below. In addition to these, the columns of global stitch-bonded wires down a wafer will be extended between wafers, right down through the column of 30 wafers. So a single global wire will have 1000 stitch bonds, and traverse the full height of the 1000-wafer machine. That is, it will traverse 30 wafers.

Each node comprises a processor, something like a serial 6502, and one megabit of ram. It also contains four serial output ports and four serial input ports, enabling local data transfer with adjacent nodes to the north, east, south and west. Each local inter-chip link can support data transfer at a serial bit-rate of 100Mbit/s. (The result looks much like a two-dimensional array of transputers interconnected through their serial ports.) The normal operating mode will be for all processing nodes to simultaneously carry out a series of instructions (a program) globally broadcast to all nodes down the vertical stitch-bonded wires. However, the global array controller will sometimes hand control to an individual processing node, whereupon a processor will implement a subroutine stored in its own ram.

The instruction set will include typical classes of microprocessor instructions, with some additions, as follows. First, there will



Connections between adjacent processing nodes have to be extended between wafers, as shown. In practice wafers may need to be arranged as an hexagonal or triangular array rather than a rectangular array.

be configuration instructions, which deal with the configuration of a perfect array of processing nodes by bypassing the faulty nodes. There will be local intercommunication instructions, when each node will transfer data to its neighbour to the east, and so on. In many cases, a flag in a node will determine whether that node will carry out a particular global instruction. There will be a new class of conditional (jump or branch) instructions, when a processing node decides whether it will become autonomous for a short time, obeying a subroutine in its own 1Mbit ram instead of obeying instructions coming down the global stitch-bonded lines.

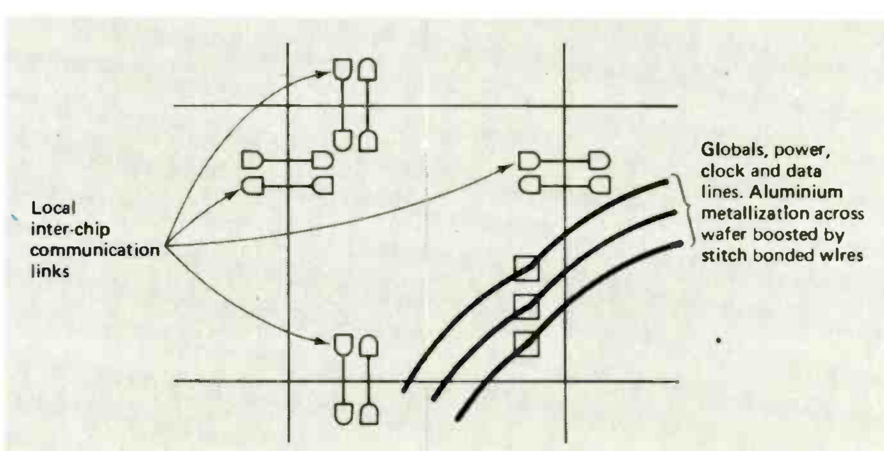
Practical considerations will have a strong influence on the choice of ram and processor. Since the development time for a state-of-the-art ram is four years, it is necessary, to benefit from the latest increases of ram bit density, to base the kernel logic design on the leading ram manufacturers' process, whether it be 1 Mbit, 4 Mbit, or whatever, even though the ideal memory size at a processing node is somewhat less, perhaps only 100 kbit. We then aim to take advantage of developments in microprocessor hardware and software and try to get the ram manufacturer to agree to mix a modified state-of-the-art processor into the ram wafer.

STITCH-BONDED CLOCK AND POWER WIRES

Conventional chips use narrow lines of aluminium metallization on their surface to deliver power and clocks to every part of the circuit.

Anamartic retained this approach in their successful wafer-scale engineering using my spiral approach. However, the resistance of such interconnections, already a minor embarrassment in a large, high power chip, became crippling in the case of a wafer, with its longer distances and greater total power (i.e. current). However, the problem is not severe if, like Anamartic's, the wafer merely houses dynamic ram. At any one time in an Anamartic wafer, only one ram on the wafer is being read and only two more are being refreshed. The rest of the wafer consumes little power. Our situation is different, because we have processing nodes active at the same time throughout the wafer. Limitation on power delivered would mean limitation in the speed of those processors, which is unacceptable. Processing nodes must all be capable of operating at maximum speed all of the time.

Fortunately, stitch bonding technology is ideal for the purpose. At a cost which is only a fraction of the cost of the processed wafer, parallel columns of aluminium wires can be stitched across the wafer, reducing the effective resistance of the aluminium track beneath. The yield on such stitch bonding is very high, and faults, on the rare occasions when they do occur are to a harmless open circuit to the bonding pad (the aluminium beneath covering for the break) rather than to a short. These wires can be either 0.12 or 0.25 mm in diameter, giving the kind of low resistance needed both for power lines and for high-speed clock lines. Further, the characteristic impedance of the transmission line made up of the pair of lines (clock and 0V) that delivers the clock is reasonable and convenient to drive.



A 'chip' or processor node is linked to the outside world in three ways: software-selectable links to adjacent good chips, conventional metallized power and clock lines not shown, and stitch-bonded 0.13 mm wires to enhance power and clock by reducing resistance and increasing speed.

CAN YOU PROGRAMME IT?

The kernel logic machine comprises a two-dimensional array of 1000 by 1000 processors, each with its local 1 Mbit ram. The processor will be something like a 6502 microprocessor. In normal operation, program instructions will be broadcast in parallel from an outside controller to all one million processing nodes, which will obey the instructions in parallel, but operate on different, local data. (This is SIMD – single instruction, multiple data.) The instruction set will include the groups of instructions contained in a 6502 or Z80, with some additional groups.

One small group of instructions will control the configuration of the perfect 1000 by 1000 array from a larger, imperfect array. This (re) configuration will take place every time the machine is switched on, and gives it a fault-tolerant, self-repair capability.

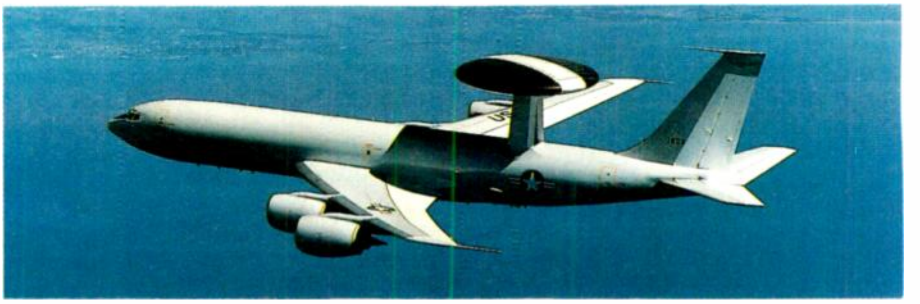
Another small group of instructions will cause local inter-node communication of data in parallel. For instance, one instruction would cause every node to exchange a particular word of data with the node immediately to the north. This local, ripple-through, intercommunication will be fast, but it will take 20 cycles for a word to traverse 20 processing nodes. (It will be used for the zoom facility mentioned elsewhere.) A 20-bit delay is of course less significant when working serially.

It is possible for the external controller to relinquish control of one group of nodes, or even of all processing nodes, so that each node can carry out a subroutine stored in its own 1Mbit ram. (At any time, the central controler can regain control of all processing nodes.) Generally, when this occurs,the external controller would divide up the one million nodes into no more than four or five groups, and each group will act in concert. The notion of a million processing nodes all implementing different programmes at the same time is unthinkable, not because of technical limitations, but because of the impossibility of assembling enough humans (programmers) for enough time to dream up all the different activities for so many computers. Of necessity, groups of processors will act in concert, obeying the same series of programming code, though not necessarily applying it to the same data. When the first kernel logic machine has been delivered and become operational, a significant fraction of all the processors in operation in the world will reside in that one kernel logic machine. It follows that they must operate in groups, and not as individuals.

On initial memory load from the external controller, each 1 Mbit memory is loaded with a number of flags. These can be employed later by the global program to define which sectors should, for the next period of time, run under global control, and which under their own local routines. The "flag" in each memory might be merely the address or 'grid reference' for that processor.

Recapture of control by global instructions could be effected by the equivalent of the Z80 DMA, or less preferably by interrupt. Using DMA, local control is relinquished when the marker (flag) in local memory is found, calling for a return to global control.

Programming the kernel logic machine is straightforward because its structure mirrors the structure of the problems to be solved by the machine – weather forecasting, air traffic control, and so forth.



Potential targets need not be thresholded in a kernel logic machine because it will not be overloaded when the number of targets tracked reaches 100 – the overload point for today's early warning systems.

APPLICATIONS OF THE KERNEL LOGIC MACHINE

For the last 20 years I have suggested that something on the lines of the Kernel Logic Machine is ideally suited to a large range of important applications. At last the technology has arrived and made it possible to construct the machine we always wanted. It will lead to enormous cost savings and speed improvements in many applications covered by the general descriptors finite and linear element analysis, finite difference methods, and computational fluid dynamics (CFD). In "Supercomputers and the need for speed", *New Scientist*, 12 Nov 88, page 50, Dr Edwin Galea, research fellow at Thames Polytechnic, says

> "The flow of air, water, burning gases, the Earth's atmosphere, ocean currents and molten metals provide scope for the partnership of computational fluid dynamics and supercomputers."
>
> "Only supercomputers can provide the speed and memory required to perform the detailed calculations for the complex geometries and flows encountered in the design of aeroplanes, automobiles and ships."
>
> ". . . manufacturers are already approaching the limits of the capabilities of single processors,. . . ."
>
> "Only parallel processing – the concurrent use of more than one processor to carry out a single job – offers the prospect of meeting these requirements."

Galea talks in terms of a partnership of a supercomputer with CFD software. The software causes the single-processor (von Neumann) computer to behave like an array processor, but at a heavy cost in loss of speed.

As Galea says, the physical processes involved in flow behaviour occur on a very tiny scale, so CFD divides the flow region into thousands of small computational cells and solves the governing equations in each cell. Generally, applications involve perhaps one million cells. A conventional, single-processor computer is caused by software to compute the next change in each cell one at a time, so that its speed is reduced by a factor of one million – hence the need to start off with a very fast computer. Even then, this massive drop in speed is unacceptable, and the application demands parallel processing, when duplicate hardware is devoted to each cell. The kernel logic machine provides this multiplicity of hardware.

Galea's article estimates the total sales of supercomputers so far to be $1000 million, and says the market is growing. Most supercomputer applications, and the applications which are expensive in computer run time, are CFD. The kernel logic machine will cause an acceleration in the growth of the supercomputer market, because applications which were too slow and expensive to run on a Cray machine or on the small-scale array of a dap or perhaps 100 transputers, will be successfully attempted on a million processor kernel logic machine. This is a very attractive market; the development of computer graphics for a space adventure movie; a task taking one hour on a kernel logic machine which previously absorbed the run time of a $5 million Cray machine for months. Another lucrative application is whole-world modelling in real time for the purpose of weather forecasting. This is only practicable on a kernel logic machine.

Applications for the kernel logic machine include airborne early warning systems, air traffic control Europe, in which one machine in London is linked to a second machine in Milan and a third in Barcelona, etc., TV image enhancement, TV compression for satellite transmission, aerodynamic design of motor cars, aircraft and spacecraft, study of airflow through gas turbine engines, weather simulation and forecasting, prospecting for oil and gas by analysing rock structures.

AIRBORNE EARLY WARNING AND AIR TRAFFIC CONTROL

In modern warfare, enemy aircraft attack by approaching very low and at high speed, so that they appear over the horizon only a short time before they reach their target. The defensive response to this is to have an aircraft flying high up so that it can look over the horizon with its radar, and give early warning of attack. The radar continually scans a cone of space stretching in front of it, starting at top left and ending at bottom right. In each complete scan, it transmits a series of pulses, one in each direction ahead of it. A single scan creates one picture "frame", but the reflections from "targets", or enemy aircraft, are weak. By repeated scanning, it builds up a picture of what is in the space. This picture is developed by a process of repeated addition of frames known as "burn-through". This process relies on the fact that the noise is random and averages out, whereas the target recurs in successive frames, and grows out of the noise.

The scanning of the space is similar to the scanning of a TV camera, except that at every point in the raster there is a further, depth scan in the third dimension. If a pulse from the transmitter is reflected from a more distant target, the reflection arrives back later, and thus its distance can be determined. A Nimrod or AWACS radar aircraft groans under the weight and volume of the digital signal processing hardware needed, plus the massive power supplies needed to generate the DC power to drive the hardware, plus the generators needed to generate the electric power, plus the fuel needed to supply the generators, plus the cooling equipment needed to cool the hardware.

The conventional approach is for the aircraft's digital signal processing to look for over-large signals being received by the radar dish among the random noise. These larger signals might be reflections of the aircraft's own output bouncing back off the target. However, they might just be noise. The procedure is to sum up repeating larger signals from one region of space, and at some point make the decision that this must represent a target.This target is then tracked through the region of space being monitored. The practical problem is that each target which has been identified and is being tracked consumes more time in the central von Neumann computer, and the total system overloads and fails if more than a handful of targets are detected. We have to ask the enemy to limit the number of aircraft they use in their initial surprise attack.

By contrast, the kernel logic machine commits one processor in its array to one element in the raster of space. Within that processing node, the first page in its 1 Mbit memory is committed to the cube of space nearest to the aircraft. Further pages in memory are committed to further cubes of space, all of them in the same direction from the radar aircraft, but at different distances. This way, space is divided into one thousand million data cubes in a 1000 by 1000 by 1000 array, although in fact the array only contains one million processing nodes. The third dimension is accommodated by stacking up through pages in ram. (The disadvantage is that there is only one set of inter-node communication links, not one set per page of ram, so there is a resulting drop in local inter-node communication data rate proportional to the number of segments ("pages") used in a ram.) Possible targets need not be thresholded into definite or downgraded to random noise in the kernel logic machine, because such a powerful machine will not be overloaded if the number of targets tracked exceeds 100 – the point at which today's early warning tracking systems overload.

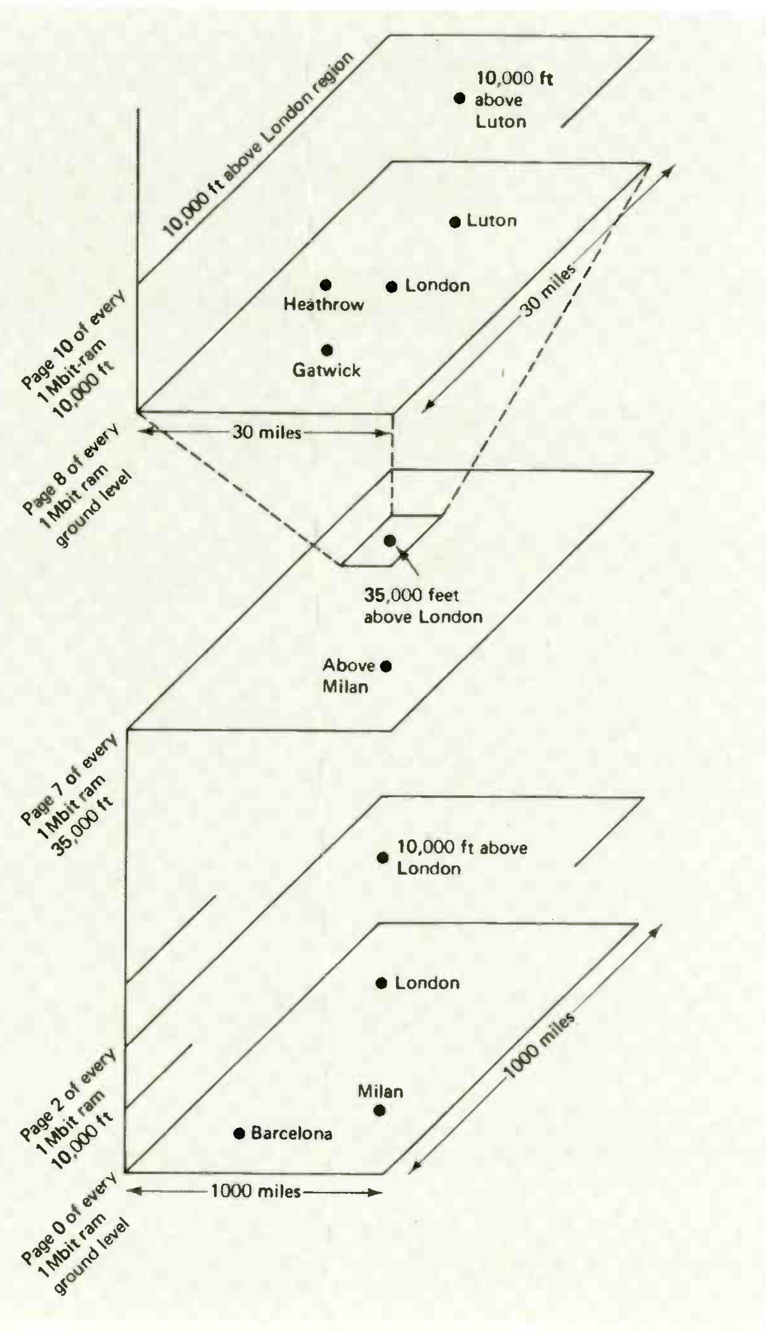
Parallel processing in an array makes implementation of the tracking software much more straightforward and fast. Each detected target is a sort of amoeba which moves through the array, carrying its amplitude, velocity and probability with it, to be reinforced from that region of space; or alternatively to diminish down towards zero each time the radar scanner picks up no reflection. Uncertainty over the latest direction and velocity of an amoeba-like possible target results in the amoeba growing into a larger probability volume. However, at the same time, failure of the target (signal) to rise above noise during the last scan (last frame) leads to a reduction of its probability weighting at all points within its amoebae.

Air traffic control Europe would use essentially the same machine, with minor enhancements. Europe will be divided into 1000 by 1000 squares, each of one mile square. However, since this is inadequate for the London airspace, an enlarged model of 30 miles square around London will be housed in the upper reaches of 1 Mbit rams of the array processor. This model will use the full 1000 by 1000 array, and so provide a high precision array of 30 by 30 nodes for each square mile. In an ordered manner similar to the action of the zoom lens in a camera, the local London micro-model and the Europe macro-model will update each other once per second. During this update, the new data will ripple through the array in parallel in an ordered manner.

The reporting of position and speed by a commercial aircraft will result in the collapse down to point size (a single processing node) of a tracking aircraft which, because of increasing uncertainty resulting from lack of recent position reporting or recent definite radar detection, had developed into a large amoebae.

Aircraft collision avoidance will be achieved by causing the current data cube contained in the kernel logic machine, that is the most recent record of location and

For air traffic control Europe Kernel Array Processor commits one processor to the airspace above each one square mile of earth, one page of ram per 10,000 feet of height. Higher pages are committed to an enlarged data cube.



velocity of all aircraft, to be transfered to an identical machine (in the higher pages of the 1 Mbit rams) which will be accelerated into the future by (in effect) increasing clock rate. Potential hazards between a pair of aircraft will then be flagged up because of actual collision between two of the growing (future tense) amoebae in this accelerated machine, one representing each aircraft that is at risk.

TV IMAGE COMPRESSION

The cost of transmission of TV signals by satellite can be high. We may be able to justify investment at source and at destination in order to reduce the data flow needed to send one TV channel. If we use the standard kernel logic machine, each TV frame is loaded into the 1000 by 1000 processor array in parallel down 1000 columns. Since a TV frame has far less than 1000 by 1000 pixels, we would need only one quarter of our standard machine, costing well below $1 million. Also, since the power of the machine is still far greater than is needed for the purpose, we will probably make each processing node time share between four or eight pixels, thus reducing the cost of the machine from $3 million for the standard array to $200,000 or so. There are 1000 input channels in parallel, each channel having a serial input rate of 100Mbit/s. This gives a total input data rate of 100,000Mbit/s; well above the bit rate of a sequence of rasters of TV pixels. The compressed result is outputted down the columns, exiting from the array at the bottom. The compression will involve comparison of the new frame with previous frames, and the most recent 20 frames will be stored in the array. It is possible that the compressed output will travel in parallel down the columns of processors, and then finally exit to the right along the bottom (extra) row of processing nodes, which will have a bit rate capability of 100Mbit/s.

TV IMAGE ENHANCEMENT

If, as seems likely, a reasonable performance TV data compression machine will only cost $200,000 or so by reducing the number of processing nodes and making the survivors time share between four or eight pixels, then the same machine will be attractive for TV image enhancement. We can envisage all sorts of modifications to the video tape being programmed in via such a machine. We could correct for errors in shooting, and also programme in the background to a scene being shot in much more sophisticated ways, developing forward from the blue background.

ANALYSIS OF MEDICAL SCAN IMAGES

X-ray and ultrasound scanning machines are expensive, and so sophisticated processing of the resulting images may be justified. Further, it is likely that if we add more image processing power using the kernel logic array, we will be able to tolerate lower quality in the scanning hardware, and therefore lower price.

WHAT IS CATT'S SPIRAL?

There is only one proven method for generating a perfect array of chips out of an undiced wafer that contains faulty chips among the perfect ones. My approach is to develop a one-dimensional array (spiral) of good chips, adding further chips on to the far end, but all testing being under control of external test circuitry at the beginning, near-end of the array. Each prospective additional chip is put through its paces by instructions travelling down the developing array through the chips already passed as good and already included in the array. If the next chip is adjudged faulty, it is disconnected and another chip adjacent to the penultimate one is tested out instead.

In my approach, the distinction between faults in manufacture and faults developing in service is blurred. On switch off, the array connections are destroyed – all links having been volatile – and the array is reconstructed from scratch each time the machine is powered up.

The chip does not test itself. The problem that a mad chip might demonstrate its madness by reporting that it is sane is evaded by having the main testing hardware outside the wafer. But all the same, the fact that powerful test-dedicated circuitry and also chip interconnection logic will consume me only a tiny portion of today's chip's real estate is exploited.

I steal up on wafer-scale integration in a somewhat crabwise fashion. If (as is clear) we should start off with all chips, good and bad, cheaply interconnected during chip manufacture, and then open and close these connections by volatile information as a cheap way to exclude faulty hardware, it becomes inevitable that the major unit will be of maximum size – i.e. a complete wafer.

If I ask a mad man (mad chip) whether he is mad, then surely his answer is useless? The flaw in that remark is that I could ask not the whole chip, but only a small portion of that chip. Now today, it is possible for a portion of the chip to reply to such a question, yet that portion to be so tiny that the possibility of its being faulty can be, for practical purposes, ruled out.

There are three weaknesses in the spiral approach. It is a one-dimensional array so access is limited to one entry point. This is particularly limiting if the array contains many processors, each one needing continual input of raw data and also needing to deliver the results of its data processing.

The second and third weaknesses result from the high resistance of the aluminium lines across the surface of the wafer. This limits the amount of current and therefore power that can be delivered to the wafer. And secondly it limits the clock speed to 30MHz. Both of these are more damaging for an array processor than for an Anamartic wafer which is quietly storing data in ram. All three weaknesses are overcome in the kernel logic machine.

AERODYNAMIC DESIGN

A recent article by Dr E. Galea (see bibliography) discusses the pressing need for array processors in aerodynamic design and the ideal machine is clearly the standard kernel logic array processor with one million processing nodes. Galea shows that wind tunnel testing is unsatisfactory for car design because the ground beneath the car 'moves', introducing major errors in the results. This is one of many reasons why supercomputers are gaining favour in such applications.

WEATHER SIMULATION AND FORECASTING

The kernel logic array Processor will commit one processing node to each square mile of area. This is a good example of finite element analysis, where pressure, temperature, etc in one square will affect adjacent squares, and the array processor will have the power to let these effects ripple through the array. Weather forecasting will radically improve as a result of the greater (and also more appropriate, because distributed,) processing power.

A network of kernel logic array processors will make possible, and highly profitable, the real-time monitoring of weather throughout the globe giving highly accurate forecasting through the absence of the edge problem.

Ivor Catt's Kernel Consultants, PO Box 99, St. Albans, is currently seeking £5 million financial backing to build the prototype kernel logic machine.

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7-2564/10ms	21-27512	35-8742	49-63701X
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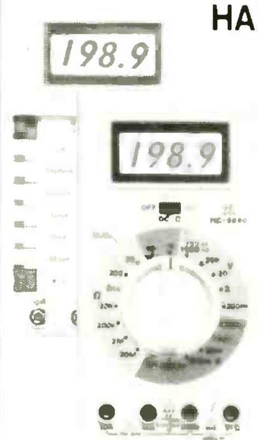

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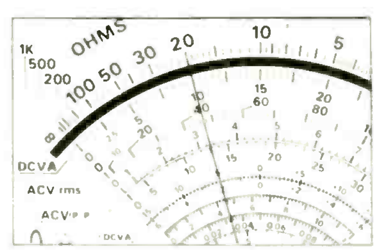

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Class A/AB mosfet power amplifier

A discussion of the effects on performance of capacitors and transistors, and a practical design to illustrate some solutions

J.L. LINSLEY HOOD

The design of audio amplifiers, like that of any other equipment for use in the sound reproduction chain, suffers from the difficulty that, since its purpose is to produce a response from a human sensory organ, the quality of the final result cannot be determined, with absolute confidence, from engineering measurements alone, nor can anyone be certain that the stage has been reached at which no further worthwhile improvements could be made.

Many attempts have been made to relate engineering specifications to perceived sound quality, but these have been complicated by the fact that the ear, like any other sensory organ, varies from person to person, and from time to time. It is also a very poor instrument for assessing sound quality and its memory of sound characteristics is even worse. Nevertheless, in spite of its apparent insensitivity to some quite major defects in the reproduction of the audio chain – such as significant amounts of second harmonic distortion – it can be exceedingly perceptive of some others, especially if trained to listen for them.

THE EMERGENCE OF THE 'SUBJECTIVISTS'

It is a matter of historical observation, and some considerable regret, that circuit design engineers have, in their enthusiasm to exploit new technology, allowed new and unsuspected forms of signal distortion to occur because of their reliance on test procedures such as measurements of total harmonic distortion at full output power, which had not shown anything amiss.

This discrepancy between relatively poor observed sound quality and high claimed performance specification was noted by the lay users of the equipment and tended to undermine their confidence in the validity of engineering specifications as a whole, rather than causing them to demand that fuller, and more searching, test measurements should be made.

It also led to the growth of the opinion that specifications, on their own, were meaningless as a measure of performance, and to the emergence of a minor host of self-appointed pundits, together with a number of magazines dedicated to their views, who claimed particular skills in assessing the quality of equipment, by listening to its performance on a suitable range of sound recordings.

This abandonment of instrumental tests in favour of 'subjective' judgments has led to the proliferation of claims, some of which are exceedingly unlikely on any engineering basis, about the benefits of a host of add-on bits and pieces, and has now led also to the evolution of design procedures based on ideas which are supposed to be good for sound quality, without reference to any instrumental test results.

Since whether or not these design techniques do indeed lead to better sound quality is often judged by the same people who proposed these ideas, this approach tends to be self reinforcing and self sustaining and renders their proponents impervious to any arguments based on physics or engineering principles.

A recent article by Self[1] provided a salutary reminder that it is impossible to make progress in any form of technical development without performance standards which are both measurable and verifiable, against which the effect of design changes can be seen, and against which the validity of design theories or calculations can be tested.

In general, I agree entirely with Self's views, though I entertain a few reservations which I made in a subsequent letter.[2] These arise because I am well aware of the mistakes which have been made in the past, when circuit designers have offered designs which were clearly less good than they should have been – in respect of residual 'crossover distortion' artefacts; or because of proneness to 'slew-rate limiting; or because of inadequate loop-stability margins when used with akward LS loads; or because of poor transient response under reactive load conditions; or because of output device protection systems which caused premature 'clipping' on LS systems which had a low impedance at some part of their frequency response; and so on and on – and I lack adequate confidence that contemporary test procedures will reveal all of the faults which may remain.

In particular, I feel that while a great deal of work has been done in reducing the magnitude of steady-state non-linearities, not enough attention has been paid to circuit behaviour under discontinuous or transient signals, where prominent intermodulation effects may arise. Measurable malfunctions may therefore still lurk in this area.

This concentration on steady-state harmonic distortion figures is probably due, for commercial reasons, to the excessive importance which the layman attaches to the number of zeros behind the decimal point in the quoted THD figure as a criterion of quality.

Steady-state measurements may also tend to minimize the result of sudden changes in signal level upon components which are sensitive to thermal or voltage-dependent effects, such as capacitors and semiconductor devices, and I do not think that we are adequately knowledgeable to be confident that no audibly untoward effects whatever will occur as a consequence of these known shortcomings – particularly when these phenomena can be quite clearly seen with other physical test procedures.

CAPACITORS

Capacitors are the most complex of all the 'passive' components, in respect of their underlying physical behaviour, and differ considerably from the notional 'pure' capacitance which one might depict with the symbol shown in **Fig. 1(a).** A broad distinction can be drawn between 'polar' (i.e., 'electrolytic'), and 'non-polar' (i.e., film, mica or ceramic dielectric) types, in terms of the effective equivalent circuit introduced by the component but, in general, this will be more nearly that of Fig. 1(b).

In this, C is the effective capacitance of the unit, which will be somewhat dependent on frequency, temperature, and operating voltage. In series with this element of capacitance is a resistance, R_k, representing the dielectric-loss factor, which is strongly dependent on temperature and operating frequency, and in parallel with C is the leakage resistance R_l – also very temperature dependent.

In all capacitors, there will be a series element of resistance, R_s, and a series inductance, L_s, simply due to the mechanical

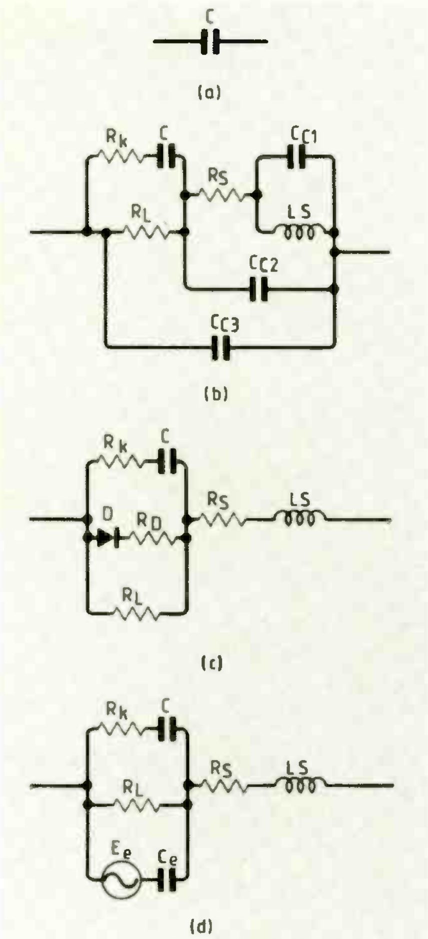


Fig.1. At (a) is a "pure" capacitance, which is more nearly represented by the equivalent circuit at (b). The diode in (c) represents the unidirectional conductive path in an electrolytic capacitor, while (d) shows a generator and resistor to indicate the stored charge and dielectric hysteresis exhibited by film dielectrics.

construction of the component, with a small amount of inherent distributed parasitic capacitance, C_c, which can probably be ignored except at radio frequencies.

Electrolytic types. In these there will also be a unidirectional conductive path, D, in series with a further non-linear resistance R_d as shown in Fig 1(c), which comes into effect if the polarity is reversed, but can also have an effect under zero polarizing voltage conditions when these have persisted for some time, due to the gradual deterioration of the electrolytically formed dielectric layer.

The action of the polarizing voltage has a complex electrochemical/ionic effect and, if reversed polarity conditions are allowed to arise, modifications to the nature of the dielectric layer can permanently affect the other characteristics of the component.

As regards the common electrolytic capacitor types, the tantalum-bead types are more compact for a given capacitance value, have a lower series inductance and a higher reverse breakdown voltage (2-3V vs. about 0.5—1V for aluminium types) and a dielectric layer which is more resistant to deterioration during zero polarizing voltage conditions. On the other hand, the equivalent series resistance (ESR) is significantly greater and even more non-linear than that of equivalent aluminium types. Tantalum bead capacitors are only available in relatively low working voltage forms.

Non-polar film dielectric capacitors. Although these avoid some of the undesirable characteristics of the electrolytic types, they can suffer to a much greater extent from dielectric hysteresis and other stored charge effects of the 'electret' type, represented in Fig. 1(d) by the generator E_e, and the series capacitor C_e.

The possibility of building into the dielectric layer a semi-permanent polarization, usually by heating the material above its first-order transition temperature and then allowing it to cool while exposed to an electric field, has been known and exploited in 'electret' microphone diaphragms for some years, but it can also arise in normal use with suitable materials. In general, the proneness of a dielectric material to this effect is dependent on its molecular structure and upon its crystallinity, physical hardness and rigidity.

Of the commonly used film dielectrics, those such as poystyrene, polycarbonate or polysulphone, from which thin films are made by band casting from a solution, are both limp and amorphous and are therefore less likely to retain molecular-scale electromechanical distortions than the more rigid and highly crystalline types of film such as those based on polypropylene or polyesters which are manufactured by biaxially stretching a thicker extruded sheet.

However, the molecular (polar) asymmetry of the solution-cast materials is typically greater, with the exception of polystyrene, than that of polypropylene, say, which makes a clear preference difficult.

A desirable quality in these components is that they should be compact, and offer a high capacitance/volume ratio. Unfortunately, since both the dielectric constant of the material and the dielectric loss factor are dependent on the asymmetry of the polar groups within the molecule, it is implicit that the desirable qualities of low dielectric loss and high capacitance values cannot be obtained in physically small components.

Stacked film/foil capacitors, where the conductor/dielectric combination is assembled like a pack of cards, offer a lower series inductance (L_s) than spiral wound forms. In all of these types, film/foil components offer both a lower series resistance, (R_s), and a higher leakage resistance, (R_l), than the metallized-film types, but are physically more bulky.

Ceramic dielectric capacitors. Certain piezo-electric ceramic materials, such as titanium dioxide, barium titanate, and barium titanate zirconate, offer dielectric constants in the range 80-50,000, which permits the construction of very small, high-capacitance and low-ESR components. However, the frequency and temperature dependence of capacitance and dielectric-loss values of these capacitors can be very high, which limits their use to RF applications where the overriding consideration is for a low ESR.

Other types. Both mica and air dielectric components are free of most of the problems noted above, but are only available in small capacitance values. Waxed-paper dielectric components are now, thankfully, seldom found.

TRANSISTORS

Transistors are the other main source of non-ideal behaviour in electronic circuitry, in that they are strongly temperature, current, voltage, and frequency dependent in nearly all of their characteristics. Bipolar (NPN/PNP) junction devices are bad in all these respects, though manufacturing techniques have lessened the effects of some of these and circuit layouts have been evolved to reduce the influence of others.

A major residual problem with bipolar junction devices is that of 'hole storage' which prevents a clean current switch-off following a high-current pulse. This can be minimized by ensuring that the device is never driven into saturation, but hole-storage effects are always present. These defects are at their worst in power-output stages because of the high peak currents involved and it is in this position that fets and mosfets offer their greatest advantages.

The mosfet is a particularly attractive device to use in this application in that, since the conduction mechanism is that of an electrostatically induced charge layer in a relatively lightly doped substrate, it does not promote hole-storage effects. It also has a better HF response, which facilitates the design of stable negative-feedback systems, and their greater independence of gain on output current improves circuit linearity. When optimally biassed, their quiescent characteristics can also be less temperature-sensitive.

Power mosfets are available in several forms, as shown in **Fig. 2**, of which the two most common are 'U' and 'T', named after the shape of the active region or the nature of the current flow, and shown in 2(b) and 2(c).

Various manufacturers have introduced their own versions of these topologies, to optimize advantages or lessen disadvantages but in general the 'V' or 'U' mos types are faster, but less rugged and less well suited to complementary polarity than the 'T' mos forms. They all suffer from a high gate source capacitance, particularly in the higher current versions where multiple parallel channels are employed to lower the impedance of the conducting path, and this factor must be born in mind in designs employing them.

They are also prone to gate/source breakdown — causing device failure — if the permitted gate/source potential is exceeded, and this also must be guarded against in the design. This problem exists because, unlike small-signal (RF) mosfets, or –mos logic elements, protective zener diodes cannot be incorporated within the diffusion structure without introducing the possibility of thyristor action.

The remaining design problem is that, because of their excellent HF response, it is possible that RF oscillation may occur, in the tens or hundreds of MHz range, due to the unwise layout of external connecting wiring. Some care should be taken to avoid parallel paths for gate and source or drain leads, and gate stopper resistors should be employed where necessary, especially in the output stages. These should not be too large because of the presence of the fairly substantial gate source capacitance, which can be at least 1 nF, in the case of power devices.

AN ALL-MOSFET AUDIO POWER AMPLIFIER

With the various design considerations discussed above in mind, and since small-signal U-mos transistors are now available in both P– and N– channel versions at a reasonable price, it seemed to be an interesting exercise to design an audio power amplifier using only mosfets. The objects of the circuit design were to limit the need for capacitors in the signal path, and to adjust the circuit component values so that the capacitor/s in the negative feedback path, where their imperfections could have a direct influence on the performance of the circuit, could be of a non-polar type.

My original intention was to use mosfets throughout, but these are more expensive than bipolar devices. In places, such as in the constant current sources, where there was little or no signal voltage and no particular advantage seemed to be offered by the use of a mosfet transistor, I have therefore opted for the less expensive bipolar component.

The final circuit layout chosen for the amplifier is shown in **Fig. 3** and is of fairly conventional form. A pair of P-channel mosfets, (Tr_3/Tr_4), is arranged as an input long-tailed pair, fed from a constant-current source, (Tr_1/Tr_2), driving a single N-channel, small-signal U-mosfet gain stage

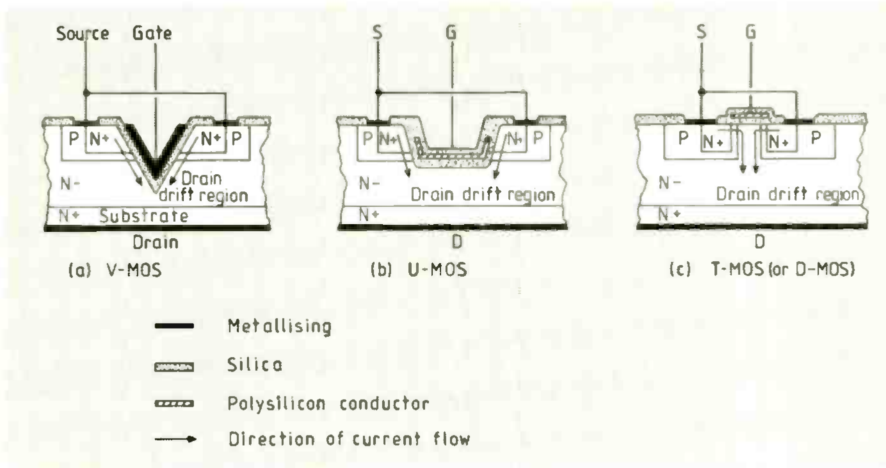


Fig.2. Three forms of the power mosfet.

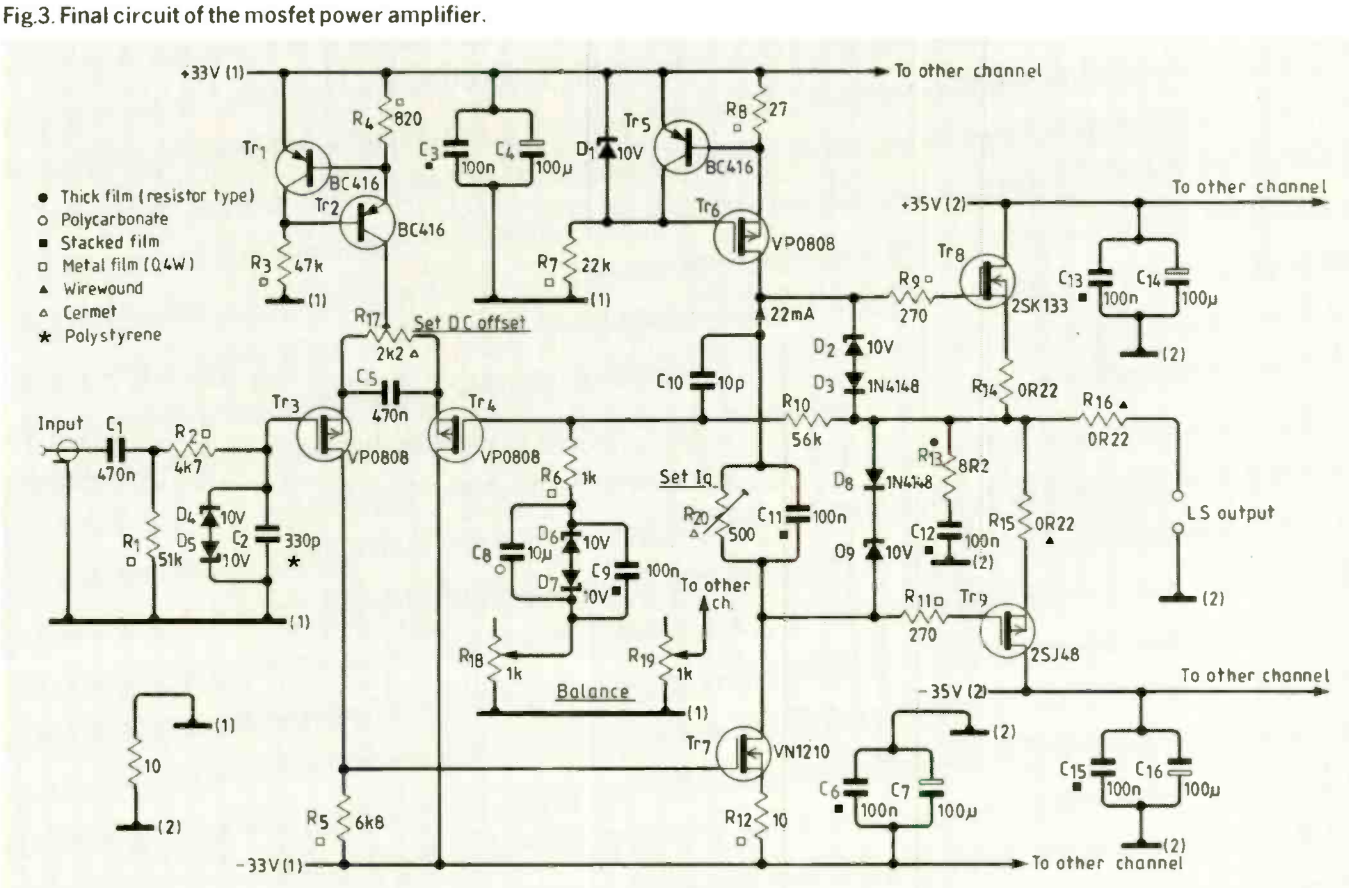
(Tr_7). Since it was intended that the output stages of the amplifier should operate largely in class A, in which the residual harmonic distortion of the circuit would be very low, it was not thought necessary to use a 'current mirror' as the load for Tr_3/Tr_4. This use of a current mirror is a conventional technique for increasing both circuit gain and available negative feedback for a given overall loop gain, as a means for 'cleaning up' a less-good performance.

Again, since the output impedance of both Tr_6 and Tr_7 is very high, and is largely independent of operating voltage within the range employed, I did not consider it necessary to 'bootstrap' these devices to improve their linearity or to lessen the dependence of gate-drain capacitance upon gate-drain potential.

There is always a temptation for circuit designers to 'lily-gild', but experience suggests that more elaborate circuit structures aimed at further reducing already-low THD values also make the problems of loop stability more complex, and may impair the overall transient performance.

In the design of Fig. 3, the 'Zobel' network C_{12}/R_{13}, together with the small capacitor, C_{10}, is all that is needed to provide an adequate gain and phase margin in the feedback loop; C_{10} is employed in a position which greatly lessens the tendency to slew-rate limiting, in comparison with the more conventional and less satisfactory technique

Fig.3. Final circuit of the mosfet power amplifier.



in which C_{10} would be connected between drain and gate of Tr_7 to provide a 'dominant lag' form of HF compensation. This latter approach gives better THD figures at the upper end of the frequency passband, but impairs 'slew-rate' characteristics and transient behaviour.

As I have already said I do not feel that there is any particular virtue in striving for ultra-low THD figures – certainly not below the 0.01% level – at the expense of circuit complexity and cost, or with the possible penalty of impaired or more complex transient response. The design shown, though relatively simple in layout, has an excellent performance in respect of both THD, (better than 0.01% at all power levels, within the frequency range 20-5kHz, and less than 0.03% up to 20kHz) and step-function response which is quite free of ringing and overshoots.

Layout, and power supply. Circuit designers tend to assume that power supply lines will be pure DC, of a known and stable value and devoid of signal residues or mains frequency ripple, and tend to ignore the ill effects which might arise if this is not the case. While there are well known circuit techniques which improve the degree of supply-line signal rejection, it is more elegant to remove this problem at source by using properly stabilized DC supplies. With modern devices this approach offers no problems and any well designed supply circuitry will suffice.

I would also recommend that both the small-signal and the power output parts of the circuit are fed from separate supplies, to lessen the need for a very low source resistance from them. With the circuit shown, there will be no significant penalty in channel separation from operating both channels from the same low-power and high-power supply lines.

With conventional circuit-design procedures, it is quite easy to design stabilized power supplies with an output impedance which is only a small fraction of an ohm. To the 'subjective-sound' fraternity – among whose current fads is the employment of entirely independent power supplies for each channel, with massive and costly reservoir capacitors (but only in a crude rectifier/capacitor system), and filing cabinet sized mains transformers – I would observe that, to obtain a supply line impedance of 0.1 ohms at 5Hz would require a reservoir capacitor of 0.3F. Four of these would not appear to be a cost-effective (or space saving) alternative to a stabilized PSU.

In the case of the feedback-path DC-blocking capacitor, C_8, I would prefer that this should be of polycarbonate dielectric type and, if this is of spiral-wound rather than of stacked-foil type, it should itself be bypassed by a smaller stacked-foil component to lessen the impedance of this path.

Operation mode. I noted above that this design was intended to operate 'largely in class-A'. My experience and observation over a number of years suggests that the bulk of domestic listening, even with relatively inefficient loudspeaker units, is at peak output power levels in the range 0.1 – 3 watts.

For a nominal speaker impedance of 8 Ω, this could be met with an output stage quiescent current of 0.4 ampères/channel, set by R_{20}. On higher output-power demands, the circuit slides quite gracefully into class-AB operation.

Those quoted in Fig. 3 will allow a maximum output level of about 35-40 watts/channel, with a static thermal dissipation for each output device of some 14 watts, for which adequate heat sinking (3° C/watt for each device) should be provided. For higher power class-A operation, a higher quiescent current should be chosen, with more massive output device and power supply heat-sinking. Beyond I_q values of 1A, it would probably be helpful to parallel the output devices, together with their associated emitter and gate-stopper resistors.

Overload protection. I would prefer this to be provided by a simple re-entrant style of current limit in the power supply itself, which could be combined with some electronic sensing circuitry to shut down the PSU in the event of an unacceptably large DC offset appearing at the output terminals. The Hitachi output mosfets appear to be sufficiently rugged for simple gate-protection zener diodes to prevent device breakdown.

References

1. Self, D.R.G., *Electronics and Wireless World*. July, 1988, pp692-696.
2. Linsley Hood, J.L., *Electronics and Wireless World*, Letters, September 1988, pp860-861.

Hart Electronic Kits Ltd., of Penylan Mill, Oswestry, Shropshire. SY10 9AF, can supply all the components needed for this design.

Communications test equipment

Farnell Instruments Limited manufacture a wide range of test and measuring instruments for use with mobile radios, pocket pagers and other communications equipment. Instruments include synthesized signal generators, transmitter test sets, communications test sets, power meters, automatic modulation meters, frequency meters, etc.

Field portable units, bench or rack mounting models and complete systems are available. The latter are for manual use or microcomputer control via GPIB bus. Various software packages for standard measurement routines and self-test diagnostics are available. These allow non-technical staff to test complex communications equipment.

Designed and manufactured in Britain, a short form listing of Farnell communications test equipment follows. Further information is available on request.

MODEL	DESCRIPTION	MODEL	DESCRIPTION
PSG520H	100kHz to 520MHz portable synthesized signal generator	SGIB-B	GPIB (IEEE488) Interface bus for SSG520/TTS520 combination
PSG520	10MHz to 520MHz portable synthesized signal generator	SWIB	GPIB (IEEE488) 32 channel switching unit
PSG1000	10kHz to 1GHz portable synthesized signal generator	F952	Power supply programming module for use with SWIB
SSG520	10MHz to 520MHz synthesized signal generator	0B1	GPIB (IEEE488) interface — non dedicated
SSG1000	10Hz to 1GHz synthesized signal generator	0B2	GPIB (IEEE488) interace with A/D converter and digital panel meter non dedicated
SSG2000	10Hz to 2GHz synthesized signal generator		
LA520	1.5MHz to 520MHz linear amplifier	TM8	Autoranging r.f. millivoltmeter 10kHz to 1Ghz+
TTS520	10MHz to 520MHz transmitter test set	AMM (B)	Automatic modulation meter 1.5MHz to 2GHz
PTS1000	1.5MHz to 1GHz portable transmitter test set	TM10	Directional r.f. power meter 25MHz to 1GHz
CTS520	100kHz to 520MHz communications test set	2081	RF power meter
352C	Spectrum Analyser 300kHz to 1GHz	FM600(B)	Digital frequency meter 20Hz to 600MHz

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DATA ACQUISITION USING THE IBM PC

This article discusses how the IBM PC XT or PC AT can be used for data acquisition; no consideration is given to the source of data and throughout the discussion an 8-bit A/D convertor (ADC) is assumed to provide the digital data. The article covers all aspects of the transfer of data from ADC to, in the first instance, computer memory and subsequently, for logging purposes, to an ASCII file.

The PC XT and PC AT buses are widely used and have achieved industry-wide acceptance. The PC XT bus is an 8-bit data bus implemented in a 62-pin edge connector. The PC AT bus adds 16-bit data operation, via a second, 36-pin, edge connector, and also includes additional interrupt lines and DMA channels. One feature to appreciate about the buses, a consequence of the operation of the Intel 8086 and 80836 microprocessors, is the way in which they treat I/O (Input/Output) and memory devices as distinct devices; memory and I/O devices can occupy the same address space without any contention. The potential conflict is avoided by having separate read and write lines for the two types of devices. Most add-on cards for PCs are I/O-mapped but it is possible to memory-map add-on cards – provided the card's memory is mapped above the host's memory.

The main bus signals – full details are given in the IBM or equivalent technical reference – are outlined below; the details given apply to the PC AT bus but the only signals that are not common to the PC XT bus are the eight additional data lines and some of the interrupt lines. Each signal is specified as an I, O or I/O signal to indicate an Input, Output or Input/Output signal. The construct [0..n] indicates an n+1 wide signal bus.

- SA[0..19] (I/O) – address lines for memory and I/O devices. The 20 address lines can access up to 1Mbyte of address space. Note that I/O address space only extends to 64K.

- CLK (0) System Clock. Frequency is dependent on computer. The frequency of this signal should not be considered definitive as the signal is really intended for synchronising purposes.

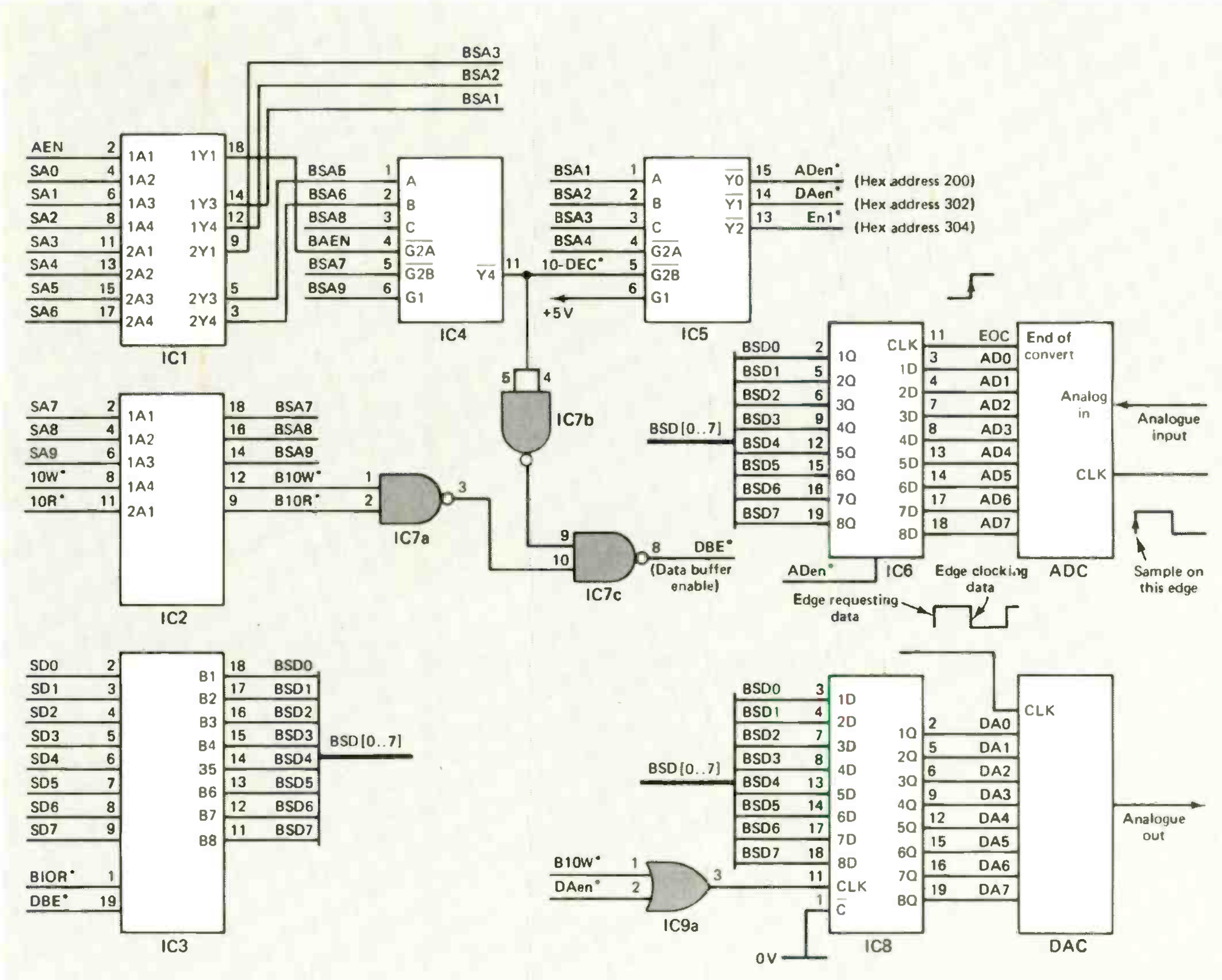
- RESET DRV (0) – used to reset external logic during power-up time. This is an active high signal.

- SD [0..15] (I/O) – system data lines. SD_0 is the least significant.

- IRQ_3-IRQ_7, IRQ_9-IRQ_{12}, $IRQ_{14, 15}$ (I) – interrupt request lines. They are prioritised, with the highest priority signal first, in the following order: 9,10,11,12,14,15,3,4,5,6,7. To generate an interrupt, the IRQ line is raised from low to high. The line must be reset when the interrupt is serviced.

- IOR (I/O) – instructs an I/O device that the microprocessor is ready to accept its data; i.e. the device must drive the data lines. Active low.

- IOW (I/O) – instructs an I/O device to read data off the data bus. Active low.



IC	IC	+5V pins	GND pins
1	LS244	20	1, 10, 19
2	LS244	20	1, 10, 19
3	LS245	20	10
4	LS138	16	8
5	LS138	16	8
6	LS374	20	10
7	LS00	14	7
8	LS374	20	10
9	LS32	14	7

Fig.1. Interface circuitry for an I/O-mapped eight-bit device. Asterisks indicate active-low signals.

- SMEMR/SMEMW – equivalent of IOR/IOW for memory devices. Active low.

- AEN – isolates the processor and other devices from the bus – also known as the I/O channel – and passes control to the DMA controller. Active high.

HARDWARE DESIGN OF INTERFACE CIRCUITRY

As with any bus, the interface circuitry always depends on the particular application; there is no unique way of interfacing to the bus. However there are two main factors that have to be considered in all circumstances:

a) Loading – each bus output can only drive up to two LS TTL loads. It is therefore advisable to buffer all inputs to the I/F (interface) card. This also serves to protect the host in the event of a fault on the I/F card. In addition, some bus inputs have certain current-sinking thresholds which have to be observed. It is always advisable to refer to the Technical Reference of the particular computer you are using.

2. Contention – certain input lines are shared by many boards – data lines being the most obvious example – and the designer must ensure that not more than one bus component activates these lines at any one time. Also, certain lines must not be activated for longer than a pre-determined period and these criteria have to be rigidly observed.

In our example, the I/F card is I/O-mapped as the ADC is a single address device. Because the ADC produces an 8-bit data output, and to ensure that the card can be used on a PC XT or a PC AT computer, 8-bit data operation is employed. Also there is an I/O address space – 300 to 31F Hex – especially reserved for prototype cards and our I/F card is mapped into this space.

The interface circuitry is shown in **Fig.1.** The circuit includes an ADC and a D/A convertor (DAC). A brief description of the circuit is given below.

$IC_{1,2,3}$ serve to buffer the system address and data lines. IC_4 is an address decoder, and its output, IO-DEC, signals an I/O operation at an address between 300 Hex and 31F Hex. IO-DEC is used, via DBE, to enable IC_3 and this ensures that IC_3 is only enabled when the card is addressed; this prevents contention with other cards on the bus. IC_5 is used to subdivide the address range 300 to 30F into eight 2-byte segments to provide separate enables for the ADC, DAC and any other device on the card.

The output of the ADC is latched into IC_6 by the End-Of-Convert (EOC) signal available from some ADCs; if this signal is not available then the sample clock can be suitably delayed to provide such a signal. IC_6 is mapped at address 300 Hex. The EOC, or a similar, signal will be used to signal to the host, either directly or indirectly, that data is available – this is discussed below.

The DAC, which is included for the sake of completeness, is mapped at the address 302 Hex. The DAC is not discussed further in this article and exact details of its operation cycle are left to the prospective user.

The signal EN1 is used to enable a device mapped at address 304 Hex; the use of this signal is discussed in the next section.

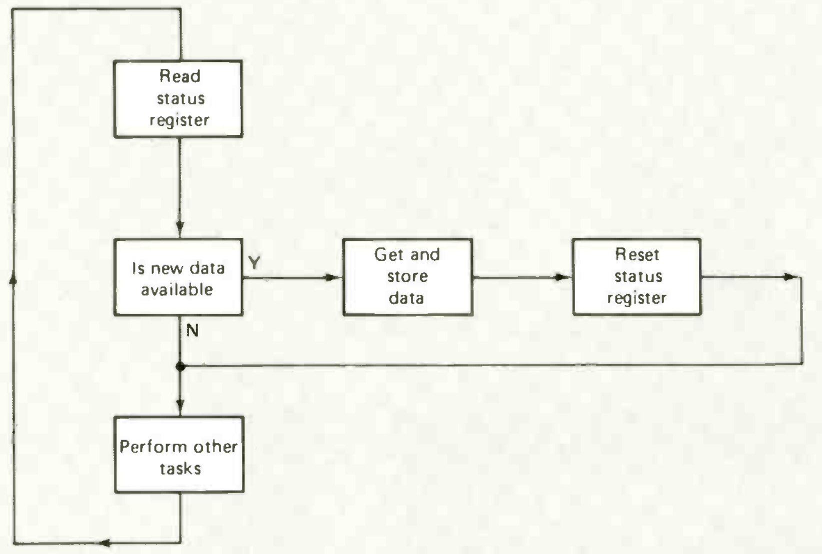


Fig.2. Polling provides an attractively simple method of signalling to the host that data is available.

SIGNALLING TECHNIQUES

There are two main methods of signalling to the host that data is available:

a) Polling.
b) Interrupts.

Polling is a simple concept to understand and it is illustrated graphically below in **Fig.2.**

In our example, the EOC signal sets a status register (which can be a D-type flip-flop) to indicate that a sample is present. The program loop running on the host includes a routine which reads the status of the register. If this status register is set – i.e., a data sample is present – then the routine calls on acquisition routine to read and store the data sample.

The main advantage of using polling – simplicity – is thus immediately apparent; programs can be written in a high level language and are easy to write and debug. The main disadvantage of using polling is that the host is not directly informed of the presence of data: if the host has to perform a lengthy task in its loop, then data can be easily lost. However when the tasks in the loop are short, polling is a highly convenient, and also a very fast, method of getting the data into computer memory.

The hardware and software to support polling are not discussed here as elements in the discussion of interrupts more than adequately cover these aspects.

Interrupts, as the name suggests, involve directly signalling to the host that a peripheral – ADC in this case – requires servicing. Hardware interrupts in the IBM PC XT and PC AT are initially handled by the interrupt controller chips – Intel 8259As. The PC AT has two of these chips and the PC XT has one. The interrupt controller translates the hardware interrupt into, effectively, an INT n instruction, where n is the interrupt number associated with the hardware interrupt. The processor then responds by invoking a special subroutine – an interrupt service routine. The address of this service routine is stored in computer memory and is known as the **interrupt vector address.** As it is required to invoke the user's service routine when the interrupt is detected, the vector address has to be altered to point to the user's own routine. This is known as redirecting the interrupt and will be discussed later.

Clearly, as in the case of polling, a scheme using interrupts requires supporting hardware and software. Before discussing these aspects, it is worth outlining the advantages and disadvantages of using interrupts.

The advantages are:

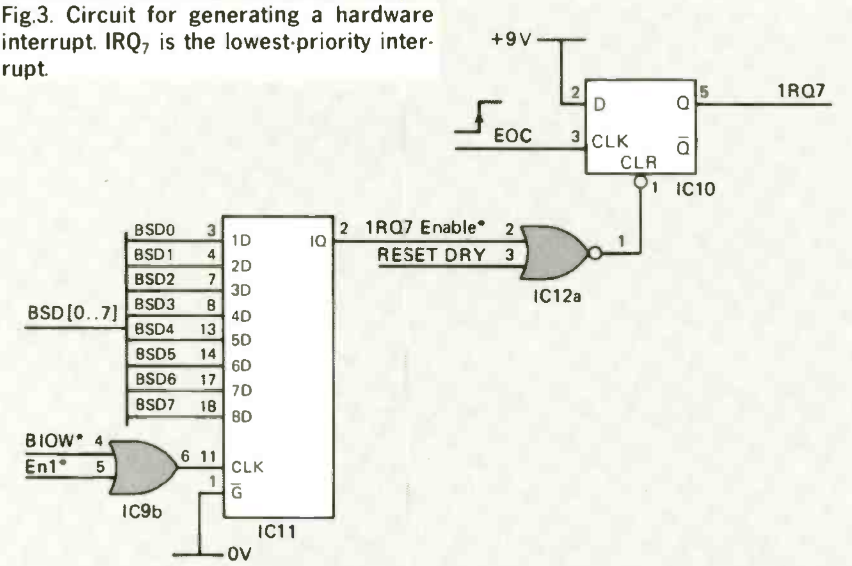
a) Accuracy – response of the host occurs immediately after the event.
b) Versatility – the host can service a number of peripheral devices because, unlike polling, it does not have to constantly interrogate each peripheral. Furthermore, the host can undertake lengthy tasks, especially if they are not time critical, without jeopardising peripheral servicing.

The disadvantages are:

a) Increased complexity – programs using interrupts are more difficult to write – and debug.
b) Servicing overheads – responding to an interrupt has an inherent time overhead. It is instructive to examine exactly what this entails. When the host detects an interrupt, it completes its current instruction, saves its status registers and instruction pointer on the stack, calls the appropriate service routine – which must ensure that all the general-purpose registers are saved on entry and restored on exit, and finally restores its status registers and instruction pointer when the interrupt has been serviced. There is a thus a minimum amount of time that must be expended in servicing any interrupt. These considerations ultimately limit the rate at which interrupts can be generated and faithfully serviced – in our case, it limits the acquisition rate.

It is not possible to exactly determine the maximum throughput of a program using interrupts as it depends on processor clock speed, processor type, complexity of service routine and bus performance. However a ball-park figure can be obtained by counting the total number of clock cycles in the interrupt service routine instructions, adding to this total the number of interrupt entry cycles (number of cycles required by the INT instruction) and then multiplying the total number of cycles by the time-per-cycle. It is then usual to allow a 20 per cent margin to allow for bus limitations.

Fig.3. Circuit for generating a hardware interrupt. IRQ_7 is the lowest-priority interrupt.



IC No	IC type	Pins to +5V	Pins to 0V
10	LS74	4, 14	7
11	LS374	20	10
12	LS02	14	7

HANDLING INTERRUPTS

A circuit for generating a hardware interrupt is shown in **Fig.3.** The interrupt is generated on IRQ_7 – lowest priority interrupt. The EOC signal sets the interrupt and the IRQ_7-Enable signal is used to reset it. IRQ_7-Enable acts as an interrupt enable/disable when it is set low/high: the interrupt is reset by disabling and then enabling it. IRQ_7-Enable is activated by writing to the LSB at I/O address 304 Hex (i.e. the EN1 signal is used to enable the latch IC_{11}). Note also that RESET DRV resets the interrupt during computer power-up.

The software routine to support the use of interrupts is generally written in assembly language, although some high-level language compilers can support interrupt routines – e.g. Microsoft C-compiler Ver. 5.1. The code for supporting IRQ_7 is shown in Listing 1. It assumes a working knowledge of 8086 assembly language programming, the Microsoft macro-assembler and Dos 21Hex-type interrupts, and an appreciation of some of the features of interrupt controllers. The code can be divided into two logical sections: a section dealing with the house-keeping tasks – these tasks involve, in the first instance, preparing the system to handle the interrupt and, ultimately, restoring the system parameters to their original state before the program is exited – and a section

LISTING 2

Listing 2. this short routine stores the acquired data in a file.

```
;the next two lines should be included in main progam data segment
filename        DB      'C:\TEST',0
file_hand       DW      0

;the following code can be included as a routine after the data has
;been acquired, the original interrupt parameters restored and before
;the main program is exited.

;create file
                mov     ah,3Ch
                lea     dx,filename
                mov     cx,00h
                int     21h
                mov     file_hand,ax
;open testfile
                lea     dx,filename
                mov     al,1
                mov     ah,3Dh
                int     21h
;add EOF code to end of acquired data
                mov     BYTE PTR acquired_data[index],EOF
                inc     index

;write to file
                mov     bx,file_hand
                mov     cx,index
                lea     dx,acquired_data
                mov     ah,40h
                int     21h
;close file
                mov     bx,file_hand
                mov     ah,3Eh
                int     21h

;end of code
```

LISTING 1

Listing 1: code for supporting IRQ_7, in 8086 assembly language.

```
AD_address      =       300h
DA_address      =       302h
enable_address  =       304h

irq7_vecno      =       0Fh             ;vector number
irq7_mask       =       07Fh
mask_address    =       021h
EOI             =       20h             ; end of interrupt code
ctrl_address    =       020h


data            SEGMENT public
index           DW      0
old_segment     DW      ?
old_offset      DW      ?
old_mask        DB      ?
acquired_data   DB      2000 DUP(0)     ;memory area where acquired data is
stored
data            ENDS

code            SEGMENT public
                ASSUME  cs:code,ds:data
start:
                mov     ax,data
                mov     ds,ax           ;load data segment address into ds
                cli

;redirect irq7 interrupt vector to point to int_service routine

                mov     al,irq7_vecno   ;get old vector address
                mov     ah,35h
                int     21h             ;es:bx contains old vector address
                mov     ax,es
                mov     old_segment,ax  ;store old vector address
                mov     old_offset,bx

                push    ds
                mov     ax, SEG int_service
                mov     ds,ax
                lea     dx, int_service ;ds:dx contain new vector address

                mov     al,irq7_vecno
                mov     ah,25h
                int     21h
                pop     ds

; enable interrupt controller to respond to irq7
                in      al,mask_address


                jmp     $+2
                mov     old_mask,al
                and     al,irq7_mask
                out     mask_address,al
                jmp     $+2


;enable hardware interrupt
                mov     ax,0
                mov     dx,enable_address
                out     dx,ax

                sti
loop:
;insert some procedure, such as keyoard check, which enables loop
;to be exited
                jmp     loop

                cli

;disable hardware interrupt
                mov     ax,1h
                mov     dx,enable_address
                out     dx,ax

; disable interrupt controller from responding to interrupt

                mov     al,old_mask
                out     mask_address,al
                jmp     $+2

;restore interrupt vector address

                push    ds
                mov     dx,old_offset
                mov     ax,old_segment
                mov     ds,ax
                mov     al,irq7_vecno
                mov     ah,25h
                int     21h
                pop     ds

                sti

exit:
                mov     ah,4Ch
                int     21h                     ;return to dos

int_service     PROC    NEAR
                push    ax
                push    bx
                push    cx

                push    dx
                push    ds
                sti

                mov     ax,1                    ;clear and disable interrupt
                mov     dx,enable_address
                out     dx,ax

                mov     ax,data
                mov     ds,ax

;interrupt service routine - get and store data
                mov     dx,AD_address   ;get next sample
                in      ax,dx
                mov     bx, index
                mov     BYTE PTR acquired_data[bx],al
                inc     index

                cli     ;disable interrupts before clearing interrupt.

                mov     al,EOI                  ;clear interrupt controller
                out     ctrl_address,al
                jmp     $+2

                mov     ax,0                    ;enable hardware interrupt
                mov     dx,enable_address
                out     dx,ax

                pop     ds
                pop     dx
                pop     cx
                pop     bx
                pop     ax

                iret
int_service     ENDP

code            ENDS

stack           SEGMENT stack
                DW      64 DUP(?)
stack           ENDS

                END     start
```

dealing with the interrupt service routine – which is the procedure int_service.

The initial housekeeping tasks are:

a) Redirecting the IRQ$_7$ vector to point to the int_service routine – i.e. modify the interrupt vector address associated with IRQ$_7$ to point to the int_service routine. This is achieved by reading and storing the original vector address. The original segment and offset addresses are stored in old_segment and old_offset respectively.

b) Enabling the interrupt controller to respond to the IRQ$_7$ interrupt. The master controller, which handles IRQ$_0$ to IRQ$_7$, is I/O-mapped at address 20-3F. The contents of the register at address 21Hex determine which of the interrupts is enabled. The contents of this register are modified to ensure that the controller responds to IRQ$_7$.

c) Enabling the hardware which actually generates the interrupt. This is achieved in our example by writing 0 to I/O address 304 Hex.

To restore the system parameters, the above steps are reversed: the I/F card hardware is disabled from generating the interrupt, the interrupt controller is disabled from responding to IRQ$_7$ and the original vector address is restored.

INTERRUPT SERVICE ROUTINE

The main tasks in the service routine are:

a) Reset the hardware generating the interrupt – by writing 1 to 304 Hex.

b) Read the next sample and store it. The data is stored in a memory area with the start address 'acquired_data'; the variable 'index' is used to scan this memory area. The size of the memory area is set at 2000 bytes but this parameter can be easily changed.

c) Clear the interrupt controller. This is necessary as it allows the controller to respond to subsequent interrupts. The controller is cleared by writing an End-Of-Interrupt – EOI – code to its control register. Note also that the processor is prevented from responding to further interrupts – via the CLI instruction – before the controller is cleared: this is to prevent the processor responding to another interrupt before the service routine is existed.

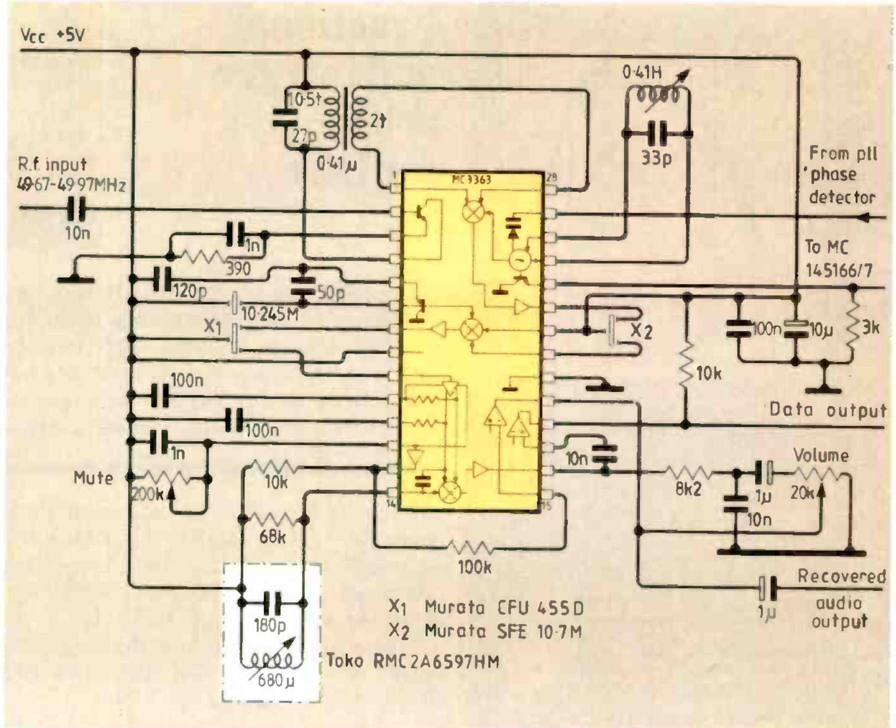
d) Enable the hardware interrupt.

FILE STORAGE OF ACQUIRED DATA

Listing 2 is a short routine which stores the data, in computer memory, into a file. The number of bytes is indicated by index. Before the data is stored, an End-Of-File (EOF) code is tagged onto the data. This EOF code can be any byte which is not generated by the ADC. It is intended that this section of code is inserted before the 'exit' label in listing 1 and the two data declarations are inserted in the main data segment. It is left to the user to determine the EOF code, as it depends on the range of codes produced by the ADC.

Dual-conversion f.m. receiver

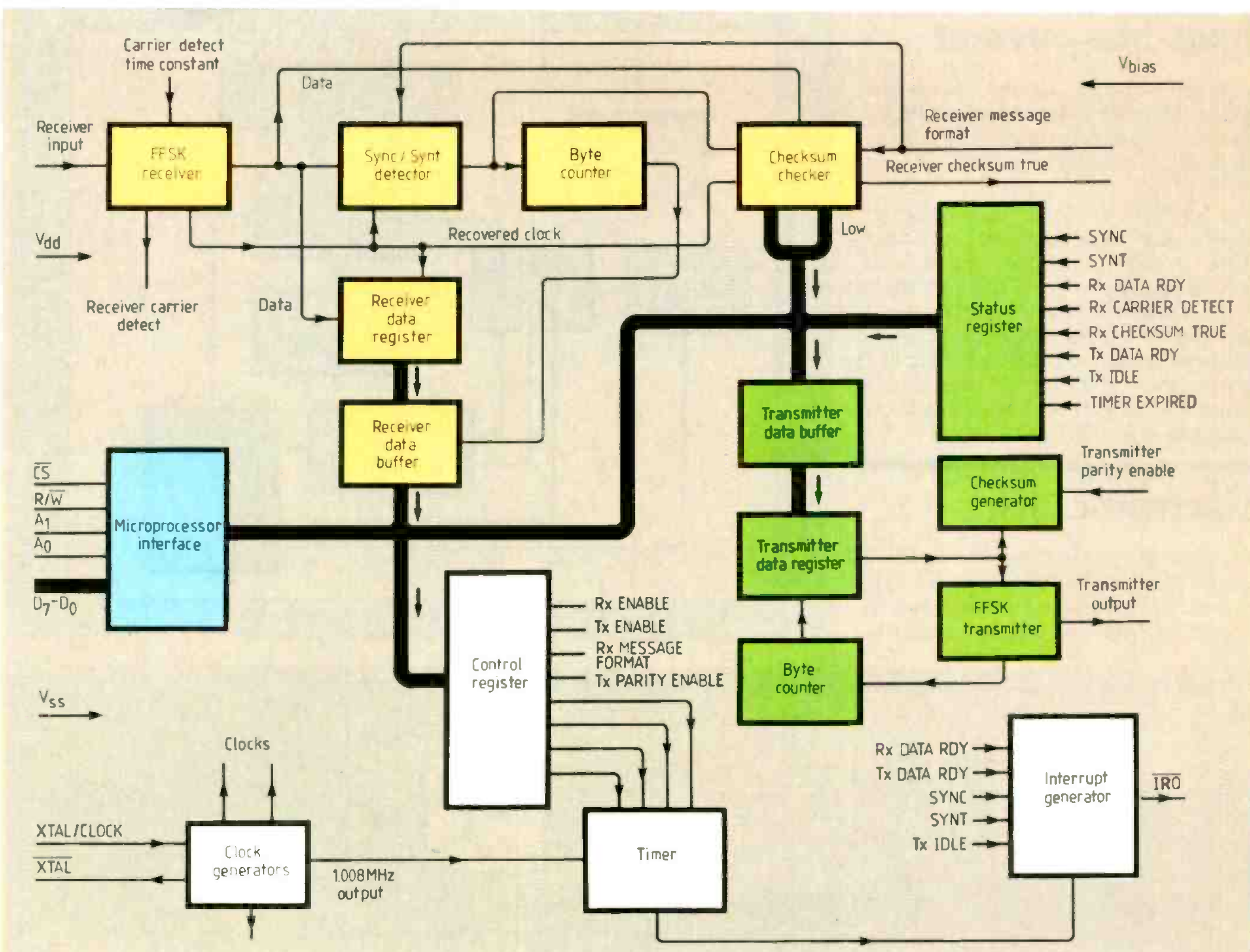
Two applications for the MC3363 narrow-band VHF FM receiver are presented in the device data sheet. This one is a 49MHz synthesized receiver which, together with the MC145166/7 frequency synthesizer, does all the work from r.f. input to demodulated output with just two i.cs. *Motorola, Macro Marketing, Burnham Lane, Slough, Berkshire SL1 6LN. 06286 4422.*



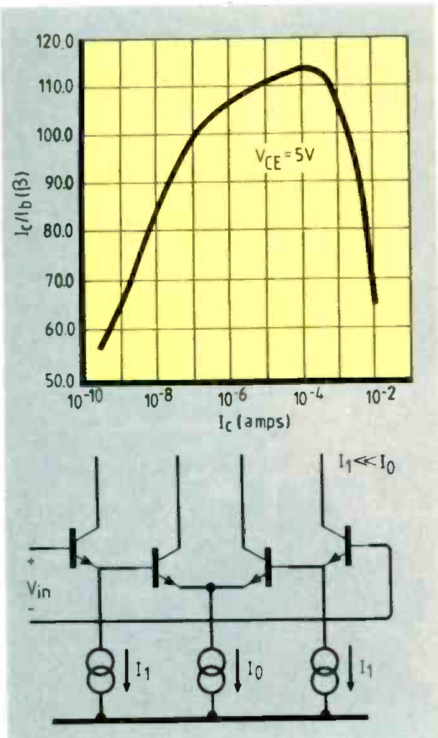
Intelligent modem

Primarily, the FX429 1200-baud modem is intended for Band III trunked radio systems, but it also has more general-purpose applications.

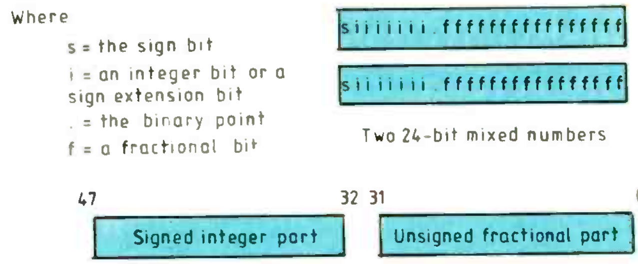
Publication D/429/2 from Consumer Microcircuits describes how the full-duplex device operates in sufficient detail to allow design of both Band III and general-purpose radio or line-data modems. *Consumer Microcircuits, Wheaton Road Industrial Estate East, Witham, Essex CM8 3TD.*



APPLICATIONS SUMMARY



Fractional and integer arithmetic for DSP



One of the unusual features of the 56000 DSP chip is that its one-chip multiplier directly supports fractional data formats, and it indirectly supports integer data formats. Motorola note APR3/D describes how it does this, and presents well documented routines for mixed and real-number addition and subtraction, signed multiplication and signed division. *Motorola, Macro-Marketing Burnham Lane, Slough, Berkshire SL1 6LN. 06286 4422.*

Designing for low input-bias current

In bipolar analogue systems, input bias current can be reduced by lowering collector current, but in terms of noise, slew rate and bandwidth, low collector currents can have adverse effects.

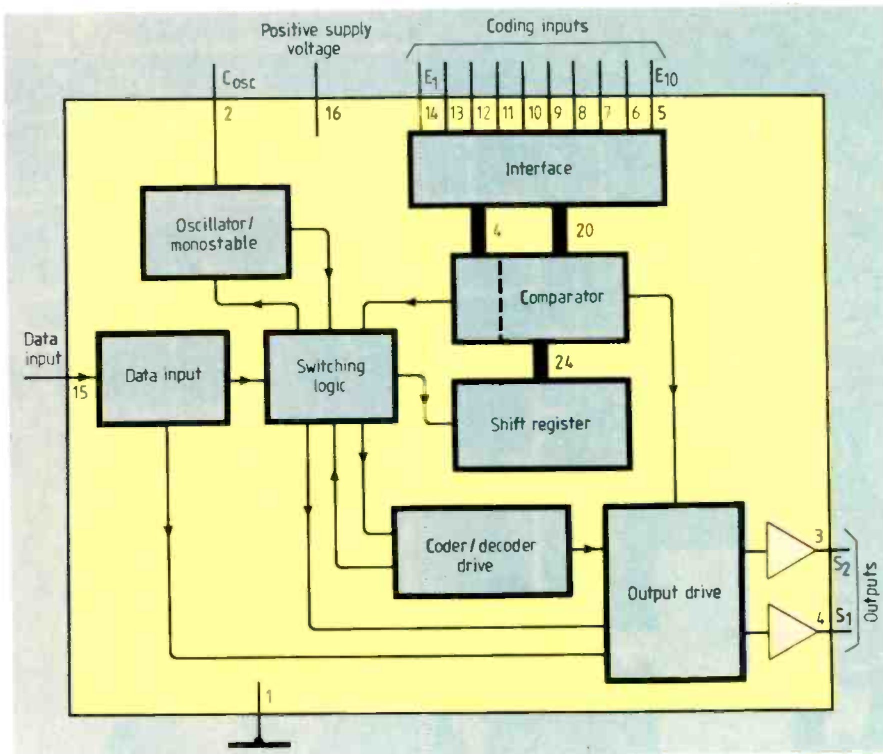
Darlington input configurations, as shown, solve some problems but cause others: voltage gain suffers, and so does offset voltage. Application note 3 from Micro Linear, 'Design Techniques, for Low Input Bias Current', describes these solutions in a little more detail, and it discusses input bias current cancellation. *Micro Linear, Ambar Cascom Ltd, Rabans Close, Aylesbury, Buckinghamshire HP19 3RS. 0296 434141*

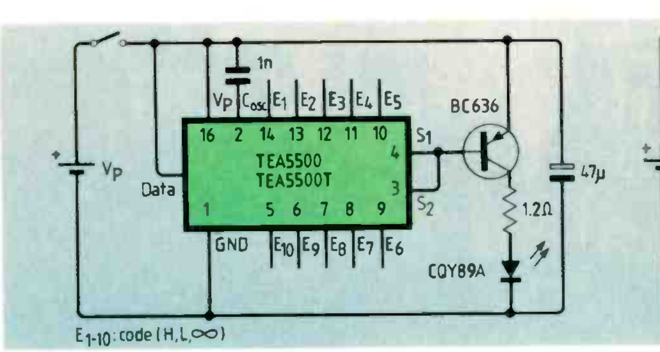
Electronic lock

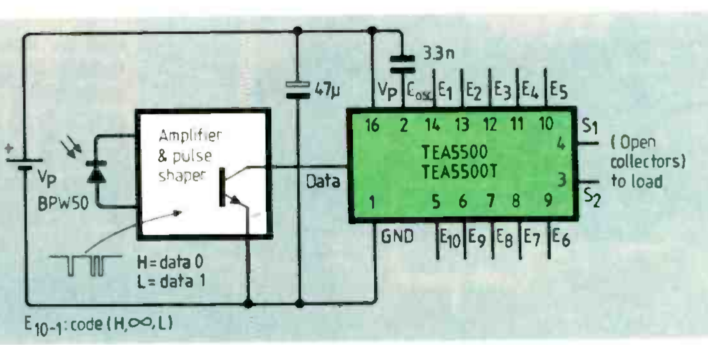
It is possible to select any one of $3^{10}-2$ security codes on the TEA5500 coded locking circuit, and each combination is directly selectable in hardware, despite the fact that the device has only ten code-select input pins. Such a large number of combinations is possible through the use of three logic states on the code-select pins – logic high, logic low and open circuit.

These two diagrams, from the device data sheet, show how the 5500 acts either as a code sender or receiver.

In coding mode, the coder completes three coding runs then stops automatically after every power up. In decoding mode, the data input is temporarily closed and one of the outputs is activated when the code is recognized. *Philips Components, Mullard House, Torrington Place, London WC1 7HD. 01 580 6633*

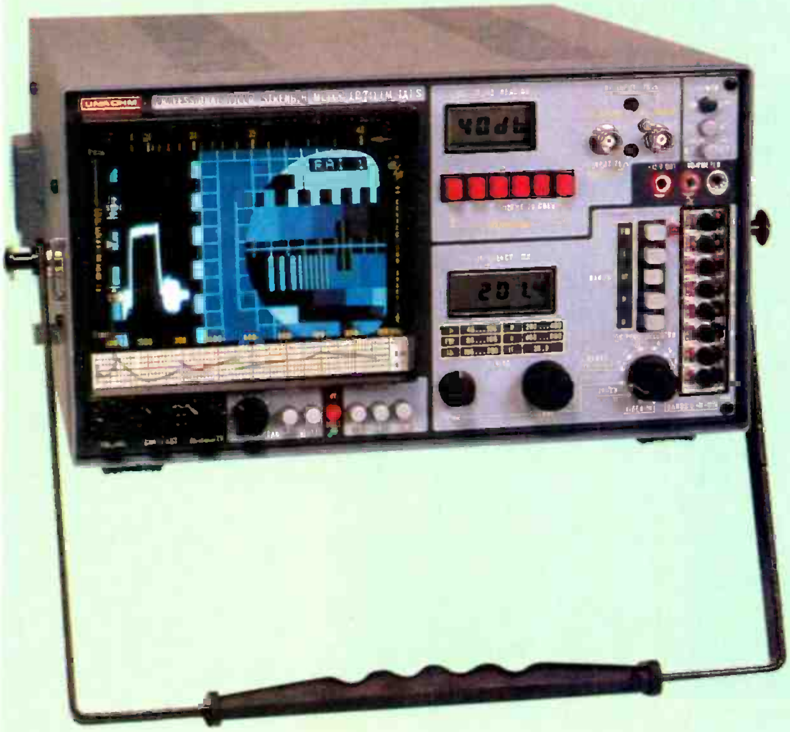






TAYLOR RF/VIDEO MEASUREMENT INSTRUMENTS

MEASUREMENTS MADE EASY



UNAOHM EP741FMS FIELD STRENGTH METER/SPECTRUM ANALYZER

Frequency Range: Continuously adjustable via a geared-down vernier as follows:

IF	38.9MHz
Band I	46 to 106MHz
FM Band	88 to 108MHz
Band III	106 to 290MHz
Band H	290 to 460MHz
Band U	460 to 860MHz

Frequency Reading: TV Bands — 4 digit counter with 100KHz resolution
FM Band — 5 digit counter with 10KHz resolution
Reading Accuracy: reference Xtal +/−1 digit.

Function: TV Monitor NORMAL: picture only
ZOOM : 2 to 1 horizontal magnification of picture
: picture + line sync pulse (with chromaburst if TV signal is coded for colour)

Panorama: panoramic display of the frequency spectrum within the selected band and of tuning marker.

Panorama Expansion: Adjustable expansion of a portion of the spectrum around the tuned frequency.

Analogue Measurement: 20 to 40dB. Static measurement of received signal. Scale calibrated in dBuV (at top of picture tube) to rms value of signal level.

DC/AC Voltmeter: 5 to 50V.

Measurement Range: 20 to 130dBuV in ten 10dB attenuation steps for all bands; −60 to 130dBuV in nine 10dB steps for IF.

Measurement Indication: ANALOGUE: brightness stripe against calibrated scale superimposed on picture tube. The stripe length is proportional to the sync peak of the video signal.

Video Output: BNC connector. 1Vpp max on 75 ohm.

DC Output: +12V/50mA max. Power supply source for boosters & converter.

TV Receiver: tunes in and displays CCIR system I TV signals. Other standards upon request.

Additional Features: (1) Video input 75 Ohm. (2) 12V input for external car battery. (3) Output connector for stereo earphones.

Price: **£1344.00** exc. VAT and Carriage.

UNAOHM FSM5987 T.V. FIELD STRENGTH METER

INPUT

Sensitivity: from 20dBuV to 110dBuV (−40dBmV to 50dBmV) or 10uV to 0.3V, in eight 10dB steps.

Reading: dB reading proportional to peak value for video signals; proportional to mean value for AM or FM sound signals. For both signals scale calibrated to rms value and expressed in dBuV. Two more scales are available: volt from 0 to 50, and ohm from 0 to 2000 ohm. Battery status is also provided.

Accuracy: +/− 3dB for bands I & III +/− 6dB for bands H & IV/V

Impedance: 75 ohm unbalanced; DC component blocked up to 100V.

FREQUENCY

Range: 46 to 860 MHz as follows:

Band	
I	46 to 106MHz
III	106 to 206MHz
H	206 to 460MHz
IV/V	460 to 860 MHz

Reading: 4 digit LCD readout. 100KHz resolution.

Price: **£378.00** exc. VAT and Carriage.

UNAOHM EH 1000 TELETEXT AND VIDEO ANALYZER

Function: Eye Pattern display of RF and video-frequency teletext signals by means of eye pattern diagrams both in linear representation and lissajous figures (O and X). Line selection: display of video signals and line by line selection. Measurement of modulation depth. Teletext: monitoring of teletext pages.

RF Input: Freq. Range: 45 to 860MHz. Frequency synthesis, 99 channel recall facility, 50KHz resolution, 30 channel digital memory. Level: 40 to 120dBuV; attenuator continuously adjustable. Indication of the minimum level for a correct operation of the instrument. Impedance: 75 ohm. Connector type: BNC.

Video Frequency Input: Minimum Voltage: 1Vpp. Impedance: 75 ohm or 10K ohm in case of a through-signal. Connector type: BNC.

Teletext Input: Voltage: 1Vpp/75 ohm.

Teletext Clock Input: Voltage: 1Vpp/75 ohm. Measurement: Aperture of eye pattern: linear or Lissajous figures, selectable. Indication: directly on the picture tube. A calibrated scale shows percentage of eye pattern aperture. Error: the instrument introduces an error of ⩽5% with video input and 20% with RF input. Jitter on regen'd clock: ⩽25ns. Line selector: Selection of any TV line between the 2nd and the 625th scanning cycle by means of a 3 digit thumbwheel switch.

Oscilloscope: VERTICAL CHANNEL: Sensitivity: 0.5 to 2Vpp/cm. Frequency Response: DC to 10MHz. Rise time: pre & overshoot ⩽2%. Input Coupling: AC. Input Impedance: 75 ohm/50pF. TIME BASE: Sweep Range: 20 to 10ms (1.1/2 frames); 32; 64/192us (1/2; 1; 3 lines). Linearity: +/−3%. Horizontal Width: 10 divisions; x5 magnification.

Price: **£1670.20** exc. VAT and Carriage.

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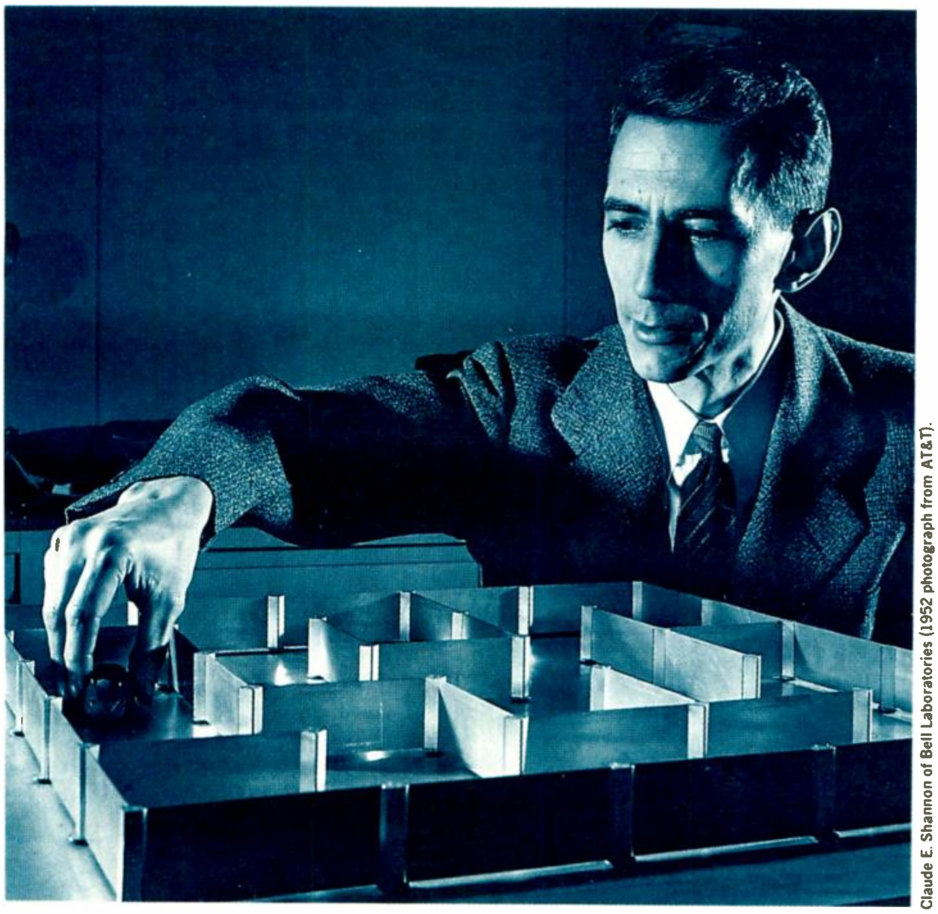


Claude E. Shannon of Bell Laboratories (1952 photograph from AT&T).

SHANNON, CODING AND SPREAD SPECTRUM

In part 2 of this short series on advanced communications techniques, the author examines the system known as direct sequence spread spectrum.

L.C. WALTERS

In last month's article, we saw that it is always possible in theory to effect, for a given communication performance, a linear exchange of bandwidth for signal-to-noise ratio. I also showed that for input signal-to-noise ratios less than a threshold level, r_t say (I suggested $r_t=¼$ or −6dB as a practical criterion), this linear exchange is close to the maximum attainable; but that for higher signal/noise ratios a logarithmic exchange could be envisaged. I discussed a somewhat simplistic model to demonstrate how the linear exchange might be implemented, but pointed out that this model was of little practical use in general.

We now consider more realistic implementations. In all cases I shall implicitly assume a *radio* communication system, though most of the properties discussed could apply to carrier-borne or base-band line communications and sometimes also to other systems such as radar or sonar.

REDUNDANCY

All bandwidth expansion involves redundancy in some sense. That is to say the bandwidth is expanded by sending more "data" than is required for the desired *information* transfer. However, while for error correction/detection the transmitted data and the information are closely functionally related, this is not necessarily the case when one seeks only a linear exchange of bandwidth for signal-to-noise ratio.

It is possible to expand the bandwidth of a signal in a variety of ways. For example, one may intermittently change the carrier frequency. This results in a so-called frequency-hopping system (briefly discussed last month) for which the "instantaneous" bandwidth is much less than the total bandwith used. This technique is well known: its major properties are fairly obvious and so is the general nature of its implementation, even though the details of such implementation may involve some subtlety. For these reasons I shall not discuss it further here — except to comment that in general terms it should theoretically permit the previously described linear exchange in respect of jamming provided that the jammer is unable to anticipate the movement of the carrier. It does not, however (contrary to some assertions), readily provide low detectability; and indeed it is often easier to detect the presence of frequency-hopping transmissions (and even to locate their source) than to detect many conventional signals. On the other hand, in the absence of information encryption, it is appreciably more difficult to intercept and extract the *information* from frequency-hopped transmissions.

Bandwidth may also be expanded by decreasing the duty-cycle: that is to say, by transmitting discontinuously. For example, a binary communication signal could be transmitted in short pulses (or bursts of such pulses) with substantial intervals (perhaps irregular) between them. Such systems are sometimes called time-hopping systems, and again the signals are fairly readily detectable (though less so than frequency hoppers) but can permit the linear exchange provided the jammer is unable to predict future patterns in the time domain.

The third type of spreading is direct sequence spread spectrum (DSSS) which is the chief topic of this article.

DSSS

Conventional radio systems employ a single frequency carrier; or in other words, a very narrow-band carrier on to which the information is impressed. Thus, a characteristic of such systems is that the information bandwidth is very much greater than that of the unmodulated carrier. Consequently, the total bandwidth occupied is determined primarily by the information bandwidth, though it will also depend to some extent on the type of modulation employed.

In contrast, DSSS systems employ a carrier whose bandwidth is much greater than that of the information to be conveyed. (It is arguable that the same applies to other bandwidth expansion techniques such as frequency hopping, but there is a very real sense in which it is a more fundamental feature of DSSS).

There are many ways in which a wideband carrier can be generated, but by far the most common and convenient is to phase-modulate a conventional narrow-band (i.e. sinusoidal) carrier with a wide-band signal. Almost always, the latter is a binary (or quaternary) signal, usually derived using some sort of logic clock. It can be represented (in the binary case) as a sequence of 1s and −1s (or 0s), i.e. as a binary code or a combination of such codes.

As for other spectrum-spreading techniques, for success in countering jamming (or, for DSSS, in achieving low detectability) it is highly desirable (though, in the jamming case, often less essential than is sometimes thought) that the jammer or interceptor is unable to predict the wide-band carrier wave-form. For this reason, the codes chosen are almost always some form of pseudo-random sequence. Ideally they would be derived from a truly random source such as thermal noise, but since their use demands the availability of replicas at the receivers, pseudo-noise two-level codes are much more convenient. When used for DSSS they are termed "spreading codes".

Since we are here concerned only with principles, I shall henceforth restrict discussion to implementations which employ as a carrier a sinusoid which is phase-shift keyed (i.e. phase reversed) by a binary pseudo-random sequence. (The possibility of extension to more complicated constructions such as quadri-phase modulation is fairly apparent but implementations can involve some quite complex features.)

BINARY CODE

The choice of binary code is of considerable importance in DSSS systems, primarily because of the reception techniques normally employed. In general, one seeks good auto-correlation properties. That is, that the result of multiplying the code (represented as 1s and −1s) by a delayed version of itself, and then adding linearly a predetermined number of successive resulting binary digits should be of very small magnitude for all delays other than zero (where, of course, the sum will equal the number of digits summed). Here we need consider delays only in terms of whole numbers of code bits or clock periods. (For DSSS systems these periods are often called "chips".) This restriction simplifies the reasoning and the description and does not in any significant manner invalidate conclusions, even for delays involving fractions of chips.

The general question of code generation and determination of auto-correlation and cross-correlation properties is highly complicated and involves advanced mathematics of some profundity. It is still the subject of much research by mathematicians. For the present we shall merely note that one type of code which is quite popular in many applications is that known as a maximum length or m-sequence. Although such sequences have some drawbacks, their auto-correlation properties (when the summation is over the whole code length) are excellent. For the purposes of this article we shall henceforth assume the use of an m-sequence as a spreading code, though many practical systems use rather different codes

M-SEQUENCES

If a clocked binary shift register has its input provided by a logical combination of the contents of its last and some intermediate stages it is called a feedback shift register. If it has n stages, then during any clock (or chip) period it will contain n binary digits, (the "fill"), which may be deemed to represent an n-bit binary number. Since there are two possible values for each bit, there are 2^n possible fills for the register. However, if the feedback logic is linear, (e.g. obtained using only exclusive-or gates) then one of these fills (such as "all 0") will be self-generating and will result in a completely static or unchanging fill. Consequently, only 2^n-1 binary fills are possible if a dynamic situation is to be achieved.

In general, such a register will produce a limited number of fills forming a sub-set of the whole set; but it is possible to select the intermediate stages and the feedback logic in such a way that every one of the possible fills occurs at some time; and since the feedback is assumed linear, the whole sequence must then repeat. As a result, such a sequence (taken, for example as the succession of bits from the last stage or from the feedback logic) is a maximum length or m-sequence, and for an n-stage register is 2^n-1 chips long.

In general there is more than one combination of feedback stages and logic which will achieve this for any given n, giving rise to more than one m-sequence of a given length. For these, although the fill cycles through all possible values but one, the order in which it does so differs for the different m-sequences. Note that one of the fills will be the "all ones" set of n 1s and that the next digit fed back from the feed-back logic must be a zero. (If it were not, then the fill would not change on that or any succeeding clock cycle, and so we would have a static situation instead of a dynamic one). Moreover, each fill can occur only once in an m-sequence cycle so any m-sequence of length 2^n-1 chips will contain no sequence of 1s longer than n and only one sequence of exactly n 1s. When n is very small, the number of possible m-sequences is also very small, but as n (and hence the sequence length) increases it becomes possible to generate more and more different m-sequences from a given length of register. Thus for n=5 there are just 6 different sequences of length 31 chips. For n=7 there are 18 sequences of length 127; for n=11 there are 176 of length 2047; and for n=19 there are 27 594 of length 524 287. It should be noted that it is quite easy to generate m-sequences of enormous length. Thus, a 64-stage register, even if clocked every microsecond, could be connected to produce an m-sequence which would not repeat for nearly 600 000 years!

All m-sequences have the property that their autocorrelation function, computed over one complete cycle of 2^n-1 chips is −1 for all (integral chip) delays other than zero (or a multiple of the sequence length) where, of course it is 2^n-1. Clearly, however, this admirable property can hardly be exploited for very long codes. For example, the n=64 case cited above would involve a delay of 600 000 years before one could even transmit the complete code, let alone perform

Shannon and the Gibraltar inquest

At the recent Gibraltar inquest, a technical witness, Dr Michael Scott, suggested that it was technically impossible for the IRA members to have detonated a bomb in the supposed target area from the point at which they were shot. His argument appeared to be that using a nominally powered radio (sited where the shootings occurred) normal speech was not intelligible at the supposed target site because of inadequate signal strength, i.e. inadequate signal/noise ratio.

The absurdity of such an assertion is obvious from Shannon's equation, $C=W\log_2(1+S/N)$ — see page 48, January issue. Typical VHF FM speech reception will fail at a signal-to-noise ratio of the order of 6dB to 8dB. But to operate a switch one needs only to receive one binary digit (bit) of information and it would not be unreasonable to assume that one might be prepared to transmit for say one second to achieve this. Thus the information rate involved could well be of the order of one bit per second. According to Shannon, and assuming the 25kHz bandwidth typical of many vhf transmitters and receivers, such *capacity* corresponds to a signal-to-noise ratio of −45dB.

Even assuming an inefficient implementation operating at as much as 14dB below this performance, (i.e. at −31dB), "successful" operation could be achieved at a signal-to-noise ratio some 30dB below, (i.e. 1000 times less than) the level at which speech would fail and far below the measurement capability of *any* conventional equipment.

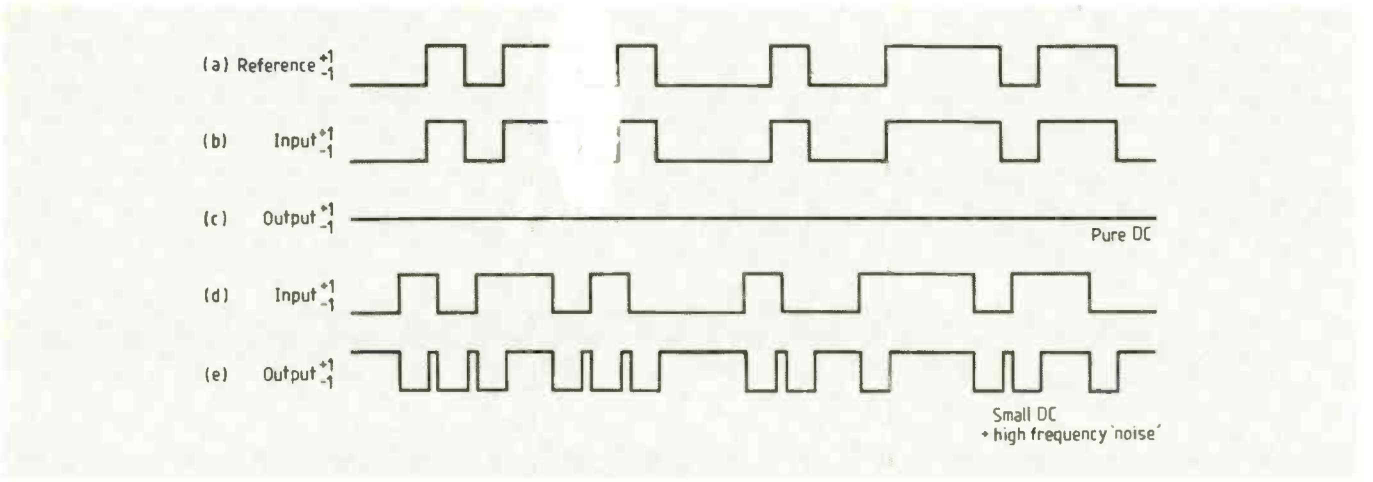


Fig. 1. Correlation process. Waveform(e) is the product of (a) and (d).

correlations; and not even our most maligned communication services would contemplate that!

Shift registers were originally used (and still are) to generate suitable spreading code sequences, but the ubiquitous microprocessor is resulting in increasing use of code generation by software, at least for the lower clock rates.

CARRIER BANDWIDTH

If a sine wave of frequency f_0 is phase switched by a binary sequence with a clock (i.e. chip) period τ, then the resulting broad band "carrier" waveform will have a power spectrum of the form

$$G(f)=P[\sin\pi(f-f_0)\tau/\pi(f-f_0)\tau]^2$$

where P is a factor defining the total power. This spectrum has its energy primarily concentrated in the range f_0-1/τ to f_0+1/τ. (Over 90% of the energy lies in this range.) In other words we may assess the RF carrier bandwidth as $2/\tau$.

For simplicity we shall assume that all the information to be conveyed is expressed in binary form as a sequence of 1s and −1s. However, since for DSSS the information bandwidth is much less than the carrier bandwidth, each information bit has a duration which is many times that of a spreading code chip, i.e. many clock periods. It is usually desirable and convenient to ensure that each information bit is an integral number of chips long and starts and finishes on a clock edge. However, this is not essential. It is also usually (though not always) desirable and convenient to employ the same type of modulation for information as for generation of the wide-band carrier. In the case of phase reversal modulation (PSK), this is equivalent to modulating the original sinusoid with the algebraic product of the spreading code and the information sequence, each expressed as 1s and −1s. Alternatively, it is equivalent to modulation of the sinusoid by the output of an exclusive-or gate fed by the spreading code and the information, both expressed in terms of 1 and 0. This is perhaps the simplest type of information modulation and will be assumed in the following paragraphs though other techniques have also been employed in practice.

DETECTION OF SIGNAL

Almost all DSSS systems rely heavily on correlation processes for detection and reception of signal. Correlation is discussed briefly below, but may be shown to be equivalent to true matched filtering. Indeed, some DSSS systems actually employ so-called matched filters for this purpose but they are usually not true matched filters in so far as they respond to an appropriate input *pattern* whenever it occurs. In contrast, a true matched filter will respond to this pattern only if it also occurs at a precisely defined epoch.

CORRELATION

The finite period auto-correlation function $R_T(\tau)$ of a waveform F(t) is defined as the average value over the period (T) of the product of F(t) and a delayed version of itself, $F(t-\tau)$ where τ is the delay. Thus

$$R_T(\tau)=\frac{1}{T}\int_{t_0}^{t_0+T} F(t)F(t-\tau)dt$$

In general, it will be a function of the "starting point" t_0. However, in some circumstances it may be independent of t_0, and one such case arises when F(t) is an m-sequence, T is the sequence duration or repetition period, and τ is an integral multiple of the chip period. As indicated in the section on m-sequences, we then have (for sequences taking the values +1 and −1):

$$R_T(\tau)=-1 \quad \tau\neq mT \text{ where m is an integer}$$
$$R_T(mT)=2^n-1$$

In general, of course, the product of a waveform with a delayed (or non-delayed) version of itself will be a third waveform whose statistics differ from those of the original. If the two waveforms are noise-like or randomized, then the product will also be noise-like and even after low-pass filtering (equivalent to the integration process of equation 19) the output will remain noise-like even for $\tau=0$. In other words, if N(t) is a noise waveform,

$$N^2(t)=DC+AC \text{ ("self-noise")}$$

If, however, N(t) is a binary sequence [N(t)=C(t)] taking only values +1 and −1, then

$$N^2(t)=C^2(t)=+1=DC \text{ only}$$

Thus $R_T(0)$ is pure DC for a binary waveform but $R_T(\tau)$ is primarily a non-DC function for $\tau\neq0$.

The correlation process is illustrated in **Fig. 1** in which time is represented on the horizontal axis. Waveform (a) represents a binary reference waveform, C(t). Waveform (b) is the same waveform in perfect synchronism with (a) corresponding to $\tau=0$, i.e. it is also C(t). Waveform (c) is their product $C^2(t)=1$, i.e. pure DC.

Waveform (b) is said to correlate perfectly with (a). Note that if either (a) or (b), but not both, is inverted, the product becomes −1, i.e. DC of opposite polarity. This is an important property. Waveform (d) is the reference waveform (a) but shifted in time to give $C(t+\tau)$ and waveform (e) is the product of (a) and (d) which has only a small DC component and some AC components containing quite high frequencies. In this case, the correlation (at the shift τ) is said to be small. (Note that it is irrelevant whether one considers delayed or advanced waveforms since, reverting to equation (19), the integrand $F(t)F(t-\tau)$ is identical to $F_1(t)F_1(t+\tau)$ where $F_1(t)$ has been written for $F(t-\tau)$. If F(t) is such that $R_T(T)$ is independent of the "start" time t_0, then from equation (19) there is no difference between that equation and the similar equation using F_1.)

If we now imagine that (a) is a transmitted waveform but that binary information is impressed by reversing its polarity if the information bit is a −1, and if, at the receiver, we produce the synchronous waveform (b) but with no such reversals, then the product of the two will alternate between +1 (positive DC) and −1 (negative DC) in precise agreement with the information bit stream.

If the input waveform is translated to radio frequencies by a linear modulation process, the same principles will apply, although depending on the modulation/correlation implementations some further demodulation may be required.

FUNDAMENTAL FEATURES

We may summarize the essence of an archetypal DSSS system as follows, with C(t) (taking values +1 and −1) representing the binary spreading code and I(t) (also taking the values +1 and −1) representing the binary information sequence.

At the transmitter, the transmitter signal is given by

$$I(t)\times C(t)\times \sin\omega t = \cos[\omega t-(\pi/2)\times I(t)\times C(t)]$$
(info) (WB carrier) [Wideband (WB) PSK]

Figures 2 and 3 show a transmitter and receiver according to the above functions. As indicated by the dotted lines, it is often (but by no means always) possible or convenient to use, in the transmitter, a sinusoidal initial carrier (sinωt) whose frequency is related to the spreading logic clock rate. (For example, the clock could be derived by counting down from the frequency ω/2π.)

We now have the problem of generating C(t) at the receiver and getting it in synchronism with the received signal. We also have the problem of providing a narrow band local oscillator, sinωt, in phase synchronism with the output from the despreader. These two functions are here considered separately because they are often performed separately, though conceptually they might be combined and in some cases have been. Here, as elsewhere, I shall merely indicate a possible technique for solving each problem. You should not infer that they are the only possible techniques or even necessarily the best for any particular implementation. They are, however, well-tried techniques in common use.

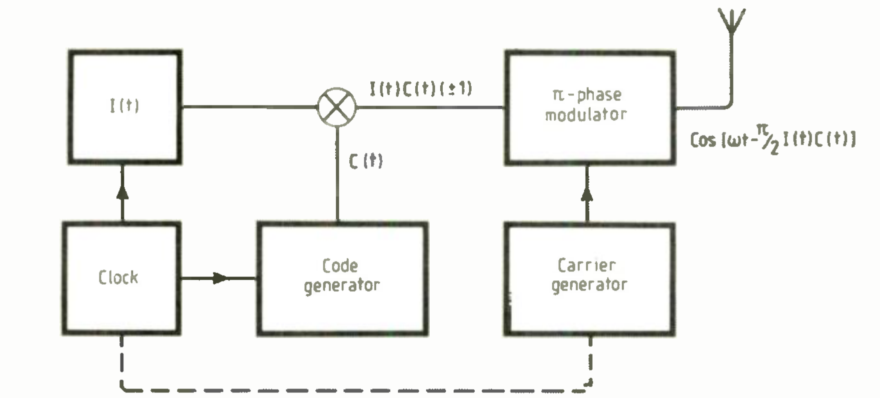


Fig. 2. Transmitter essentials in a typical direct sequence spread system.

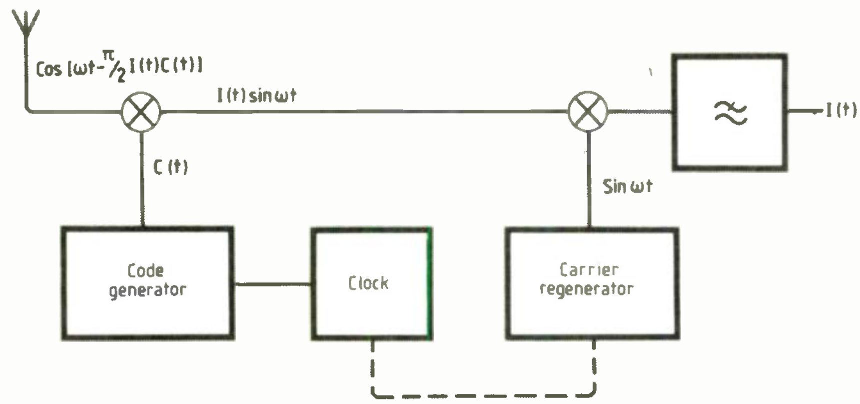


Fig. 3. Basic receiver for a DS spread system.

CODE ACQUISITION

It is clear that if the spreading code C(t) is defined in terms of a particular algorithm or of a particular set of shift register feedback connections and combining logic, then C(t) can be reproduced at the receiver. It is also apparent that provided this receiver code is in perfect synchronism with the received signal, the system will work well regardless of the auto-correlation properties of the code. (We here ignore some subtleties related to intelligent jamming.) However, in general the receiver code will not be synchronized with the incoming signal *ab initio* and it is in the process of obtaining such synchronism (or "code acquisition") that the auto-correlation properties are particularly significant.

Note that the accuracy required for synchronism is within a small fraction of a chip period, so that for typical clock rates of say 10MHz this implies accuracy of the order of 10 nanoseconds. For immediate purposes we shall consider a base-band system only and ignore complications due to translations to higher frequencies.

In principle, of course, one could envisage a huge bank of correlators, each fed by the received signal and by a delayed version of the locally-generated code, the delays being slightly different for each correlator. If there were sufficient correlators to cover all conceivable code phases (within the acceptable small fraction of a chip error), then the correlator giving the largest low frequency output power within the information bandwidth would be that for which the local code and the received signal were most nearly synchronized.

In practice, the cost and complexity of such a system would normally be prohibitive, though some systems do incorporate partial parallelism of this sort. Consequently, code acquisition is normally attained by means of a serial search procedure.

In passing, it is important to realize that DSSS systems are expected to work at very low signal-to-noise ratios (i.e. much less than unity or 0dB) so that the idea of detecting the received signal directly and extracting the modulation (including the spreading code) is a mere pipe-dream. Indeed, it is only by the correlation process that the signal can be extracted.

The idea of sequential searching immediately imposes constraints. Since the synchronizing precision required is within a small part of a chip period, the search must either be quantized into similarly small steps of local code delay or must progress continuously at a correspondingly low rate. In the quantized case, the search must be halted after each step for a sufficient time (the integration period T) to allow adequate assessment of the degree of correlation; and the more powerful the system (i.e. the lower the signal/noise ratio to be handled), the longer this time must be. In the continuous case, the "sweep" must be sufficiently slow that it does not, over the correlation or integration time T, result in a relative displacement or drift of more than the permissible fraction of a chip period. Thus the search is slow, and in the absence of any other timing information must be expected sometimes to need to proceed through almost the entire length of the code.

For long codes, the corresponding time to acquire code lock can be prohibitively long; times of hours, days, months, years, centuries or millenia can easily emerge from the relevant arithmetic and indeed many practical systems do allow minutes or even, in exceptional cases, a small number of hours to attain lock. Nevertheless, for most purposes, it is necessary to acquire lock in a time much less than an hour and often much less than a minute.

As a result, various subterfuges are employed to achieve more acceptable synchronization times. Most of these result in some theoretical degradation of performance, but two are especially simple to appreciate and are of some importance in practice.

Firstly, if both transmitter and receiver contain very high precision (e.g. atomic) clocks and have previously been synchronized, for example by the use of transfer standards, then the only timing error between the received and local codes at the receiver will be due to propagation delay (and equipment delays which can be measured and allowed for). If this propagation delay is also accurately known then no code acquisition system is required in theory. However, even if it is not known precisely, for radio systems it will not normally exceed a few milliseconds; and if the approximate separation of transmitter and receiver is known, the actual *uncertainty* in delay may be much less. Only a very limited search is

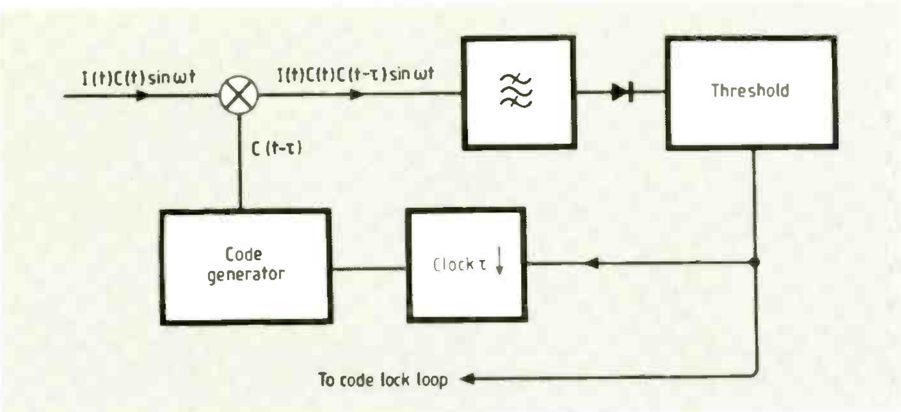


Fig. 4. Signal acquisition in a DS spread system.

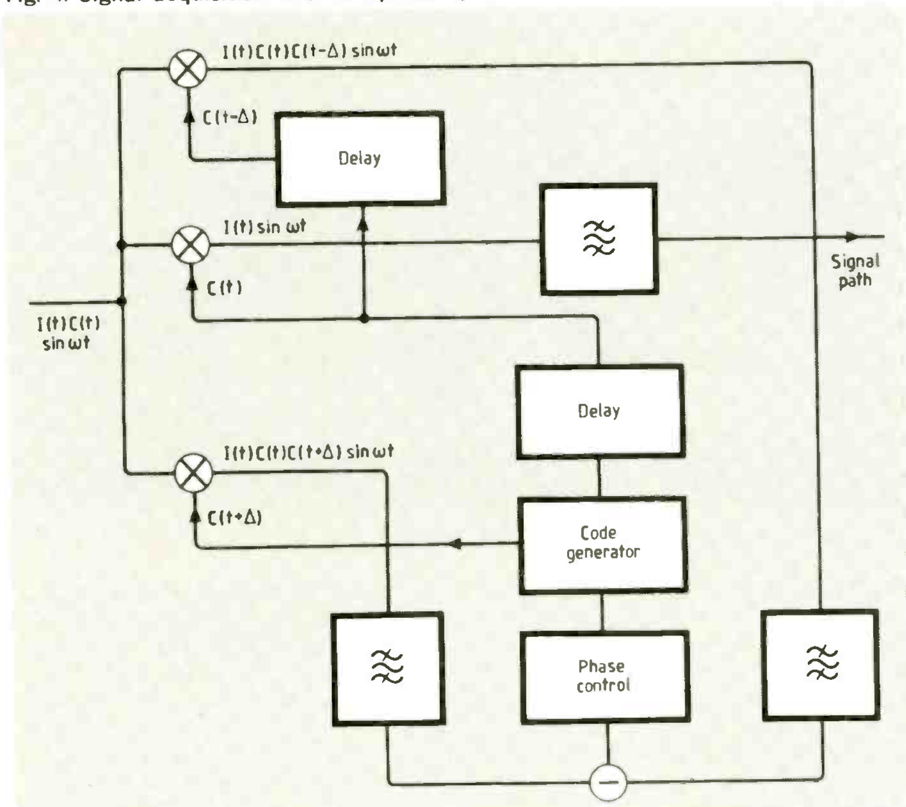


Fig. 5. Code lock loop. This generates three versions of the local code, slightly shifted in time or phase.

sufficient for code lock in such cases. Secondly, systems such as the US GPS (Navstar) satellite system can also provide highly accurate time references to both transmitter and receiver, thus reducing the need for atomic clocks. Navstar itself employs DSSS as an interference-resistant means of communicating its information.

If no high precision timing is available, then one may employ short codes so that the amout of searching required is limited to this shorter code length. However, short codes have some potential disadvantages in respect of both intelligent jamming and low detectability; and so they are often combined with long codes in such a way that the short code is used primarily to achieve code lock which is then "transferred" to the long code, a relatively simple process since the two codes can be driven by the same clock. The chief weakness of such schemes in respect of jamming is then restricted to the initial code acquisition period and is usually far less serious than is sometimes believed. Nevertheless, all schemes to expedite code acquisition introduce some potential degradation of overall performance, though its exploitation by a jammer may be much less easy than a superficial examination would suggest.

We shall henceforth ignore these complications and merely consider how one might implement an acquisition system involving sequential search, and for simplicity we shall assume that the local code is advanced in steps of some suitably small fraction of a chip period. At each code phase position the code phase is held for the selected integration (or correlation) period, here assumed to be the m-sequence repetition period (T), and the correlation factor is evaluated essentially by assessing the bandwidth of the resulting output. For example, if the correlation is performed at base-band, then, when synchronized, the output will be dominated by a large narrow-band component centred on zero frequency, i.e. a low frequency component.

If, on the other hand, correlation is performed at IF or at RF then the synchronized output will be dominated by a narrow-band component centred on that IF or RF. Unless the received and local codes are in synchronism or very close to it, the output will be like wide-band noise of low power density so that if it is followed by a narrow-band filter and rectifier (or low-pass filter in the base-band case) the output will be small. Hence we may terminate the search when such output attains an adequate magnitude. This also gives rise to a scheme for maintaining code synchronism when once achieved. The circuit which performs this function is called the *code lock loop* and is sometimes switched into the system only when synchronism has been detected. **Figure 4** depicts a signal acquisition system.

CODE LOCK LOOP

There are many variants on the basic theme for code lock loops but we shall here describe only one of them, commonly known as the "early-late gate" or "delay lock" loop. In this, three slightly time or phase shifted versions of the local code are produced, the phase shift or relative delay being the same between successive pairs. If the codes, in order of increasing delay, are designated C_E, C_P, and C_L (for early, prompt and late) and if each is fed to a correlator for which the other input is the received signal, then when C_P is in synchronism with the received signal, the "prompt" channel will have maximum despread output (used for information extraction) while the "early" and "late" channels will both have despread outputs of magnitude rather smaller than the prompt channel but virtually equal to each other. Thus the difference between these two outputs will be nominally zero. But if the codes C_E, C_P and C_L "drift" with respect to the incoming signal then one of them will be nearer synchronism than the other and its output will therefore be greater. The difference between the two outputs will then be nonzero and, in the base-band case, the polarity of this (DC) difference will depend on which is the larger and hence on the "direction" of the drift. It can therefore be used to control the phase of the local code (usually by controlling the clock frequency) so as to maintain synchronism in the prompt channel.

Figure 5 shows a code lock loop based on these principles but does not explicitly show the circuit (outlined in Fig. 4) for detecting synchronism in the prompt channel and switching in the loop itself.

In passing, it may be noted that the code lock loop does not have to be switched in after synchronism despite the advantages of so doing. If it is left permanently in circuit it can actually acquire lock prior to maintaining it.

SIGNAL EXTRACTION

In the implementation of Fig. 4, once code synchronism is achieved the output from the central prompt channel will be a narrow-band (i.e. sinusoidal) carrier, phase-reversal modulated by the information waveform I(t). This output is represented by I(t)sinωt.

To extract I(t) we must employ a coherent demodulation technique which requires generation of a reference signal sinωt as indicated in Fig. 3. This is achieved by feeding the signal output into a square-law device; and because I(t) is a binary waveform and $I^2(t) = 1$, its output will be

$$I^2(t)\sin^2\omega t = \tfrac{1}{2} - \tfrac{1}{2}\cos 2\omega t$$

If a narrow band filter, centred on ω/π is now applied, a relatively pure signal of the form $\cos 2\omega t$ is available which can be further fed into a frequency halving circuit to produce $\pm\sin\omega t$. (Small phase errors arising from the filtering etc. can be measured and allowed for.)

Figure 6 shows a signal extraction system based on this principle. Note the inherent uncertainty arising from frequency halving. That is to say we produce either $+\sin\omega t$ or $-\sin\omega t$ but we do not know which. Thus use of this output for coherent demodulation produces either I(t) or −I(t).

Various techniques can be used to resolve the ambiguity. For example, a predetermined code sequence can be incorporated within the information sequence I(t). If this appears inverted at the receiver output then that output can be inverted to correct the "polarity". This approach demands reasonably stable propagation delay between transmitter and receiver, and so a rather more popular technique is to employ differential encoding of the information delay between transmitter and receiver, and so a rather more popular technique is to employ differential encoding of the information. In one implementation of this, the phase of the carrier is reversed whenever the data bit is +1. The information is then extracted by comparing the received bit phase or polarity with that of its immediate predecessor. Thus, even if the reference sine wave in the receiver is inverted, the information will still be correctly received apart from one or two bits at the beginning of reception. Allowance can easily be made for this.

Differential encoding tends to double error rates because if one bit is incorrectly decoded the following one will probably be also. In other words errors will tend to occur in pairs. However, if the error rate is sufficiently low (and after despreading it *should* be), differential encoding is a very useful technique.

EFFECT OF NOISE AND JAMMING

For simplicity and ease of understanding we have so far considered noise-free signals at the receiver. Since a major aim of DSSS is to counter high levels of interference we shall conclude with a brief discussion of what happens when the signal is deeply immersed in noise of some sort. We must note, however, that all the processes described above, with the exception of the code-lock detection and coherent detection regeneration circuitry, are linear, so that noise and interference can be viewed as entirely linearly additive features. (This also applies if, as is usual, the received frequencies are heterodyned down to some lower intermediate frequency.)

Referring to Fig. 3, if the input signal contains additive noise or jamming which is uncorrelated with the signal, that component will also, in the correlator, be multiplied by the local code C(t). If the noise bandwidth is wide, this will make it even

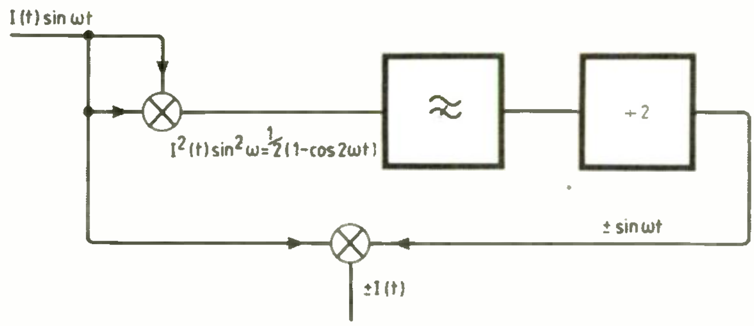


Fig. 6. Carrier regeneration: signal extraction system based on a narrow-band filter.

wider. If it s small (e.g. a sinusoid), it will be spread to give the same sort of spectrum as the original DSSS signal. On the other hand, all the energy in the true DSSS signal will have been translated into the narrow bandwidth of the information. The ensuing filter will therefore pass almost all the signal energy but reject all but a small fraction of the noise energy. Of this small amount, on average half will be "in phase" with $\sin\omega t$ and half in quadrature, and this last half will be further rejected after coherent demodulation and filtering. Hence noise and interference rejection of a high order is achieved.

The first, and major, noise reduction also applies to the signal used for regeneration of the carrier $\sin\omega t$ (Fig. 5). To reduce noise further in this circuit, a *very* narrow band filter at the double frequency may be employed since this filter does not even have to accommodate the information bandwidth. In practice one might use a fairly narrow-band filter followed by an injection-locked oscillator to achieve the desired very narrow band filtering. This oscillator could be at the double frequency or at the desired output frequency $\omega/2\pi$, thus performing filtering and frequency halving simultaneously.

Note the importance of performing correlation *before* coherent demodulation. If one were to attempt the two processes in reverse order, the nonlinear "square-law" device would result in the translation of a substantial amount of noise *from the entire RF bandwidth* into the narrow bandwidth of the filter whose output is used to determine the required phase of the local oscillator. In consequence, this oscillator would be subject to much greater phase jitter, resulting in degraded performance.

Most of the description above is related to analogue implementations. This is quite deliberate since in many instances these are the only feasible techniques at the present state of technology. However, in many other instances a primarily digital implementation is possible. In fact, implementation is heavily constrained by system parameters and current technology, so it is not useful in an article of this kind to pursue the matter further. Suffice it to say that entirely digital implementations would in many cases demand extremely high clock rates.

Before concluding, I should mention one other property of spread-spectrum which I have so far ignored. If the chip period is fairly small compared with likely differential propagation delays, then DSSS provides significant protection against multi-path propagation and fading. The inherent redundancy would in any case give some protection of this type; but if the receiver locks on to the shortest delay path signal (which can be arranged by choice of code search "direction") then other replicas, delayed by more than say a half-chip period, will be rejected in the same way as other interference. Indeed, with further complexity it is possible to conceive receiving systems with parallel reception which accept several differently-delayed versions of the signal, to correct for the delays (which are easily assessed from the relative code delays in the various channels) and then to combine the outputs coherently (with appropriate weighting for signal-to-noise-ratio) to provide maximum use of all the received energy. One such system was in fact implemented in the late 1950s[3], but whether the complexity is justified by the performance gain is a matter of debate.

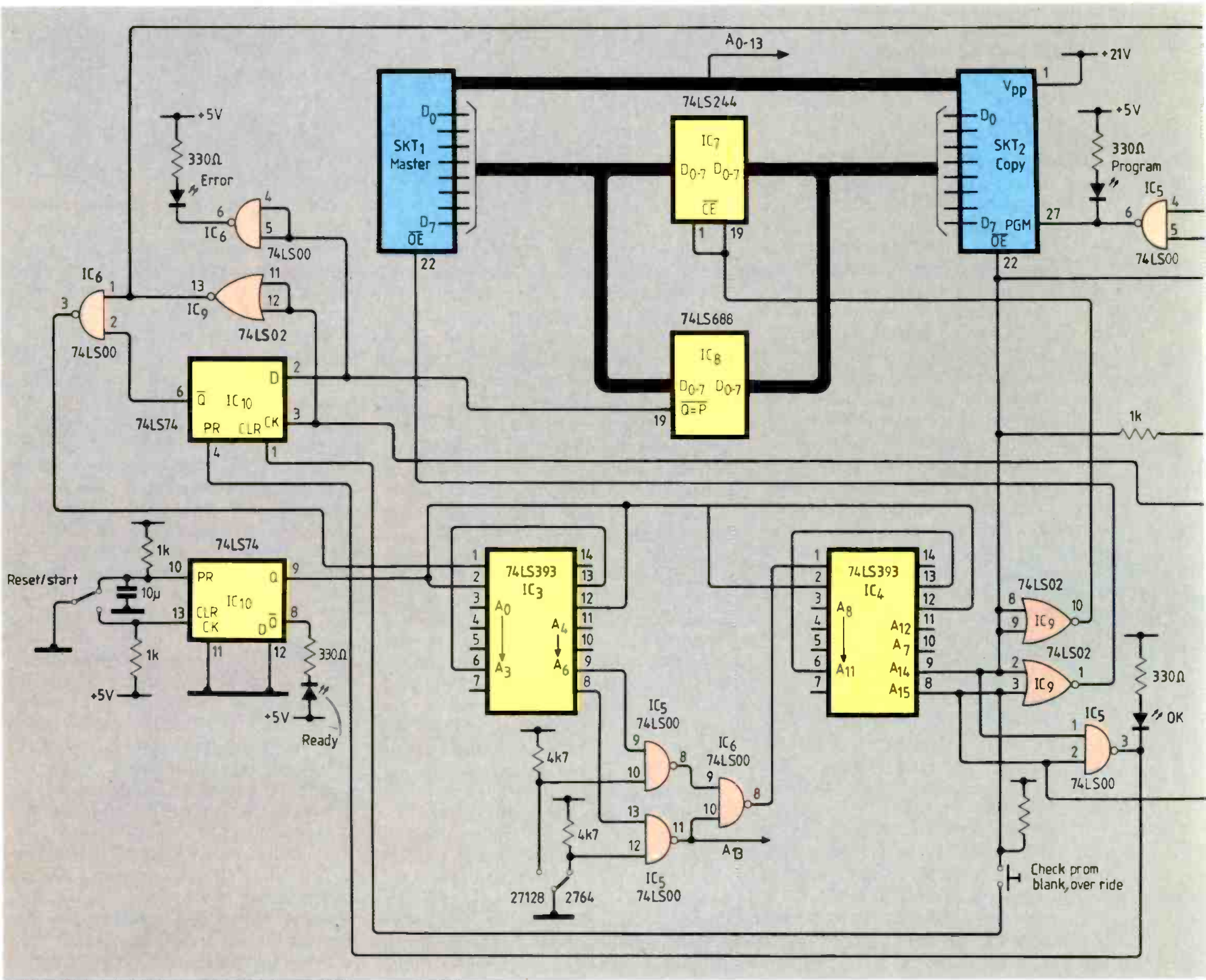
Finally, I should mention the possibility of systems in which many transmissions exist *simultaneously* within the same (wide) bandwidth. Since all but the signal to which the receiver is locked can be considered as interference and will therefore be rejected, such "multiplexing" is possible and does not demand any sort of "co-operation" between the transmitters in respect of timing (cf. time division multiplexing, TDM) or frequency allocation (cf. frequency division multiplexing, FDM). It therefore offers attractive features for some applications. However, to ensure that each receiver locks on to its intended signal, it is necessary that each transmitter has its own distinctive spreading code. This gives rise to the description "code division multiplex" or CDM for such schemes.

When CDM is employed, it is essential that there is little risk of the receiver locking on to the "wrong" code, even if the signal level associated with that code is much greater than that of the desired signal. To ensure this, the *cross*-correlation properties of the set of codes employed is of great importance; and again, highly advanced mathematics is involved in deriving such sets. Again, also, this continues to provide an area of research for mathematicians. In a future article I shall mention a type of CDM system which received much attention in the 1960s and early 1970s.

In the next article the author will consider error-correction and detection systems.

Reference

3. A Communication Technique for Multipath Channels. R. Price and P.E. Green. Proc. IRE, March 1958.



Eprom copier

Both 2746 and 27128 eproms can be copied quickly and easily using only a handful of standard i.cs.

Two 393 counters are clocked by a 555 timer that can be set for two different timings – fast for erase checking/verifying and slow (10 to 50ms set by the potentiometer) for programming. All reading and programming is done while the clock is high, leaving the low period for address and data changes.

Sequencing of the check, program and verify phases is controlled by address lines $A_{14,15}$, which are the two most significant outputs of the counter. When both lines are low, i.e. on the first time through the count, pins one and ten of IC_9 and A_{14} provide signals for disabling the buffer and setting the 555 to its fast mode. Comparator IC_8 compares output of the copy with the disabled master; if they are not the same, output of IC_8 goes high, taking the D input of IC_{10} high to stop the count and light the error led. If all locations are FF, the count continues until A_{14} goes high.

During the programming cycle, IC_9 pins one and ten together with A_{14} enable the master rom, enable the buffer and select the slow clock. When A_{14} is high and A_{15} is low, programming pulses from the 555 pass to the rom via IC_9, pin 5 and IC_5, pin 6.

Verification is achieved in the same way as blank checking but with the master enabled.

To change from 2764 to 27128, clock input to IC_4 is taken from A_6 rather than A_7 and A_7 and A_{13} are swapped. A facility for overriding the erase-checking phase is included for occasions when an attempt at programming a rom was unsuccessful and a second cycle is needed. An oscilloscope is needed to set the programming pulses.

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Z80 accelerator

In Z80 systems with no dynamic ram, the processor wastes time producing refresh cycles. This is also true for systems using a separate dynamic-ram controller.

Provided that the processor is running at 4MHz or slower a cycle can be gained by applying an 8MHz clock during refresh. This accelerator, which gives speed gains of up to 25%, requires the use of an 8MHz Z80 but all other existing components remain the same.

Note that the two seemingly redundant Or gates are to introduce delays. A two-to-one-line data selector is unsuitable for this application.

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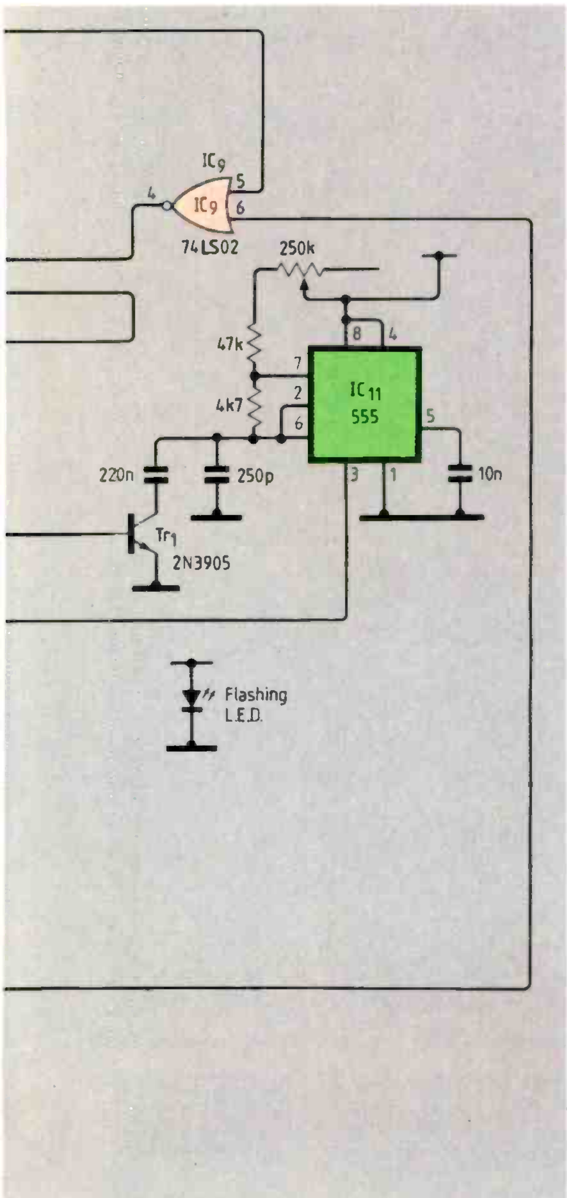
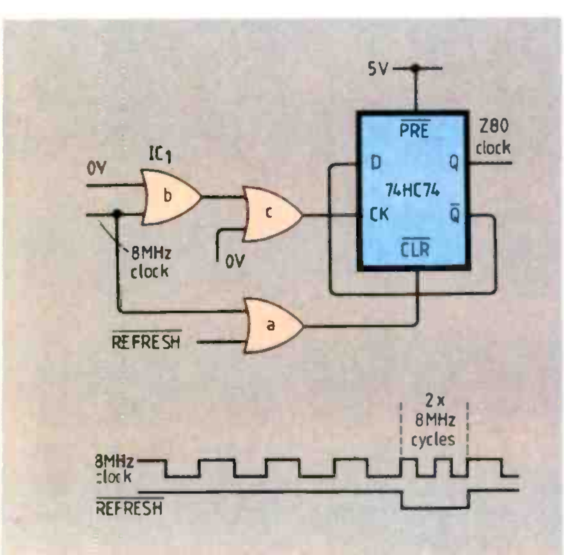
CIRCUIT IDEAS



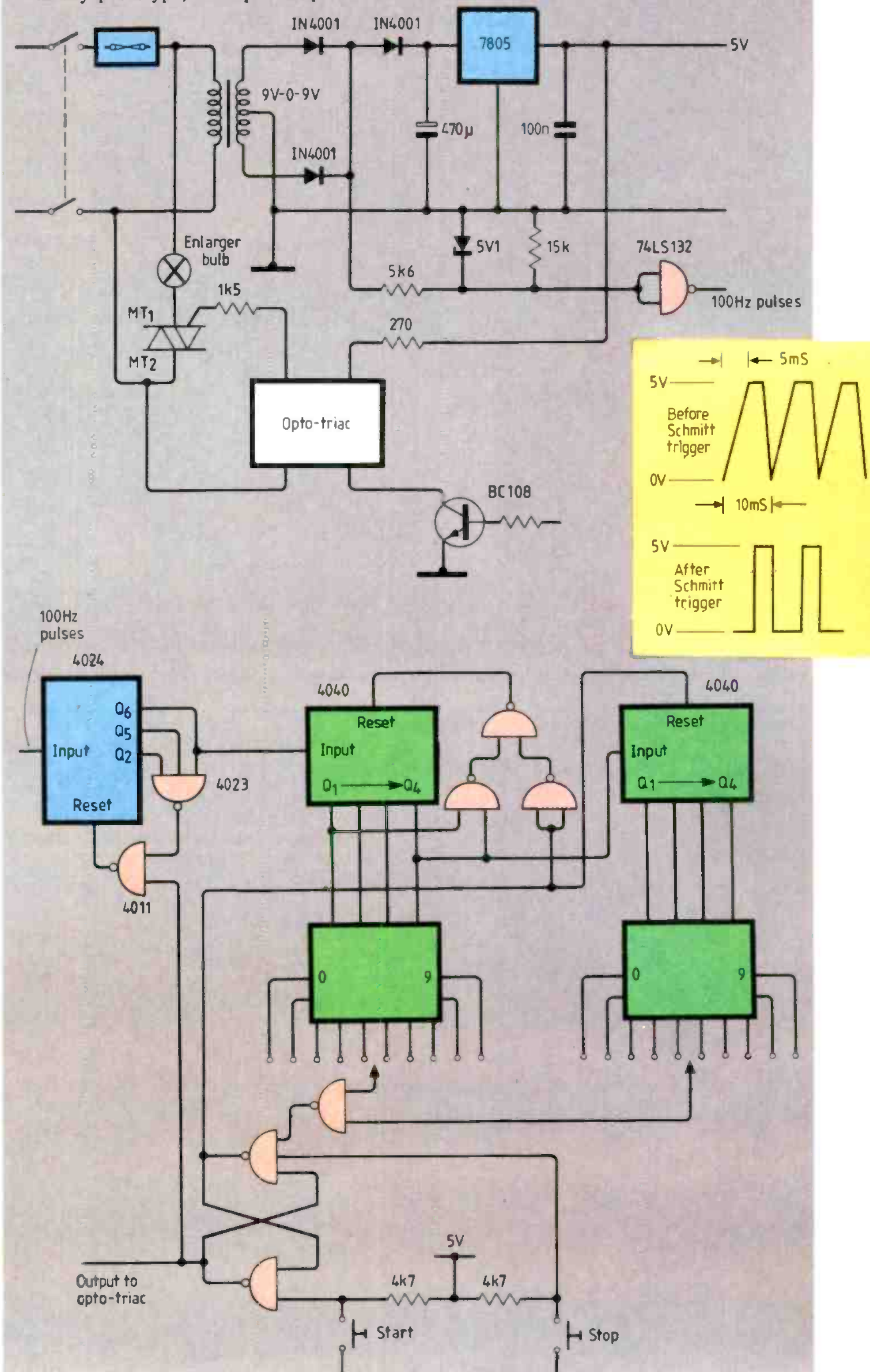


Accurate lamp timer

Mains-derived pulses determine delays of between 0 to 49.5s in this accurate lamp timer. Two ten-way switches set the time — a fine control for 0-4.5s and a coarse control for 0-45s. Manual start and start and stop buttons tuns the lamp on and off.

In my prototype, the opto-coupled triac was rated at 24W and the bulb at 60W — hence the second triac. Exercise great care in construction, following the regulations regarding equipment connected to the mains.

S.J. Churchman
Richmond
North Yorkshire



CIRCUIT IDEAS

Economical 16bit converter

Two eight-bit data converters and a switchable-gain amplifier could be used to make an economical 16bit a-to-d converter suitable for audio use.

Input is buffered, sampled, then fed to a differential amplifier with programmable gain. During the first clock cycle, gain of this amplifier is one so the original signal is converted directly to digital form and stored to the latch as the eight most-significant conversion bits.

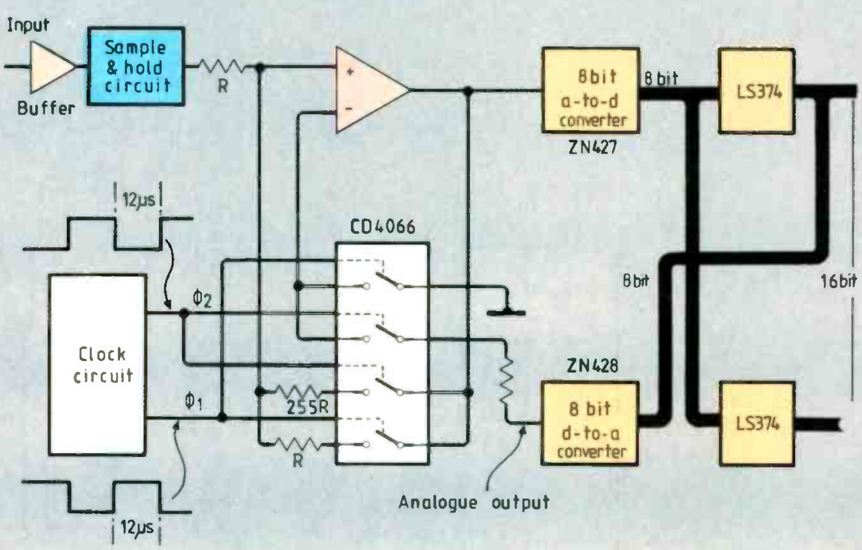
These bits feed a d-to-a converter, output of which is compared with the sampled original signal in the second clock cycle. After being amplified by 255, the difference signal is fed to the d-to-a converter to produce the eight least-significant bits.

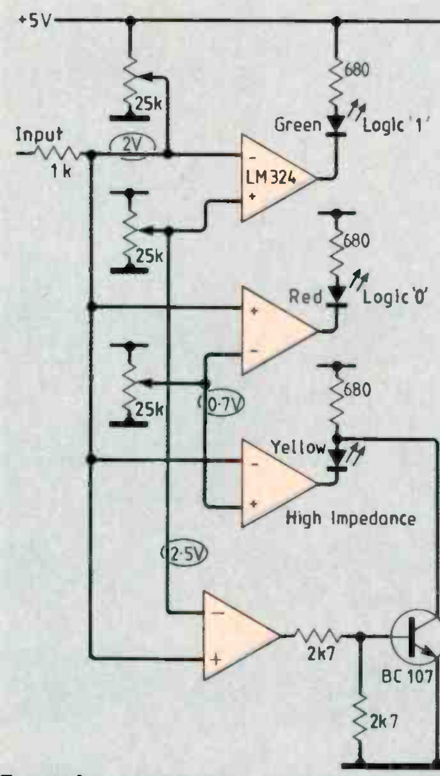
For an a-to-d converter with 10μs conversion time and a d-to-a converter with 1μs settling time, a sampling frequency of,

$$F_s = \frac{1}{(12+12)\mu s} \approx 40kHz$$

is fast enough for audio purposes.

For the programmable amplifier, input buffer and sampler, I suggest an NE5534. Data conversion could be carried out by a ZN427 and ZN428.





Logic tester

Power consumption of this tester is about 10mA. Potentiometers allow the thresholds to be set to suit a variety of logic technologies.

Igor Sinovcic
Split, Yugoslavia

NEXT MONTH

Decoding satellite TV transmissions

When the film companies demanded a fool-proof system of programme encryption from Rupert Murdoch's Sky Channel with a £25 million forfeit as the price for breaking the code, they put every self respecting hacker under starter's orders. Reach for the sky with Electronics & Wireless World.

A designer's guide to RS232

Spitting Image knew what it was doing when it wrote the RS232 song in praise of the total confusion surrounding the subject. If you don't find the subject a system designer's joke read the article and gain confidence to laugh with all the rest of them.

The enigmatic ball bearing

Would you believe that ball bearings can be made to rotate by passing a large current between the inner and outer sections of the ball race? We didn't either until Bulgarian dissident Dr Stefan Marinov demonstrated the effect. It wasn't a marginal one either. Whatever its origin, it possessed enough speed and torque to remove the skin from the editor's thumb.

Object oriented programming

Conventional programming languages provide an applications framework which accepts data into the holes within the frame. Customising the application depends on filling the holes in a specific way. OOPs integrates the supporting structure into the data to form a series of communicating objects which combine to form the application.

Decoding RDS

Following his examination of the RDS signal in last month's article, the author goes on to describe a practical implementation of the non-executive functions

SIMON J. PARNALL

Autotuning is obviously the single most important benefit that listeners will be able to derive from RDS. The ability to drive from A to B without having to re-tune, without even being aware that the set is re-tuning for you, is a highly significant gain for the motorist.

Aware of this fact, car radio manufacturers are actively developing the LSI necessary to pack the autotuning features into the standard DIN/ISO case. An RDS decoder interfaces with, and controls, the synthesized tuner in such a set. It may well be that the only RDS display feature incorporated in such a set is the PS (programme service) name.

In this article I should like to ignore the car radio market and describe instead the type of decoder which might well be built into a hi-fi tuner, concentrating on the display aspects of RDS. The design I shall describe could, of course, be used in the car but does not have any of the executive functions that an RDS car receiver would have. Its only interface with a receiver, unless power is derived from the latter, need be a feed of stereo multiplex, derived after the IF stage and before the stereo decoder.

DISPLAY FEATURES

In deciding upon the RDS features to support in this design it was necessary to eliminate any feature that required the unit to interface with the tuning control system of the set, simply because a generalized design could not be produced which would interface with a wide range of commercial receivers.

Instead, features which may be displayed have been selected, the only possible exception being the provision of uncommitted open-drain outputs for the TP and TA flags. These could be used for executive control (e.g. raising the volume, stopping a cassette) but are intended to be used for external lamps or leds.

The RDS features supported are as follows:

PS	programme service name
PTY	programme type
RT	radiotext
CT	clock time (date not supported)
TP	travel programme
TA	travel announcement

Having decided on the above features, the choice of a suitable display had to be made. A dot matrix LCD module offering lower-case letters was selected. Lower case letters are particularly important when displaying the PS names of BBC local radio stations because the names are often condensed by omitting vowels, and legibility decreases dramatically if upper-case letters are used to display the result.

The EBU has defined the meanings of the PTY (programme type) codes. These may be expressed in as few as eight characters, but 16 characters provide room to express the codes without any unfortunate abbreviations, "Serious Classics" for example. However, radiotext requires up to 64 characters. A display offering this amount of space would be large and costly, therefore I decided to use a smaller display and introduce a scrolling action, bringing the radiotext message, character by character, through the available window at a readable rate.

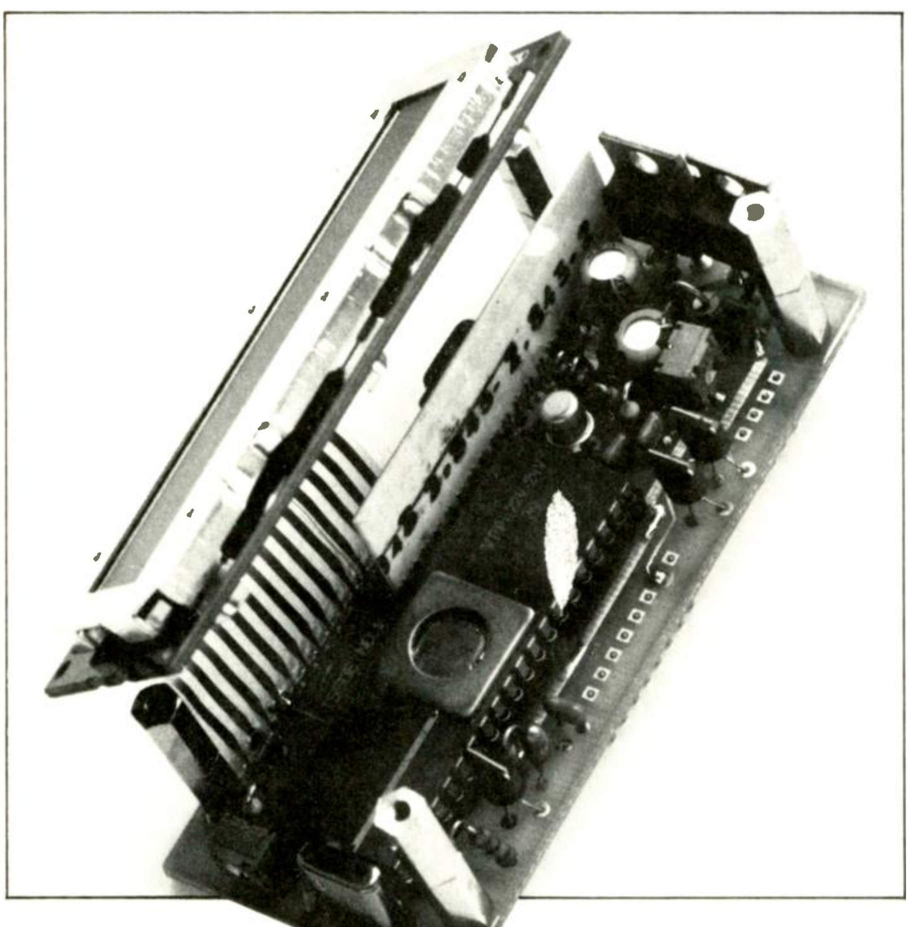
Three basic display modes were chosen, all fitting on to a 16-character display module: Mode 0 (PS and time); Mode 1 (programme type); and Mode 2 (scrolling radiotext).

Radiotext messages are formatted by the BBC as two lines of 32 characters, 64 in total. Text is often centred on these two lines by the introduction of leading and trailing spaces. It was important that the text should look sensible on the scrolling 16 character display; therefore it was decided that the unit should condense multiple spaces, reducing such intervals to one to aid intelligibility.

Clock time information, although transmitted every minute (only by the BBC at present in the UK), may not be accurately decoded every time. The decoder must therefore maintain its own internal clock and lock this to CT information when decoded.

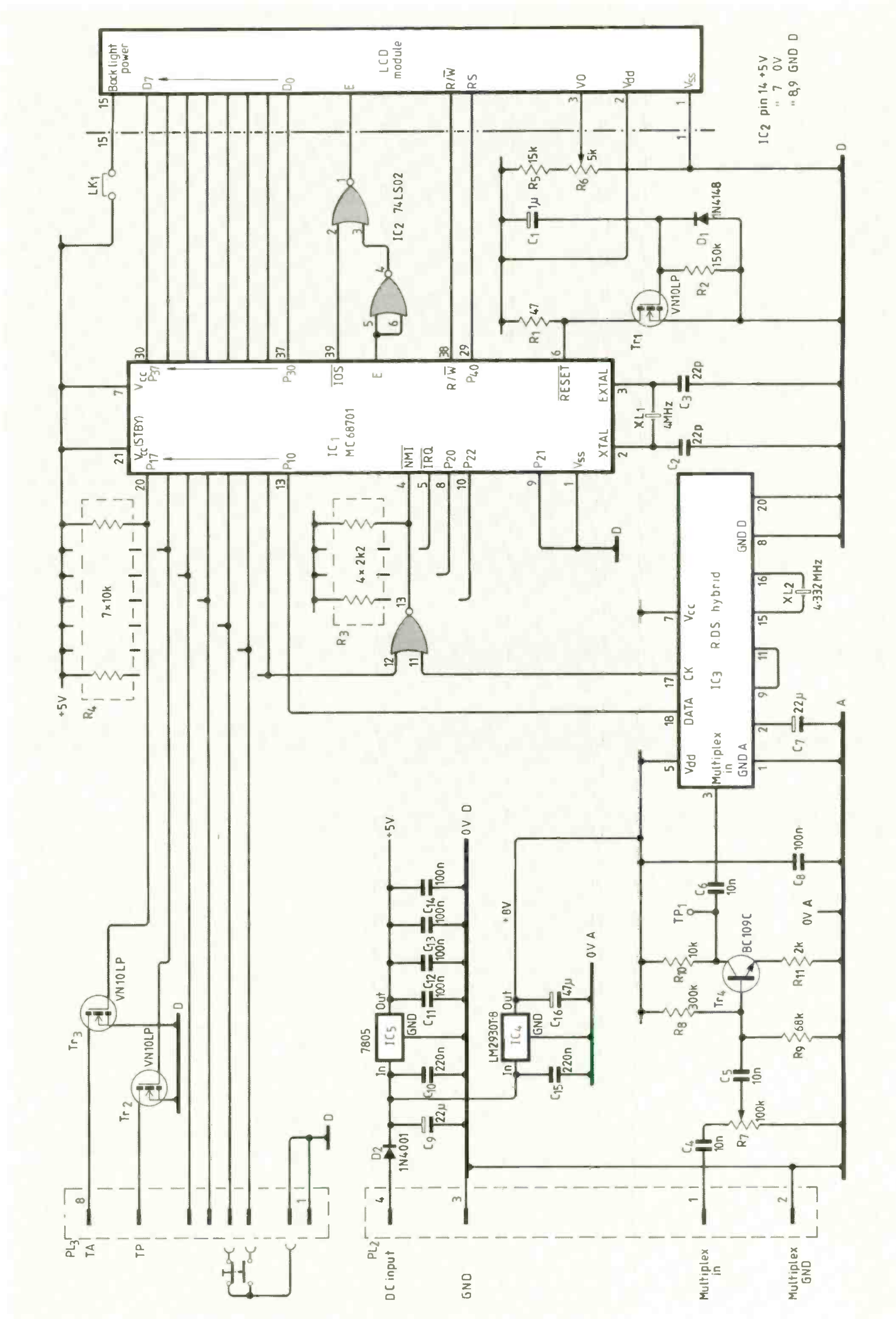
RDS DEVICES

Hybrid devices incorporating the 57kHz bandpass filter, synchronous demodulator, bi-phase symbol decoder and differential decoder are now available to OEM's. One such device, made by Blaupunkt GmbH of West Germany, is used in this design. It



Recovery of the raw data is dealt with by a hybrid module (left); implementing an RDS receiver is largely a matter of software. In a commercial receiver, the same micro-computer could control the synthesizer.

Fig.7 (right). Circuit diagram of the complete unit. Suitable LCDs are Sharp LM16155 and Hitachi LM020L or LM087LN; this last includes a LED back light. Specialized components and completed modules are available – for details, see text footnotes.



LCD module
Back light power
LK1
IC2 74LS02
IC1 MC68701
IC3 RDS hybrid
XL1 4MHz
XL2 4·332MHz
7×10k
4×2k2
VN10LP
BC109C
1N4148
1N4001
7805
LM2930T8
IC2 pin 14 +5V
" 7 0V
" 8,9 GND D
+5V
+8V
0V D
0V A
PL3
TA
TP
PL2
DC input
GND
Multiplex in
Multiplex GND

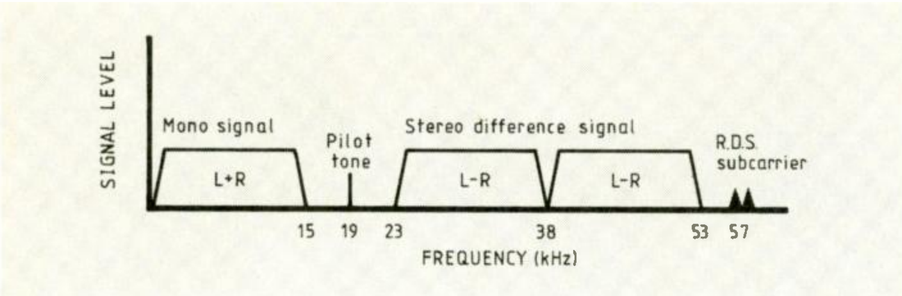


Fig.8. Spectrum of the multiplex signal.

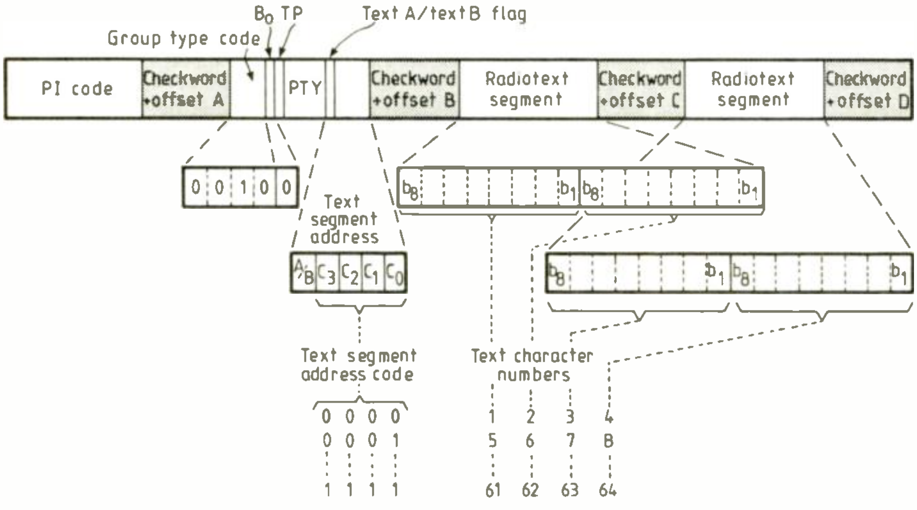


Fig.9. Decoding RDS groups: this one is type 2A.

requires only a few external components, including a 4.332MHz crystal for the phase-locked loop – this frequency being 76 times that of the RDS subcarrier.

Using the hybrid bit-decoder it was possible to consider building a decoder processing board the same size as that of the display module itself (90×36mm). To achieve this aim it would be necessary to build the group decoding and display control functions into a fairly small area. The decision was made to use a single-chip microcomputer with on-chip ram and rom. The 68701 from Motorola offered a simple display interface, an on-chip timer, 128 bytes of ram and 2Kbytes of rom. It is a version of the mask-programmable 6801. Several speeds are available but the cheapest, the 1MHz device, may only be clocked at up to 4MHz. A faster device would enable the hybrid's crystal to be shared but the relative costs negate this advantage. Thus the slowest device is used, with a separate crystal.

The most important question of all was: would the 68701 be capable of performing the decoding matrix calculation and syndrome evaluation in less than one bit period (842μs)? This is an essential requirement if the unit is to synchronize to an RDS signal as rapidly as possible. After much work the maximum bit service time was reduced to 820μs. This may seem to leave very little time for the processor's other activities. Indeed during synchronization this is so, but in normal operation the syndrome calculation need only be made once every block, 26 bits. The only activity at other bit periods is to transfer the received bit into a buffer; this takes 60μs, including all interrupt service latency. Thus in overall terms only 11% of processor time is spent at the bit-service level, leaving 89% for group processing and display control.

HARDWARE

The circuit diagram of the unit is shown in **Fig.7**. It centres on three main components: the MC68701 single-chip microcomputer, the liquid-crystal display module and the RDS decoder (IC_3). Two power-supply voltages are used, 8V for analogue circuitry and 5V for digital devices. The two rails are derived from a common supply and separately regulated by $IC_{4,5}$. The use of a low drop-out regulator for the 8V rail enables the unit to operate from a supply of as little as 8.6V. If D_2, the supply reversal protection diode, is included this figure will rise to 9.2V. Maximum supply voltage is determined by the specification and dissipation of the two regulators.

The microcomputer operates in Mode 5. In this mode the device supports on-chip ram and rom, but decodes 256 bytes of address space off-chip. This is known as the expanded non-multiplexed mode. Mode selection is made by setting the voltages present on P20, P21 and P22 upon reset. In this application these are permanently fixed, since Port 2 is unused. Port 4 echoes the lower eight bits of the internal address lines, and IOS marks accesses to the 256 byte external space. Since we require only two byte of external space for the control status and data registers of the display modules, only P40, the least significant bit of Port 4, is used. Port 3 extends the internal data bus off-chip.

The microcomputer is reset by Tr_1 and its associated timing components. The reset pin of the processor is used to supply power to the on-chip eprom during operation. To ensure that the supply voltage of this pin is within tolerances, R_1, the supply resistor, must be of a low value. The 47Ω resistor specified meets this condition.

DISPLAY

At least three physically and electrically equivalent LCD modules may be used in this particular unit. One of the Hitachi devices specified has the added benefit of a led backlight facility. If this device is used the backlight power may be disconnected (to reduce power consumption) by removing Lk_1. Viewing angle is optimized as usual by R_6.

INTERRUPTS

Two external interrupt mechanisms are provided on the MC68701: a maskable, level sensitive interrupt (IRQ) and a non-maskable, edge-triggered interrupt (NMI). The RDS hybrid bit-decoder produces a 50% duty cycle bit-rate clock with a rising edge at the centre of each bit cell. Use of the IRQ pin would have necessitated an external flip-flop circuit to prevent multiple triggers at each clock period. The NMI pin required only one inverter, and the availability of a spare NOR gate from the display interface permitted the incorporation of a switching facility, controlled from Port 1. This is used to enable/disable NMI triggers.

Individual bits of Port 1 may be assigned as either inputs or outputs. Bit 0 is the RDS bit-stream input. Bit 1 is an output, used to disable NMI triggers. Bits 2 and 3 are used, as inputs, to set the display mode. A single-pole changeover push-button is connected to these lines as shown in the circuit diagram. Bit 4, an input, selects an automatic display feature when grounded, and Bit 5, also assigned as an input, is currently unused. Bits 6 and 7, outputs, drive Tr_2 and Tr_3 to indicate TP (traffic programme) and TA (traffic announcement) respectively.

SIGNAL INPUT

The unit requires a feed of stereo multiplex. This is the signal presented to the stereo decoder within a receiver. It contains baseband audio, pilot-tone, stereo-subcarrier, and now RDS.

Some receivers incorporate a low-pass filter to remove signal components above 53kHz. Ideally the signal should be extracted before the filter.

Any DC component in the input signal is removed by C_4 before this is presented to the load, R_7. Transistor Tr_4 gives a gain of about 14dB. Potentiometer R_7 should be adjusted to obtain an overall multiplex envelope of 1V pk-pk at the collector of this transistor, measured at TP_1. This corresponds to the peak deviation of ±75kHz specified for FM broadcasting in Europe.

Modulation	Deviation (kHz)	Voltage (pk-pk)
Maximum	75	1.0V
Pilot-tone	6.075	81mV
RDS	2.0 (no mod.)	27mV
RDS (Radio 3)	1.2 (no mod.)	16mV
RDS (min.)	1.0 (no mod.)	13mV

This adjustment is most easily made by setting pilot tone level to 81mV, as shown in the above table. Pilot tone is of constant amplitude, and easily recognised on an oscilloscope. I recommend Radio 3 as a source for making this adjustment. The wide dynamic range in classical music offers periods of near-silence when pilot tone dominates the audio signal.

When the input level is correctly set the bit-decoder should have no difficulty with RDS signals at the minimum level specified by the EBU (an injection of 1.0kHz).

SOFTWARE

The software is divided into three parts, each operating at a distinct 'priority'. These priorities are, respectively, **interrupt**, **fork** and **loop**.

The interrupt handler is invoked by each falling clock edge. As mentioned previously the length of time taken for the consequent servicing may be as little as 60μs, or as much as 820μs. Variations in interrupt service time are a function of the degree of completion of the accumulated block and group. Maximal time is taken when the received bit results in completion of a block *and* completion of a group. This happens when successive blocks yield syndromes A, B, C/C', and D. The interrupt handler signals this event by setting a flag, indicating that the group buffer contains the four consecutive group data words. This is known as the fork flag.

The loop code checks the state of the fork flag whenever it waits for completion of display activity or for the timer. If set, the fork flag indicates that the processor should service a received group. This is performed by the fork code and must be accomplished within 22ms (one block period), as at the end of this period a new Block 1 would be expected to overwrite that held within the buffer.

The fork service code inspects Block 2 of the group to determine which group type is presented. Our decoder responds to a subset of the possible group types, using those which carry the major features supported. Other groups are ignored. Types 0A and 0B have already been described and shown (**Fig.4,5**). The other supported types are shown in **Fig. 9, 10, 11**.

A software handler for each of the supported group types uses the group data buffer to update the internal database for the PS, PTY, TP, TA, RT and CT features. Additionally, when received, the TP and TA bits are written directly to the relevant physical lines (Port 1), ensuring that these lines reflect a change in state as quickly as possible.

The loop code, as its name suggests, repeats continually until it is interrupted, or voluntarily passes control to the fork code. As such it may be described as a background task. The loop operates on a 0.05s cycle, waiting for the internal timer to indicate the elapse of this period before repeating. A count of 0.05s cycles is maintained in the variable TICKCOUNT. Twenty "ticks" constitute one second. When TICKCOUNT reaches 21, the count is reset to zero and the hours, minutes and second variables maintained in memory are accordingly increased. Thus the unit is

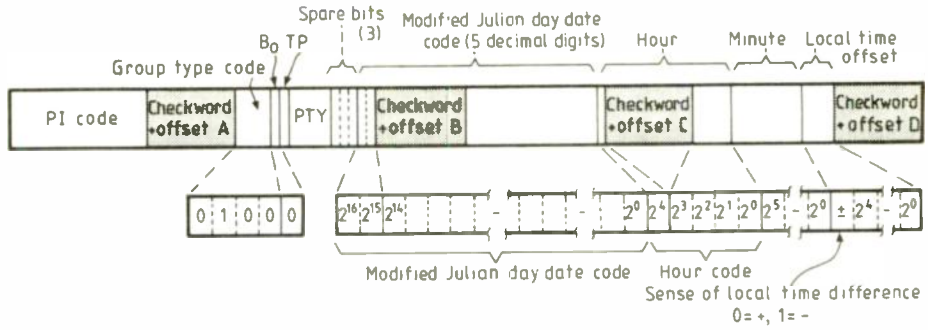


Fig.10. Type 4A group.

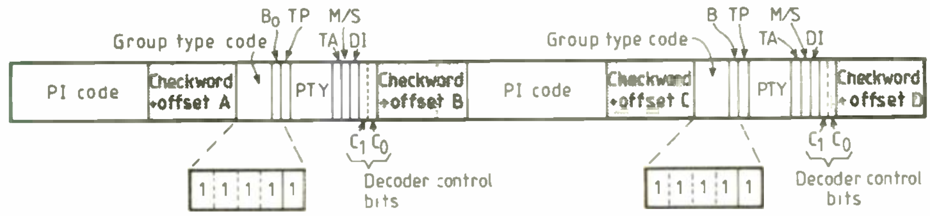


Fig.11. Type 15B group.

not reliant upon the minute-by-minute reception of type 4A groups for accurate timekeeping, but has its own "flywheel", maintaining an accuracy of about ±10s per day. When successfully decoded, a type 4A group updates the time variables *and* resets TICKCOUNT to zero, synchronizing internal timekeeping and preventing double increments.

DISPLAY MODE

At the start of each loop cycle the display mode control button is sampled, de-bounced (using a parity test) and compared with the last value read. A positive edge calls for the display mode to be incremented.

The display mode is held in memory as two nibbles:

D.MODE | DECAY

D.MODE is the actual display mode (i.e. 0, 1 or 2). DECAY represents the number of 0.1s intervals left in this display mode, and is set to 15 every time the display mode is increased. If D.MODE were 1 and DECAY were 6 (0.6s remaining in Mode 1), then after a button press D.MODE would become 2 and DECAY 15 (1.5s remaining in Mode 2). On subsequent cycles at 0.1s intervals when TICKCOUNT is even, the DECAY value is decremented. When this reaches zero D.MODE itself is reset to zero. This facility holds each higher display mode for 1.5s before returning to the basic mode. If the button is pressed again during this period the next display mode is engaged and so on. This mechanism could support as many as 16 modes, but at present only three are used.

The display cycle rate is halved when Mode 2 (radiotext display) is selected, resulting in a 5Hz character rate – about right for scrolled text. As mentioned earlier, multiple spaces are condensed to one for intelligibility, rendering the complete time to display a message as a variable. As each character is written DECAY is held at 15, holding the timeout period (now double because of the reduced rate) until the last character is written.

If the automatic display option is selected, by holding P14 to ground, the display mode is automatically incremented at 20s past each minute, or whenever DECAY reaches 1. Normally the display will show PS and time: at 20s past the minute's edge PTY will be shown, and 1.4s later the radiotext message will scroll across the display. Three seconds after completion the display will return to PS and time.

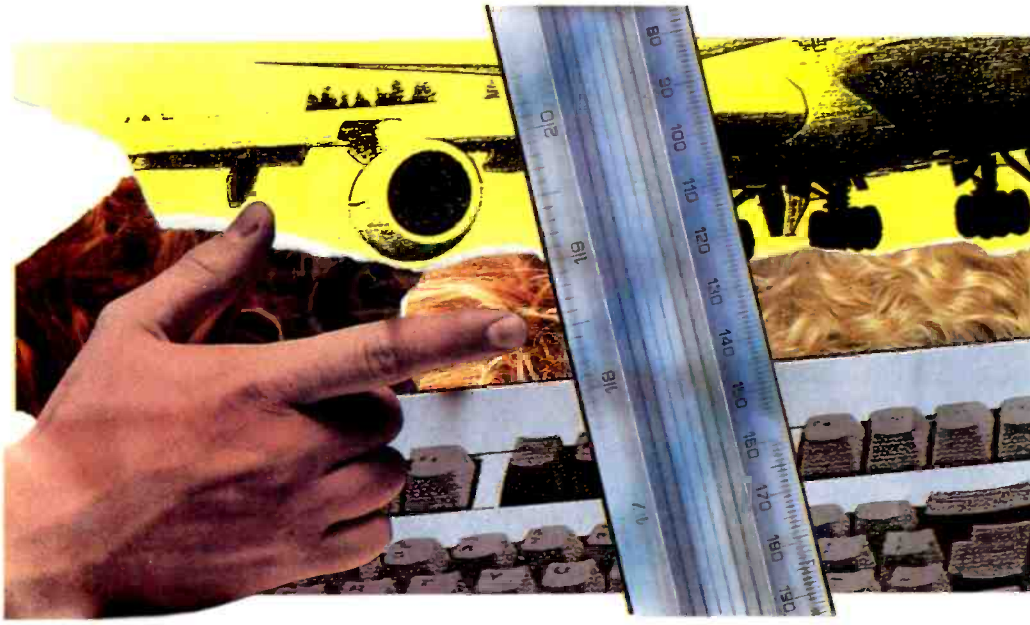
SYNCHRONIZATION CONTROL

One important aspect of the operation of this device is the use of a confidence count to monitor block synchronization. The unit does not make use of the bit-slip detection and correction system described earlier because of the complexity and increase in memory requirements. Instead, a confidence count monitors the number of valid and invalid syndromes detected. The first valid syndrome detected sets the count to 42; subsequent valid results increment this number by 4, to a maximum of 60. An invalid syndrome decrements the count by 1. Resynchronization (i.e. a bit-by-bit syndrome check) is performed when the figure drops below 41. When the figure drops below 10, the input signal is assumed to have disappeared, and the RDS programme-related features stored in memory are re-initialized to their default state.

The author would like to thank the BBC's Director of Engineering for his permission to publish this article.

Specialized components and completed modules are available for the decoder design. For details, send a stamped, addressed envelope (or two IRCs) to the *E&WW* editorial office, marking your covering envelope "RDS". A copy of the author's object code for the 68701 is available from the same source, as a Motorola S-format hex listing.

Simon Parnall is a senior design engineer with the BBC, which he joined after graduating from Imperial College, London, in 1980. He has been involved with RDS since 1986, mainly in designing the BBC's implementation of the system, and has written much of the software for the central RDS computer at Broadcasting House.



HARD DISK DEVELOPMENTS

MANEK DUBASH

A storage sub-system traditionally meant Winchesters. Magnetically-coated hard disks are still the first choice of the vast majority of systems builders although other technologies are catching up. In particular, optical technology could become the developer's preference of the 1990s. Naturally, hard disk manufacturers disagree but there is a considerable body of disinterested opinion which concurs.

A look at the development of hard disk sub-systems over the lifetime of the PC standard suggests there is still plenty of life left in magnetic storage. When IBM's PC/XT erupted onto the computing scene five or six years ago, its full height, 10Mb Winchester had an access time of around 80ms. Phenomenal though it seemed at the time, probably few imagined how quickly that 10Mb could be gobbled up and how slow such a device would seem when servicing today's enormous applications. At the high end of today's market, you subsequently find hard disks with capacities of up to 330Mb, and average track-to-track access times of well under 20ms.

Although access time is a common rule of thumb method for assessing hard disk performance, it is not the only one nor is it necessarily the most meaningful. It only describes how quickly the read/write heads move on average from one track to the next. The data transfer rate is often more helpful when evaluating disk sub-system performance as a whole, as it takes into account the design of the controller and the drive's electronics.

Controllers convert the operating system's instructions into specific head movements and have a strong influence on end users' perception of computer performance. For example, many of today's high-performance controllers include large quantities of cache memory that boosts the disk's performance out of recognition. One 80386-based PC controller has an integral hardware cache of 3MB that, when tested, returns track-to-track access times of half a millisecond and data transfer rates of tens of megabytes per second. The consequence for the user is almost instant response – as long as the data required is already in the cache.

Controllers also determine the number of sectors per track that can be supported, and the type of drive. Here too developments have overtaken expections with the PC industry spawning a wider range of formats and of drive types than was at first envisaged. This development has had serious repercussions for the type of interface employed to integrate computer and hard disk systems.

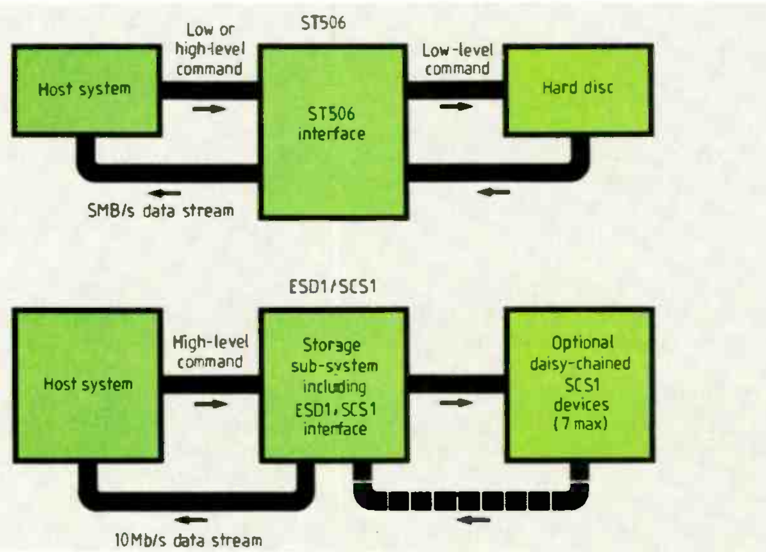
THE INTERFACE

Between the computer and hard disk sub-system of most PCs can be found the ST506 interface, which Seagate derived in 1980 from its floppy disk controller. In a modified form, it became the IEEE 412 specification and was used first in the PC/XT. The technology in the ST506 reflects the state of hard disk technology at the time. For instance, manufacturing accuracy of contemporary hard disks was relatively low. Flying heights of hard disk read/write heads were over 12 microns, motor speed variations were high at between one and four percent, and stepper motors – used to position the heads above the tracks – were relatively inaccurate.

The ST506 was designed with the relatively low data densities that flow from such technological constraints.

The drawbacks are not confined to relatively poor performance. The original designs didn't include checking and error correction, which meant that error rates had to be kept to an absolute minimum.

More prevalent these days is the Enhanced Small Device Interface (ESDI) which is becoming a stamp of respectability for PCs at the mid to high end of the power spectrum. It was created by a consortium of 22 manufacturers out of a desire for better hard disk performance. It followed improvements in the manufacturing tolerances of the drives themselves. Particular improvements include tighter motor speed tolerances – commonly around one percent; flying heights of 10 microns or less; and more coercive media – now 600-700 oersted as against 300-350 oersted in 1980. ESDI also supports formats of up to 34 sectors per track and a maximum formatted capacity of 340Mb. The upshot is



The ESDI standard puts a degree of intelligence into the disk interface. This leaves the system host CPU free to get on with other jobs

that the interface can offer double the data throughput of ST506, up to its maximum of 10Mbit/s.

And finally, due to the proximity of the data recovery circuitry to the read/write head, mounted within the drive itself, ESDI is less prone to externally-generated errors, while at the same time being more fault-tolerant due to more sophisticated error correction.

ESDI, like other computing standards, has been implemented by various manufacturers in ways that suit them. Western Digital's ESDI copies the drive tables off the disk into shadow ram, where they can be altered to cater for new types of drive as they emerge. WD also builds drive tables into its controllers' rom bios and adds value by including utilities such as a formatting program.

Part of ESDI's higher performance stems from its ability to delegate. Unlike the ST506, it possesses some independence from the main system. This permits a limited degree of multi-tasking, so that the host can carry on processing while the controller is accessing the disk. Another advantage stems from its so-called common command set, one it shares with the more powerful standard SCSI (Small Computer System Interface). With a single command, the host computer can initiate formatting, leaving the controller to deal with the technicalities – the number of sectors, tracks and so on. The host can be oblivious to the drive's physical nature.

Miniscribe, a leading hard disk maker, anticipates that the standard interface for the more powerful PCs of the future will be SCSI, which can also handle data transfer rates of up to 10Mbit/s. Like ESDI, it is media independent but it also allows up to seven devices to be daisychained off the back of any single SCSI control device. Huge amounts of data then become accessible to a single PC through the SCSI conduit.

SCSI's flexibility results from its data transfer method. It talks not in terms of heads and cylinders but in blocks of data. These could originate from any storage device, whether optical, tape or even those as yet unthought of. It delivers its best performance when mounted with blocks of data. Miniscribe predicts that SCSI will eventually supplant the ST506 altogether.

On top of improvements in controller technology, refinements in media technology – the magnetic film itself – mean that more data can now be packed into a smaller area of the disk. One consequence is the widespread adoption of Run Length Limited (RLL) encoding, patented, and introduced in 1986, by IBM. Standard controllers use a data storage method known as Modified Frequency Modulation (MFM). But by packing 50 percent more data per unit area RLL controllers can turn a 20Mbyte drive into a 30Mbyte drive. RLL is more prevalent on 200Mbyte drives and upward but is infiltrating the lower, commodity end of the market as costs fall.

In recent months controller manufacturer, Perstor, has launched a further enhancement called Advanced RLL (ARLL). Perstor's claims for ARLL include an expansion of hard disk capacity by at least 80 percent.

A BETTER FILM

There is a trade-off against greater capacity; simply swapping a standard controller for an RLL equivalent is likely to produce unpredictable results. While a modern, high-quality platter can provide a reliable basis for a high-density storage device with a high data throughput, not every disk is capable of storing data reliably at such densities. RLL controllers require a high coercivity of 600-700 oersted, motor tolerances of less than one percent and a highly accurate head positioning mechanism. Not all drives are capable of meeting such standards. One RLL user I know found this out the hard way.

The quality of the hard disk platter is crucial. Modern manufacturing methods mean fewer and smaller surface imperfections. With a flatter platter, read/write heads can fly closer to its surface, with distances between the two components of between eight and 12 microns being typical.

Tolerances of this magnitude have been compared to flying a Boeing 747 at one inch above the ground; a human hair is four times as thick.

Rotating at 3600 rev/min, the platter's ferric oxide coating is being driven to ever higher packing densities. The lower the altitude at which the read/write head flies, the more tightly defined the domain from which data is read. That enables manufacturers to reduce the distance between each data fragment as well as between each track.

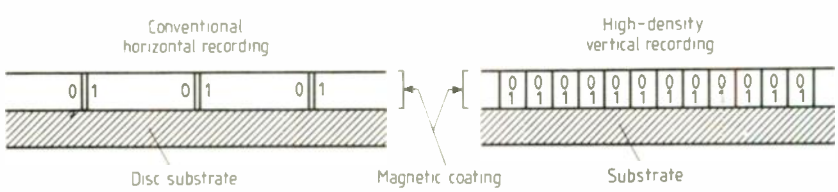
Higher densities can be attained through thinner but more coercive coatings. Ferric oxide coatings as thin as 30 millionths of an inch have served up to now but the material is reaching the limits of its performance. The response has been to abandon iron and coat the disk with a film of magnetic cobalt 1.5 millionths of an inch thick. The aluminium blanks are plated with nickel, polished and then either sputtered or plated with cobalt. Protection is provided by a finishing layer of carbon.

Being thinner, the magnetic field is more concentrated, making it better suited to low-flying, narrow-gapped heads. Not only is cobalt harder and more wear-resistant than ferric oxide but it has a higher coercivity, enabling it to carry a stronger magnetic field. As an added bonus, thin film cobalt reduces the number of defects caused by to air bubbles and impurities, leading to fewer bad sectors and adding further to capacity.

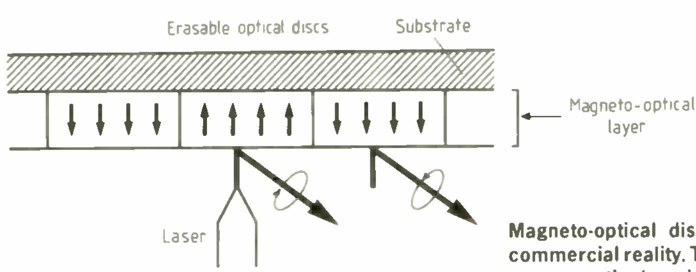
Read/write heads have changed to meet the demands. Conventional heads are built up of ferrite wound with a coil of wire. To reduce their size, instead of physically winding wire round the head, the spiral winding is laid down in a series of etched depositions – thin film – on a block of titanium carbide.

Thin film heads are less susceptible to external electro-magnetic noise but are twice as expensive to make. Despite their improved performance, such heads are found mainly in high capacity drives, typically of 100Mbytes or more. The major thin film head manufacturer is IBM.

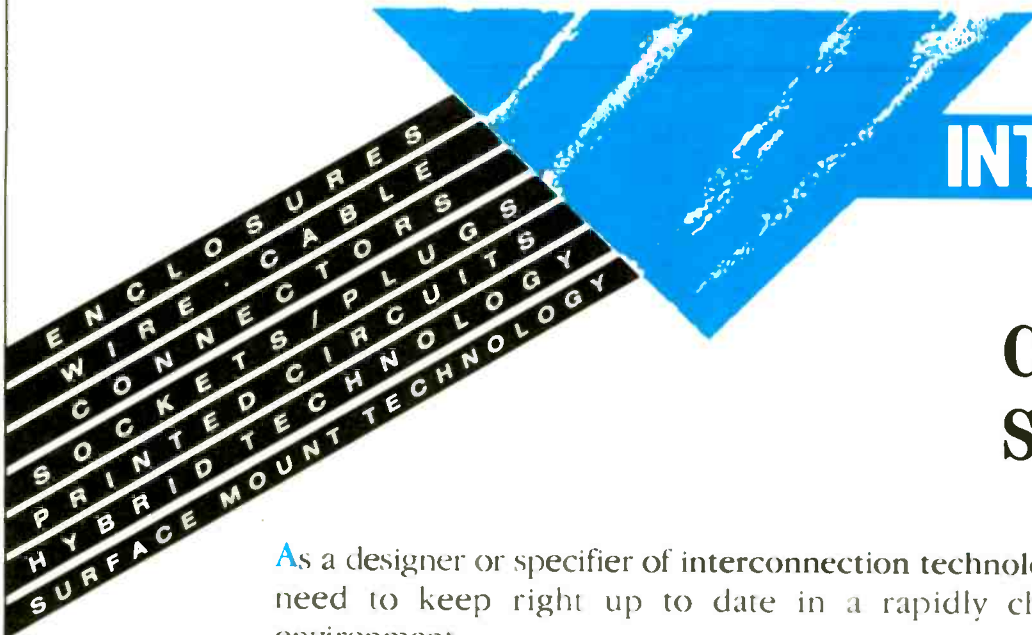
But the next five years could see 170Mbyte or larger drives in ordinary personal computers as more applications involve networking.



Vertical recording places the domains in the vertical direction increasing data packing density substantially. This technology promises to extend the usefulness of conventional magnetic media



Magneto-optical disks are not yet a commercial reality. The laser heat written magnetic domains in the magnetic layer produce a polarisation twist in the optical layer of just a few degrees.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16" Decca, 80 series budget range, colour monitors, features include PIL tube, attractive teak style case, **guaranteed 80 column resolution**, only seen on monitors costing 3 times our price, ready to connect to a host of computer or video outputs. Manufacturers fully tested surplus, sold in little or hardly used condition with 90 day full RTB guarantee. 1000's Sold to date.
DECCA 80 RGB - TTL + SYNC input for BBC type interface etc.
DECCA 80 COMP 75 Ω composite video input with integral audio amp & speaker ideal for use with video recorder or TELEBOX ST or any other audio visual use.
Only £99.00 (E)

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BRAND NEW **CENTRONIC** 14" monitors in attractive style moulded case featuring hi res Mitsubishi 0.42 dot pitch tube with 669 x 507 pixels, 28Mhz bandwidth. Full 90 day guarantee.
Order as 1004-N2 for TTL + sync RGB for BBC etc £159.00 (E)
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Superbly made, UK manufacture, PIL tube, all solid state colour monitors, complete with composite video and sound inputs, attractive teak style case. Ideal for a host of applications including Schools, Shops, Disco's, Clubs etc. Supplied in EXCELLENT little used condition with 90 day guarantee.
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MOTOROLA M1000-100 5" CRT black & white compact chassis monitor measuring only cm 11.6h, 12w, 22d, ideal for CCTV or computer applications. Accepts standard Composite video or individual H & V syncs. Operates from 12v DC at apprx 0.8a. Some units may have minor screen marks, but still in very usable condition. Fully tested with 30 day guarantee & full data. Only £29.00 (C)
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KGM 324 9" Green Screen. Little used fully cased, mains powered high res monitors with standard composite video input. Fully tested and in excellent condition. £49.00 (E)
20" Black & White monitors by AZTEK, COTRON & NATIONAL All solid state, fully cased monitors, ideal for all types of AV or CCTV applications. Units have standard composite video inputs with integral audio amp and speaker. Sold in good, used condition- fully tested with 90 day guarantee. Only £85.00 (F)

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EQUINOX (IMS) S100 system capable of running either **TURBO** or standard **CPM**. Unit features heavy duty box containing a powerful **PSU, 12 slot S100 backplane, & dual 8" double sided disk drives.** Two individual **Z80** cpu boards with **192k of RAM** allow the use of multi user software with upto **4 RS232 serial interfaces**. Many other features include battery backed real time clock, all IC's socketed etc. Units in good condition and tested prior despatch, no documentation at present, hence price of only £245.00 (F)
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Ultra Fast 240 cps NEWBURY DATA NDR 8840 High Speed Printers Only £449 !!

A special purchase from a now defunct Goverment Dept enables us to offer you this amazing British Made, quality printer at clearance prices. **SAVING YOU OVER £1500 !!** The **NDR8840 features high speed 240 cps** print speed with integral, fully adjustable paper tractor, giving exceptional fast paper handling for multi part forms etc. The unit features **10** selectable type fonts giving **up to 226 printable characters on a single line.** Many other features include internal electronic vertical and horizontal tabs, Self test, 9 needle head, Up to 15.5" paper, 15 million character ribbon cartridge life and standard **RS232 serial interface**. Sold in **SUPERB** tested condition with 90 day guarantee. Only £449.00 (F)
EPSON model 512 40 column 3.5" wide paper roll feed, high speed matrix (3 lines per second) printer mechanism for incorporation in point of sale terminals, ticket printers, data loggers etc. Unit features bi directional printhead and integral roll paper feed mech with tear bar. Requires DC volts and simple parallel external drive logic. Complete with data. RFE and tested. Only £49.95 (C)
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PHILIPS P2000 Heavy duty **25 cps** bi directional daisy wheel printer. Fully **DIABLO, QUME, WORDSTAR** compatible. Many features include full width platten - up to 15" paper, host of available daisy wheels, single sheet paper handling, superb quality print. Supplied complete with user manual & 90 day guarantee plus **FREE** dust cover & daisy wheel. **BRAND NEW Only £225.00 (E)**

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DATEL 4800 / RACAL MPS 4800 EX BT modem for 4800 baud sync use. £295.00 (E)
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TRANSDATA 307A 300 baud acoustic coupler with RS232 I/O Brand New £49.00 (E)
RS232 DATA CABLES 16 ft long 25w D plug to 25 way D socket. Brand New Only £9.95 (A)
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PLESSEY PL12/2 Fully enclosed 12v DC 2 amp PSU. Regulated and protected. Dim cm 13.5 x 11 x 11 New £16.95 (B)
AC-DC Linear PSU outputs of +5v 5.5a, -5v 0.6a, +24v 5a. Fully regulated and short proof. Dim cm 28 x 12.5 x 7 New £49.50 (C)
POWER ONE PHC 24v DC 2 amps Linear PSU fully regulated New £19.95 (B)
BOSHERT 13088 switch mode supply ideal disk drives or complete system. +5v 6a, +12 2.5a, -12 0.5a, -5v 0.5a. Dim cm 5.6 x 21 x 10.8 New £29.95 (B)
BOSHERT 13090 same as above spec but outputs of +5v 6a, +24v 1.5a, +12v 0.5a, -12v 0.5a New £39.95 (B)
GREENDALE 19AB0E 60 Watt switch mode outputs +5v 6a, +12v 1a, -12v 1a, +15v 1a. D. 11 x 20 x 5.5 RFE Tested £24.95 (B)
CONVER AC130-3001 High grade **VDE spec** compact 130 watt switch mode PSU. Outputs give +5v 15a, -5v 1a, +&-12v 6a. Dim 6.5 x 27 x 12.5 Current list price £190. Our price New £59.95.00 (C)
FARNELL G6/40A Compact 5v 40 amp switch mode fully enclosed New £140.00 (C)
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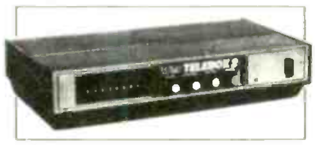
Special Offer EXPERIMENTORS PSU — ONLY £16.95 (C)

Made to the highest spec for BT this unit gives several fully protected DC outputs most suited to the **Electronics Hobbyist.** +5v 2a, +&-12v 1a, +24v 1a and +5v fully floating at 50ma. Ideal for school labs etc. Quantity discount available.
Fully tested with data RFE = Removed From Equipment

The AMAZING TELEBOX Converts your monitor into a QUALITY COLOUR TELEVISION

Brand new high quality, fully cased, 7 channel UHF PAL TV tuner system. Unit simply connects to your TV aerial socket and video monitor turning same into a fabulous colour TV. Dont worry if your monitor doesn't have sound, the TELEBOX even has an integral audio amp for driving a speaker plus an auxillary output for Headphones or Hi Fi system etc. Many other features: LED Status indicator, Smart moulded case, Mains powered, Built to BS safety specs. Many other uses for TV sound or video etc. Supplied BRAND NEW with full 1 year guarantee. Carriage code (B)



TV SOUND & VIDEO TUNER ONLY £29.95

TELEBOX ST for monitors with composite video input £29.95
TELEBOX STL as ST - but fitted with integral speaker £34.95
TELEBOX RGB for use with analogue RGB monitors £59.95
Colour when used with colour CRT. RGB version NOT suitable for IBM-CLONE type colour monitors. DATA sheet on request. PAL overseas versions CALL

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Maintenance free, sealed longlife LEAD ACID
A300 12v 3 Ah £13.95 (A)
A300 6v 3 Ah £9.95 (A)
A300 6-0-6 v 1.8 Ah RFE £5.99 (A)

NICKEL CADMIUM

Quality 12 v 4 Ah cell pack. Originally made for the **TECHNICOLOUR** video company, this unit contains 10 high quality **GE nicad, D** type cells, configured in a smart robust moulded case with DC output connector. Dim cm 19.5 x 4.5 x 12.5. Ideal portable equipment etc. **BRAND NEW £24.95 (B)**
12v 17 Ah Ultra rugged, all weather, virtually indestructable **refillable NICAD** stack by **ALCAD.** Unit features 10 x individual type **XL1.5** cells in wooden crate. Supplied to the **MOD** and made to deliver exceptionally high output currents & withstand long periods of storage in discharged state. Dim cm 61 x 14 x 22 **Cost over £250** Supplied unused & tested complete with instructions £95.00 (E)
EX EQUIPMENT NICAD cells by GE Removed from equipment and believed in good, but used condition, 'F' size 7Ah 6 for £8 (B) Also 'D' size 4Ah 4 for £5 (B)

BRAND NEW 85 Mb Disk Drives ONLY £399

End of line purchase enables this brand new unit to be offered at an all time super low price. The **NEC D2246 8" 80 Mb** disk drive features full CPU control and industry standard **SMD interface,** Ultra high speed data transfer and access times leave the good old ST506 interface standing. Supplied **BRAND NEW** with full manual Only £399.00 (E)
Dual drive, plug in **135 Mb** sub system for **IBM AT** unit in case with PSU etc. £1499.00 (F)
Interface cards for upto **4 dives** on IBM AT etc available **Brand new at £395.00**

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Please call for availability or further info.
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DEC VAX11/750 inc 2 Mb Ram DZ, and full doc etc. Brand New £8500
HP7580A 8 pen digital A1 drum plotter with IEEE interface As New £4750
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SOLDER SYSTEMS tin lead roller tinning machine for PCB manufacture £350
CALLAN DATA SYSTEMS multi user **INTEL** based **UNIX** system complete with software and 40 Mb winchester disk drive. £2750
WAYNE KERR RA200 Audio, real time frequency response analyzer £3000
TEKTRONIX 1411/R PAL TV test signal standard. £6900
TEKTRONIX R140 NTSC TV test signal standard. £875
HP 3271A Correlator system £350
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ACTIVE

A-to-D and D-to-A converters

8-bit A/D converters. Two c-mos 8-bit serial I/O A-to-D converters feature a $6\mu s$ conversion rate – including sample-and-hold acquisition – that allows digitization of a 0V to 5V sine wave at 40kHz with better than 45dB signal/noise. Micro Linear Corporation 408 433 5200

The IDT75MB38 is a high-speed, c-mos, triple 8-bit, **video D-to-A** module that can be used in place of the TDC1318 or BT109. The IDT75MB38 offers the benefits of high speed with low power, running at 125 MHz. It features an on-board voltage reference. Micrologic Limited 048 62 29551

Active hybrid circuits

BICMOS channel-less arrays. AMCC announce the channel-less "sea-of-cells" Q6000B and Q14000B BICMOS logic arrays in channel-less architecture, with 5760 and 13400 equivalent 2-input Nand gates respectively. The architecture uses macro cells rather than rows of transistors, as in the sea-of-gates. Applied Microcircuits Corporation 0256 468186

Crystal oscillator. The QC6112 quartz crystal oscillator has an operational frequency range from 200kHz to 16MHz, accurate to within 100ppm of the nominal frequency. It is c-mos compatible. Salford Electrical Instruments Limited 0706 67501

Data communications products

Optical-fibre transceiver. NEOLINK 1312 has been designed specifically for fibre-distributed data-interface (FDDI) applications. It is a transceiver which operates with an optical-fibre cable having $62.5\mu m$ core diameter and $125\mu m$ outer diameter, conforming to the physical layer of the FDDI specification. NEC Electronics (UK) Limited 0908 691133

Synch/asynch conversion. A one-chip solution to the problem of synchronous-to-asynchronous data conversion comes from Micronas. The MAS 7838 consists of two separate data channels which can be used for both async-to-synch and synch-to-asynch conversion. Data rates up to 64Kbits/s are supported. The asynchronous character lengths can be from 8 to 11 bits including start, stop and parity bits. Micro Call Ltd 084 421 5405

Discrete active devices

Depletion mode mosfets. Siliconix has introduced a family of high-voltage, depletion-mode mos transistors. They have the normally-on switching aspects of a j-fet, and the speed and performance characteristics of a mosfet. The mosfet offers the high speed of a mos device and an on-resistance as low as 0Ω. Siliconix Ltd 0635 30905

RF mos power transistors. Power mosfets for HF, VHF and UHF transmitters have output powers ranging from 2.0 to 300W. Additions in the near future will extend the range to UHF and add features such as wider bandwidth and higher gain. Philips Components 3140 757189

Linear integrated circuits

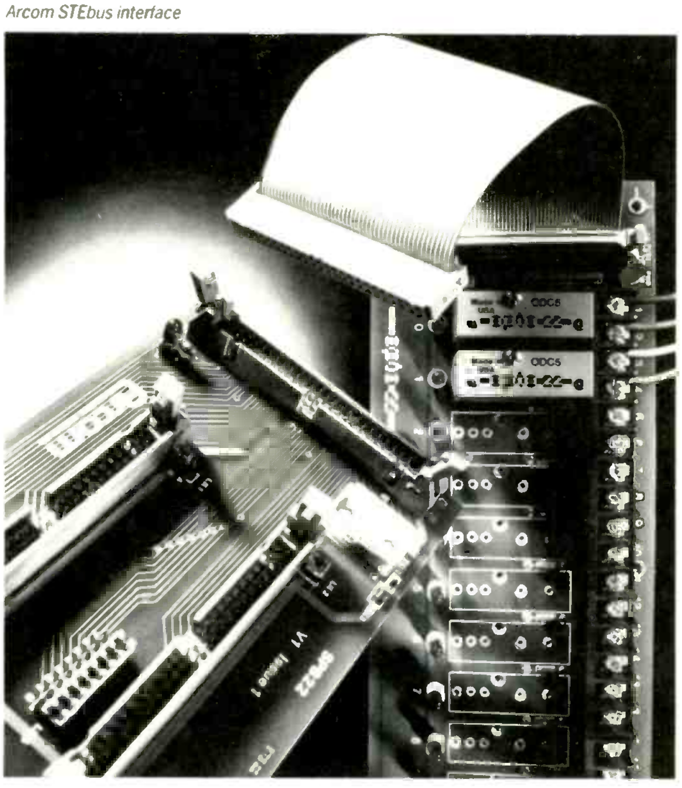
Half-bridge driver in surface-mount. Half-bridge driver integrated circuit, Type Si9950DY, contains a complementary pair of 50V, 0.3Ω on-resistance MOSPOWER transistors connected in a half-bridge configuration. Siliconix Limited. 0635 30905

Quad switched-capacitor filter. The LTC1064 is a quad clock-tunable, switched-capacitor filter that can be used to implement up to 8th order Cauer, Butterworth, Bessel, Chebyshev and other filters. The noise, speed and offset performance of the new device compares favourably with discrete fast-op-amp RC active filter realization. Linear Technology (UK) Limited 0932 765688

Single-rail op-amp. The ALD 1701 c-mos operational amplifier can operate from single-sided voltage rails ranging from 2 to 12V. Slew rate is $0.7V/\mu s$, and the useful bandwidth is 700kHz. No frequency compensation is required. Steatite Microelectronics Ltd 021 643 6333

Voltage regulator. The STA 2931 is a 5V positive-voltage regulator in TO-92 plastic package. It has a low quiescent current (typically 0.4mA at 10mA output), and maintains regulation with input-output differential typically down to 0.05V. ITT Semiconductors. 0932 336116

Arcom STEbus interface



Optical Devices

GaAs chip set. for optical-fibre transmission. A set of GaAs ICs that provides a transmit/receive interface for optical-fibre communications at data rates of 2.4 Gbits/second. The set consists of a multiplexer and a laser diode driver for the data transmission functions and five devices that provide signal conditioning and demultiplexing at the receiver end of the fibre. Micro Call Ltd 084 421 5405

Multichip led device. A multichip light-emitting-diode packing designed for use with the EAO Series 11, Series 19 and Series 99 illuminated pushbutton switches. The use of several chips on a single substrate produces a very wide angle of illumination. Highland Electronics (Distribution) Ltd 0799 26699

Pin photodetectors. UV-enhanced pin photodetectors are now available with active areas from $19.5mm^2$ up to $900mm^2$, and with a choice of packages. Absolute responsivity is typically 0.16 A/W at 250nm and 0.65 A/W at 950nm. Spectral coverage is 190-1100nm. Hero Electronics Limited 0525 405015

Programmable logic arrays

Programmable logic. The GAL6001 programmable logic device utilizes high-performance E^2CMOS to achieve a maximum clock-to-output delay time of 15 nanoseconds, a 25ns maximum setup time, and a 30ns maximum propagation delay time. The use of Lattice E^2 cell technology also provides reconfigurable logic and reprogrammable cells. Silicon Concepts Limited 0428 77617

Power semiconductors

Avalanche transistor. The ZTX415 is for use in laser-diode driving and fast, high-voltage/high-current pulse generation. Avalanche transistors are characterized by a negative resistance region in their V-I breakdown curve, which allows them to provide a guaranteed 60A 20ms capability. Plessey Semiconductors 0793 36251

Hall-effect power IC. A custom integrated circuit merges Hall-effect sensing with the control circuitry, protective functions and high-current output drivers to power a new series of brushless d.c. fan motors. Sprague Semiconductors 44 932 253 355

PASSIVE EQUIPMENT

Passive components

Filters. A new series of T-circuit filters is rated at up to 530VDC/375VAC, 400Hz within the temperature range −5°C to 125°C. Of hermetically sealed coaxial construction, the filters are specified over the frequency rage 30kHz to 1GHz and have BS9121-F0011 approval. Beck Electronics Limited 0493 856282

Flat electrolytics. The FLK series of flat aluminimum electrolytic capacitors from ECC Electronics features a maximum operating temperature of 105°C and high capacitance values – $22,000\mu F$ for 10VDC capacitors and $390\mu F$ for 250VDC types. Capacitors in the range feature ripple currents as high as 4A. ECC Electronics (UK) Ltd 0494 36113

Low-profile electrolytics. LPR capacitors are designed to provide 'snap in' insertion to PCB power supplies. The series is designed for use in applications that require a high CV from the smallest possible size. The capacitors operate over the temperature range of −40 to 85 deg C. AVX Limited 0252 333851

Miniature feed-through capacitors. The Stettner 2700 series of miniature feed-through capacitors features a voltage rating of 160V DC and capacitance values ranging from 1.5pF to 5600pF. The devices offer low series inductance values and feature series-resonant frequencies of over 200MHz. Steatite Insulation Ltd 021 643 6888

SM metallized-film capacitors. Multilayer, surface-mountable film capacitors (Surfilm Type ST) are available in capacitance values from $0.01\mu f$ to $2.2\mu f$ in ±5%, ±10% and ±20% tolerances at 50VDC. C.&C.D. Ltd 0494 882848

Connectors and cabling

Phase-adjustable sma connectors. This connector is a combination of connector and phase shifter that allows phase adjustments and trimming to be performed during and after installation. Available in two models, 5999-1 for 0.141in cable and 5999-2 for 0.085in cable, these coaxial phase shifters permit repeatedly accurate, continuous phase adjustments. March Microwave Ltd 037644277

Displays

Colour filter windows. NFI has introduced integral colour-coordinated filter windows, designed for various led, plasma and CRT alphanumeric displays. A number of windows of different colours can be included within a single membrane assembly. N.F.I. Group Ltd 0983 526535

Dual-colour led lamps. Model LL232EG uses a GaASP-on-Gap orange die and Gap-on-Gap green die to produce luminous intensities of 5.0mcd from a 20mA drive current. The led dies are matched for uniform light output and are produced in a white diffused T-1 ¾ package. Each lamp can be lit independently to produce a mixture of the two colours. Kentec Limited 0732 456188

Fluorescent displays. Azure displays are constructed using either 14 segment or 5 × 7 dot matrix characters which produce excellent readability and offer a viewing angle of 130°. Characters can be arranged ina single or multi-line format and up to 15mm in height. The Azure displays are provided in a base blue/green colour. Norbain Technology 0734 764411

Membrane with leds. A range of membrane switch panels features surface-mounted, light-emitting diodes implanted within the membrane sandwich layers. The resulting panels are much cheaper than systems using PCB-based membranes. Diamond H Controls Limited 0603 45291/9

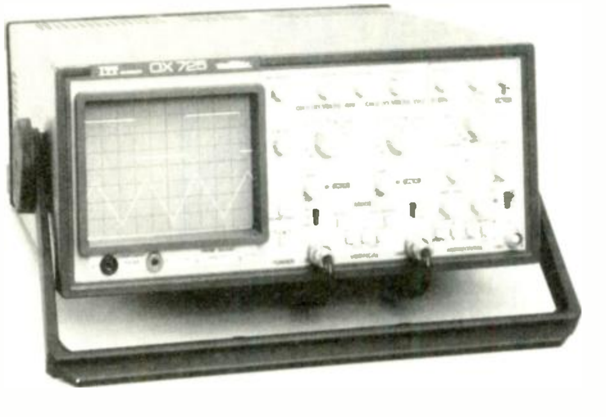
Instrumentation

2 Gsamples/s oscilloscope. The HP54114A accessory for the HP54111D digitizing oscilloscope, increases the maximum sampling rate of the oscilloscope from one to two gigasamples per second. The additional sampling speed has increased the single-shot bandwidth of the 54111D from 250MHz to 500MHz, ensuring that glitches as narrow as 500 picosecond can be captured. Bandwidth filters provide 6, 7 and 8 bit vertical resolution. Hewlett-packard Ltd 0895 72020

20MHz oscilloscopes. Two 20MHz oscilloscopes incorporate many features normally found only on instruments with bandwidths up to 50MHz at £295 for the OX722 and £335 for the OX725. Features include an X/Y mode and variable hold-off. Both instruments are also fitted with curve tracers. ITT Instruments 0753 824 131

Acoustic-intensity vector analyser. VC-4100 offers a versatile method of determination of a noise source in factory areas or auditoria. The system allows the plotting of the flow or distribution of energy in an area or from a machine. Hakuto International (UK) Ltd 0992 769090

Datacomms analyser. Model TE803 is a data communications analyser, which carries out error performance measurements from 50 bit/s to 2 Mbit/s. The instrument stores and dates faults. The



ITT 20MHz oscilloscope

TE803 embodies V24, V35, X24 V11 and 64Kbit/s G703 integrated interfaces together with V24/V28 interfaces for remote control and printer. Tekelec Communications Ltd 0734 771020

Multimeter. The Fluke 80 series multimeter measures frequency, duty cycle, capacitance and provides min-max-average recording in addition to the more common DMM functions. Next Generation Instruments Ltd 0908 260560

Instrumentation tape recorder. The SCR 8100 is an 8-channel digital instrumentation recording unit. The system incorporates up to eight signal-conditioning amplifiers which can be selected from a range of 12 plug-in modules which include a high-gain DC amplifier, a transient capture module, a thermocouple amplifier, a variable attenuator and a high-impedance adaptor. Earth Data Limited 0703 869922

Rack mounting LCR bridge. The 6458 offers 0.1% measurement accuracy of L, C, R, D and Q at three test frequencies of 100Hz, 1kHz & 10kHz. It is intended for remote operation and has full talk/liaison facilities via both IEE-488 and RS232 interfaces, all functions are also controllable from the front panel. Standard features include four-terminal measurements and 2V DC bias for electrolytic capacitors. Prism Electronics 0480 62225

Scalar/spectrum analyser system. The HP 71100XL scalar/spectrum analyser provides a broad range of transmission, reflection and distortion measurement capabilities for general purpose component, sub system and systems testing. Capabilities include a 124 dB dynamic range with fast continuous sweep and an average displayed noise of −134 dBm. As part of the HP Modular Measurement System, the HP 71100XL extends from 100Hz to 2.9 GHz - options extend this capability to 22 or 26.5 GHz, with or without preselection. Hewlett Packard Ltd 0895 72020

Printers and controllers

Electrostatic plotter. The Hewlett-Packard 7600 monochrome electrostatic plotter is capable of producing an A0-sized plot in seconds using the Integraph drawing package. It has the feature of being able to produce a solid fill area at the same speed as the rest of the plot. Protek 01 245 6844

Graphic plotter. The Plotmate XY 500 graphic plotter runs at 30cm/s and has automatic selection of 10 pens provided as standard. It has full implementation of HP-GL with features such as Bezier curve fitting and complex polygon fills. The XY-500 retains all the compatibility with BBC graphic commands. Linar Graphics Ltd 0686 29292

Production equipment

Bench top soldering. The Modusol bench top soldering machine has been designed to provide fast and efficient PCB soldering for boards up to 200 × 255mm in size. It can be used to solder only a few boards at a time or with a cycle duration of approximately 90 seconds it can process hundreds of boards in a few hours. Capa Ltd 0202 304551

Monolithic pin driver. The EL2021 is a pin-driver circuit that is designed specifically to include all the functions necessary to drive programmed voltages into difficult loads. Primarily, it has a programmable slew rate from near zero up to 250 volts per microsecond. Microelectronics Technology Ltd 084468781

Surface-mount assembly tool. Bench-top dispensing unit applies exact amounts of solder paste and adhesives for attaching surface-mounted devices. Incorporated in the unit is an adjustable vacuum pickup pencil for easy handling of components. Fluid deposit size is controlled by selecting air pressure, pulse time and dispensing tip size.

Power supplies

DC-DC PSU modules. With a footprint of only 43 × 10.5mm the DCV501, DCV1201 and DCV1501 will deliver 0.5W at 1.2W and 1.5W at 5V, 12V and 15V respectively, from a nominal supply of 5V. Maximum current for all models is 100mA. The modules are flow solderable and can operate over a temperature range from −20 to +85 C. FR Electronics 0202 897969

DC-to-DC converter. The LT1026 is a DC-DC converter for a 4 volt to 10 volt input and up to ±18 volt and 20 milliampere output. The LT1026 converts a single-input supply to a dual output of higher voltage. The device uses bipolar switched capacitor technology so no inductors are needed. Linear Technology (UK) Limited 0932 765688

DC/DC converters. Measuring only 2 × 2 × 0.375 inches, the 1500/2100 series of 15W/20W DC/DC converters has a power density of up to 13.3W/in. The converters features 2:1 input covering a wide voltage range from 9-18 VDC, to 36-72 VDC with three families of single, dual and triple output voltage configurations 15/20W. Amplicon Electronics Limited 0273 608331

Dip miniature DC/DC converters. Power Industries Series offers single or dual 5, 9, 12 and 15V outputs at 0.3-6W from 5, 12, 24 and 48V inputs. There are over 100 models of non-regulated and regulated converters including special LAN converters. Ericsson Components AB 0203 553647

OEM power supplies. The "RL 300" gives 300W in the same space as conventional 200W models. The air-cooled units also offer four outputs (with voltage adjustment on each), and a choice of 115 and 220V inputs. Coutant Electronics 0271 63781

Switches and relays

All-position mercury-wetted switch. C P Clare has launched its all-position mercury-wetted MYAD switch. The MYAD is 16mm in length and contains a symmetrical 1 form A contact with specifications of 30 W/350V/1A contact rating and a 2000VDC breakdown voltage. All these parameters are available in a range of 35 to 60 At or Ni. C P Clare International 010 12 23 33 11

COMPUTER

General microprocessors

80306SX chip set. An 80386SX compatible chip set enables manufacturers to build an 80386SX computer with a total of nine devices plus microprocessors and drams. The G-2 chip set supports the current 80386SX processing speeds at 16 megahertz with no-wait states. In addition the chip set contains a full hardware Extended Memory System (EMS) 4.0 capacity and features PAGE Mode interleaving and Shadow ram for fast memory access. G 2 Ltd 0344 426544

Enhanced controller chip. An enhanced version of the 80C52 8 bit microcontroller features an enlarged rom area and a 32 bit timer register. Designated 83C154 the controller permits clock speeds of up to 16MHz. Rom capacity is 16kbytes and the new part is pin- and functionally compatible with the existing device. Matra Harris Semiconductor Ltd 0344 485757

Multiple CPU OS-9/68000 V2.2. For low cost VME OS 9 multiprocessor systems each processor comprises a choice of 68000 or 68010 CPU, 512 Kbytes dual ported dram, two serial ports and 128 Kbytes eprom area. Bicc-Vero Electronics Ltd 0703 266300

Interfaces

Analogue interface chip. The TLC 32040 CN/FN (dual in line surface mount) and TLC 32041 CN FN analogue interface circuits feature Lincmos silicon-gate process technology. Both interface chips are complete A-to-D and D-to-A input/output systems each held on a single chip. Hi Tek Electronics 0223 213333

High noise-immunity serial interface. The SL801 is a serial communication controller offering eight RS-485 ports on a single-height Eurocard for the STEbus, for use in applications requiring reliable high speed serial data transmission over distances up to 2 km in noisy environments. The board is capable of full duplex operation at asynchronous speeds to 38 400 baud and at synchronous speeds to 1 Mbit/s. DSP Design Limited 01 482 1773

Interface for STEbus. The SPB22 interface board provides connection between the standardized digital I/O of STEbus computer systems and the range of Opto 22 digital signal conditioning racks. Digital I/O is taken direct from the STEbus computer board with a 50-way ribbon cable connection to the SPB22 interface and this converts the standardized STEbus format to the Opto 22 scheme. Arcom Control Systems Ltd 0223 411200

PC into system controller. The 70618 is an inexpensive RS232/IEEE 488 converter which enables a PC to become an IEEE 488 controller without sacrificing any PC slots. The converter is a length of cable with an enlarged 25 way D connector shroud housing the interface. Dryden Brown Limited 0703 229041

Vision imaging systems. A high-resolution imaging system for the processing of information discharged from the camera by linking Fairchild CCD technology with plug in IBM XT AT compatible interface boards and software by Sentel Messtechnik GmbH. The Sentel CCU-M interface boards can control up to four line-scan or solid-state TV cameras. Optimum Vision 0730 64016

Memory chips

256K eeprom. The Samsung 256K c-mos eeprom (KM28C256) is designed for applications up to 10,000 write cycles per byte and over 10 years of data retention. Features include 150ns maximum access time, low power, fast write cycle times and enhanced write protection. Dram Electronics Ltd 061 429 0626

C-mos eeprom family. A family of c-mos-based eeprom modules, organized as 16 × 8, 24K × 8, 32k × 8, 128k × 8, 64k × 16, 8k × 16 and 16k × 16 feature access times of 55, 70 or 90ns. These devices utilize internal error correction. Emm Dense Pac Ltd 0682 72134

Cheap flash from Amega. 48F512 and 48F010 flash eeproms made by Seeq are now available. The Flash Pack is a half card size programmer board that fits into a single expansion slot on any IBM PC/XT AT. The unit also has a ribbon cable connected to a 40 pin ZIF DIP socket and MS/DOS compatible software. Amega Electronics Limited 1256 843166

Programmable memory. Reprogrammable memory offers eprom or eeprom performance at a similar cost to sram. The PEROM requires only 5 volts and can be completely reprogrammed in only four seconds. Ambar Cascom offer a 256K PEROM, the AT29C256 in a 28 pin dual-in line package. Ambar Cascom Ltd 0296 434141

Programming hardware

Programmer up-grade. An upgraded module for the PP39 portable programmer and the PP40 series of Gang and Set programmers supports bipolar compatible eproms in 0.3in wide packages and the newer "Skinny DIP" 0.3in wide packages. Stage Electronic Designs Limited 0707 332148

Software

Asic design software. MHS has launched a design software package which offers four high level user interfaces for its own ASIC processes. The four input options are state diagrams, Boolean equations, truth tables and Micro Instructions. Matra Harris Semiconductor Ltd 0344 485757

C Language debug for Z80. XRAY, a C language orientated debug for the Z80 microprocessor, is now available for the Zilog Z80. Initially, it is hosted on IBM PC (or compatible) running MSDOS, but other hosts will be released soon. The XRAY debugger simulates a target environment for program execution and testing. Microtec Research Limited 0256 57551

LabView Version 2.0. LabVIEW is an icon based graphical programming system that simplifies engineering and scientific programming on the Apple Macintosh SE and Macintosh II personal computers. Version 2.0 now has a graphical language compiler, diagram rubberbanding, complete clipboard cut and-paste capabilities, multiple object selection and other enhancements. Amplicon Electronics Limited 0273 608331

Lotus Measure is a software package that collects data from instruments and down loads directly onto a 1-2-3 worksheet for analysis, storage and display. It automatically collects data in real time from a wide range of instruments directly into 1-2-3 worksheet cells. Amplicon Electronics Limited 0273 608331

OS-9 development on IBM PC. PCBridge is a development and supervisory system which allows the user to develop OS 9 applications on IBM PCs, XTs or ATs (or compatibles). PCBridge resides on the PC host system with a special utility package resident on the OS 9 target system. Microwave Systems (UK) Limited 0489 886699

Pascal compiler for Transputer. Hawke Components announces a Pascal compiler that can be used to build programs running on a single IMS T414 and IMS T800 Transputer or used in conjunction with the Toolset (IMS D705) to program networks of Transputers. ISM D712 runs under LOD on a Transputer add-in card for the IBM PCAT allowing programs written in Pascal to be ported to the Transputers. Hawke Components Distribution 01 979 7799

MICROWAVE DISTRIBUTION SYSTEMS

Local distribution of broadcast signals by microwave is the subject of much conjecture. Jim Slater of the IBA peers into the near future

J. N. SLATER

One example of a microwave distribution system that has been the subject of many reports in the technical press anticipates the use of a low-power microwave transmitter mounted on a lamp post at the end of the street to carry one or more channels of video to receiving dishes mounted on the roofs of the houses in that street. Although this might be possible, we shall see that this scenario is rather too simplistic to be practicable in many cases, but it does at least serve to illustrate the basic principles of MVDS systems.

The popular theory which, as we shall see later is quite wrong, says that, because microwaves only travel by line of sight, the signals will be restricted to within a short distance of the transmitter, providing a truly local service without any chance of interference to viewers in nearby communities. Thus, the same frequencies can be used in adjacent areas, giving rise to the possibility of almost unlimited numbers of local stations. Since the frequencies used are in the microwave bands of 2GHz and above, there should be no trouble in finding a few hundred megahertz to carry dozens of different television channels, and there should also be plenty of room for the wider-bandwidth, higher-definition television channels of the future.

This type of system, which would appear to provide broadcasters with everything they have ever wanted, also has great appeal to the operators of cabled distribution networks. It is well known that the most difficult and expensive part of a cabled distribution network is the so-called 'last mile'.

The costs of digging up the road and making individual connections to all the houses in a street are colossal in a country like this where we insist on cables being buried. Imagine, then, a cable system which terminates at the local MVDS lamp-post; the multiplicity of cable channels could then be transmitted by microwave from the lamp-post, to be received on small dishes provided by the cable operator.

MVDS is sometimes called 'wireless cable', and is commonly said that it will prove the saviour of the cable television industry. Although I would not like to decry that view, I think that there is far more to the subject than is usually envisaged. The same technology that allows signals originating from a cabled distribution network to be radiated from a lamp-post at the end of the street could also provide many different neighbourhood radio and television broadcast stations,offering a choice of programmes previously undreamed of except on the major cable networks of the United States.

Governments and broadcasters are constantly being bombarded with requests for more truly local broadcasting. This demand for community or neighbourhood broadcasting has so far proved difficult to satisfy even in radio broadcasting, and seems totally impossible for television where we already have over 3500 transmitters sharing just forty-four channels in the relatively tiny slice of the UHF spectrum that has been allocated for broadcasting.

As with so many new developments, this one started in the United States, and since 1974 something like 200 MDS (Multipoint Distribution Service) transmitters have been built.

MDS – MULTIPOINT DISTRIBUTION SERVICES

It is important to note that these MDS transmitters are *not* multichannel, and are effectively low-power television transmitters which operate in the microwave bands. The Federal Communications Commission has defined MDS as "A common-carrier service intended to provide one-way radio transmission (usually in an omnidirectional pattern) of subscriber supplied information from a stationary transmitter to multiple receiving facilities at fixed points designated by the subscriber".*

MVDS	**Microwave Video Distribution System**
MDS	**Multipoint Distribution System**
MDS	**Metropolitan Distribution System**
MMDS	**Multipoint Microwave Distribution System**
MMDS	**Multichannel Microwave Distribution System**
MMDS	**Multichannel Multipoint Distribution System**
M^3VDS	**Millimetre-wave Multichannel Multipoint Video Distribution Service**

The FCC allocated only two channels to provide services throughout the whole of the United States, and only one channel was allocated to any licensee in any given metropolitan area, the service originally being called a Metropolitan Distribution Service. The channel allocations for MDS are

Channel 1	2150-2156MHz	6MHz wide
Channel 2	2156-2162MHz	6MHz wide
Channel 2A	2156-2160MHz	4MHz wide

The second channel can only be used at its full 6MHz bandwidth in some areas of the USA, other areas being restricted to 4MHz.

The FCC originally expected MDS services to be used for the transmission of high-speed computer data, facsimile, and message transmissions as well as for television, and although all these uses have occurred, it is the transmission of television programmes, generally for payment, which has put MDS on the map. This ties in well with what has been found in a different field, that of Specialised Satellite Services. A similarly wide range of service applications was foreseen by the British Government when it advertised six new licences for SSS earlier this year, but once again the vast majority of applicants wanted to use the satellites primarily for some form of video distribution.

During the late 1970s, MDS proved a great success in the United State, first of all being used to carry recently released films to hotels and apartment blocks, and later to serve individual homes. Several large towns in the USA had a single-channel MDS service and millions of households could receive a service of this type by the early 1980s. There were some financial problems caused when pirate down-convertor units came on to the market at low cost, depriving the MDS operators of much revenue, but it was the steady growth of multi-channel cable systems in the USA that really caused a significant drop in the number of subscribers to MDS services in the early 1980s. Viewers

* *F. C. C. Rules & Regulations Part 21, Subpart G.*

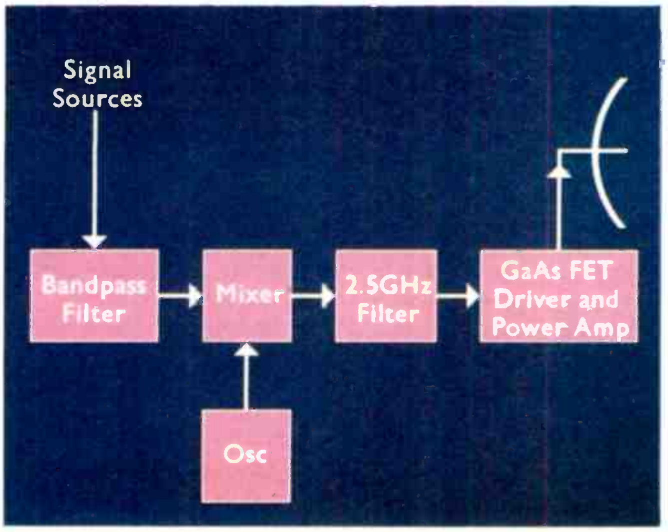


Fig.1. The basic MVDS transmitting system.

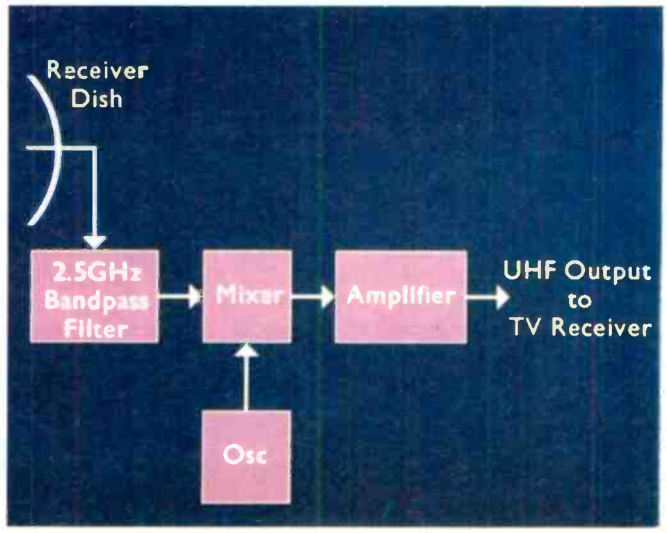


Fig.2. MVDS receiving equipment.

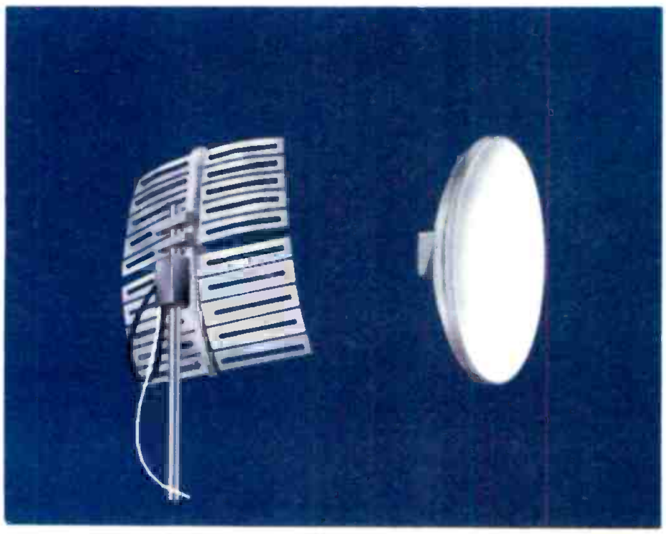


Fig.3. MVDS receiving aerials for 2.5GHz.

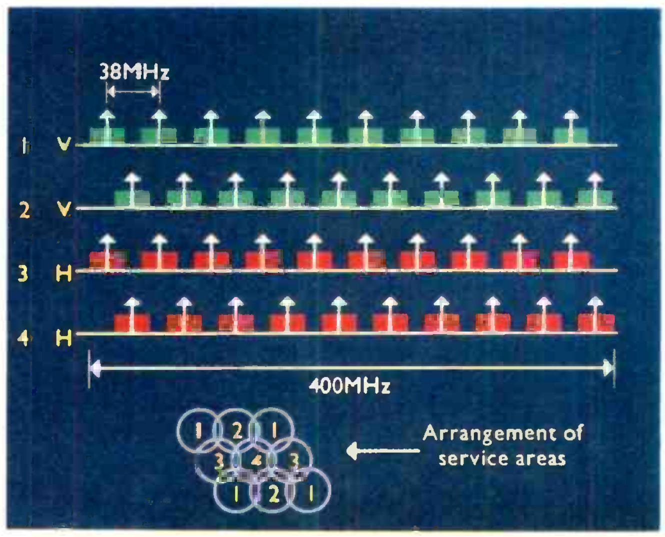


Fig.4. FM 10-channel MVDS plan with lattice arrangement.

who had previously been happy to pay for an extra programme service via MDS frequently decided to change over to cable services which could give them far larger numbers of programmes to choose from at little extra cost.

These problems for the MDS operators led to the FCC being lobbied for more channels so that multichannel services could be introduced, the aim being to enable the MDS industry to provide real competition for the cable operators.

MMDS – MULTI-CHANNEL MICROWAVE DISTRIBUTION SERVICE

By June of 1983 the FCC allocated twelve, 6MHz-wide channels at just above 2.5GHz, slightly higher frequencies than those used for the existing MDS services. This then allowed multichannel microwave distribution systems to be set up, and almost 17,000 applications for licences were received by the FCC. This caused many problems and delays and it was not until 1987 that some of the major conurbations in the USA could actually make use of MMDS services. The first company to get into multichannel microwave distribution with full FCC approval was Microband in New York, and its system is designed to compete head-on with the cable companies, offering similar numbers of channels at less cost.

The American MMDS transmitting stations, some of which consist of little more than a microwave module mounted on a lamp-post, radiate standard NTSC amplitude-modulated, vestigial-sideband television signals in standard 6MHz bandwidth channels. The transmissions are normally divided into 'high-power', which means from 10 to 100 watts, and can provide a service area of up to about 35km radius, and 'low-power', from one to ten watts, which might typically cover a radius of three to four kilometres.

The normal technique, especially for the higher-power systems, is to use an individual solid-state transmitter for each programme channel, and then to combine the 2.5 GHz outputs before feeding the combined signal to one or two broadband transmitting antennas. See **Fig. 1**.

Each transmitter is modulated using a separate AM modulator, rather like those used for standard cable systems, accepting composite video and audio at its input, and giving a combined audio and video output signal. On the high-power systems, it is usually possible to adjust the modulation depth of the video, and the deviation of the audio, and metering and carrier-level adjustments are also sometimes included. Since the equipment is, in many cases, intended to work at the end of a cable system, and since historically MMDS and cable systems have been seen as complementary, the output frequencies of the modulators are usually chosen to be at standard cable television frequencies, usually in Bands I or III. The channel frequency is usually generated by a crystal oscillator forming part of the modulator, although it is obviously possible to use a synthesized oscillator if it is felt that there might be a need to change frequencies.

The output signal from each modulator is then fed to an up-convertor, which is phased-locked to the master oscillator, and then to a 2.5GHz amplifier stage before being fed to the combining unit. The up-convertor frequently consists of a balanced-diode mixer with a passive output filter and a high-stability local oscillator.

An incidental advantage of using the standard cable channel frequencies before up-conversion is that, when the signals are down-converted in the viewers' home, they will automatically be on the normal cable channel frequencies, which can simplify matters for the cable operator, who can use his normal cable receivers without modification. This compatibility can also help the operator who wishes to change over from an MMDS system to a cable system after an initial period of using MMDS before his cable system is fully developed and installed. This technique of using MMDS to provide 'wireless-cable' services to customers more quickly than could be achieved by laying cables, is often known as cable 'pull-through', and is being considered by several UK companies as a temporary measure.

Low-power MMDS installations generally have a simpler arrangement of equipment, since it is now possible to buy a single, low-cost solid-state common up-convertor and power amplifier, which can feed the transmitting aerial directly.

Transmitting aerials for MMDS can be either dishes of around 50cm diameter or slot aerials or dipoles. Gains of around 16-18dB are common. In American MDS systems, much use is made of slot arrays with either omnidirectional or cardioid horizontal radiation patterns. Gains of around 10-13dB are common for the omnidirectional arrays, with perhaps another 3dB being available from the cardioid designs. Remember, though, that the American MDS systems are rather like straight transmitting stations aiming to cover as large an area as possible, whereas some MVDS stations will be intending to cover relatively compact communities which will allow for the use of higher-gain directional aerials.

RECEIVING EQUIPMENT

Low-cost receiving equipment for the 2.5 GHz MVDS transmissions is readily available in the United States, and generally consists of the dish, a low-noise block convertor preceded by a 2.5GHz band-pass filter, and a set-top box or 'indoor unit'. This provides the power supply for the convertor and allows for channel selection and for the connection of the MVDS signals to the receiver as well as those from the normal VHF or UHF antennas. The indoor unit will also contain the circuitry required to descramble the pictures in systems where some form of scrambling is used. See **Fig.2**.

Fifty-centimetre dishes are reasonably easy to mount and, with a beamwidth of around fifteen degrees, their installation should not pose many problems. In the United States, modified versions of perforated dish aerials are also used, as well as designs which are Yagi based. See **Fig.3**.

SIGNAL STRENGTH REQUIREMENTS

In UHF terrestrial broadcasting transmission, we usually calculate the field strength required to provide pictures with a particular signal-to-noise ratio with a given type of receiving aerial, but when using microwaves it has become traditional to use link-budget calculations, since these work well when considering the point-to-point links which microwaves have usually been used to provide. For this reason, then, link-budget calculations are usually used for MMDS services, although we must of course remember that other factors as well as the strength of the signal will have to be considered, including the need for protection against possible co-channel interference from other nearby transmitters using the same frequency. Microwave signal strengths will also vary with weather conditions and, since the signals travel virtually by line-of-sight, there may be many unserved locations within any nominally served area; ghosting may also cause problems in some areas. The normal technique used to overcome the variations in signal strength is to increase power.

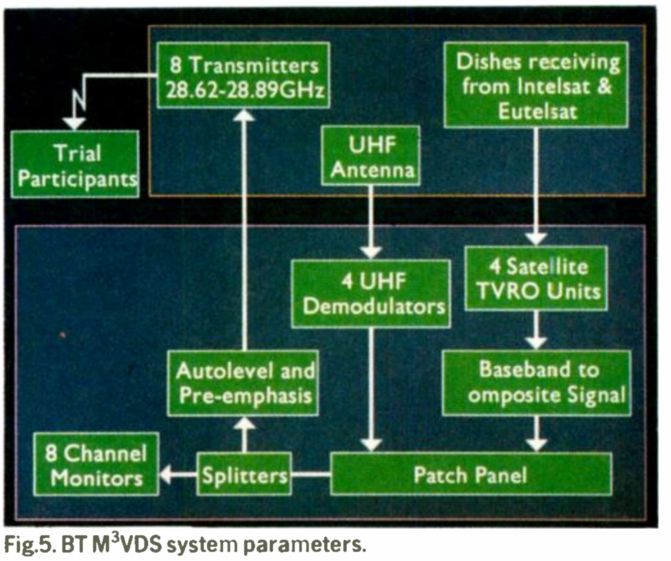


Fig.5. BT M^{3}VDS system parameters.

Let us now look at a typical link budget for a 2.5GHz MVDS system so that we can gain some idea of the figures involved, first considering how good a picture we require. Broadcasters use the CCIR five-point grading to subjectively assess pictures.

quality	grade	impairment
excellent	5	imperceptible
good	4	perceptible but not annoying
fair	3	slightly annoying
poor	2	annoying
bad	1	very annoying

To give some idea of what this means, a normal domestic VHS video recorder gives pictures of around grade 3. For a broadcast system we, of course, wish to provide rather better picture, so for the purpose of our calculations, assume that we are going to attempt to provide pictures of at least grade 4, let us say grade 4.5. This corresponds to an unweighted video signal-to-noise ratio of around 40dB, so we must aim for this figure.

The signal-to-noise ratio of the chain between the transmitter and the receiver corresponds to the following link budget.

transmitter EIRP
− path loss
+ receiver antenna gain
− receiver noise
+ random noise floor
= signal-to-noise ratio

Assume a 10W transmitter for the example, which it is convenient to regard as a power of 10dBW. There will be some loss in the transmitter feeder, say 4dB, and the antenna will have a gain of say 15dB, giving a net EIRP of 10−4+15=21dBW.

The path loss can be obtained from the formula

$$\text{path loss (dB)} = 103.3 + 20\log D,$$

where D is the length of the path in miles. Assume a path length of 10 miles,

$$\begin{aligned}\text{then path loss} &= 103.3 + 20\log 10\\ &= 103.3 + 20\\ &= 123.3\,\text{dB}\end{aligned}$$

A typical 50cm receiving dish might have a gain of 15dB, and we shall assume that the noise figure of the receiver is 3dB.

To find the random noise floor, use the equation

noise = Boltzmann's Constant +10 log bandwidth +10 log temperature in K.

Boltzmann's Constant = −228.6 dBW/Hz K i.e. 10log 1.38×10^{23}

therefore,

$$\begin{aligned}\text{noise} &= -228.6 + 10\log 5.5\times10^{6} + 10\log 290\ (\text{ambient temp} = 17°\text{C})\\ &= -228.6 + 67.4 + 24.6\\ &= -136.6\,\text{dBW}\end{aligned}$$

The signal-to-noise ratio is then

$$21 - 123.3 + 15 - 3 + 136.6 = 46.3\text{dB}$$

This is better than we need, but is only the figure for the link; any noise in the incoming signals, whether these are from a satellite feed or a videotape machine, will reduce the overall signal-to-noise ratio.

FREQUENCY SHARING

Since radio waves at 2.5GHz are unaffected by sporadic-E and only very rarely subject to tropospheric ducting, there is very little chance of co-channel or adjacent-channel interference occurring, especially since the transmitter powers are usually kept fairly low, and alternate polarizations are used to give discrimination between wanted and unwanted signals.

Frequency sharing in parts of Europe which want to adopt 2.5GHz MVDS is likely to be very much more difficult, since towns using MVDS may well be only a few kilometres apart. The number of available frequency channels is likely to be fairly restricted, and if a large number of programmes is to be provided a carefully worked out frequency plan will be necessary. The Irish Government is currently planning to make The Republic of Ireland the first country in Europe to have a country-wide MVDS service, and their plan is to provide 11 television channels to virtually the whole of the population within a period of five years.

MVDS FOR THE UK?

At the end of 1987 the DTI and the Home Office commissioned management consultants Touche Ross to investigate the use of microwaves for broadcasting in the UK. The Touche Ross report turned out to be very optimistic regarding MVDS systems, and said that a national microwave transmission system could be providing services as early as 1991 if the British Government so decided.

Without giving any more than a cursory look at the possibility of introducing more up-to-date television systems such as MAC, the authors of the report make their calculations of the required spectrum space on the asumption that the 'obvious standard' to use is amplitude-modulated PAL system I with a bandwidth of 8MHz.

On this basis they calculate that about 400MHz would be required for a 12-channel nationwide service, and that a 30-channel system would take up about 1GHz. It was not part of the Touche Ross brief to see whether spectrum space could be made available, but this would obviously be vitally important in determining whether a practical service could be established. The report looked at three possibilities for microwave broadcasting frequency bands: their so-called 'low-frequency' band between 1000 and 6000 MHz, the 'medium-frequency' band from 6 to 20 GHz and the 'high-frequency' band from 20 to 70 GHz.

1GHz to 6GHz	– mature technology, inexpensive equipment.
6GHz to 20GHz	– technology still developing
20GHz to 80GHz	– technology immature, some years before domestic equipment could be made available

These divisions seemed rather strange to those of us who know a little about propagation conditions in the various bands, but it turned out that the authors had chosen this division because it made sense in terms of equipment costings. Because MVDS and medium-power C-band satellite reception equipment is readily available in some parts of the world at reasonable cost, the report considered that if MVDS were to be allocated a band somewhere within the range of 1 to 4GHz there would be an excellent chance of a mass market developing very quickly.

2.5GHz MVDS equipment is to be used in Ireland in the very near future, and so it might appear that 2.5GHz would be the ideal band for our use. Unfortunately for the backers of that scenario, until very recently there seemed very little chance of the UK frequency allocation being granted around this part of the spectrum, since it is currently very well used. The UK broadcasters are now using around 12 channels for ENG vision links in the 2.5GHz area, and sound and vision links also make daily use of frequencies around 1.5GHz and 5.5GHz and 7GHz, so broadcasters are not going to be lobbying heavily for these frequencies to be used for MVDS!

The IBA Engineering Division has recently taken an interest in MVDS at 12 GHz, and their engineers believe that it would make a great deal of sense to use the 12GHz band for MVDS purposes, since this could allow the millions of viewers who, they hope, will be buying satellite receiving equipment to use the same equipment for MVDS – a truly low-cost solution!

If this idea were to be adopted, frequencies in the DBS Band 11.7 to 12.5 GHz might well be available for MVDS use. When the WARC plan for satellite broadcasting was drawn up in 1977 it was by no means certain that receiver manufacturers would be able to build receivers capable of covering the whole of the broadcast band, since low-noise GaAs fet amplifiers were still in the research laboratories and it was felt that the only way to obtain sufficient gain would be to restrict the bandwidth. For this reason the five channels for each individual country in Europe are all positioned in just one half of the band. The UK was allocated five channels in the lower part of the band, which means that there is a strong possibility that the upper part of the band could be used for MVDS without causing interference to other satellite operators, since the MVDS signals would be radiated from relatively low transmitting masts with aerials designed to concentrate the energy in the terrestrial service area. In other words, it is most unlikely that anyone with a dish pointing up in the air at a satellite would pick up interference from an MVDS transmitter. In addition, in the years since 1977 satellite receiver technology has progressed faster than originally anticipated, and modern GaAS fet amplifiers now comfortably cover the whole of the 11.7–12.5 GHz band which makes the idea of a dual-purpose satellite/MVDS receiver operating at 12 GHz a practical proposition. **Figure 4** shows how this frequency sharing could work.

THE POTENTIAL FOR IMPROVED PICTURES FROM MVDS

All existing and planned MVDS systems use ordinary NTSC or PAL amplitude-modulated, vestigial-sideband transmissions, using the same standards as are used on terrestrial UHF and VHF systems. If the 12 GHz system suggestion were to be taken up, however, as well as the advantages that I have indicated, there would be the potential for the adoption of a better, more modern broadcasting system that has already been adopted for direct broadcasting from satellite – the MAC system, using frequency modulation.

UK DBS Characteristics

Multiplexed Analogue Components – MAC
frequency modulation – 24dB less power needed for the same s:n, compared with AM
27 MHz-wide frequency channels
multi-channel digital sound/data system
built-in conditional-access/encryption
built-in future enhancements/wide screen/EDTV

Comparison of S/N ratios for AM and FM MVDS signals

For a video S/N ratio of 45dB (weighted luminance) in each case

AM VSB 5.5MHz bandwidth

C/N + peak sync. carrier/noise in 5.5MHz + 46dB

Carrier to noise density + 46 + 10 log (5.5×10^6) = 112.9dBHz

FM 27 MHz bandwidth

C/N + carrier/noise in 27MHz = 44-30 = 1dB

Carrier to noise density = 14 + 10 log (27×10^6) = 88.3dBHz

Therefore difference in carrier power = 112.9 – 88.3 = 24.6dB

An FM MVDS system of the type being described would also gain from having the advantage that the co-channel protection ratio would be around 30dB, rather than the 45dB which is needed for the AM-VSB services, and this would mean that transmitters using the same frequencies could be more closely spaced, allowing better coverage with a given number of channels. FM systems are also less sensitive to interference from transmitters on adjacent channels, which again allows us to re-use frequency channels more often.

Terrestrial AM UHF transmissions use polarization discrimination at transmitting and receiving aerials to achieve better use of the band, and it should similarly prove possible to use polarization at 12GHz on our MVDS systems.

By siting the various MVDS transmitters at appropriate distances apart and using a combination of different groups of frequencies, polarization discrimination and carefully-shaped transmitting aerial radiation patterns, IBA engineers believe that a nationwide service of ten new television channels could be provided within a bandwidth of 400MHz, or this could be increased to twelve channels if 480MHz could be found.

As **Fig.4** shows, it has been assumed that four separate groups of ten frequencies would be used over and over again in a carefully laid out lattice pattern of transmitter areas. This is something of an oversimplification, because the topography of the land is tremendously varied, so that real-life service areas will be far from circular in many cases. We also have the problem that 12GHz signals are deeply attenuated by anything that obstructs their path, including both buildings and trees. This means that in any nominally served built-up area there will be many potential viewers who will have difficulty in receiving a clear line-of-sight transmission, and it is this so-called 'urban clutter' that may make life difficult. Even with 2.5GHz systems, clutter is known to bring problems, and these will be accentuated at 12GHz.

One advantage of 12GHz systems is that fairly high gains can be achieved with small parabolic receiving aerials, which allows us to think realistically of viewers being able to use saucer-sized dishes on poles above their houses, this periscope-like antenna arrangement enabling viewers to see above the rooftop clutter to the local transmitter. A corresponding disadvantage of this idea is that it may conflict with planning regulations.

THE MAC SYSTEM FOR MVDS

I mentioned earlier that it would make sense to use MAC for MVDS because viewers will already be equipped with MAC satellite receivers, or that is BSB's earnest hope! Using MAC would also bring to MVDS all the advantages and enhancements that MAC is bringing to satellite services, so providing better quality pictures with the option of wide-screen viewing and higher definition in the future.

If MVDS services use MAC they willl be able to compete effectively against satellite and cable services which will soon be offering the higher definition wide screen pictures that will become the norm in the next few years. An MVDS system using PAL with AM-VSB would be condemned to obsolescence from the day of its opening, and would be a retrograde step as far as the development of the radio and television industry in this country is concerned. The recent report of the Home Affairs Committee recognised this, and recommended to Government that it should consider the development of MVDS in the 12GHz band as part of an integrated programme distribution service.

HIGHER AND HIGHER?

The parameters of what BT regards as a typical M^{3}VDS system are shown below.

15 – 20 channels
100mW transmitter power per channel
FM – deviation 16MHz
PAL system (could support MAC)
Transmit antenna gain 15dB
Receive antenna gain 27dB
Receive bandwidth 30MHz
Threshold carrier-to-noise ratio 14dB
Unfaded carrier-to-noise ratio 22dB
Video S/N 52dB
Picture quality – better than CCIR grade 4 (good)

There are, however, currently two major snags with 30GHz. The millimetric wave amplifiers needed are currently high-cost items used for professional communication purposes and costing many thousands of pounds. BT engineers are confident, however, that this snag will shortly be overcome, since the latest generation of monolithic microwave integrated circuits (MMICs) has now started to become available in production quantities, and they believe that within five years GaAs MMICs will be available at prices to suit consumer equipment.

The other snag with using 30GHz in rather more fundamental. Since the signals behave somewhat like rays of light, any obstruction such as a tree or a tall building will kill the signal virtually completely, and it is predicted that as many as 30% of the viewers in a nominally served area would remain without satisfactory signals. Work is in progress to see just how bad this effect would be, and whether it will be possible to use tiny fill-in transmitters to cover these gaps.

For some years now communications have been possible at even higher frequencies, although once again only using very expensive professional equipment and some MVDS protagonists have suggested that within a few years it will be possible to manufacture domestic equipment which will permit the use of frequencies around 60HGz. As one goes higher in frequency it is generally easier to obtain a wider chunk of spectrum for your service, so that it is anticipated that many tens of channels could be provided in this area. Against this, however, go the inevitable laws of propagation, with all the difficulties of providing a service to a high percentage of the customers in a built-up or tree-lined environment.

INTERACTIVE MVDS?

Although it is generally accepted that MVDS systems are essentially one-way, I would like to speculate on the possibility of households having their own miniature microwave transmitters which could squirt signals back to the MVDS transmission point, which must obviously be within line of sight. I have been looking at the simple microwave burglar alarms that are now on the market for just a few pounds.

These consist of a solid-state microwave oscillator mounted in a cheap metal horn which radiates signals at around 10GHz. They are currently very crude devices, but are cheap and effective, and I reckon that with just a little bit of research effort a device suitable for allowing domestic users to talk back to their MVDS transmission points could be developed. I would not, however, like to solve the potential interference problems that a street of terraced houses each transmitting its own microwave signals could cause!

Broadcasters and cable protagonists have been living through interesting times this last year or so, and you may remember that to cause somebody to live in interesting times was an old Chinese curse; things haven't been so different for those with an interest in the future of broadcasting!

FEEDBACK

Faster than light?

The following is an edited version of some of the correspondence we have received as a consequence of the article by Obolensky and Pappas in our December issue. Regrettably, there is insufficient space to reproduce all of it in full.

Coulomb action

What is so fascinating is that the test configuration has the ability to overcome the familiar problem of the relativist who insists that there must be a way of synchronizing clocks at the test locations before the flight time of a signal can be measured between those locations.

The remarkable fact is that the onset of the precursor signal sets the clock running at the receiving location and the subsequent arrival of the dominant electromagnetic pulse gives the second time check, the time difference in relation to the length of transmission line being such that superluminal speeds are recorded. This result clearly shows that the precursor signal travels very much faster than light speed.

The telegraph equation concerns the travel of an electrical signal along a transmission line that is essentially resistive and capacitive. No inductance is assumed. When a step signal is applied at one end there is a definite delay before any measurable signal arrives. Then there is progressive signal build-up. Obviously, one cannot just measure the speed of propagation by initiating the time measure from the moment the build-up is seen. If that is all that is measured in the Obolensky test it cannot be trusted as an indication of superluminal signal speed.

The point is that the dominant electromagnetic signal arrives *after* the onset of the precursor signal and we *know* the dominant signal has travelled at light speed as determined by the inductive restraints.

The precursor signal has travelled in a way governed by non-electromagnetic action.

Nothing in our text books establishes that the signal speed is limited by light speed. It is inferred, because we suppose that charge does not travel faster than light speed, but we know that the charges carrying current in wires do not travel at anything like the speed of light, yet their electromagnetic action causes current to exhibit that speed of light. There are two actions in the field set up by the electric charge: one is the action at the electromagnetic wave velocity and the other is the direct Coulomb action. The latter is assumed by many to be subject to the same propagation delay via what are known as retarded potential effects, but there are those who question the theory.

(If) the Coulomb action does propagate at faster-than-light speed, the Obolensky effect is justified because it is a weak signal that could arise from direct electrostatic induction progressively propagated along the transmission line with no speed of light limitation.

H. Aspden
Visiting Senior Research Fellow
Dept of Electrical Engineering
University of Southampton

Switches, sparks and arcs

I am troubled that, having observed my Causality Triangle Experiment employing *switch-closing* wave structure, our "joint" paper advanced your unsupported opinion that the observed effects were due to *switch-open* wave structure. Oscillographic evidence shows why the observed effects are due only to switch closing. The oscillograph correlates the instantaneous current and causative voltage measurements to eliminate conjecture about switch-opening inductive flash-back.

The spark modes involving inductive flash-back have been investigated with a view to writing a paper in support of Webber's "two-fluid" electric current. *Both* positive-going "huge spikes" and negative-going coherent surges can be shown to coexist in a unique energy resonance. This impulse cohering energy resonance appears to reduce total entropy. It may also model natural lightning, since the current surges appear to display lightning's 50 microsecond spark structure!

To introduce this contact-opening spark/arc mode into my Causality Triangle Experiment requires eliminating the two 68 000 ohm current limiting resistors. They are simply replaced with an inductor having the same DC resistance. I made a 115 000 ohm inductor by winding 10 miles of #42g magnet wire on a standard 3in spool. This 10 miles of ordered space is simply added to the wire connecting the opposed reflectors. It is noteworthy that this added line impedance has only a negligible effect on the so-called "huge spikes" of current. In addition, this arrangement becomes so sensitive to stray AC fields that no *external* battery is required to effectively replicate the superluminal causality effects that I demonstrated publicly in 1982.

In addition to clarifying the difference between contact sparking and contact arcing, this modality provides an easily measured example of negentropy as well as clear evidence that causality links are connected by instantaneous action-at-a-distance, spin angular momentum change.

I have completed numerous experiments and employed entirely different modalities; in every case, the superluminal cause or pilot wave is seen to precede the material effect by one piradian. This demonstrates the "last shall be first", time-reversed sequence, widely reported in optical phase-conjugate resonance. The consistent observation of "two-fluid" spin current components demonstrates the existence of spin waves. The magnetizing vector, which globally connects cause and effect independently of time, can be studied by simply correlating the instantaneous cause and effect currents, in both the real and complex domains.

I have established that differential current measurement can isolate the evanescent common-mode subluminal current signals. By also modifying the relay magnetizing method and grounding both reflectors, artefacts introduced by stray magnetic and AC field gradients can be eliminated. The apparent anisotropy, with respect to charge polarity and direction, can be largely removed without changing the observed superluminal signals.

Alexis Guy Obolensky
President Bromion Inc.
NY, USA

Catastrophe and creation

Ludvik Kostro's article in the March issue reported that "it (the ether) not only conditions the behaviour of inert masses, but is also conditioned, as regards its state, by them".

Einstein was clearly talking about action, and thus about the energetic states of mass and space which I see as capacitive and inductive energy stores respectively, representing order and chaos: then let us accept that order must embody a plan and that mass is a plan of ordered Limiting Sub Masses within a random field of LSMs.

For Einstein's statement to be fulfilled, there must be an iterative equation between the energetic states of mass and space, i.e. between mv (momentum) and $\frac{1}{2}mv^2$ (kinetic energy), from which we may deduce that v=2, the combined approach velocity of the two energies during the interaction in which space "winds up" mass and vice versa. The v^2 of KE is due to the planar full frontal which mass provides to the energy during the interaction.

Now, v=2 whether the interaction is vast and cosmological or tiny and local: if mass is fixed relative to the viewer the energy appears to move at twice the speed of light because the viewer is linked to the mass: this might be likened to the speed of the current outside the wire as it is guided by the wire. To understand this, one much invoke Catastrophe Theory and say that, with adequate excitation, bonds can be broken and the plan destroyed: we are talking about the plan of the electron which jumps out of the wire as a cloud of LSMs, commencing the act of radiation through the field while leaving an instantaneous hole. Catastrophe is an instantaneous change from order to chaos because there is no half-way state, but a domino catastrophe might take time because of propagation delay.

In Obolensky's experiments, it seems to me that what the sensor coils are detecting is the inverse of catastrophe (i.e. creation) when the electrons reform in the holes in the wire: this action occurs at all points along the wire more or less simultaneously, hence the enormous spikes. The length of wire does not add distance to the path.

James A. MacHarg
Wooler
Northumberland

Difference or absolute?

The article contains several clues to its own downfall . . . Consider the case where the transmission line length is 56ft and the antenna base line (capacitor plate spacing) is 10ft. The common value of c is about 1ft per nanosecond.

The circuit is broken at one of the mercury vapour relays and the charge starts to build up on the capacitor plates. This sends out a wavefront through air in all directions at very close to c. 56ns later, much spread out, this reaches the points where the screens of the coaxial cables enter the oscilloscope: these inputs are only a few inches apart and about equal distances from the relay that opened, so a small signal starts to build up on both traces simultaneously. This signal builds up slowly as it is joined by other bits of the wavefront which intercepted the coaxial screen further away from the oscilloscope and then came in at a speed rather less than c.

Meanwhile, the main high-level signals from the pick-up coils are coming down the inside of the coaxial cable at about two thirds of c (as is usual for coax.). The cable nearest the relay which opened delivers its signal 84ns after opening (56ft at ⅔c). The other cable delivers its signal 10 or 11ns later than this, as expected through having to travel an extra 10ft between the capacitor plates, through air.

The result is exactly as observed, without the need for any faster-than-light travel: a gently rising signal on both traces starting 56ns after the start, followed by a large pulse on one trace 28ns later, and a large pulse on the other trace 10-11ns later. The only observation which holds any water is the transmission between the capacitor plates at exactly the speed expected: the speed of light in air. What the authors call transmission at twice the speed of light is due to the difference between the transmission through air (at c) and the transmission through coaxial cable (at ⅔c).

Tim Bierman
Hendon
London NW14

The writer of the following letter made roughly the same points as the above, but presented these calculations.

Time taken to travel a distance equal to the coaxial line length but in air

$$t_a = l/c$$

For the example of 74.5ft for l(=22.708m),

$$t_a = 75.692\text{ns}$$

Time taken to travel a distance of 74.5ft in a coaxial line with a relative permeability of 2.2

$$t_c = 112.269\text{ns}$$

Difference in arrival times at the oscilloscope

$$112.269 - 75.692\text{ns} = 36.5773\text{ns}$$

If the calculations are made for the other line lengths quoted in the article it works out just as well.

By applying the same calculations to the experiment where the extra line length is added, an extra insight into the results is obtained.

Propagation time for short length of 74.5ft (22.708m)

in air	75.692ns
in coaxial cable	112.269ns
difference	36.577ns

Propagation time of one metre longer cable (23.708m)

in air	79.027ns
in coaxial cable	117.215ns
difference	38.188ns

Apparent extra time to travel 1 metre

$$38.188 - 36.577\text{ns} = 1.611\text{ns}$$

Apparent speed of light (distance/time)

$$1\text{m}/1.61\text{ns} = 6.21 \times 10^8\text{m/s}$$

This result is the same as that in the article and is brought about by the manipulation of mathematical quantities which are DIFFERENCES and not ABSOLUTE values. If the authors had considered the arrival times with the initiation of the relay as the reference, then it should have been apparent that the event followed the initiation at the speed of light.

Neville Carrick
Andover
Hampshire

Leakage

For many years research has been undertaken to study the coupling between braided coaxial cables. For the last few years I have become involved in the research program and the article seemed to highlight a few effects which have been observed in cable coupling experiments.

If two braided coaxial cables are set up in a parallel configuration and one of the cables is connected to a signal generator, a small amount of signal will leak out of the cable due to the braided nature of the cable. The fields from the leaked signal will propagate in free space which the other cable will pick up. Could it not be this leaked signal which the other cable is picking up? We have found that if the cables are far enough away from each other and any surface, the velocity of the wave will be that in a free-space condition (3×10^8m/s).

The environment is very important on the propagation characteristics of any 'signal' existing between the two cables. We have found that if you bring two braided cables near to the ground then the velocity of the wave existing between the two cables reduces. This might explain why the 'fast signal' reduces when the cables are brought near an object or ground. Any changes to the environment will cause a change to the propagating wave.

The level of 'leaked signal' is dependent on the transfer impedance (Z_t) of the braid, so is the level of the 'quick signal' changed by using a different type of cable i.e. a coax. which has an outer conductor which is solid?

I throw these observations into the 'pot'.

Julian M. Tealby
University of York

What travels faster than the speed of light in coaxial cables? Radio-waves in air, of course. At the closing of a relay there will be a large RF pulse which can be expected to leak to the coaxial lines down their length. The earliest event seen on the 'scope is thus due to leakage closest to the 'scope. The effect of the slower propagation velocity in the cables (I calculate 2×10^8 m/s) disperses the pulse in time. Had the cables been laid on the ground then this unfortunate break-through might have been greatly reduced.

C. G. Flewellen
Institute of Oceanographic Sciences
Godalming
Surrey

Unbalanced currents

Might one suggest that the authors repeat the experiment using open-wired balanced line, or using a balanced-to-unbalanced transformer at the launch end? Many an amateur operator can tell tales of 'hot' gear with unbalanced currents travelling on the screen of a coaxial cable – caus-

FEEDBACK

ing feeder radiation, if the sparks weren't enough!

The coil used at the launch end will include such an unbalanced current, travelling at a velocity close to C (in free space, the line supported above ground, somewhat similar to a Gobau line[1] with a severely mismatched launcher). The TEM wave in the coax., however, will travel at a substantially lower velocity, due to the dielectric material in the transmission line. Taking a velocity factor of 0.75 for the coax., the time delay will be approximately 1.57 µs/m, with some phase shift due to the reactive nature of this signal's coupling to the oscilloscope input. The stretching of the pulse into a ramp as displayed on the oscilloscope can also be postulated as due to the capacitative nature of the coax. cable.

As to the anisotropy of the velocities with regard to direction, I'll leave that to A. E. Einstein *et. al* for the explanation!

Dave Hicks G0IZY
Aldershot
Hampshire

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Common-mode

One very basic aspect of the experiment which is not mentioned at all in the article, and which the experimenters perhaps neglected to take into account, is the huge common-mode voltage change which occurs at the same time that the mysterious low-level signals are being generated.

At the moment that a relay is energized, the voltage of the small section of antenna wire through the current probe next to the relay changes by 250V. This change is capacitively coupled to the current probe and travels *as a common-mode signal* along the associated transmission line. The outer conductor acts as signal path, and the return path is diffusely spread in the space around it, approximately as in a surface-wave transmission line. (See e.g. G. Goubau, "Designing Surface-Wave Transmission Lines", *Electronics*, vol. 27, pp. 180-184, April 1954). The dielectric medium is primarily air, and hence the signal travels at a velocity of about 300 000 km/s. It arrives at the outer case of the oscilloscope in some way. Through minimal asymmetries in the oscilloscope construction or mismatches in component properties, this common-mode signal of perhaps several hundred volts can easily cause effects corresponding to an apparent differential signal of several mA. Since the potential of the oscilloscope as a whole with respect to the space around it is being changed, it is no surprise that the apparent signal appears on *both* input terminals. The described effect corresponds to a common-mode rejection ratio of about 80 dB – a figure of which no oscilloscope manufacturer needs to be ashamed.

The velocity of about twice the normal speed of light, which the authors deduce for the low-amplitude signal along the transmission line, also has an alternative explanation based on the common-mode hypothesis. Pappas and Obolensky determine this velocity from the *difference* in arrival times of the low-level signal and the first high-level spike. In my hypothesis, Pappas and Obolensky determine this velocity from the *difference* in arrival times of the low-level signal and the first high-level spike. In my hypothesis, the low-level signal travels at about 300 000 km/s (0.3 m/ns) on the outside of the coax. cable as described above. The high-level spike is the real signal generated by the current probe, which propagates as a differential-mode signal between the inner and outer conductors of the transmission line at a veolcity of about 200 000 km/s (0.2 m/ns), the velocity C1 as reported in the article.

If the length of the transmission line in meters is set to L, then the travelling time of the low-level signal is (L/0.3) ns and the travelling time of the high-level signal is (L/0.2) ns. The time *difference* is therefore (L/0.6) ns. And the "velocity" of the low-level signal (distance divided by time difference, as defined by the authors) is L/(L/0.6) m/ns, or 0.6 m/ns, or apparently twice the speed of light in a vacuum.

The base wire also may be seen as a surface-wave transmission line with a diffuse return path consisting of the ground and the space between the capacitor plates. It is not unreasonable to suppose that the parameters of this "return path" will play a role in the measured velocity. Changes in temperature and/or humidity of the air as well as the distance and orientation with respect to the ground change these parameters to some extent, and may therefore account for the minimal velocity changes.

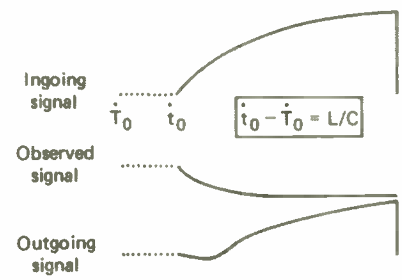
I can think of several experiments to provide evidence for or against my alternative theory. If Pappas and Obolensky are interested, I would be happy to discuss such experiments with them.

F. Heutink
Eindhoven
The Netherlands

When one of the two relays is excited with 12V AC at 60Hz and the other non-excited relay is closed, the (primary) base wire induces AC signals in the (secondary) coils feeding the two coaxial lines. These equal AC signals feed into the oscilloscope via its plates and, by some internal rectification, charge up the *entire* CRT (i.e. gun, grid, deflector plates etc.) uniformly. Such a uniform charge would not be revealed on any beam trace.

Forget, for the moment any signal coming *into* the oscilloscope via the two coaxial cables. When the non-excited relay is open, this uniform charge on the 'scope starts to decay *after* a pause of L/C seconds. (L being the length of either coax. and C the speed of light). As this charge decays, its plates lose their potential relative to its entirety, so that *after* a pause of L/C seconds the trace of either cable becomes increasingly negative and *visible*. I take it that the brightness of the trace is enhanced electronically when a signal is present.

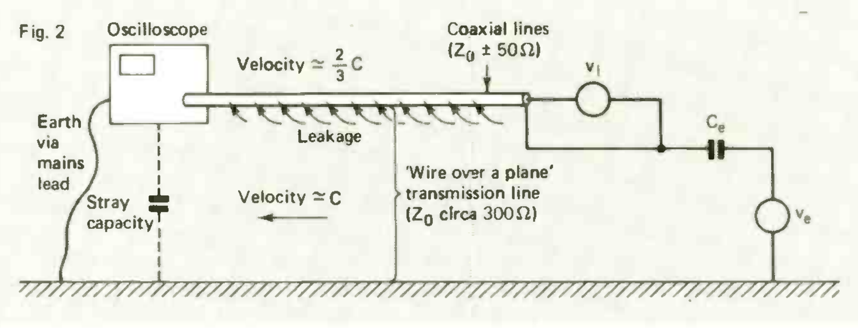
What all of the above means is this. What the authors believe is an *instantaneous* signal *entering* the oscilloscope is simply a signal *leaving* it; not instantaneously, but after a delay time of L/C seconds. During this delay time the trace remains unenhanced, so invisible.



Now that we have dealt with this (previously-induced) signal leaving the oscilloscope, let us deal with the signals entering it when the above relay is operated as above. [The reason for dealing with these outgoing and incoming signals separately is because they overlap (time-wise) hence the trace is composite.]

We repeat the above sequence for the incoming signal to the oscilloscope. When one of the two relays is excited with 12V AC at 60Hz and the other non-excited relay is closed, pulses of DC from the 250V DC battery charge the large capacitor plates.

Now forget, for the moment, any signal coming *from* the surreptitiously-charged oscilloscope plates and travelling along the two coaxial cables. The DC charge on the large capacitor plates begins to flow along the coaxial cables, taking L/C seconds to reach the oscilloscope. After the above L/C second pause, the trace on the oscilloscope starts to rise, and steadily increases in *positive* direction. When the non-excited relay is opened, a mighty surge occurs as the large capacitor plates discharge, setting up oscillations. This causes the massive spike on



the trace.

Now (still considering only one of those double beams on the oscilloscope) we combine those outgoing and ingoing signals which are travelling along the coax. line we are considering. When we do this combining for either line, we shall obtain a curve with a *flattened* part near the supposed beginning of the trace (referred by the authors as the origin).

To sum up, then, we can say that signals along coaxial cables behave as we would expect them to do.

A. H. Winterflood
London, N10

Strays

Typically, for polythene or PTFE insulated lines, the velocity is only about two thirds that of light. Thus for, example, it would take 150ns rather than 100ns for a signal to traverse 30m (100ft approx) of normal 50 ohm coax. cable, a difference of 50ns. If you do these calculations for the various cable lengths mentioned, the time difference obtained is very close to the 'time lapse' values given in Table 1.

Next, it should be realised that, when an oscilloscope is triggered from the signal that is being displayed, the resultant trace contains absolutely no information about the time the signal originated or when it arrived at the input socket.

Thirdly, coax. cables are not perfect; signals can leak in or out of them.

Finally, circuit strays are often very important, particularly when one is trying to measure signals of a few tens of millivolts in the presence of an unscreened circuit switching two or three hundred volts. For example, it would take only −80dB of stray coupling to produce a 25mV signal at the oscilloscope.

Figure 1 is an equivalent circuit showing one of the coaxial lines together with what I think are the important strays. For convenience it is the one going to the end of the base wire with the energized relay. This can be simplified into Fig. 2 where v_i is the voltage induced in the current transformer and C_e is the total effective stray capacitance from the end of the coaxial line to the equivalent earthed voltage source v_e that would produce the same effect as the base wire and its various strays.

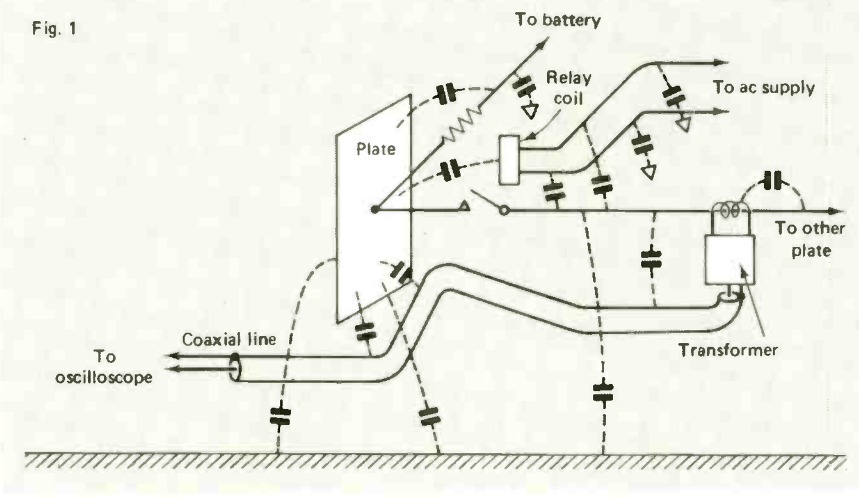
Although the actual waveform of v_e may be found a little difficult to visualize, it should be quite apparent that rapid changes equal to half the supply voltage will occur. These couple via C_e to a 'wire over a plane' air-insulated transmission line formed by the outer of the coaxial line and the earth, and propagate towards the oscilloscope at a velocity close to that of c. Some of the energy in this wave will leak into the coaxial line and travel down it at about 0.66c.

Suppose the transit time for the 'wire over a plane' line is T. Then the transit time for the coaxial line will be about 1.5T. Suppose also, for the moment, that C_e is large and that v_e is a fast voltage step starting at $t = 0$. For time $t < T$ nothing will be seen at the oscilloscope. At $t = T$ the wave will arrive at the oscilloscope and with it the signal that leaked into the very last bit of the coaxial cable. As t increases the signal that leaked into earlier bits of the cable will also arrive at the oscilloscope adding to the existing signal until at $t = 1.5T$ all the cable will be contributing to the signal. Thus, assuming that the oscilloscope triggers as soon as the signal becomes non zero, the signal will appear to ramp linearly from zero over a period of 0.5T and then remain constant. Of course C_e is not large and v_e is not a simple voltage step, so the signal seen will not be a simple ramp but must always start as one. Further, at $t = 1.5T$ the signal from the current transformer will reach the end of the coaxial line and add its (large) contribution to the signal seen at the oscilloscope.

Judging from the photograph, for most of their length the two coaxial cables are separated by a distance no greater than their height above the ground. Thus a similar but somewhat smaller leakage will occur into the second cable giving rise to a ramp type signal on the other channel of the oscilloscope. As the distances from the energized relay to the cables as they approach the oscilloscope are virtually identical, the 'ramps' will start together. Closer to the base wire the distances to the two cables are by no means identical so the later parts of the 'ramp' waveforms will diverge.

The impulses from the relay also propagate along the base wire to the other current transformer and are coupled by its C_e into a 'wire over a plane' transmission line formed by the second coaxial line. A similar leakage effect then occurs with this one but this time the second cable has the greater 'ramp' signal. Reflections back and forth along the base wire will produce further sets of 'ramps' of various polarity and amplitude with a periodicity dependent on the length of the base wire. The summation of all these signals is what is seen on the oscilloscope. The first three waveform pictures in their article show this effect quite well.

P. F. Gascoyne
Wantage
Oxfordshire



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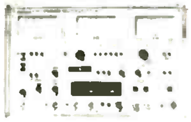

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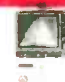

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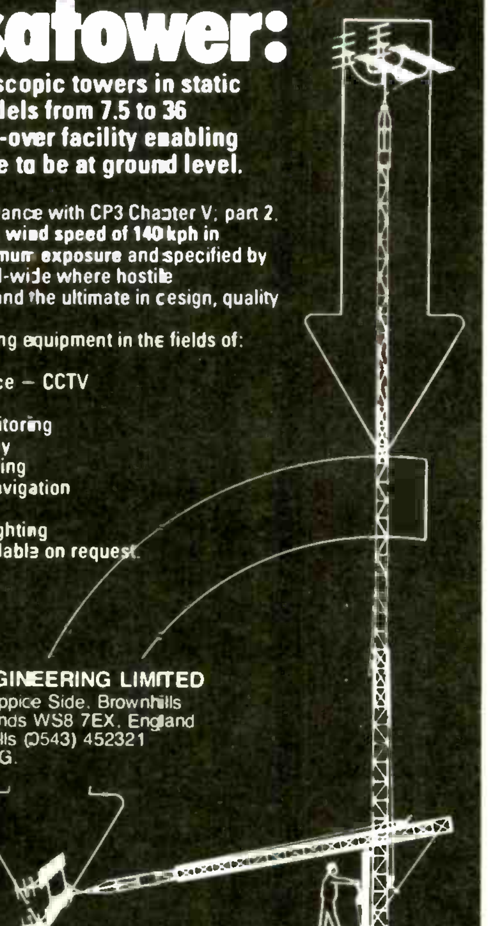

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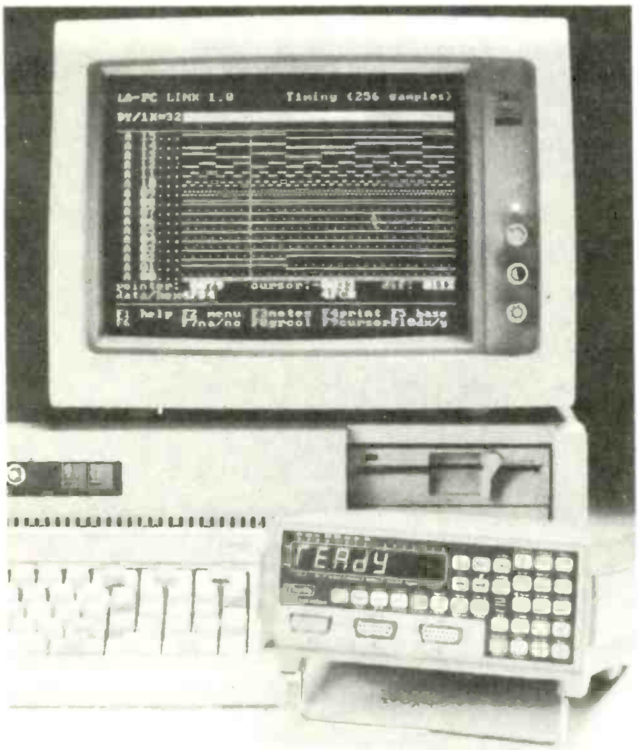

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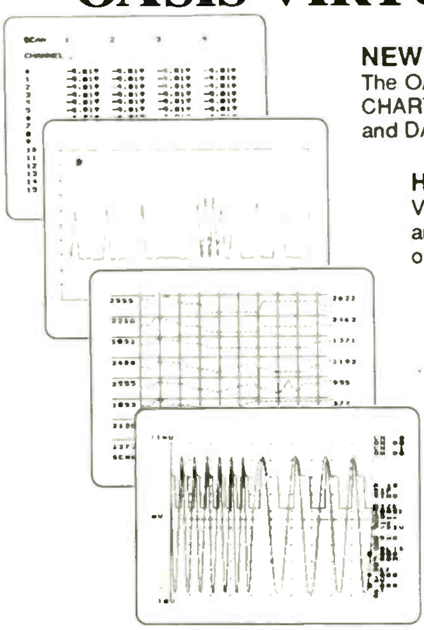

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A desperate race for people

DOM PANCUCCI

People are the key to success in information technology. All the hardware available cannot compensate for a lack of skilled engineers to develop systems that meet the precise needs of the user.

Information itself is the cornerstone of successful business: training the right number of professionals to make a structured use of IT is an industrial responsibility.

The problem is that industry as a whole has not fully assumed its role as prime IT trainer. A traditional over-reliance on recruitment of graduates and poaching from rivals has left many companies without the drive to train within the ranks. And it is mid-career training which will be an essential part of industry's attempts to ensure enough skilled IT people come through.

Government statistics show the IT skills situation is already desperate. Around 30 000 unfilled vacancies exist at any one time, compounded by a reluctance among technology graduates to enter industry. Falling numbers of young people into the 1990s, the rapid pace of technological development and demands from an increasing range of companies for IT recruits are all factors adding to the problem.

Last December the House of Commons Trade and Industry Committee released its first report on information technology. Although the published findings contained only two paragraphs on the training issue, the committee's position was clear. "The best solution to the worsening IT skills shortage is increased in-service training," says the report. "Companies need to invest more in training. Time and again our witnesses referred to the need for professional management retraining on a sustained basis."

The committee heard testimony that the UK's training record is inferior to its international rivals. The present training gap is blamed on cutbacks during the recession earlier this decade and high staff turnover deterring investment. But UK companies still fall below the minimum level of spending on training. "Best practice is for four to five per cent of payroll costs being spent on growing management competence while the UK average is only one per cent," says the report.

Evidence was provided by the Secretary of State for Industry that companies are now putting more cash into training, but the committee wants more proof that the "revolution in attitude" has taken place.

Two recommendations were made by the committee about IT training:

- that Government compile and publish comparative figures and trends in the UK and competing countries for expenditure (in terms of both money and time) by industry in training both in IT skills and in management generally;
- that investment in training should be disclosed in company accounts.

The report was broadly welcomed by both trade bodies and companies, such as the Electronic Engineering Association and Hewlett Packard. But one of the committee's witnesses complained that the training recommendations did not go far enough. "We would have liked to have seen the disclosure of training costs recommended to a standard formula; say, training as a percentage of turnover," said Tim Webb, national officer for the Manufacturing, Science and Finance Union. "It would also have been helpful for more to have been said about employee rights to re-training, as a part of the contract of employment."

Webb and MSF have campaigned for over a year to get companies to sign a model agreement which guarantees in-service training, so far without much success. Other unions have tried less publicly than MSF to get ink on similar agreements, with similar results.

Reluctance by companies to pledge themselves to training, betrays a common fear over commitment to an investment always seen as disposable in hard times. The spread of IT throughout the economy could change this. Sectors such as retailing and financial services are pitching for IT and communications specialists with competitive salaries. Companies will be forced into training just to survive.

Responsive, not reactive

Companies often fail to plan for manpower needs during technology cycles and so suffer a skills crisis, according to a leading training company.

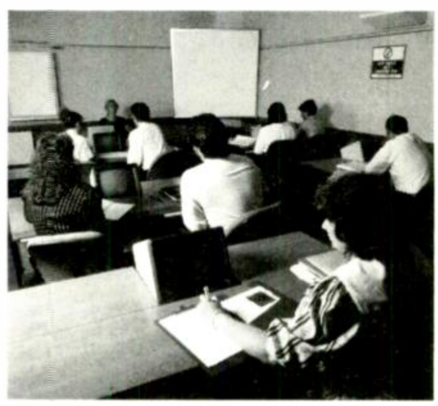
"Lots of companies are not geared to forward planning and then technology moves faster than the minds of people planners", said Howard Wright, general manager of BOC Training Services in west London. "When a company buys a system, say an IBM or Amdahl box, it should last about five years. During that time future training should be planned, but often the technology is here before we know it and training becomes reactive."

BOC can train between 1500 and 2000 people a year, with extra provision on a client's site. Communications, networks and data processing are all areas covered in the courses. Particular emphasis is given to local area networks, operating systems, structured programming methodology and systems analysis. This indicates where future skill demands will lie.

Evidence that IT has spread throughout the economy is contained in BOC's client base. One hundred people at Trent Water Board were trained in AS, an uncommon computer language. British Gas in Croydon ran two computer groups, mixing experienced staff with graduates through BOC.

Rothmans, Sainsbury's and Eagle Star go to BOC, alongside high-tech companies such as Apricot and Ferranti.

Most of the people tutored by BOC are experienced technical staff who need to be reskilled to meet the fresh IT demands on their employers. Wright believes that encouraging signs are coming through that industry and commerce are grooming personnel specialists to plan IT training more coherently



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BSX60	1.25
BT100A/02	0.85
BT106	1.49
BT116	1.20
BT119	3.15
BT120	1.65
BU105	1.95
NU108	1.69
BU124	1.25
BU125	1.25
BU126	1.60
BU204	1.55
BU205	1.30
BU208	0.95
BU208A	1.15
BU208D	1.35
BU326	1.20
BU326S	1.50
BU407	1.24
BU408	1.50
BU426A	0.75
BU500	2.25
BU508A	1.95
BU526	1.90
BU807	2.25
BUY20	2.15

BUV41	2.50
GET111	2.50
GEX542	9.50
MJ3000	1.98
MJE340	0.40
MJE350	0.75
MJE520	0.48
MJE2955	0.95
MPSA13	0.29
MPSA92	0.30
MRF237	4.95
MRF450A	15.95
MRF453	17.50
MRF454	26.50
MRF455	17.50
MRF475	2.95
MRF477	14.95
MRF479	5.50
OC16W	2.50
OC23	9.50
OC25	1.50
OC26	1.50
OC28	5.50
OC29	4.50
OC32	5.50
OC42	1.50
OC44	1.25
OC45	1.00
OC70	1.00
OC71	0.75
OC72	2.50
OC75	1.50
OC81	1.00
OC84	1.50
OC139	12.50
OC171	4.50
OC200	4.50
OC201	5.50
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R2008B	1.45
R2009	2.50
R2010B	1.45
R2322	0.58
R323	0.66
R2540	2.48
RCA16029	0.85
RCA16039	0.85
RCA16181	0.85
RCA16334	0.90
RCA16335	0.85
RCA16572	0.85
S2060D	0.95
SKE5F	1.45
T6021V	0.45
T6027V	0.45
T6029V	0.45
T6036V	0.55
T9002V	0.55
T9011V	0.75
T9015V	2.15
T9034V	2.15
T9038V	3.95
THY15/80	2.25
THY15/85	2.25
TIP29	0.40
TIP29C	0.42
TIP30C	0.43
TIP31C	0.55
TIP32C	0.42
TIP33C	0.95
TIP34B	0.95
TIP41A	0.45
TIP41C	0.45
TIP42C	0.47
TIP47	0.65
TIP48	0.65
TIP50	0.65
TIP120	0.60

TIP125	0.65
TIO142	1.75
TIP146	2.75
TIP161	2.95
TIP2955	0.80
TIP3055	0.55
TIS91	0.20
TV106	1.50
TV106/2	1.50
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2N1100	6.50
2N1308	1.35
2N1711	0.30
2N2219	0.28
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2N2905	0.40
2N3053	0.40
2N3054	0.59
2N3055	0.52
2N3702	0.12
2N3703	0.12
2N3704	0.12
2N3705	0.20
2N3706	0.12
2N3708	0.12
2N3733	9.50
2N3773	2.75
2N3792	1.35
2N4280	3.50
2N4427	1.95
2N4444	1.15
2N5294	0.42
2N5296	0.48
2N5298	0.60
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2N5496	0.95
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2N5643	16.50
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2SA715	0.55
2SC495	0.80
2SC496	0.80
2SC784	0.75
2SC785	0.75
2SC789	0.55
2SC931D	0.95
2SC937	1.95
2SC1034	4.50
2SC1096	0.80
2SC1106	2.50
2SC1124	0.95
2SC1162	0.95
2SC1172Y	2.20
2SC1173	1.15
2SC1306	1.75
2SC1364	0.50
2SC1413A	2.50
2SC1449	0.50
2SC1628	0.75
2SC1678	1.50
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AN316	3.95
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AN7140	3.50
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AN7145M	3.95
AN7150	2.95
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CA3086	0.46
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LA4422	1.50
LA4430	2.50
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LC7130	3.50
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LC7137	5.50
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SAA5020	5.75
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SAS570S	1.75
SAS580	2.85

SAS590	2.75
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SL1327	1.10
SL1327Q	1.10
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SN7421	0.85
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SN76115N	1.25
SN76131N	1.30
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SN76227N	1.05
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SN76533N	1.65
SN76650N	1.15
SN76660N	0.90
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TA7129P	2.50
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TA7204P	2.15
TA7205AP	1.15
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TA7227P	4.25
TA7228P	1.95
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TA7314P	2.95
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TA7629	2.50
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TAA350A	1.95
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TBA396	0.75
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TBA480Q	1.95
TBA510	2.50
TBA510Q	2.50
TBA520	1.10
TBA520Q	1.10
TBA530	1.10
TBA530Q	1.10
TBA540	1.25
TBA540Q	1.35

TBA550Q	1.95
TBA560C	1.45
TBA560Q	1.45
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TDA1010	2.15
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TDA2160	2.50
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TDA2532	1.95
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TDA2541	2.15
TDA2560	1.15
TDA2576	4.50

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TDA3310	2.95
TDA3510	3.50
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TDA9503	3.15
TEA1009	1.35
UPC41C	3.50
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UPC1032H	0.95
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UPC1181H	1.25
UPC1182H	1.50
UPC1185H	3.95
UPC1191V	1.50
UPC1350C	2.95
UPC1353C	2.45
UPC1360	2.95
UPC1365C	3.95
UPC2002H	1.95
UPD2114LC	2.50
555	0.35
556	0.60
723	0.50
741	0.35
747	0.50
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7808	0.50
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BA145	0.16
BA148	0.17
BA154	0.06
BA156	0.15
BA157	0.30
BA244	0.75
BA301	0.75
BA302	0.85
BA313	0.75
BA318	2.95
BA328	2.95
BA521	1.75
BAV21	0.30
BAW62	0.19
BAX13	0.04
BAX16	0.12
BB105B	0.30
BT151	0.79
BY126	0.10
BY127	0.11
BY133	0.15
BY164	0.45
BY176	1.20
BY179	0.63
BT182	0.55
BY184	0.35
BY187	0.45
BY199	0.40
BY206	0.14
BY208-800	0.33
BY210-800	0.33
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BY298-400	0.22
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BYX10	0.50
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M24.122WA	55.00
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M31 184W	55.00
M31 190GR	45.00
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DET23	35.00
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DF91	1.50
DF92	1.50
DF96	1.25
DF97	1.25
DG10A	8.50
DH63	1.50
DH77	0.90
DK91	1.20
DK92	1.50
DL35	2.50
DL63	1.00
DL70	2.50
DL73	2.50
DL91	3.95
DL92	1.50
DL93	1.50
DLS10	13.50
DLS16	10.00
DM70	5.25
DM160	6.50
DOD-006	79.50
DY51	1.50
DY86/87	0.85
DY802	0.85
E55L	49.50
E80CC	19.50
E80CF	12.50
E80F	18.50
E80L	29.50
E81CC	5.50
E81L	12.00
E82CC	4.50
E83CC	4.50
E83F	5.50
E86C	9.50
E88C	7.95
E88CC	3.50
E88CC-01	6.95
E88CC MULLARD	4.95
E90CC	7.95
E90F	7.95
E91H	4.50
E92CC	3.95
E99F	6.95
E130L	18.50
E180CC	10.50
E180F	6.50
E182CC	9.00
E186F	8.50
E188CC	7.50
E235L	12.50
E280F	19.50
E283CC	12.00
E288CC	17.50
E810F	25.00
E1148	1.00
EA50	1.00
EA52	55.00
EA76	1.95

EA79	1.95
EABC80	1.50
EAC91	2.50
EAF42	1.20
EB34	1.50
EB41	3.95
EB91	0.85
EBC33	2.50
EBC41	1.95
EBC81	1.50
EBC90	1.95
EBC91	1.95
EBF80	0.95
EBF83	0.95
EBF89	0.95
EBF93	0.95
EBL1	4.50
EBL21	4.50
EC52	0.75
EC70	1.75
EC81	7.95
EC86	1.95
EC88	1.95
EC90	1.95
EC91	5.50
EC93	1.50
EC95	7.00
EC97	1.10
EC8010	12.00
ECC32	3.50
ECC33	3.50
ECC35	3.50
ECC81	1.50
ECC81 SPECIAL QUALITY	2.25
ECC82	0.85
ECC82 PHILIPS	1.95
ECC83	0.95
NEW ECC83 SPECIAL Low cross coupling, Low noise, Low microphony	£3.50
ECC83 BRIMAR	2.15
ECC83 PHILIPS	1.95
ECC83 SIEMENS	2.50
ECC85	1.50
ECC86	2.75
ECC88	1.35
ECC89	1.50
ECC91	2.00
ECC189	2.50
ECC801S	6.95
ECC803S	6.95
ECC804	0.60
ECC2000	7.95
ECF80	1.15
ECF82	1.50
ECF86	1.70
ECF200	1.85
ECF202	1.85
ECF801	0.85
ECF804	6.50
ECF805	2.50
ECF806	10.25
ECH3	4.50
ECH4	4.50
ECH35	3.50
ECH42	1.50
ECH81	1.75
ECH83	1.50
ECH84	1.00
ECH200	1.50
ECL80	0.60
ECL82	1.00
ECL83	2.50
ECL84	1.00
ECL85	0.95
ECL86	1.50
ECL805	0.95
EF37A	2.50
EF22	3.50
EF39	1.50
EF40	4.50
EF42	3.50
EF50	2.50
EF54	4.50
EF55	4.95
EF70	1.20
EF72	3.50
EF73	1.50
EF80	0.55
EF83	3.95
EF85	0.85
EF86	2.50
EF86 MULLARD	4.50
EF86/CV4085	5.00
EF89	1.50
EF91	195
EF92	2.15
EF93	1.50
EF94	1.50
EF95	1.95
EF97	0.90

EF98	0.90
EF183	0.75
EF184	0.85
EF731	4.50
EF732	4.50
EF800	11.00
EF804S	19.50
EF805S	25.00
EF806S	25.00
EF812	0.65
EFL200	1.50
EFP60	3.50
EH90	0.72
EK90	1.50
EL32	0.95
EL33	5.00
EL34	3.25
EL34 MULLARD	6.50
EL34 SIEMENS	4.50
EL36	2.50
EL36 MULLARD	3.95
EL38	9.00
EL41	3.50
EL42	2.00
EL71	4.50
EL81	6.95
EL83	7.50
EL84	0.95
EL84 MULLARD	4.50
EL84 SIEMENS	2.50
EL85	4.50
EL86	1.75
EL90	1.75
EL91	6.00
EL95	1.75
EL152	15.00
EL360	6.75
EL500	1.95
EL504	1.95
EL506	5.95
EL509	5.25
EL509 MULLARD	7.50
EL519	6.95
EL802	3.65
EL821	6.95
EL822	12.95
ELL80	22.50
EM34	12.50
EM80	1.65
EM83	1.65
EM84	1.65
EM85	3.95
EM87	2.50
EN32	15.00
EN91	2.25
EN92	4.50
EY51	0.80
EY70	7.50
EY81	2.35
EY82	1.15
EY83	1.50
EY84	5.95
EY86/87	0.65
EY88	0.95
EY91	5.50
EY500A	1.95
EY802	0.70
EZ35	1.00
EZ40	3.50
EZ41	3.50
EZ80	0.75
EZ81	0.75
EZ90	1.50
FW4 800	4.50
G55/1K	9.00
G180/2M	6.95
G240/2D	9.00
GC10B	17.50
GC10D	17.50
GC10/4B	17.50
GC10/4E	17.50
GC12/4B	17.50
GD86W	6.00
GDT120M	5.00
GN4	6.00
GN10	15.00
GR10G	4.00
GS10C	16.50
GS10H	12.00
GS12D	12.00
GT1C	14.00
GU20	35.00
GU50	17.50
GXU1	13.50
GXU3	24.00
GXU50SS	14.50
GY501	1.50
GY802	1.50
GZ32	2.50
GZ33	4.50
GZ34	2.50
GZ37	4.50
HBC90	1.95
HL41	3.50
HL90	3.50
KT8C	7.00
KT33C	3.50
KT36	2.95
KT44	5.95
KT45	5.95
KT61	5.00

KT63	2.00
KT66 USA	11.95
KT66 GEC	25.00
KT66 TEONEX	5.00
KT67	9.00
KT77 GEC	11.95
KT81	7.00
KT88 USA	12.95
KT88 Selectron	15.00
KTW61	2.50
KTW62	2.50
KTW63	2.00
KTZ63	2.50
LB7-20	95.00
LS9B	6.95
M508	195.00
M5143	155.00
M5199	295.00
M8079	6.00
M8082	7.50
M8083	3.25
M8091	7.50
M8096	3.00
M8098	5.50
M8099	5.00
M8100	5.50
M8136	7.00
M8137	7.95
M8161	6.50
M8162	5.50
M8163	5.50
M8190	4.50
M8195	6.50
M8196	5.50
M8204	5.50
M8223	4.50
M8224	2.00
M8225	3.95
ME1400	3.50
ME1401	29.50
ME1402	29.50
MHLD6	4.00
MP25	195.00
MS4B	5.50
MU14	3.50
N37	12.50
N78	9.85
OA2	1.50
OA2WA	2.50
OA3	2.50
OB2	1.50
OB2WA	2.50
OC3	2.50
OD3	2.50
OM4	2.50
OM5B	3.00
OM6	1.75
ORP43	2.50
ORP50	3.95
P61	2.50
P41	2.50
PABC80	0.95
PC86	0.75
PC88	0.75
PC97	1.10
PC900	1.25
PCC84	0.40
PCC85	0.55
PCC88	0.70
PCC89	0.70
PCC189	0.70
PCC805	0.70
PCC806	0.80
PCE82	0.80
PCF80	0.65
PCF82	0.60
PCF84	0.65
PCF86	1.20
PCF87	1.25
PCF200	1.80
PCF201	1.80
PCF801	1.35
PCF802	0.85
PCF805	1.25
PCF806	1.00
PCF808	1.25
PCH200	1.50
PCL82	0.85
PCL83	2.50
PCL84	0.75
PCL85	0.80
PCL86	0.85
PCL805	0.90
PD500	5.95
PE1-100	69.00
PEN25	2.00
PEN40D	3.00
PEN45	3.00
PEN45DD	3.00
PEN46	2.00
PFL200	0.95
PL36	1.75
PL38	1.50
PL81	1.25
PL82	0.60
PL83	0.52
PL84	0.78
PL500	1.25
PL504	1.25
PL508	1.50
PL509	4.85
PL519	4.95
PL802	6.00
PL802T	3.50
PL820	2.95
PY32	0.60
PY33	0.50
PY81	0.70
PY82	0.70
PY83	0.70

PY88	0.65
PY500A	1.95
PY800	0.85
PY801	0.85
QB3-300	72.00
QB3-1750	139.00
QB5-3500	595.00
QQE02-5	19.50
QQE03-12	7.95
QQE03-20	35.00
QQE06-40	45.00
QQV02-6	19.50
QQV03-10	5.50
QQV03-10 MULLARD	15.00
QQV03-20	25.00
QQV06-40A	27.50
QQV06-40A MULLARD	39.50
QQV07-50	55.00
QQZ03-20	42.50
QQZ06-40	45.00
QS75/20	1.50
QS95/10	4.85
QS108/45	4.00
QS150/15	6.95
QS150/30	1.15
QS150/40	7.00
QS1205	3.95
QS1213	5.00
QU37	9.50
QV03-12	6.50
QV05-25	2.50
QV06-20	29.50
QV08-100B	145.00
QY3-125	85.00
QY4-250	85.00
QY4-400	95.00
R10	4.00
R18	2.50
RG1-240A	14.50
RG3-250A	6.50
RG3-1250A	35.00
RR3-250	15.00
RR3-1250	35.00
S11E12	38.00
S104-2K	10.00
SC1/1300	6.00
SP61	3.50
STV280/40	11.95
TB2-5/300	95.00
TB2-300	195.00
TB3-750	115.00
TB3-2000	450.00
TBL2-300	395.00
TBL2-500	495.00
TD03-10/D/E/F	35.00
TT15	45.00
TT21	45.00
TT22	39.50
TT100	69.00
TY2-125A	85.00
TY4-400	85.00
TY7-6000A	600.00
TY8-600W	365.00
U19	9.50
U26	0.90
U35	3.50
U37	9.00
U41	6.95
U50	2.00
U82	3.00
U191	0.70
U192	1.00
U193	1.00
U251	2.50
U801	3.50
UABC80	1.00
UAF42	1.95
UBC41	3.95
UBC81	1.50
UBF80	0.95
UBF89	1.00
UBL21	1.75
UC92	1.20
UCC84	0.70
UCC85	0.60
UCF80	1.00
UCH21	2.50
UCH41	2.50
UCH42	3.95
UCH81	1.00
UCL82	1.75
UCL83	2.50
UF41	2.25
UF42	2.25
UF80	1.75
UF85	1.20
UF89	2.00
UL41	10.00
UL44	3.50
UL84	1.50
UL85	0.85
UU5	3.50
UU6	6.00
UU7	8.00
UU8	9.00
UY41	3.50
UY85	0.70
V235A/1K	250.00
V238A/1K	295.00
V246A/1K	250.00
V246A/2K	315.00

V241C/1K	195.00
V453	12.00
VLS631	10.95
VP4B	9.50
VP41	4.95
VR101	2.50
VR105/30	2.50
VR150/30	2.50
VU39	2.50
W21	4.50
W61	4.50
W77	5.00
W81M	4.50
W739	1.50
X24	4.50
X41	4.50
X66/X65	4.95
X76M	1.95
XC24	1.50
XC25	0.50
XFW47	1.50
XFW50	1.50
XG1-2500	75.00
XL628FT	7.50
XNP12	2.50
XR1/1600A	49.50
XR1/3200A	79.50
XR1-6400A	149.50
Y65	6.95
YD1100	75.00
YJ1060	265.00
YL1020	42.50
YL1060	195.00
YL1070	195.00
YL1071	195.00
YL1290	65.00
Z77	1.20
Z300T	6.00
Z302C	12.00
Z359	9.00
Z520M	4.00
Z700U	9.50
Z759	19.85
Z803U	18.95
ZA1000	12.50
ZA1001	1.50
ZM1001	12.00
ZM1005	8.00
ZM1020	6.00
ZM1021	8.00
ZM1023	7.95
ZM1041	14.00
ZM1082	9.00
ZM1084	10.00
ZM1175	6.50
ZM1177	9.00
ZM1202	55.00
ZM1263	4.00
1A3	4.50
1AE4	3.50
1AX2	3.50
1B22	10.00
1B27	55.00
1B3GT	1.95
1B35A	45.00
1B63A	75.00
1K3	2.50
1N5GT	2.50
1P28	25.00
1R5	1.50
1S5	1.50
1T4	1.50
1U4	1.75
1U5	1.50
1X25	2.50
2A3	16.50
2AS15A	11.50
2B7	4.50
2B22	69.50
2C36	70.00
2C39A	32.50
2C39BA	39.50
2C40	37.00
2C42	29.50
2C43	60.00
2C51	2.50
2CY5	1.50
2D21	2.25
2D21W	3.15
2E22	49.00
2E26	7.95
2J55	295.00
2K25	49.50
2K26	95.00
2K29	250.00
2K48	140.00
2K56	250.00
2X2A	5.00
3A/107B	12.00
3A/108A	9.00
3A/109B	11.00
3A/110B	12.00
3A/141K	11.50
3A/146J	7.50
3A/147J	7.50
3A/167M	10.00
3A3A	3.95
3A4	1.50
3A5	4.50
3AT2	3.35
3B22	25.00
3B26	24.00
3B28	15.00
3BZ6	1.50
3C45	39.50
3CX3000A7	650.00
3CYS	1.50
3D21A	29.50

3E22	49.50
3E29	39.50
3EJ7	1.95
3H	0.40
3J.170E	1450.00
3L	0.40
3Q4	2.50
4-65A	75.00
4-250A	85.50
4-400C	87.50
4-1000A	425.00
4B32	35.00
4BQ7A	1.75
4BZ6	1.95
4C28	25.00
4C35	145.00
4CS250R	285.00
4XC125C EIMAC	150.00
4CX250B	45.00
4CX250BM	65.00
4CX250K EIMAC	115.00
4CX250R AMPEREX	125.00
4CX350A	100.00
4CX1000A	425.00
4CX1500B	475.00
4CX5000A	1000.00
4D21/4-125A	85.00
4D32	125.00
4E27A	125.00
4GS7	2.25
4GV7	2.25
4J6A	2.95
4KT6	1.50
4TB5P	150.00
4X150A	35.00
4X150D	55.00
4X500A	350.00
5A/102D	9.50
5A152M	9.00
5A163K	10.00
5A170K	6.25
5A-180M	9.00
5A-206K	10.00
5B-110M	10.00
5B-254M	14.50
5B-255M	14.50
5B-256M	15.00
5B-257M	15.00
5B258M	14.50
5C22	125.00
5CL8A	2.50
5J180E	1950.00
5JL8	2.95
5R4GB	5.50
5R4GY	4.95
5R4WGY	5.95
5T4	5.95
5T8A	1.95
5U4G	4.50
5U4GB	4.50
5V4G	2.50
5W4	4.95
5X4	4.95
5Y3GT	2.50
5Z3	4.50
5Z4G	2.50
6/30L2	0.70
6A/203K	9.00
6A7	4.95
6A8	2.50
6AB7	4.50
6AC7WA	2.00
6AG5	2.50
6AG7	2.50
6AH6	3.50
6AJ4	3.50
6AJ7	2.00
6AK5	1.95
6AK6	2.50
6AL5	0.85
6AM4	3.25
6AM5	6.00
6AM6	1.95
6AN5	4.50
6ANBA	4.50
6AQ5	1.75
6AQ8	1.50
6AR5	8.95
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	1.95
6AT8	1.75
6AU4GT	2.95
6AU5GT	4.50
6AU6	0.95
6AV6	1.95
6AW8A	3.50
6AX4GT	1.95
6AY3B	1.95
6AZ8	4.50
6B8G	2.50
6B10	1.95
6BA6	1.50
6BA7	4.50
6BA8A	3.50
6BC8	1.50
6BR3	2.95
6BE6	1.50
6BG6G	3.00
6BH6	1.95
6BH8	1.50
6BJ6	1.50

6BK4	6.50
6BL6	85.00
6BL8	1.15
6BM6	115.00
6BN6	1.65
6BN8	3.95
6BQ5	1.35
6BQ7A	1.50
6BR7	4.95
6BS7	5.50
6BW6	5.35
6BW7	1.50
6BZ6	2.50
6BZ7	2.95
6C4	1.95
6C5	2.50
6C6	3.50
6C8G	2.50
6C9	4.95
6CA4	4.95
6CA7	3.50
6CB5	3.95
6CB6	2.35
6CD6GA	4.50
6CF6	1.95
6CG7	4.50
6CH6	6.95
6CL6	3.25
6CL8A	2.95
6CM7	2.95
6CS6	0.75
6CS7	0.95
6CW4	8.00
6CX8	3.95
6DC6	2.35
6DJ8	1.35
6DJ8 SPECIAL	3.50
6DK6	1.50
6DQ5	8.50
6DQ6B	2.50
6DT6A	1.50
6DW4B	3.50
6E5	3.95
6EA7	2.50
6EA8	2.50
6EB8	3.50
6EJ7	0.85
6EM5	2.50
6EM7	2.50
6EU8	1.75
6EV7	2.95
6EW6	1.50
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	10.50
6FH5	8.50
6FH8	15.00
6FL2	4.50
6FQ7	4.50
6GE5	3.95
6GH8A	2.50
6GJ7	0.85
6GK6	3.95
6GM6	2.65
6GS7	21.5
6GV8	0.95
6GW8	2.50
6GY5	4.95
6GY6	2.50
6H1	9.50
6H6GT	2.50
6HB7	1.95
6HF8	3.50
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	9.50
6JE6C	9.50
6JM6	9.50
6JU8A	2.50
6JS6C	9.50
6K7G	2.00
6K8G	3.00
6KD6	9.50
6KG6A	6.95
6L1	2.50
6L6GC	3.50
6L6GC USA	9.50
6L6GT	3.50
6L7	3.50
6L15	3.15
6L19	3.95
6L18	2.50
6LD20	1.15
6LF6	11.50
6LQ6	9.50
6P28	2.00
6Q7GT	1.50
6R7	3.15
6RHH8	10.00
6S4A	1.95
6SA7	1.95
6SC7	1.95
6SH7	1.95
6SJ7GT	1.95

6SK7	1.95
6SL7GT	1.95
6SN7GT	1.95
6SQ7GT	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
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
10D2	1.25
10DE7	2.50
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Alvey management criticised – again

The Public Accounts Committee, a parliamentary watchdog made up of back-bench MPs which monitors how well Government spends the taxpayers' money, has heavily criticised the management of the Alvey Programme. In a report published in December the Committee says* that effectiveness of the Alvey Programme may have been hindered by an initial lack of technical and clerical support staff, and that the absence of information as to actual costs of projects until the fourth year of the Programme made sound financial planning impossible. In addition, the Committee pointed to an unsatisfactory "hands-off" management style.

The first (and last!) Alvey Programme was established in 1983 with three primary objectives; to rectify a serious and deteriorating balance of trade in IT products (then a deficit of £836 million), to improve collaboration between academic institutions and industry, and to target r&d spending into areas where a return in investment in r&d was likely. To realise these objectives, the Government were to supply £200 million and industry a further £150 million.

> **"Nearly 50% of the Alvey contribution came from just five firms."**

According to the Report, the only objective actually realised was the bringing together of academia and industry. This was despite "severe delays" resulting from the Alvey Directorate's narrow view that its role was to concentrate on contractual relationships between participants. In short, the Committee complained that too little was done by the Directorate, to assist potential collaborators in exploring possible research topics before the contractual stage.

As a result, the Report states that Alvey became dominated by the large electronics firms who regularly contract with Government (i.e. those companies that were in a position to be 'in the know'). Thus, the top five participating firms in the Programme accounted for nearly 50% of the total of the 428 'participations', and the small firms, who were expected to exploit quickly the results of the research (and to justify Alvey in an economic series), were absent from many projects.

The Committee was not convinced that the other objectives of the Programme were met. It withheld judgement on the technical merits of the research, and its subsequent exploitation, until the Government's final report on Alvey due in 1990, (although readers will be aware of Rob Morland's optimistic report in January's issue of *Electronics & Wireless World*), while in an appendix, the Committee noted that the latest trade figures put the current IT trade deficit at £942 millions.

In conclusion, the carefully phrased Report highlights several shortcomings of the management of the Alvey Programme. It also recognises that new ground had to be broken, and that some of the errors made were the cost of climbing up the inevitable learning curve. However, the Committee leaves the impression that if these lessons are not applied to ESPRIT and other EEC collaborative projects, the next report will not be so measured or restrained.

* 51st Report from the Committee of Public Accounts, The Alvey Programme of Advanced Information Technology, HC 477, £5.10, published by HMSO.

Moulded-on plug – no shocks, no surprises

Impoverished readers of Electronics and Wireless World have no fear: Eric Forth, Minister of State responsible for technology and consumer affairs, has decided not to force industry to fit moulded-on plugs on the electronics equipment or domestic appliances you buy.

The issue arose on the floor of the House before Christmas, when concerned MPs suggested that the time was right for the UK to fall in with the rest of Europe and ensure that all electronic and domestic equipment was sold with moulded-on plugs. This would help the old and disabled, who have difficulties in fitting plugs, to use their electrical appliances in a safe manner. Safety was very important, MPs added, because the UK is one of the few countries that allows an unqualified electrician to practice.

The Minister dismissed such concerns. The Government was against compulsion and regulation in principle, and felt that making moulded-on plugs compulsory would "give rise to problems, perhaps among people on low incomes". In addition, the Minister pointed out, between 5% and 10% of the population still use round pin plugs and the proposed change would discriminate against them.

In fact, the Minister's argument makes the safety argument more pressing. People on low income are likely to purchase second hand equipment and moulded plugs should begin to identify outdated equipment; if 5% to 10% of the population do have the old round pin plugs, Government statistics show that between 3 to 6 million people use wiring daily that is at least 25 years old.

City technology colleges

City Technology Colleges (CTCs), one of the Government's brightest hopes in the educational field, are in trouble. Despite the technological bias in their curriculum, and their popularity with parents, CTCs have failed to succeed in the way the Government had originally hoped. The reason is simple; CTCs are proving deeply unpopular with local education authorities of all political persuasions, with the result that private sponsors are wary of making donations.

Supporters of CTCs point to the fact that much private money (over £31 million pledged so far) is already involved, and that any public funding (currently about £86 million) is additional money that the Government has found for the CTC initiative. Consequently, the Government argues that the financial impact of CTCs on education authorities is minimal, that private sponsorship brings in new money, that CTCs improve parental choice, and that the institution itself should help alleviate future technological skill shortages. Given all these advantages, the Government naturally thinks that it is on to a winner.

However CTCs are independent of education authorities. Thus, in an era of falling school rolls, where rationalising of schools and facilities is inevitable, the establishment by Government of an extra school in a locality can fundamentally affect an authority's long-term educational strategy. In addition, a CTC offering improved salaries and conditions, pupils selected for their commitment, supportive parents and modern equipment, will attract the scarce skilled technical teachers away from the authority. In short, many authorities believe that the CTCs exacerbate existing problems, and in one case, a conservative authority (Trafford near Manchester), used these arguments to refuse to convert an old grammar school into a CTC.

Several opposition MPs have been quick to speak of bias. Max Madden, a Labour Bradford MP, contrasted the Government's intention to spend £8 million on a selective CTC in Bradford, with the cutting of £200,000 from the budget of Bradford's Technical College by the controversial Conservative Council. Paddy Ashdown, for the Democrats, has complained that the limit of £16 million spent by the Government on three CTCs compares badly with the total £6.8 million available to all 845 schools in the same catchment areas as the CTCs.

As a result, CTC sponsoring has become a political act. Many private sponsors are worried that good intentions could easily be misunderstood by the local community. Several large companies, for example IBM, BP and ICI, have preferred to keep their hands in their pockets, and work instead through existing education authorities.

Technical training – who pays

Producing trained electronics engineers is expensive and the employer should foot a large part of the bill. That, coupled with the instinct to minimise the burden on the taxpayer, is the essence of Government policy towards technical training. As a result of recent statements, the Parliamentary pace has increased and the issue of 'who pays' has become part of a much wider political debate.

This was obvious from the debates surrounding the Queen's Speech, when Gordon Brown, a member of the shadow cabinet, referred to an "investment gap" in training and R&D. He said that if the UK spent the same percentage of national income as did the French, it would have spent £4 000 more per worker on training and research. In Germany that sum would have been £6 000; in Italy £7 000, and in Japan the figure would be an additional £20 000 per worker. Brown said that the "gap" has put UK high-technology industries at a serious disadvantage, and that "we end the 1980's with a training and skills position that is well below our competitors."

Concern at the skills shortage is not limited to one side of the House. In the debates, Kenneth Warren (the conservative MP who is also chair of the Select (all party) Committee investigating the information technology industry), noted that a CBI survey in 1987 shows 15% of firms experiencing a shortage of skilled staff and, despite the obvious financial incentives, one quarter of engineering courses are not taken up. By 1992, Warren remarked, the Japanese will have seven times as many qualified engineering graduates as the UK.

The Government's policy derives from its primary concern that re-training should maximise the number of jobs. Chancellor Nigel Lawson said in Washington in 1984 that Western Economies "should not be seduced by the wonders of high tech", as most of the jobs of the future will be "so much low-tech and no-tech" (i.e. labour-intensive services). Thus industry, the Government argues, has an important role in providing the basic training (schools, YTS etc.), and this leaves employers working within a free market environment to make business decisions to determine the advanced training needs of their staff. This policy objective allowed the Government to tell MPs that "it is primarily the responsibility of employers to meet their skill needs".

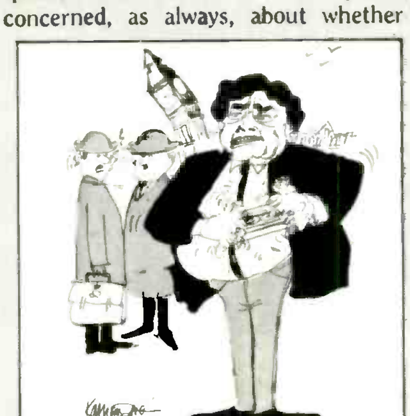
An exchange between two MPs from the high-tech town of Bristol, Dawn Primarolo (Lab) and Robert Haywood (Con), brought the different views into sharp focus. Primarolo commented that in Bristol there is a shortage of highly trained staff, and complained that the Government's training program tells people "how to clean and empty shelves", and not much else. Haywood, by contrast, defended the Government position, saying that it was the responsibility of management to train more and that "industry has the profits necessary to afford such training".

Thus technical training is part of the free market approach. The opposition parties say that this is nonsense, and public support for technical training is a worthy investment in the future wealth of the nation. In reply, the Government maintains that it has created the climate in which business can succeed and part of the price of that success is planning for the future market place. This in turn means private investment to train their staff in the skills for the future. Roughly translated; the employers get the bill.

Notes on the House is written by Chris Pounder.

Civil Servants and tape recorders

Nigel Lawson's problems with faulty tape recorders and a dozen journalists misreporting statements which were not 'misspoken' have worried MPs. They are concerned, as always, about whether Civil Servants are being properly trained, anxious that such things should not happen again.



Of course he knows how to use it – he had lessons from Nixon.

So questions on seemingly trivial issues were thick on the ground. Do Civil Servants recognise when tape recorders need servicing? Are training schemes available to assist Treasury Officials press the correct buttons? Who makes these unreliable machines? How many times have these machines failed to work before, or have tapes been lost?

As is the tradition with written questions, they must be factually answered. Even though there "are no records on the performance of tape recorders at briefings of journalists in 11 Downing Street", perhaps the answer lies in following the Government's market philosophy – the poorer hacks rely on public provision while lobby correspondents are advised to bring their own.

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Cellular growth problems

The extremely rapid expansion of UK cellular radio since the introduction of the Cellnet and Vodafone services in 1984, brought about in part by aggressive and sometimes misleading marketing by the competing retailers, has resulted in a substantial volume of complaints from users that they are not receiving the quality of service they had been led to expect. According to a survey by the Cellular Phone Users' Association, a pressure group campaigning for improved service and lower charges, problems can be experienced on up to 75% of calls, increasing costs to users by hundreds of thousands of pounds a year.

Both Cellnet and Vodafone are seeking to improve their services by setting up additional base stations, particularly in urban areas, and by providing extra channels to overcome congestion. I note, for example, that Vodafone has recently installed base-station antennas on the roof of the IBA building in Knightsbridge. Cellnet has some 400 active cells with a scheduled 50% annual increase. Nevertheless, the Users' Association believes that with increasing congestion the quality of service is likely to get worse before it improves.

For at least two years, business users have been complaining of what they regard as excessive costs involving the initial equipment, installation charges, standing charges and connection fees, in addition to the charges for both completed calls and the calls wasted when contact is lost.

Eavesdroppers

A few users of UHF/VHF mobile radiophones, both network and cellular, have become concerned at the growing availability of "scanning receivers", some covering frequencies up to over 1000MHz, that make it possible for "radio freaks" to intercept private calls. In South London, in a series of prosecutions, a group of five enthusiasts have been fined over £7000, plus £10 000-worth of equipment forfeited, for breaches of the Wireless Telegraphy Acts.

According to a report in *New Statesman and Society* "The case against the South London five began late in 1987 when radio monitors working for the DTI overheard group members exchanging details of 'interesting' frequencies by radio. For ten months thereafter, relays of DTI inspectors monitored and transcribed every word the five and their friends spoke on the air. . . Twenty officials had spied on the five and their friends, sometimes rising before 5 a.m. to do so. Finally, in July 1988, 25 police and DTI officers arrested the five in a co-ordinated series of heavy-handed raids." It appears that in this case, the over-zealous enthusiasts were monitoring the mobile networks of Government agencies, including MI-5, and were initially suspected of being "spies" or subversives.

In this connection, one cannot help feeling that few of the half-million users of "cordless" telephones are made aware of the risk of their calls being overheard by local radio listeners – not only those with receivers covering 1.6 to 1.8MHz but also, due to "image" reception, on ordinary broadcast sets.

European EMC Directive

The DTI continues to express reservations about the draft of the proposed European Community Directive on Electromagnetic Compatibility (EMC) and has been lobbying for further changes after the UK abstained from voting last October on the Directive as presented at the Internal Market Council meeting. On present timescales the Directive is due to come into force on 1 January 1992, with a transitional period in the event of non-completion of the necessary standards at the date of its implementation but with a deadline limited to 31 December 1992.

A point of some interest to the radio communications industry and to radio amateurs in particular is the interpretation of the latest form of Article 2, Paragraph 3 and Article 10 Paragraph 5: Radio Equipment.

Article 2 Paragraph 1 states that the EC Directive will apply "to apparatus liable to cause electromagnetic disturbance or the performance of which is liable to be affected by such disturbance"– a comprehensive description covering virtually all radio and electronic equipment. Paragraph 3, however, states: "Radio equipment used by radio amateurs within the meaning of Article 1, definition 53, of the Radio Regulations in the International Telecommunications Convention, is excluded from the scope of this Directive, unless the apparatus is available commercially."

This would seem to have the intention of excluding all home-built amateur transmitters, but apparently this is not the interpretation put on it by the DTI. They interpret it to imply that the Directive will apply "to all transmitters and receivers placed on the market and brought into service, including commercially available amateur apparatus. The only exception to this coverage is home-built amateur apparatus (though our interpretation is that the component part of the kit-built equipment would need to comply if on offer commercially). In addition most transmitters, but not receivers, will need to be type-tested by an independent accredited test-house. Only amateur transmitter apparatus which is commercially available will fall outside this requirement."

I hesitate to interpret the DTI's "interpretation" but, on the face of it, the notes provided by J.F.C. Ketchell of DTI's Radio Investigation Service suggest that virtually any home-built transmitter would need to be submitted for type-testing by an accredited test-house. This would inevitably be a costly process that would make it uneconomic to design and build a one-off experimental transmitter. This, surely, is not the intention of the EC Directive.

● The 8th International Zurich Symposium & Technical Exhibition on EMC is being held at Zurich, March 7 to 9. With three parallel streams the preliminary programme lists no less than 120 papers, two tutorial lectures (on March 6) and six Oper Meetings of URSI Commission E (also on March 6).

Morse at sea

The decision of the International Maritime Organization to endorse the recommendations of WARC-Mob 87 ("Radio Communications", *E&WW*, January 1988, page 93) and formally to mandate the push-button satellite Global Maritime Distress and Safety System (GMDSS), gradually phasing out the hand-morse distress service has been widely hailed as marking the beginning of the end of manual morse for maritime communications. Over the past few years, BTI have been closing most of their 500kHz coast stations, some after almost 80 years of service.

Even the Royal Navy, in which, since the adoption of RTTY, morse has continued to be used as the main fallback procedure for HF communications, has been publicizing its "low-speed diversity modem" developed during the 1980s at the Admiralty Research Establishment at Portsdown in conjunction with Redifon. According to an article "Farewell to Morse. . .?" in *DTE Spotlight*, June 1988, published by Defence Technology Enterprises Ltd, the technology of this patented modem is available for licensing through DTE.

This system is designed to achieve reliable HF communications under adverse propagation conditions and in the presence of co-channel interference, using seven-unit ASCII code with low data rates, frequency and time diversity in conjunction with an intelligent detection and decoding algorithm. The system was described at the 1985 "HF Communication Systems and Techniques" conference (*IEE Conference Publication No 245* "Comparison of 10bps modem with man-read morse"). But the parallel signals occupy a full 3kHz bandwidth compared with a few tens of hertz for manual morse at an equivalent transmission speed. The objective is to eliminate the need to train morse operators, accepting increased complexity.

Radio Communications is written by Pat Hawker.

Synchronizing the digits

Russian broadcast engineers are calling for co-ordinated efforts by broadcasting organizations and equipment manufacturers in many countries to establish a unified reference synchronizing signal for use in future digital television studio complexes. V.A. Khleborodov (Gosteleradio) in a paper "Signals for centralized synchronization in digital television" (OIRT's *Radio and Television* 1988/4) points out that following the adoption of CCIR Recommendation 601 as a universal component-digital standard and the introduction of digital videotape recorders using this 12:4:4 standard, broadcasters are now approaching the stage where digital television complexes are being planned.

Already, a variety of synchronizing signals have been used or proposed but Khleborodov argues that the choice of a unified reference signal should be made on the basis of broad-based and comprehensive technical and economic research.

The SMPTE experimental digital studio assembled in San Francisco in 1981 was synchronized by means of conventional "analogue" signals but SMPTE has since proposed a universal "component reference signal (CRS)" suitable not only for digital but also for analogue-component working, with one luminance and two chrominance signals. This is seen by Khleborodov as "not without shortcomings".

Analogue synchronizing signals were used in the first operational digital television studio, initially located in Rennes, France, and since relocated in Paris. For the experimental ITVA digital studio at Thames Television, a 4:2:2 video signal is fed directly to the video sources or to a special SPG which can be locked to the 4:2:2 signals. Khleborodov considers that this method would be uneconomical for major studio complexes partly because of the expensive transmission links that would be needed to transmit a full 4:2:2 digital stream over the distances involved.

The Russians have proposed to CCIR (Doc. 11 (USSR) CCIR, June, 1987) a "centralized digital synchronizing (CDS)" signal based on a 3.375MHz clock signal although needing two variants, one for 625/50 and the other for 525/60 systems. This is based on the premise that the clock frequency should be lower than the 27MHz clock frequency of the parallel video interfaces in order to facilitate distribution; it should also occupy the greater part of the line period to provide high phase stability of the generated clock frequencies of 6.75, 13.5, 27 and 243MHz. The applicability of the signal in analogue TV complexes hinges on the need to limit its bandwidth to 5 or 6MHz. It is claimed that an important advantage of the CDS signal for the timing of video sources is the simple realization of digital delay circuits in the decoder or coder: one IC with 64K memory can provide a delay of almost one field period.

It is admitted that a possible drawback is the need for two variants for 625/50 and 525/60 systems with consequent small differences between the respective coders and decoders, but it is pointed out that this does not rule out the possible use of a rather different concept based on a 2.25MHz clock which would overcome this problem.

MASCAM digital audio

Television Broadcast (April 1988, *E&WW*, page 409) drew attention to a digital stereo sound-in-sync system for broadcast television proposed by Russian engineers at the A.S. Popov research institute. This system reduced high-quality digital audio channels to 192kbit/s by making use of the Zwicker critical bands of hearing described in "Das Ohr als Nachrichtenempfänger" (The ear as a receiver of information) by E. Zwicker and R. Feldtkeller, published by S. Hirzel-Verlag (Stuttgart, 1967). Zwicker showed that there exist 24 audio sub-bands within which the most powerful component conceals (masks) adjacent, less powerful components, including noise, making them imperceptible to the ear.

These Zwicker critical bands also form the basis of MASCAM (Masking-pattern adapted subband coding and multiplexing) developed at the German broadcast research institute, IRT, and used in conjunction with the OFDM transmission system developed by CCETT (France) for the European Broadcast Union's demonstration of advanced digital techniques for UHF satellite sound broadcasting, at the WARC-ORB88 Conference in Geneva last September.

MASCAM reduces a high-quality audio channel, sampled at 32kHz, to 112kbit/s plus an additional 24kbit/s for the transmission of the associated scale factors. Each complete stereo channel, including error-protection bits, is assembled as a 256kbit/s multiplexed digital stream. In practice a number of such stereo channels would be further multiplexed for the CCETT digital modulation system for transmission via a satellite operating in the 1 to 3GHz range.

RDS pros and cons

The BBC will shortly extend the services provided by the VHF/FM RDS system to include an experimental traffic information service based on five local stations: Bedfordshire; Kent; WM (West Midlands); GLR (Greater London Radio); and Essex Radio. If the trials prove successful the system will be adopted throughout the BBC local radio network. Any car radio equipped with an RDS decoder, with its "traffic button" activated, will automatically retune to receive any traffic announcements made on the local stations regardless of which BBC FM station is being listened to (see also page 284).

However, it was evident at a recent IEE colloqium "The RDS system – its implementation and use" that it is likely to be many years before the full potential of the RDS system is taken up by listeners other than those with top-of-the-range car radios. BBC speakers stressed that they would like to see RDS decoders incorporated in most types of domestic and portable receivers, initially in high-quality tuners. Undoubtedly a major problem for battery powered portable receivers would be the extra power consumption of integrated decoders, amounting to some 25 to 35mA continuously throughout the period that RDS is in use.

Similarly, although RDS has been adopted by 24 of the 46 existing ILR companies and has already been implemented on 36 transmitters, there are still no dynamic data links between the studios and the encoders at the transmitter sites. This limits the service to PI (programme identification), PS (programme service name), AF (alternative frequency lists) and, shortly ON (other network). It would also be possible to transmit CT (clock time) but the motor industry is opposed to implementation on the grounds that most cars are already equipped with a clock. The IBA is anxious that the motor industry should voluntarily specify RDS radios as standard equipment.

Theo Kamalski of Philips at Eindhoven considered RDS from the viewpoint of the receiver manufacturers. While he stressed that "RDS has the potential to become very successful" he drew attention to several problems arising from the EBU specification, which he urged should be amended in some respects. The main practical problem is the occasional switching of receivers to an unwanted transmission due to multiple use of frequencies by broadcasters and inadequate specification for adjacent programmes. He noted there have also been some start-up problems due to incompletely equipped networks, incomplete AF lists and wrong PI codes. He considers that the highest priority should be given to the problem of adjacent programme specification which the car-radio maker cannot be expected to solve alone.

RDS was introduced by TDF throughout France in the autumn of 1987 including a radio-paging facility "Operateur" with a capacity for 300 000 subscribers. Some 300 encoders were delivered by the Swedish firm Teli Scandinavian. The pager provides selective calling and displays the telephone number to be called. In practice there is the problem that paging subscribers expect the system to work regardless of location and tend not to recognise that the low-level of RDS data modulation presents severe reception problems inside modern buildings.

Radio Broadcast is written by Pat Hawker.

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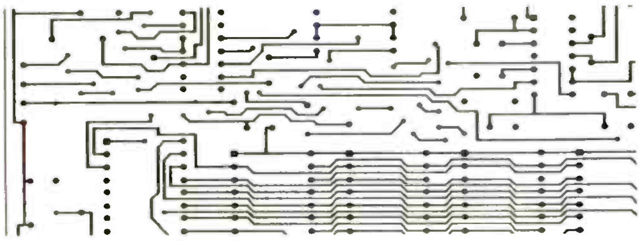

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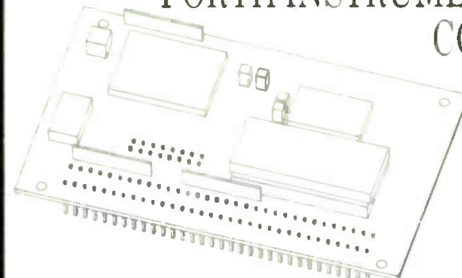

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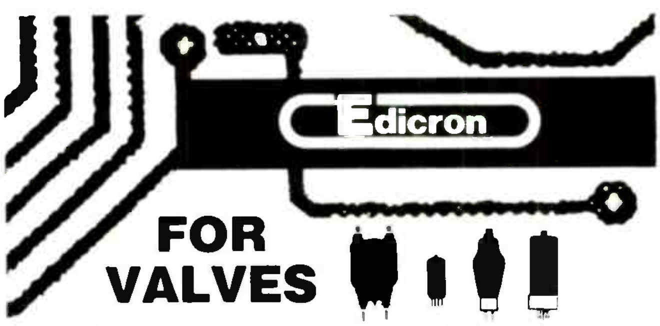

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Index to Volume 94 (1988)

Abbreviations: AS, Applications Summary; CI, Circuit Ideas; II, Industry Insight

Authors

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United States of America: Jay Feinman, Reed Business Ltd., 205 East 42nd Street, *New York*, NY 10017 – Telephone (212) 867 2080 – Telex 23827.

Printed in Great Britain by E.T. Heron (Print) Ltd, Crittall Factory, Braintree Road, Witham, Essex CM8 3QQ, and typeset by Graphac Typesetting, 181 191 Garth Road, Morden, Surrey SM4 4LL, for the proprietors, Reed Business Publishing Ltd, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. © Reed Business Publishing Ltd 1989. *Electronics and Wireless World* can be obtained from the following: AUSTRALIA and NEW ZEALAND: Gordon & Gotch Ltd, INDIA: A. H. Wheeler & Co, CANADA: The Wm Dawson Subscription Service Ltd., Gordon & Gotch Ltd, SOUTH AFRICA: Central News Agency Ltd; William Dawson & Sons (S.A.) Ltd. UNITED STATES: Worldwide Media Services Inc., 115 East 23rd Street, NEW YORK, N.Y. 10010, USA. *Electronic & Wireless World* $5.95 (74513).

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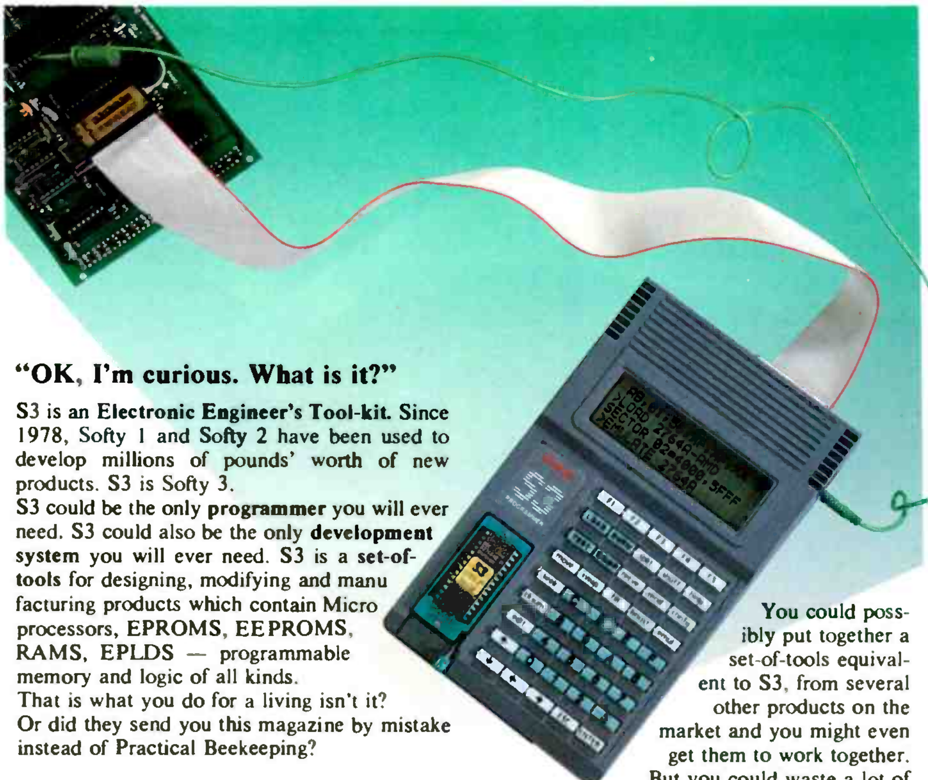

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"Unbelievably good, obviously designed by working engineers for working engineers"

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"I'll bet you sell thousands of these"

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