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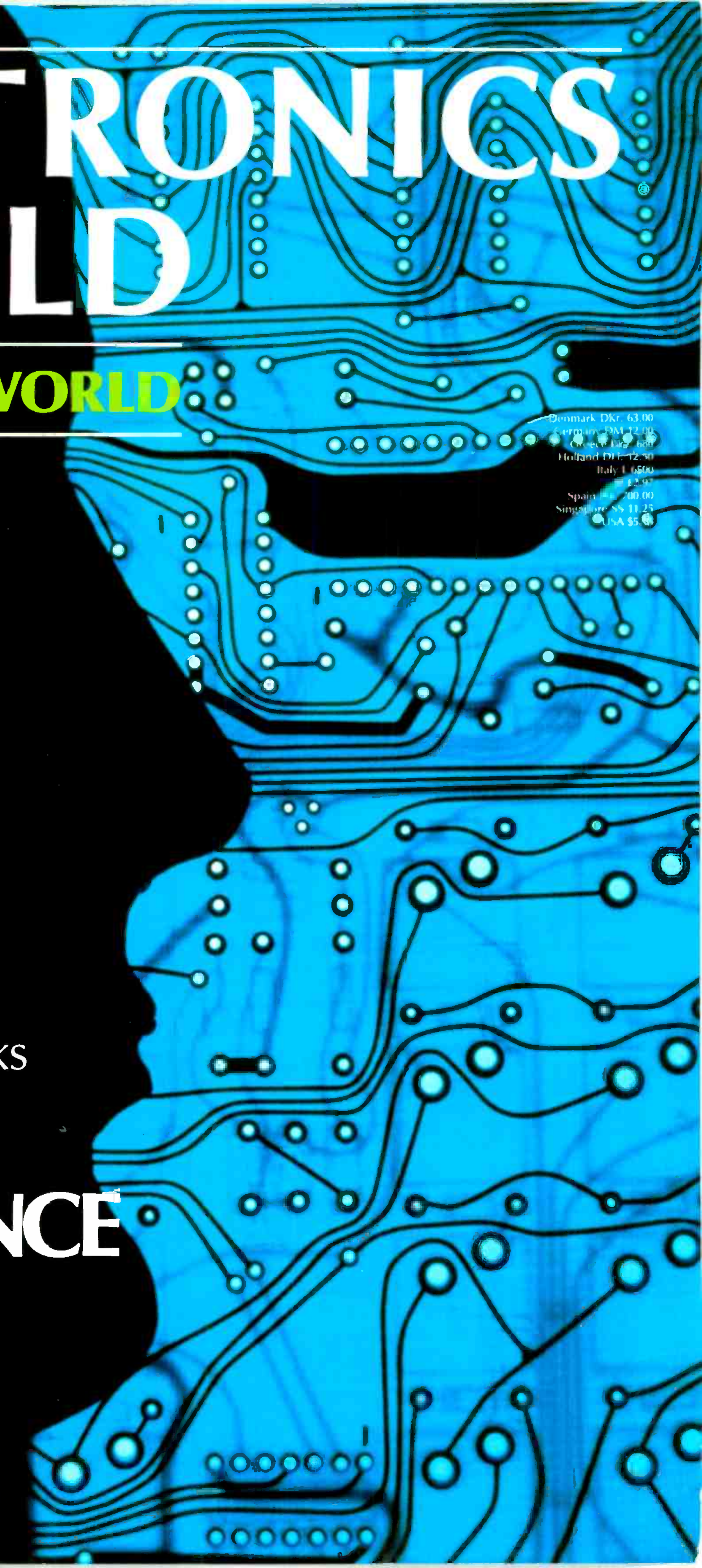

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CONTENTS

FEATURES

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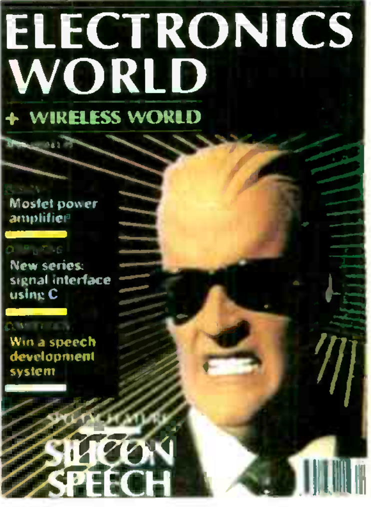

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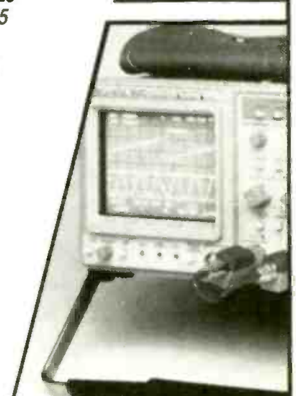

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Secretary of State for Energy, John Wakeham, has some explaining to do. If he declines, then resignation seems the appropriate action for a Minister of the Crown who allows his department, or the agents of his department, to put political expediency before public health.

In March 1988, the CEGB began a research programme investigating the possible health effects associated with power frequency electric and magnetic fields. Part of the research involved a commissioned 6000 person study into adult leukaemia following on from an earlier, smaller one looking at the childhood disease.

In September 1989, the CEGB issued an interim statement which concluded that the results of the adult health inquiry would be published at "the end of 1989". The conclusions of this study, which sets out to examine the public health implications of power line fields, have yet to be published even though Chief Medical Officer at the CEGB, Dr Robin Cox, admits to possessing the preliminary findings. Furthermore, Dr Cox is not prepared to give any further commitment on the publication date in marked contrast to the earlier CEGB written statement.

It seems legitimate to ask for a reason. Dr Cox says that the results "must await initial publication in a learned journal". This argument doesn't hold much water. The CEGB was certain enough of the publication timetable just a few months ago. It seems logical to look for other motives.

Given the weight of evidence connecting power line fields and disease derived from similar studies in the US, one might surmise that the CEGB study also casts suspicion on power line fields. Publication would most certainly interfere with the forthcoming privatisation scheduled for the end of this year. After all, the public outcry following a proven link between electricity and cancer would demand compensation and building control at the very least.

Suppression of such a report, purely on political grounds, if proven, must result in the Minister's resignation.

One can't help but make comparsion with the Government's attitude to the samonella-in-eggs affair. In that instance it acted swiftly against the egg producers and terminally against hundreds of thousands of hens. It dispossessed nuns and inspired a flock of EEC directives. All this happened in defending us from a few gippy tummies on just the merest shred of evidence.

Power line fields are implicated with a number of very serious diseases and the associated evidence, already to hand even without the current CEGB study, is far more damning than ever was the case with infected eggs.

The weight of evidence about the effects of power line fields was presented in last month's issue. It is sufficient to note that the US Congress Office of Technology Assessment concluded that "electric and magnetic fields produced by electric power systems may pose public health hazards." The report accepts that "even weak electric and magnetic fields can effect living cells." As a result, eight US states have implemented rights of way along major power lines excluding human habitation. People affected by the building of power lines in these states are entitled to compensation. Compare this with the apparent obfuscation in the UK.

We would be the first to say that more research is needed and that the links between power lines and disease have yet to be established definitively. However, there is enough evidence to state that the public interest is best served by a moratorium on house building under power lines, and that public warnings should be issued to users of certain electrical products. Any other course should be unacceptable. There is no room for politics in public health.

Frank Ogden

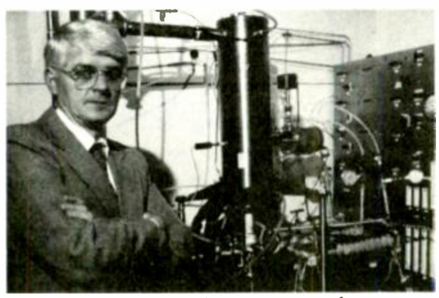
Superconducting wire by CVD

Using a new chemical vapour deposition (CVD) process to coat flexible fibres within a thin film of high-temperature superconducting material, researchers at the Georgia Institute of Technology have increased deposition rates considerably while achieving promising critical temperatures and maximum current capacity. Existing CVD technology for thin-film superconductors yields a coating just one or two microns thick during a one-hour deposition run. The new process yields 50 to 200 microns per hour, depending on production conditions.

In the past, carrier gas has been used to transport metal sources into a CVD reactor. Since the flow rate, temperature and pressure must be controlled for each vaporizer the process has often been delicate and time-consuming. To make matters even more difficult, reagent sources for the commonly-used 1-2-3 superconductor (yttrium, barium and copper) provide low vapour pressure. If heat levels are increased to speed vaporization, these metal sources undergo chemical reactions and form unwanted compounds.

To improve this situation, Principal Research scientist Jack Lackey replaced the vaporizers with a powder feeder. A combination of finely-ground yttrium, barium and copper metal-organic powders are mixed with argon gas before flowing into the horizontal reactor, thus eliminating the need for complex controls. During a 5-30 minute period, the team fed between 2 and 10 grams of powder into the reactor.

Thus far, the technique has mostly been demonstrated using rectangular, single-crystal magnesium-oxide substrates, but several types of flexible, thin fibres also have been coated. Ultimately, the team plans to coat inexpensive, commercially-available



Dr Jack Lackey with CVD equip-ment

ceramic or metal fibres, possibly made of aluminium oxide and/or silicon dioxide. Other possible substrate materials include silicon carbide and carbon coated with a layer of an oxidation-protective material. A coating barrier between the fibre and the superconductor should eliminate any undesirable chemical reactions.

Meanwhile, Lackey has designed a continuous fibre coater and hopes to commercialize the product.

Tune in for the big one

Earthquake prediction has always been something of an inexact science, rarely offering better than a 50% probability of a big 'quake in any one decade. And, while any warning is arguably better than no warning, there's little prospect of people being able to take any useful preventive action unless prediction improves greatly in accuracy. It's intriguing therefore to speculate on a finding presented by Stanford University electrical engineers at a recent meeting of the American Geophysical Union.

Antony Fraser-Smith and his colleagues were using very low frequency radio receivers set up under a US Navy contract to explore new ways of detecting submarines. Recordings, when subsequently analysed, showed that in the first few days of October – just prior to the big earth quake on October 17th – there was a sudden increase in the level of otherwise steady background noise. Three hours before the actual disaster there was an even greater peak of VLF radio noise, quite unlike anything previously observed.

Coincidence perhaps? While many US seismologists are impressed by the remarkable fit between the radio emissions and the subsequent ground movement, Fraser-Smith himself cautions that there's no proof of a causal link. On the other hand, nothing similar was previously observed during the two years the experiment had been running; nor has any alternative natural or artificial explanation been offered.

Now the US Geological Survey is to consider setting up similar VLF monitoring systems in other parts of California. And if the same VLF emission is observed prior to the next big earthquake, the coincidence would be too much to explain away. Why ground movement might generate VLF radio waves remains a mystery.

Watched pot never boils – official!

A recent experiment by Wayne Itano *et al* at the National Institute of Standards and Technology in Boulder, Colorado provides the first clear evidence of one of the strangest predictions of quantum theory – that you can influence the behaviour of a system merely by observing it.

A recent report (*Science*, Vol. 246, 888) describes how the NIST scientists took a special magnetic "pot", in which they trapped several thousand ions of beryllium-9, all initially in the ground state, level 1. By switching on an RF heater for just 256ms, the experimenters raised all the ions to a higher energy state, level 2.

That, at least, is what happened if no observations were made during the heating period. On the other hand, if the scientists took a peek at the beryllium while it was on the boil, a significant proportion of the ions failed to make it to level 2. If the experimenters looked 64 times, almost no beryllium ions changed state.

According to quantum theory, the very act of looking at the ions – done, incidentally, using ultra-short pulses of laser light – causes energy to be lost, thus returning them to a lower energy state. This, to be precise, only happens if the ions are in a transition state between levels 1 and 2. After 256ms they are safely in level 2 and hence remain unaffected. On the other hand, if the ions are watched every 4ms, then fewer than 1% of them will ever migrate to the upper level.

This finding that a watched (quantum) pot never boils is the first unambiguous confirmation of an effect noted in the late 1970s by experimenters at the University of Texas. The recent success, however, is the result of choosing an atomic process that proceeds slowly enough for the experimenters to observe it often enough to reduce significantly the probability of it taking place!

A logical question arising from this experiment is whether or not regular observation could arrest other quantum processes such as radioactive decay. In theory the answer is yes but, in practice, radioactive decay happens far too quickly for repeated observation. As Itano notes, any observation takes a finite time and there will always be gaps between observations when an atom can secretly decay without being noticed. Pity!

Ballistic electrons for high-speed switching

IBM researchers have demonstrated for the first time that fast-moving ballistic electrons can be focussed and steered as they travel at very low temperatures through gallium arsenide. The finding is the latest from a team led by Dr Mordehai Heiblum at the Thomas J. Watson Research Center in Yorktown Heights, N.Y. This group previously showed that ballistic electrons can travel through ultra-thin layers of gallium arsenide at speeds considerably greater than 10^6 kilometres per hour.

Under normal conditions, electrons moving through a semiconductor travel only a short distance (the mean free path) before colliding with atoms, other electrons, or impurities in the semiconductor and scattering. In the process they lose energy and change direction.

In these experiments, however, the mean free path is lengthened, so the electrons can travel across the semiconductor ballistically, that is, without scattering. At around 5K, the normal motion of atoms inside the semiconductor material is greatly reduced, lessening the chance of collision with the electrons as they speed past. As a result, at that low temperature, the mean free path can exceed 1 micron, providing room for the insertion of a tiny focusing device.

In their experiments, Heiblum and his team injected high-energy electrons on one side of a region of semiconductor material 2 microns across and collected them at the other. The electrons travelled ballistically though a region free of the impurities that might cause energy-wasting collisions. That region, known as a two dimensional electron gas, can be created at the interface between a single-crystal layer of gallium arsenide and another of aluminium gallium arsenide.

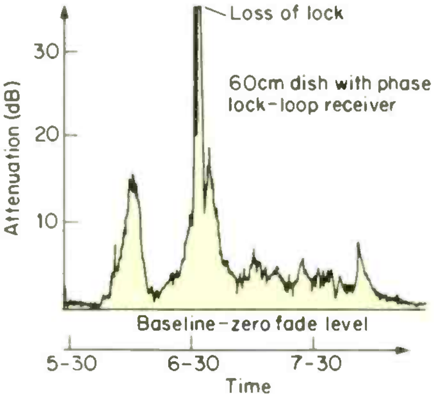
To demonstrate that the path of travel of the ballistic electrons could be controlled, the team applied a differential voltage across tiny metal gates as they injected the electrons into the semiconductor. They found they could steer the electrons about 60 degrees off the original path over a distance as great as two microns. This will, it's hoped, allow new types of extremely fast electronic switching devices and circuits to be made that use directed electron beams.

Stormy future for EHF satellite channels?

As the currently exploited microwave frequencies are beginning to fill up with an ever-growing volume of traffic, experimenters are paying increasing attention to parts of the spectrum beyond 20GHz. Until recently these wide-open spaces have remained the province of specialist users, mainly because of the high cost of low-noise receiving equipment and efficient high-power satellite-borne transmitters. There are, however, other constraints, not least the problems of absorption by the atmosphere. At frequencies where the wavelength is of the order of 1cm, raindrops behave like dielectric spheres that either absorb or scatter the signal in a random and unpredictable manner.

Above; installing the 12.5GHz dish at the Rutherford Appleton Laboratory.

First major recorded rain event on Olympus 30GHz beacon on August 10, 1989 at RAL.



One of the functions of ESA's advanced technology communications satellite Olympus, launched in July last year, is to send out test signals on 12.5, 20 and 30 GHz to enable researchers to monitor the effects of the weather on propagation.

Here in Britain a group at the Rutherford Appleton Laboratory – who incidentally were closely involved in designing the satellite itself – are in the process of commissioning three experimental propagation receivers, one for each of the Olympus beacons. The 30 GHz receiver, already working, demonstrated within a few days of switch-on just how severe can be the attenuation due to rainfall.

Dr John Norbury, who is responsible for the project, says that attenuation of 30dB or more is relatively infrequent, but must be allowed for in any future commercial systems. Experiments on counter-measures are part of a parallel programme at RAL.

As these words appear in print, the 30 GHz receiver and its 12.5GHz counterpart will be fully operational, to be followed by the 20GHz system sometime in the middle of the year.

The 12.5GHz system, as well as studying propagation, will be used to receive information for a satellite data transfer experiment to be undertaken by Dr John Burren and his colleagues at RAL's Advanced Communications Research Unit, together with collaborators at the University of Buckingham and at Graz in Austria and Pisa, Italy. Results will be awaited with interest.

Record magnetic storage density

A team at the IBM Almaden Research Centre in San Jose claims to have set a world record in magnetic data storage density by successfully storing a gigabit of information on a single square inch of disk surface. This is 15 to 30 times greater than that of current hard disks.

To achieve gigabit storage density, the IBM researchers combined a number of advanced components, including experimental thin-film recording heads and disks with advanced electronics. The demonstration was performed on a precision test apparatus, though all of the critical hardware components were made by conventional manufacturing processes. Nevertheless, say the group, several more years of development will be required before gigabit technology could be incorporated into everyday commercial products.

The experimental dual-element, thin-film recording head used in the demonstration features an inductive "write" element and a magnetoresistive (MR) "read" element. Both elements operate while the head flies over the disk at a height of less than 0.05 microns – so narrow a gap that even light can't pass through.

The electrical resistance of materials that exhibit the MR effect changes according to the strength of any magnetic field present. By monitoring the rapid resistance changes that occur as an MR head passes over recorded magnetic bits, it's possible to detect bits too small for a conventional all-inductive head to recognise. In addition, since the strength of the signal produced by an MR head does not reduce with reducing disk velocity, an MR head has the advantage of providing an identical performance regardless of disk size and speed.

The aluminium disk used in the tests is coated with a thin film of magnetic cobalt alloy designed for very high bit density and very low magnetic noise – a critical advantage in reading the recorded bits. A thin coating of a hard material protects the alloy film from contact with the recording head.

In the gigabit demonstration, bits were stored at a linear density of 62,000 bit/cm along concentric tracks spaced at 2500/radial centimetre. Each data bit measures only 0.16 microns long by 4 microns wide – comparable in area to current optical-storage bit cells.

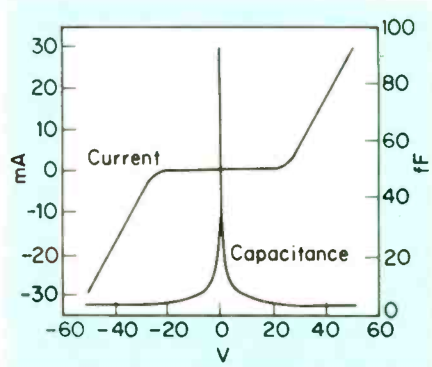
Quantum varactors for millimetre waves

Swedish researchers at the Chalmers University of Technology at Göteborg have proposed the use of a new device, the quantum barrier varactor diode (QBV), as an efficient source of millimetre waves. They say *(Electronics Letters Vol. 25 No 25)* that, because the QBV diode is a symmetrical device, it could replace conventional Schottky varactor multiplier diodes with higher efficiency and much simplified circuitry.

Conventional varactor diodes are reasonably efficient at generating over 100GHz by multiplication from lower frequencies. Thus a conventional varactor could multiply an input frequency of 35GHz by three with an efficiency of around 30%. The only problem is that, because a Schottky varactor is symmetrical, it yields even harmonics which need to be terminated reactively to avoid loss. A tripler therefore requires an "idler" circuit resonant at the second harmonic. A quintupler would require three such idlers – mechanically impossible and probably very lossy even if they could be implemented.

Enter the QBV diode with its natural property of generating only odd harmonics. A tripler based on this device would require no idler at all (there being no second harmonic) and a practical quintupler could be made with only a single idler (for the third harmonic).

The Swedish team have calculated the optimum device parameters for most efficient conversion, which could exceed 60% at an output level of around 40mW at 105GHz. Output power is limited mainly by avalanche breakdown (in either direction) due to the RF voltage swing across the diode. The main diode characteristics are shown below.



Authors E. Kollberg and A. Rydberg conclude that, because of the considerable simplification in circuitry, the QBV should prove a potentially very competitive device for millimetre wave generation.

Towards practical all-optical repeaters

Erbium (Er^{3+}) doped fibre amplifiers are an extremely attractive prospect for optical repeaters because they operate at a wavelength of 1.5μm. This is a wavelength most commonly used for long-haul optical communications. If an erbium-fibre amplifier were practical enough to put down manholes or to sink to the seabed, it would neatly avoid the present need to convert optical signals to electrical signals and then convert them back again. The problem is that, to work efficiently, erbium-doped fibre amplifiers need to be pumped at a wavelength of around 0.98μm, for which no practical semiconductor lasers are available.

The development of such a laser by a team at the NTT Optoelectronics Laboratory in Japan is therefore a significant step towards all-optical repeaters. The team, led by M. Okayasu, report (*Electronics Letters Vol. 25 No 23*) laboratory experiments in which they created a strained-layer gallium-indium-arsenide quantum well structure using MOCVD epitaxy.

Output wavelength is 0.97μm and a peak power of 85mW is obtainable at a current of 150mA. The researchers say that at a reduced power of 30mW their laser diode shows good long-term stability with no marked deterioration of output. Further study, they say, is now under way to improve stability and cure the drop in efficiency at full power.

Even before this further development began the NTT team were already testing their lasers in conjunction with an erbium fibre amplifier. Two lasers with their outputs optically combined were used to pump such an amplifier at a wavelength of 1.536μm.

Maximum gain was reported to be 37.8dB, which represents 1.9dB for every milliwatt of pumping power – an excellent figure. On this basis a practical all-optical semiconductor laser-pumped erbium-doped fibre amplifier can't be very far away. That in turn should greatly increase the reliability and the bandwidth of long-haul fibres that employ such devices.

Research Notes are by John Wilson of the BBC World Service science unit.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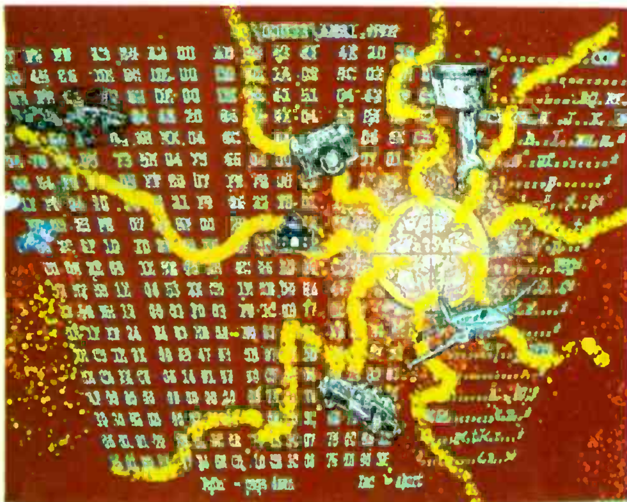


LIVING COMPUTERS

Douglas Clarkson introduces neural networks, which operate in a manner not yet clearly understood, but which nonetheless are capable of producing specific answers to specific problems

Attempts to imitate natural neural network systems bring into focus the essentially different approaches of serial digital computing and the operation of the brain, in which each element is connected to many others. But these are early days in the process; the development of the relevant computing techniques is a bare 50 years old, while natural networks have been around slightly longer.

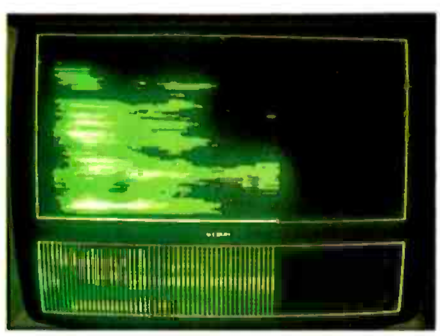
The first man-made computers were essentially fast adding machines. While there have been vast improvements in processing speeds, memory capacity and programming methods, the pattern of machine instructions being handled serially by a complex processing unit has largely persisted.

In the forward march of evolution there has been a consistent initiative to develop life forms with more highly developed nervous systems. Of course man prides himself in being the apex of cerebral achievement, but throughout nature there are many marvellous examples of various species with highly developed sensory mechanisms. It is widely realised that if man tries to imitate nature, then initially his neural network creations will be vastly inferior, even if to him they appear superbly clever.

The human brain has been referred to as "the neural network which already works". **Figure 1** shows a magnetic-resonance image of the human brain, superbly indicating even fine structures such as the optic nerve and the pineal gland; it is a superbly developed connectionist system. There is therefore no highly localized site of processing power, although nerve bundles provide important functions for the routeing of information. For those who wish to know more about the function and structure of the brain, the work of Angevine and Cotman[1] is highly recommended reading.

Networks – natural and otherwise

The basic building block in the brain is the neuron, which can vary consider-



Spectrogram of speech resulting from representation of speech applied to neural nets, shown in lower half of screen. Picture by courtesy of British Telecom and the University of East Anglia.

Pattern recognition being performed by the WISARD system, developed by Professor Igor Aleksander at Imperial College.

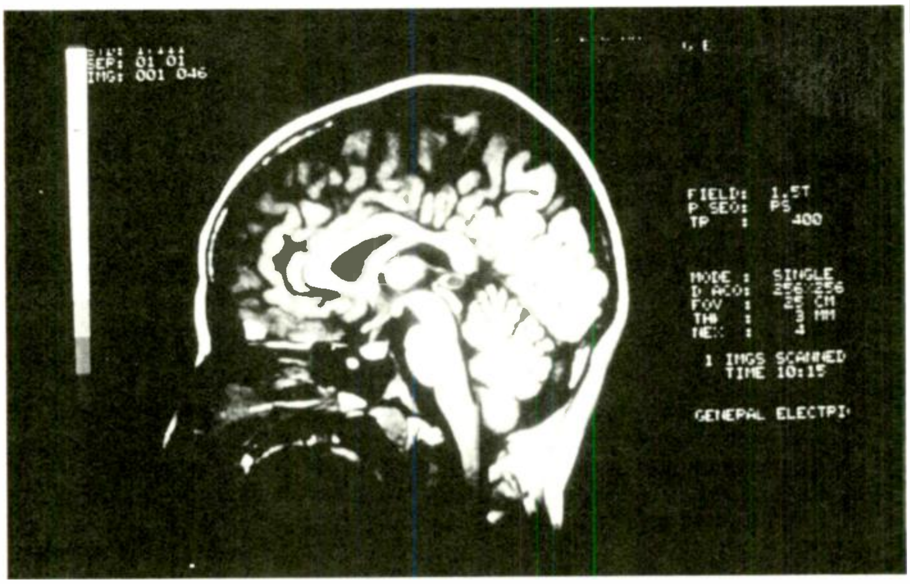


Fig. 1. Magnetic-resonance image of the human brain showing entry of the spinal column into the mid-brain and associated details of the cerebral hemisphere and cerebellum. Picture courtesy IGE.

ably in type and function but can be represented as shown in **Fig. 2.** Neurons communicate across synapses and receive inputs over larger axon connections.

This collective functioning is determined largely by the way in which neural units are connected physically together and also in the relative strengths of the interactions across the links. The mechanisms whereby cell-based networks can organize themselves to implement such intelligent functions are as yet very poorly understood. Contributing to the poor understanding is the overwhelming complexity of natural neural systems. The human brain, for example, may have as many as 10^9 neurons, each with around 1000 synaptic connections to other neurons.

Various mathematical models of neural units which could interact collectively were developed as long ago as the 1940s. The role of McCulloch and Pitts[2] was to establish the early formal rules for abstract connectionist systems. Later, Hebb[3] was to introduce the concept of neurons in the brain which were fired repeatedly or consistently together, influencing each other's metabolism and response to stimuli.

A simple and fairly widely adopted logical unit of a neural network is shown in **Fig. 3**, where the inputs A, B and C take the values 0 or 1. The values −2, +2.5, and +1 are the so-called weighting values of the inputs, so that the sum of inputs into the unit has value A(−2) +B(+2.5) + C(+1). If this value is greater than or equal to 2, then the value of the output is 1; otherwise it remains 0 as outlined in the table.

A	B	C	sum	output
0	0	0	0	0
0	0	1	1	0
0	1	0	2.5	1
0	1	1	3.5	1
1	0	0	−2	0
1	0	1	−1	0
1	1	0	0.5	0
1	1	1	1.5	0

Such logical units form building blocks of much more complex structures.

Figure 4a shows a simple two-layer association of units, while the system in **Fig. 4b** has a so-called hidden layer. Note that, to simplify the modelling of such systems, each layer only feeds forward to the next. It is thus relatively simple to design such network topologies, but as the number of units increases, so too does the number of weighting connections. **Figure 5** indi-

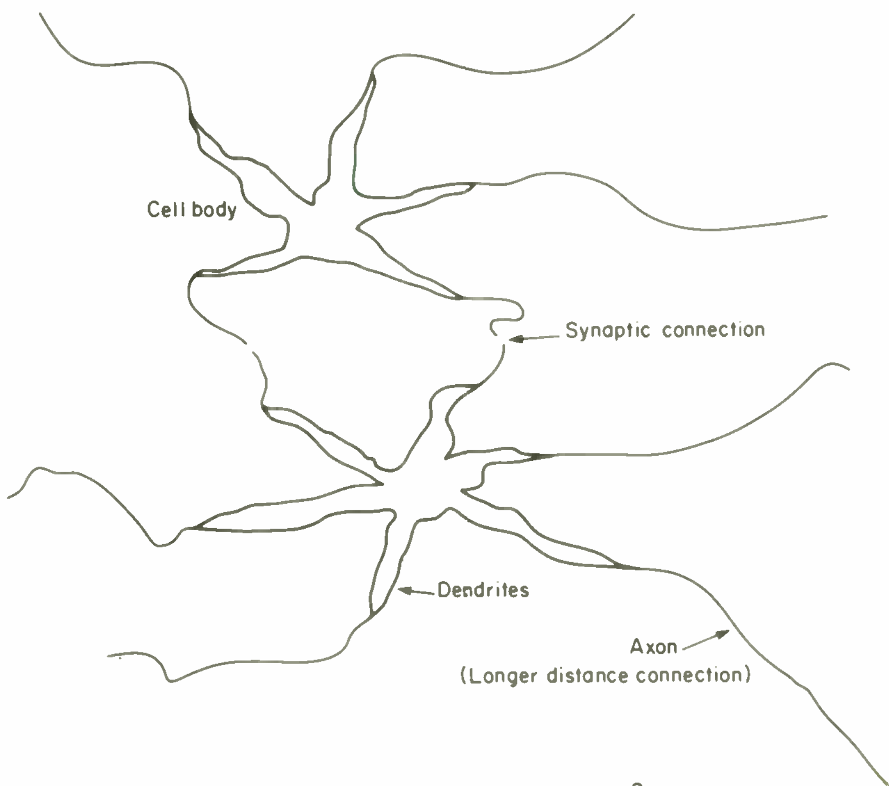


Fig. 2. Building blocks of Nature's neural networks – neurons. Connections are made across short-range synaptic links or over longer axons. Although only a few links are shown in the figure, typical neurons can have around 1000 links to other neurons

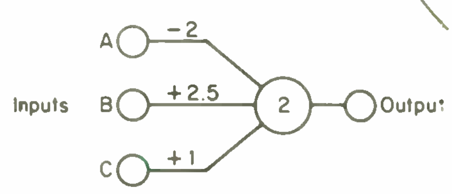


Fig. 3. Simple neural unit consisting of three inputs and an output. The unit sums the inputs (0 or 1) and incorporates a specific weighting factor for each input (−2, +2.5 and +1). The unit's output is therefore of value 1 when the summed value is greater than or equal to its threshold value (2)

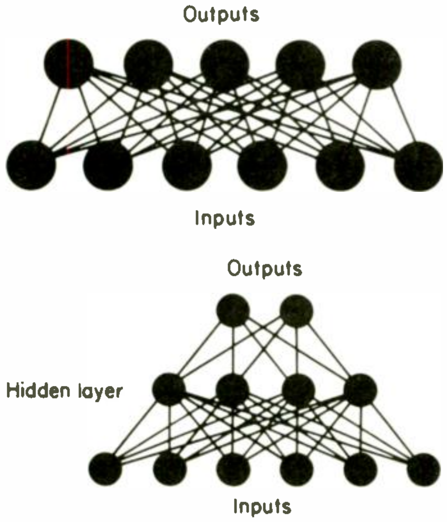


Fig. 4. Simple, two-layer forward-feed network at (a) and at (b) a three-layer network with a "hidden" middle layer. Some complex problems can only be solved by the inclusion of such layers

cates the number of weights required for a network for the configuration of Fig. 4b as a function of the number of input units. Neural networks which are more complex can undertake more sophisticated tasks, though this is compensated for by the much higher number of weighting values which have to be calculated.

This process of selecting weighting values so that a network performs well defined tasks, translating input values to output values, is called "training". The significant recent advance in neural networks has undoubtedly been the development of general-purpose training algorithms.

One of the first training algorithms was the back-propagation method. Typically, all the weighting values would be set initially to random values, a specific weighting element then being selected and the errors between desired and observed outputs determined for an input training set. The value of weighting value selected would be that which gave minimum error between the desired output and the observed output. Now software products such as NeuralWare's set of neural-network-configured programs are available for use with an IBM PC. A range of public-domain software offerings is also available.

Networks usually converge with training to a stable solution. Often it is relevant to introduce random noise into the weighting values to "bounce" the network out of a less than optimal solution. This process of introducing noise and reducing its amplitude during the training process is termed "annealing".

The field of neural network research now reveals a diversification of network models and associated training methods. Work at Imperial College London has, for example, developed ram-based network models, where the output value of the ram neuron is a look-up value corresponding to the address data presented to the input lines of the unit.

As the field develops, a particular model and training method which once provided a solution to a specific problem can be replaced by a more efficient model/training algorithm. As networks become more complex and contain more weighting values for estimation, the emphasis on speed of network analysis will become even more critical. Neural networks, however, will not be used to duplicate what present-day silicon circuitry already does well. Exact numerical representation and manipulation will remain the remit of conventional digital computers. It is very clear, however, that digital computers are an essential tool for the implementation of neural network solutions, both through their use to determine weighting factors and also to undertake simulations. One of the limiting factors in the current development of parallel, connectionist neural networks is indeed the availability of sufficiently powerful serial digital computers; solutions which take a Sun workstation several hours would occupy a PC for days on end. There is a finite level of complexity, however, beyond which even the mightiest computer grinds to a halt.

Applying neural networks

Neural networks are being widely investigated in the area of pattern recognition, one obvious form of which being that of recognition of human faces. This highlights the fact that conventional digital computers have not yet proved entirely satisfactory in solving such problems.

Neural network technology is being used, for example, in the validation of written signatures, the recognition of character patterns in the postal service and even in the recognition of star patterns for on-board satellite navigation. The WISARD pattern recognition system developed further at Imperial College under the direction of Professor Igor Aleksander has been developed using their specific ram model of the neural unit. Pattern recognition involving ram-based nets is being undertaken at the University of York.

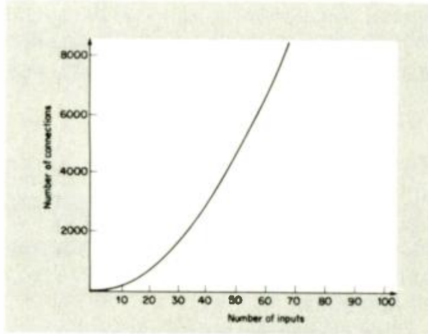


Fig. 5. For the configuration of Fig. 4(b), the graph shows the rapid increase in the number of network connections with the number of input stages. Systems to be simulated must therefore be kept to a sensible size.

Other associated application areas include classification of aircraft radar signals and automatic guidance systems for road vehicles. The ALVINN vehicle at Carnegie-Mellon University, aided by three Sun computers, can as yet only achieve a maximum driverless speed of 0.5m/s, but that may change. All these examples represent only a very small range of applications which are being developed in this one area.

Speech recognition. Significant work has also been undertaken in the field of speech recognition – an area which poses perhaps one of the greatest challenges to neural network technology. Various researchers are undertaking what could be described as an incremental approach, where each advance in performance brings the ultimate solution closer, though each improvement does not yet yield a practical solution.

An interesting project staged by the Carnegie-Mellon University and ATR Research Laboratories in Osaka highlights one promising way forward in offering a solution for efficient real-time speech-decoding facilities. The frequency spectrum of speech is dynamically analysed at 10ms intervals over 16 separate frequency bands, so that the input to the network is a rapidly changing window of sampled data. Using this system, a range of networks was developed to differentiate Japanese consonants. The approach of solving more difficult tasks just by implementing more complex networks proved somewhat counter-productive. In going from a conventional network to recognise G, D and B to one to recognise B, D, G, P, T and K, the size of the network increased from 6000 connections to 18 000; training required some 18 days of supercomputer time. A modular construction, however, which identified consonant groupings and then specific consonants within a grouping proved more efficient, leading eventually to the dynamic identification of all 16 Japanese consonant sounds for a single controlled speaker. The skill of problem design is therefore of paramount importance when tackling more complex network problems and this modular approach will doubtless be a feature of other application areas.

Considerable interest is being shown in the use of voice recognition systems by telecommunications companies, no doubt in order to allow a patient, non-human listening service to differentiate between "yes" and "no" and other responses not remotely like either. Several projects in British Telecom's CONNEX neural network initiative relate to voice recognition.

It is not surprising, therefore, that there is significant interest from the life sciences in discovering the ways in which natural networks implement highly complex tasks. This confirms that research in neural networks has expanded far beyond the narrow confines of computer science. The emergent subject of cognitive science is a much more wide-ranging discipline and employs the skills of mathematicians, neurobiologists, neurophysiologists, psychologists and electronics engineers.

Another area of significant activity is the use of neural networks to reproduce speech from text, for which there are applications such as the quoting of stock market prices over the telephone and also in improved man/machine dialogue in industry and commerce.

Speech continues to be an amalgam of well established rules and a large number of exceptions and special cases. Numerous systems using conventional digital computers and phoneme reconstruction methods have of course already been developed. On a base of the initial work by developers of NETtalk at Johns Hopkins University, work is being undertaken using neural networks at a number of centres, no doubt to produce the ultimate human voice beloved of science fiction writers who have perhaps prepared us for the prospect of failing to differentiate between natural and synthesized speech.

Work in progress, such as that being undertaken by Fujitsu on speech production, indicates how much the subject has advanced in a relatively short time. Specific neural topologies whose inputs and outputs are not simply 0 or 1 are selected to learn analogue data more accurately and a more efficient training algorithm than back-projection allows more stable solutions to be derived.

The NETtalk system was a significant initial demonstration of the ability of neural networks to respond to a training set. Progressive training of a NETtalk configuration could be demonstrated as a transition from the initial babbling of the untrained network through to the highly recognisable speech obtained after extensive training of the system. Also, NETtalk indicated the essential resilience of a neural network. If, for example, certain weighting connections were given random values, the performance of the network could be heard to have been degraded, although it was not rendered inoperative; with additional training, the system was heard to recover its performance.

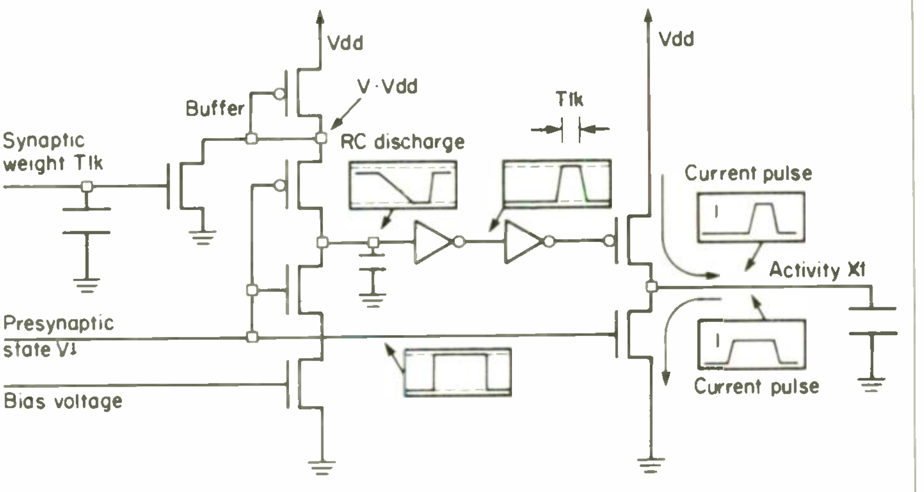


Fig. 6. Neural unit, where incoming pulse train is width modulated by weighting voltage. Output voltage of the unit is stored in charge held on output stage

Expert systems. The role of neural networks as a means of implementing expert systems is one which has caused considerable interest, some annoyance and a certain amount of confusion. The ability of a neural network to solve a specific problem, producing as it were a black-box solution where the mode of producing answers is not clearly understood, goes against the traditional attitude of scientists who are used to understanding the tools and methods they use.

It is usually difficult to make valid comparisons between conventional expert systems and connective equivalents. One relevant exception, however, is that of a specific system for forecasting solar flare activity at Colorado University. Using an identical data set, the performance of THEONET, a neural-network implementation, was found to be at least as good as a previous expert-system solution called THEO. While the performance of the two systems may have been similar, the connective solution was implemented in less than a week, while THEO had required more than a man year of work to implement. The potential, therefore, for developing connective expert systems is being taken very seriously.

Hardware

To date, most functioning neural-network systems exist as software simulations on a variety of digital computer systems. This represents a major gap between theory and application, though hardware implementation of neural network topologies has as a result become a major area of endeavour.

Part of the problem of implementing hardware-based networks lies in the conflicting demands of massive connectivity between neural elements and the degree of resolution required in the setting of values of weighting links. Many networks, for example, require at least a 10bit resolution in weighting values to implement training algorithms effectively. Also, development has largely been directed towards solutions which can be dynamically updated, in contrast to systems which have, for example, fixed-value laser-trimmed resistive networks.

Hardware implementation of ram-based models has an immediate advantage in terms of availability of VLSI chip-fabrication facilities. Greatest effort is being expended in developing systems which use analogue circuit elements. The approach adopted by several groups, including those at Edinburgh University and AT & T Laboratories, is the use of mos charge storage as the means of dynamically updating individual weighting values or storing the outputs of individual analogue neurons. Innovative analogue circuit designers are therefore at a premium in this field at present.

In the Edinburgh group's approach, voltage weighting values are implemented by off-chip D-to-A converters and used to width-modulated incoming pulses. Input pulses and modulated pulses are integrated with opposite sense at an output charge-retaining stage, so that for weighting voltages of around 2V the output voltage remains stable when the unit receives trains of input pulses. For values between 2 and 3V output neural voltage increases, while for between 1 and 2V it decreases. Such a neural unit is illustrated in **Fig. 6.**

Numerous researchers are also seeking to develop adaptive hardware networks, which will embody learning facilities to train their neural set dynamically. This will not only allow such systems to become much more self contained, but it should be possible to train them significantly faster than equivalent software simulations.

The work is spread from the one-man-and-his-PC type of activity up to the extensive R and D facilities of large corporations. The major developments have to date, however, largely originated from the outstanding work of individuals infused with original ideas. In the UK, several large companies have recently offered support for a Technology Club, founded by University College, London and the software houses Logica and SD to promote the implementation of neural-network technology. Also, the Annie project in neural networks is being funded as part of the European esprit initiative. ■

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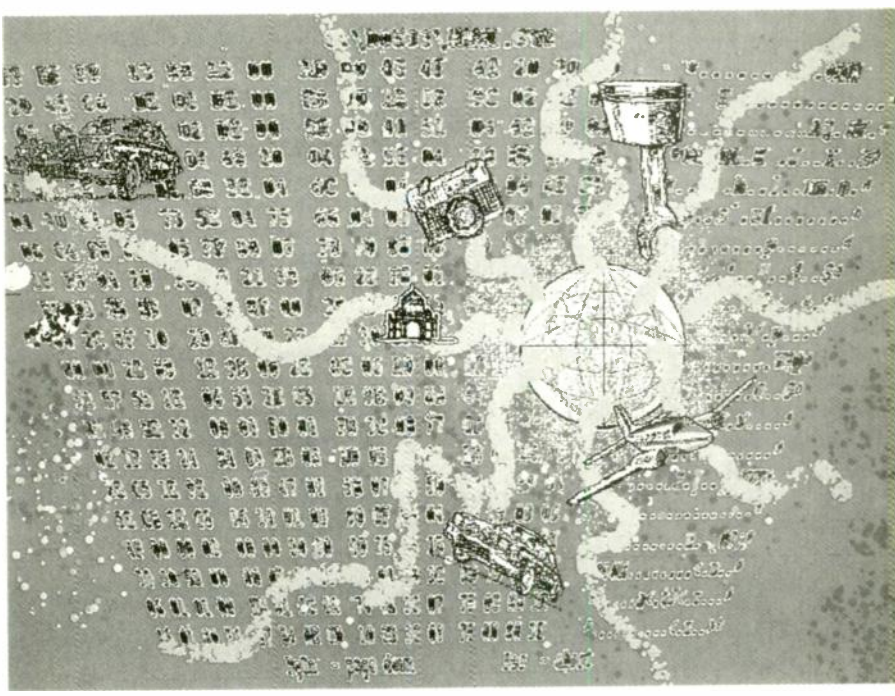
ARTIFICIAL NEURAL NETWORKS

Tom Ivall reports on the IEEE conference, which reflected the connectionist approach to AI



The artificial neural network – an electronic system of interconnected elements processing information in parallel – may yet prove to be a solution in search of real problems. After more than four decades of research and the publication of what must be thousands of papers, not to mention dozens of books, this so-called 'connectionist' computing technique doesn't seem to have found an application niche where its performance is clearly superior to those of conventional analogue or digital processing methods.

A recent IEE international conference on ANNs, as they are known, added a further 90 papers to the existing swollen corpus of literature. And this after about the same number had been rejected. But the philosopher's stone has not yet been discovered.

In spite of endless permutations of network topologies, interconnections, element characterstics, training algorithms and so on, the magic formula – of a really useful technique – did not reveal itself. That's not to say it won't appear eventually.

Charles Goodyear discovered how to vulcanize rubber not by science but just dogged experimentation. This could happen with the neural network.

These remarks are prompted by the many conference papers devoted to 'toy' problems – originated in the laboratory rather than the outside world. They came largely from the 22 British and 16 foreign universities making contributions. Industrial R&D labs were in a minority. Of course, some of these 'toy' problems could have been disguised versions of military requirements, as an MoD man hinted.

Pattern recognition seems to be the most promising field. This encompasses automatic speech recognition on the audio side and various visual tasks such as optical character recognition, robot control, tracking human face movements and identifying features of landscapes. Essentially the signal processing functions needed are discrimination and classification. This also applies to pattern recognition tasks not working on sense data but on other electrical signals. Examples include radar, electromyograph, digital telecoms, navigational bearing and non-destructive testing signals.

Network topologies

A network topology used in many of the reported experiments is shown in Fig. 1(a). This is the multilayer perception, an analogue network derived from the original Rosenblatt single-layer perceptron of 1959. Its input terminals receive signals in parallel which are features of the subject being analysed such as filterbank outputs in speech recognition and pixel values from two-dimensional image sources. The outputs give parallel data which is some function of the inputs and is meaningful as an interpretation of the input pattern.

Between inputs and outputs are several layers of interconnected computing elements or 'neurons'. The output of every neuron element in a layer is connected through adjustable weighting (multiplying) circuits to the inputs of all the neurons in the next layer. Each

The philosopher's stone is still to be discovered...

computing element Fig. 1(b) is an electronic circuit which sums the weighted input voltages, applies a threshold and passes the result through a non linearity to give an output voltage which is one of two states (on or off). Depending on the sum of the weighted inputs, it either 'fires' or doesn't, rather like a biological neuron responding to excitatory and inhibitory stimuli at its synapses.

Thus the network maps the array of inputs on the array of outputs. The actual input-output relationship is encoded in the various adjustable weights in the interconnections. With enough neurons any input-output relationship can be achieved by suitable choice of these synaptic weights. A visual labelling network developed by British Aerospace, for example, has 89 neurons in the input layer, 16 in the middle, hidden layer, and two neurons in the output layer.

Learning and training

But a highly important feature of this kind of network (and others) is that the adjustable weights may be used to make it 'learn' a required relationship of the output to the input. In speech recognition, for example, it can learn to produce an output digital code representing a text word when a particular audio signal spectral pattern is applied to the inputs.

To achieve this, 'training' is necessary, with back propagation of error, in the current ANN jargon. With input signals applied and arbitrary initial weight settings, the resulting output signals are compared with the desired output signals for that relationship. The error between them is measured and used to adjust automatically the weight settings so that the mean squared error function is minimised.

This is achieved step by step (iteratively) with repeated applications of the input signals. When there are no further changes in the neuron outputs the system has completely converged and the desired overall input-output relationship is established.

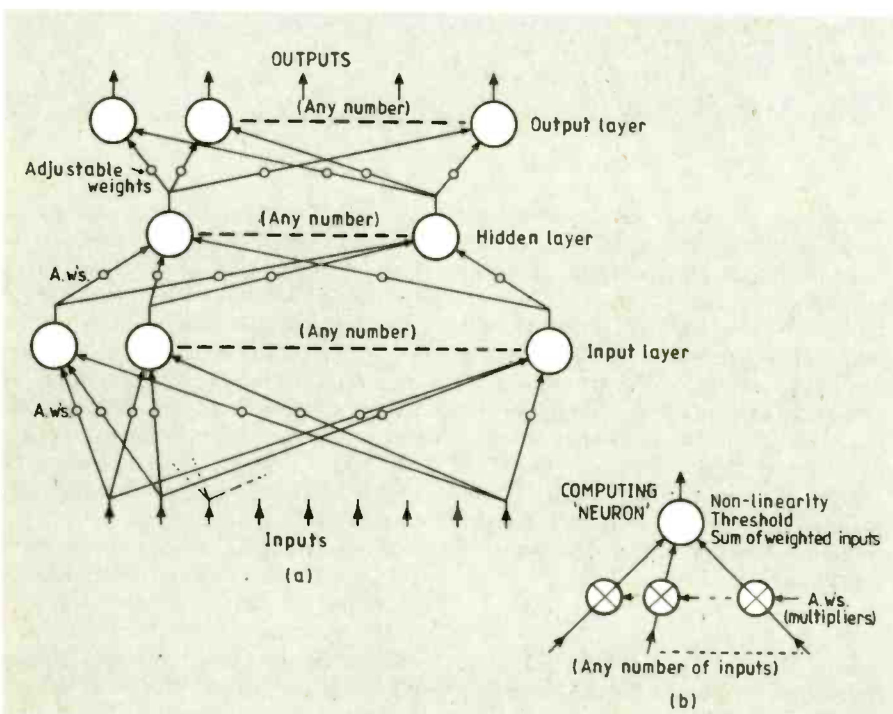


Fig. 1. Principle of multilayer perception is shown at (a). Numbers of layers, neurons in a layer and values of weights are all variable. Each neuron (b) in this network computes the sum of the weighted inputs, applies a threshold and gives a two-state output signal.

The multilayer perceptron is an example of a so-called 'feedforward' network. Other ANNs discussed at the conference have 'feedback' topologies. Here the output of each neuron is fed back to all other neurons via the synaptic weighting circuits. The Hopfield feedback network operates on binary input signals and has stimulated a lot of recent work, especially in VLSI implementation. It can be used as an associative or content-addressable memory, in which storage locations are identified by their content rather than by their physical address. Thus the input signals can be an incomplete or noise-corrupted binary pattern to be recognised, and the network uses this information to address the storage location to which the correct, complete pattern has been supplied.

A learning algorithm can be used on this feedback network in much the same way as outlined above for the feedforward multilayer perceptron. Such a network tends to find stable configurations of taught patterns from incomplete inputs of such patterns.

A third kind of ANN topography is called the self-organizing feature map. Here the 'map' is a two-dimensional array of neurons. It organizes itself – without the supervised learning described above – so that clusters of neurons in particular neighbourhoods of the array are activated in response to particular features of the input data. Thus for speech recognition the network could end up with a fixed relationship between a particular input phoneme and a physical localized area in the two-dimensional array.

This is comparable to what happens when sensory stimuli activate biological neurons in the cortex of the brain. For example, individual audio frequencies evoke responses in neurons at particular anatomical locations. Thus the self-organizing feature map can be used for classification on the basis of the spatial positions of clusters of firing neurons.

Professor T. Kohonen of Helsinki University, the originator of this technique, showed a video demonstrating an experiment on speech recognition. As each word was spoken into a microphone, a wriggly bright trace weaved briefly among the corresponding letters of the alphabet displayed in two dimensions on a CRT screen.

Apart from their topology, ANNs can be categorised in several other ways: analogue or digital input; supervised (trained) or unsupervised learning; and the characteristics of the electronic neurons.

Their performance varies too. It emerged at the conference that multi-layer perceptrons have a rapid response in operation but need a lot of training time. Many of the systems described have not been built in hardware but merely simulated on conventional sequential (Von Neumann) computers. Here the modelling process takes a great deal of time, especially for training, but research at University College Swansea showed how it could be speeded up by using a parallel array of transputers (at least seven) for simulation.

One class of networks which seems to stand out operates digitally and makes use of standard, commercial logic chips. In this it has the edge on simulations and special VLSI still under development. An early British example was the Wisard optical pattern recognition machine devised at Brunel University in 1981. This uses simple rams as the computing elements, which are connected to provide discrimination in a parallel, neural-like network.

In each ram 'neuron' the address terminals form the multiple inputs while the data output terminal provides the output. Before training these rams produce only logical 0s, then logical 1s as the system learns to recognize optical patterns. Operating on 512 – 512 pixel images in 1/25th second and using 250,000 neurons, the Wisard has been built into commercial vision systems by Computer Recognition Systems of Wokingham, Berks. But topologically this device does not resemble the multi-layer perceptron of Hopfield ANNs previously mentioned.

A recent development from this logic-based approach is a new form of neuron element called a probabilistic logic node. As explained by Professor I. Aleksander of Imperial College, London, this kind of neuron makes possible weightless ANNs. Essentially it is probabilistic in function.

The ram, instead of storing just a 0 or 1 output in response to each input signal pattern, stores an n-bit number which represents the probability of that neuron's firing. For example, if the number of bits $n \times 3$, then a range of (decimal) probability values between 0 and 7 can be stored in a ram location. So if value 4 is stored, the probability of firing is 4/7 or, more conventionally, 0.57.

ANNs built from such neurons can be trained. Here, the progressive weight adjustment in perceptrons is replaced by updating the contents of the ram neurons. Learning from errors is

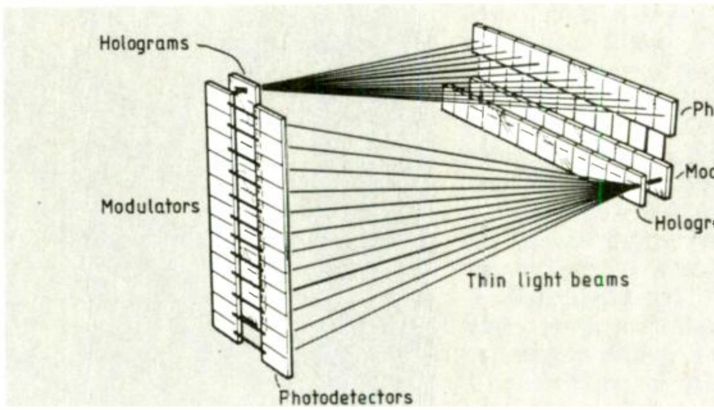


Fig.2. Optical interconnection of two VLSI layers of CMOS neurons aims to achieve high network integration density and connectivity.

claimed to be faster than in the back-propagation method. Also, with this kind of neuron, rather than the Wisard one, the typical characteristics of multi-layer perceptrons and other established topologies are said to be obtainable. And there is the advantage of being able to use off-the-shelf digital logic devices as components.

But apart from this use of standard chips, the business of constructing ANNs emerged largely as a matter of designing special VLSI devices. Several universities are working on integrated mosfet technology to mimic neurons and synapses and produce analogue adders, multipliers, threshold detectors and storage elements. Multiplication for weighting is a real problem because it needs a lot of transistors and therefore silicon area.

Not conventional

An unusual solution reported by A.F. Murray of Edinburgh University is to use streams of pulses to represent information instead of the conventional analogue or digital voltage levels. The pulse repetition frequency is varied, rather like the variable firing rate in biological neurons.

The ram is off to see the Wisard...

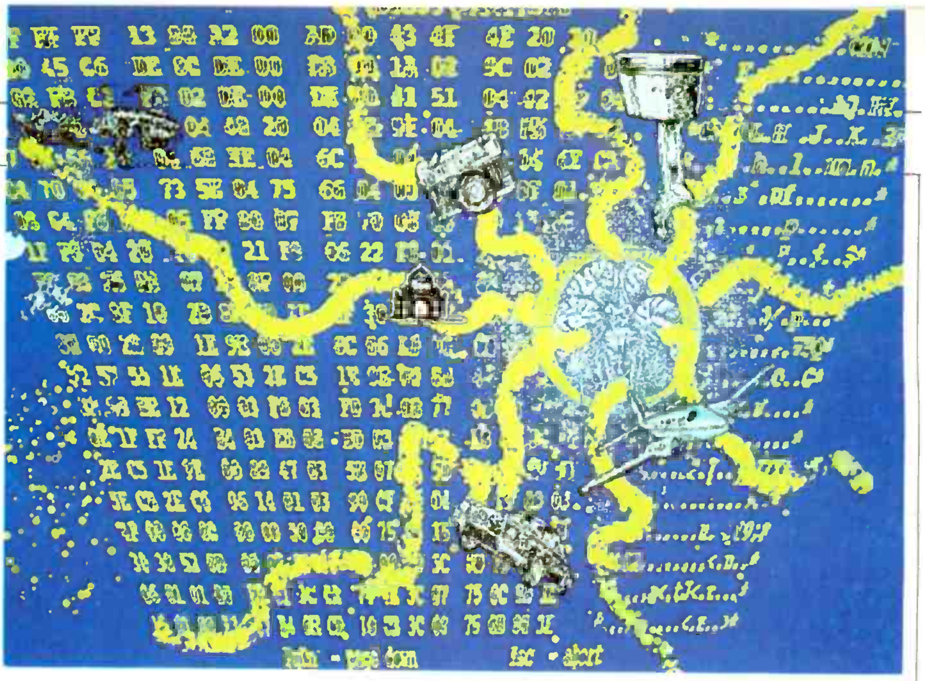
In such a pulse stream the width of each pulse is multiplied by a fraction, representing the weight value, stored as an analogue voltage on a capacitor. This weight voltage is refreshed from an off-chip via a D-to-A converter and is therefore programmable.

Definitely a blue-sky project is a proposal to interconnect VLSI network layers optically, by multiple thin light beams, rather than by conventional conductors. STC Technology and Edinburgh University reported some experimental work on this hybrid of semiconductor and optoelectronic technology. Figure.2 shows the basic principle of interconnecting two ANN layers of silicon VLSI neurons. In each layer an external incident light source is modulated by liquid-crystal cells driven by the outputs of CMOS neurons.

The reflected light from the modulator is split and deflected into multiple thin beams by a hologram to produce a fan-out as shown. These interconnection beams fall onto photodiode detectors in the next layer. The outputs of the photodetectors are then amplified to form input signals to the CMOS neurons in that layer.

The idea is to get a large number of neurons on a single chip – 256 on 1cm^2 is suggested – and also achieve high connectivity between layers. This is possible because the necessary summing for each neuron and the multiplication for weighting the neuron inputs is done through the light beams themselves. So there is no need for adders and multipliers integrated on the chip, and silicon area is saved.

Two light intensities are added when the two beams fall on the same photodetector. Multiplication is achieved when the same light beam is consecutively reflected off two liquid crystal modulators: the reflection coefficients of the two modulators are multiplied.



DUMB INTELLIGENCE

Wilfred James propounds his view that intelligence can be reduced to the two faculties of pattern recognition and memory, as a prelude to modelling the process in hardware.

In studying methods of reproducing the way the human brain works, using conventional computer hardware components, my philosophy has been to try to arrange a series of look-up tables which act at progressively higher levels until the desired result has been obtained.

The result of my efforts has not yet been a reproduction of the human brain in hardware, but a hypothesis of how it operates. I have never come across a hypothesis which answers as many questions (to me at least) so I offer my thoughts on the subject for comment and criticism.

One way of studying how the human brain works is to see how it evolved. Here, I will attempt to give a summary of the stages which led to its evolution.

Development of the brain

All animals, from the simplest to the most complex, must eat to live. The first simple animals discriminated between food and non-food items with their primitive digestive systems. The next stage of development enabled the simple animal to discriminate between food and non-food before it was ingested and to do this, the primitive animal had to be able to remember the difference. This type of animal had the first external sensor coupled to an internal memory unit. Further evolution resulted in progressive enhancements of the sensor and memory unit combination because they were advantageous. Each enhancement enabled the animal to find food more easily so that it could grow more rapidly and have more offspring.

The first sensor would have been a chemical discriminator which developed over time to become a sense of smell; where one sensor provided an evolutionary advantage, two were even better. Detection of light was possibly the next stage in evolution and, as with the development of smell, each step resulted in an improvement in the sensor and a corresponding increase in the number of memory cells needed to identify and remember what the sensor detected. An advantage is gained if the animal can learn from experience – a process which requires even more memory.

The simplest memory system which could be developed would be one which is directly linked to the sensors themselves; there is no advantage in separating the sensor and memory functions more than is necessary. If one considers the first life-form which was able to recognise a shape or a pattern, it is safe to assume that its eye sensors were linked to a set of memory cells which were an extension of the eye itself. These pattern-memory cells would be linked in turn to a group of cells which were associated with the experience memory. A pattern match could have either a good (food) or a bad (predator) association and could be as simple as a sudden change in light level or the outline of a particular shape.

The rest of the stages of evolution of the brain itself do not need much description. Each stage of development has incorporated the best features of the previous stage. Pointers along the way include the use of camouflage by zebras and the eye markings on butterfly wings; both features evolved to counter a predator's ability to recognise visual patterns. Wherever you look you will see that the animal world relies on patterns.

Intelligence

In this very brief survey of the evolution of the brain I have not mentioned intelligence. I have tried to work out where, in the path of evolution, one could say that intelligence originated and have come to the conclusion that there was no point when it provided an evolutionary advantage. Since evolution exploits advantageous developments, intelligence has never developed.

Obviously, there is something which everyone calls intelligence, or the word would never have been coined in hundreds of languages. If we take a step or three back along the evolutionary path, we can identify two advantageous facilities – pattern recognition and memory. I think I can show that what is called intelligence is only a combination of these two facilities.

Patterns and language

The ability to read is based on being able to recognise word patterns; to learn a foreign language, one has to learn the patterns of the foreign words. As one becomes more proficient in a foreign language, one learns more expressions which are not directly translatable between two languages, but relate to abstract patterns associated with the language. Some of these non-translatable patterns become transferred – glasnost, reggae, hamburger, savoir faire, le weekend – the patterns relating to the region where they occur most often. Language is only a part of pattern recognition, but it is a tool which has developed to enable the concept of a pattern to be transmitted in an abstract form from one human to another.

It is said that a picture is worth a thousand words. Here, it is even easier to see what concept is being dealt with without the need for an abstract description. Until the advent of photography just over 100 years ago there was no way of showing what something looked like except by a drawing, painting or statue. But most of us are quite happy to accept outline drawings as representations of things. A good cartoonist can capture the look of a person so that the drawing is instantly recognisable; the amount of detail shown is only a very small amount of that which would be contained in a photograph. Even if the shape is very distorted it can still be recognisable.

We obviously have an advanced pattern-recognition and storage system, which uses the minimum of memory to record the main features of whatever is represented. This in itself must be an evolutionary advantage; the more compactly data can be stored, the more can be stored within a limited space. The creature which can record and recall the greatest number of patterns is evolutionarily superior.

Pattern association

The next step is a secondary memory process to associate one pattern with another, which has to be developed if a person is to show any signs of intelligence. If it is very well developed and the person concerned has recorded many patterns, then he is thought of as being highly intelligent. If, on the other hand, pattern association is not well developed or the person has not learned a wide range of patterns, he is regarded as being mentally subnormal.

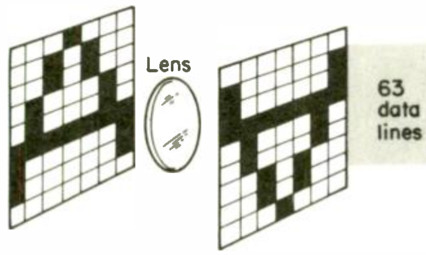


Fig. 1. Optical character recogniser input unit; typical arrangement for a 7 × 9 matrix. Each photocell connected separately. Optical fibre could be used to link photocells to image plane.

The process by which a pattern is learned is mysterious, or education would be simplified. However, there are several points which are worthy of note: firstly, a pattern is learned through necessity if one's life depends on it; secondly, a pattern is learned through repeated exposure to it; thirdly, a pattern is learned if it fills an obvious gap or solves a mystery; fourthly, a pattern is more easily learned if it is associated in some way with pleasure. (All teachers should remember this!)

Associative links between patterns depend firstly on the number of patterns learned and secondly on the connectiveness of the memory cells, which may be inherited or acquired. For most people, there is some link between the pleasure centre and the "gap filling" aspect of learning-pattern linking. The extent to which this linking operates is a guide to the motivation of the person concerned; the popularity of puzzles indicates that most of us enjoy filling in gaps. If the gap-filling pattern offered matches existing patterns, it is accepted as being valid and true – if it does not, it is taken to be false.

Humans cannot calculate

Wherever one looks, every so-called intelligent function can be explained by pattern linking. It is impossible for the human brain to perform the simplest calculation. Every so-called calculation is a series of look-ups of memorized patterns. Learning multiplication tables by rote follows the memorization of other patterns – additions and subtractions of combinations of 0 to 9 and the concept of the carry. With these patterns memorized, it is possible to learn the rest of the rule patterns of arithmetic.

Algebra is just a method of showing arithmetical patterns by alternative generalized patterns. Since mathematics operates under strict fixed rules (patterns), advancement in maths depends on learning a wide vocabulary of algebraic patterns which can be recalled for use when needed. Every step in any calculation is based on the use of patterns, ranging from the simple multiplication table to the concepts of calculus. We cannot calculate without using look-up table methods and our digital computers are programmed to use the same methods to do calculations.

Artificial intelligence

If there isn't such a thing as human intelligence, there can't be such a thing as artificial intelligence. Even so, since pattern-association ability is called intelligence in humans, the same thing must be true for machines. Von Neumann serial processing machines cannot provide a practical basis for any form of "real" artificial intelligence because they do not have a large-scale pattern-recognition capability. A machine which emulates the way a human brain works must therefore operate in a parallel manner.

Much of what is called parallel processing is, in fact, a number of sections of a serial process being dealt with simultaneously. True parallel processing is used in neural networks and a few other specialized machines, but it has been given much less exposure than serial processing in the technical press.

A parallel processor can handle a very large number of simultaneous pattern inputs and produce a secondary set of patterns which relate to the inputs. In turn, these secondary patterns can be processed again to produce tertiary patterns and so on. After several stages, the complex set of patterns will be resolved as one pattern, which will be recognised as being the logical conclusion. This final pattern could be a demand for more input or a prompt for an action.

There have been several attempts to devise neural networks which can perform the recognition function. Most of these have been based on the interconnection of a relatively limited number of memory cells and cross-linking cells.

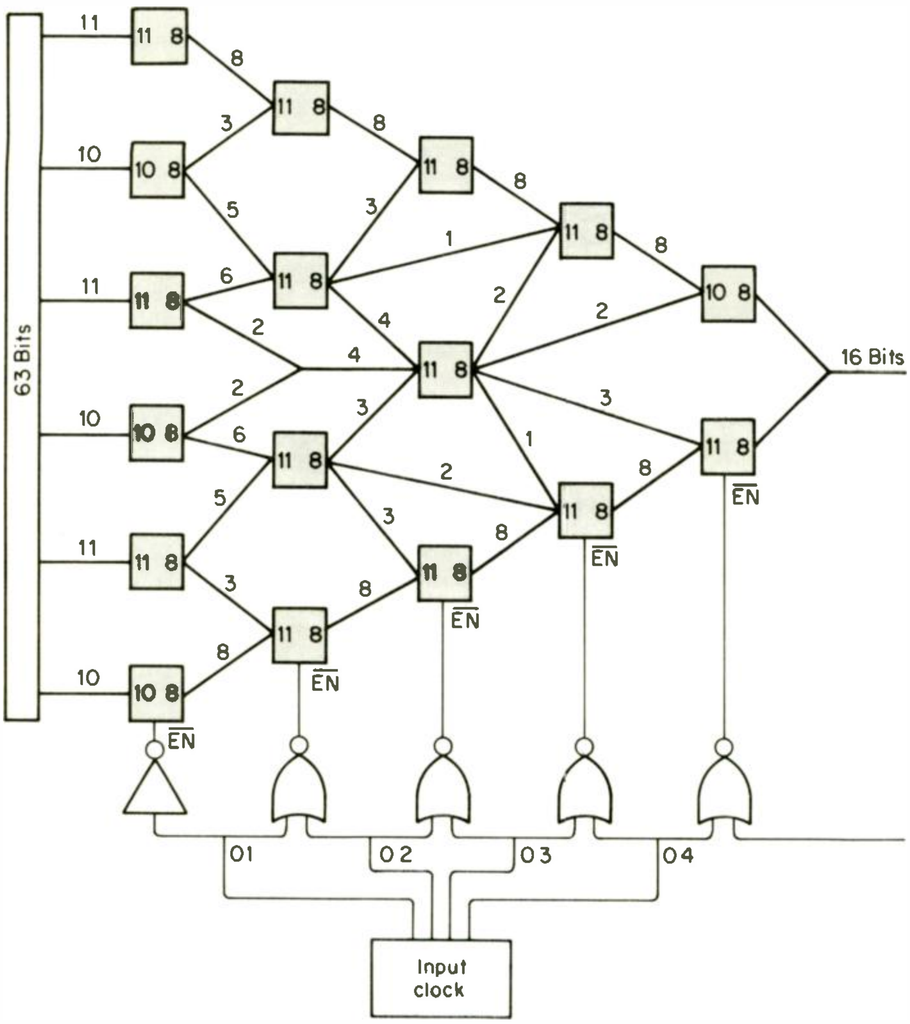


Fig. 2. Recogniser input stage mapping to suit a 7 × 9 optical unit. Timing controlled by serial processor to enable successive pairs of stages. Each chip programmed with arbitrary sequence of numbers and always in "read" state. Inputs are address lines – outputs data lines.

In an effort to avoid the problem of making a complex network of such cells from discrete components, I have tried to use ordinary memory chips. My resources have not yet enabled me to produce a working machine, but I think I have worked out the principles which will enable such a machine to be produced.

I will attempt to explain these in terms which are familiar to those who have worked with the standard chips which make up a microprocessor computer. Please note that I have used the ASCII code only because most readers will be familiar with it. Any other arbitrary numbering system is equally valid. I refer to a 2K × 8bit chip like the 6116 for the same reason. Readers may like to imagine other memory structures using any feasible type of static ram chip.

Character recognition

The dot-matrix system is now so widely used that it needs no explanation; its most common use is in printers and video displays. Quality of the display depends on the number of dots used, but a satisfactory representation of roman characters and arabic numbers can be achieved with a 7 × 9 matrix; such a matrix is made up of 63 pixels. A machine which will instantly recognise a character shown by such a display must therefore have 63 inputs, one for each pixel. Recognition of the character can be signified by the generation of the equivalent ASCII code for the character.

Only a few hundred different characters are needed, so a mapping process which will transform 63 inputs to eight outputs would be suitable. This could be done with 2K static ram/rom chips in stages. Six such chips have a total of 66 address lines and 48 data lines between them, which would enable 63 bits to be mapped down to 48 bits. A second stage could use four chips to reduce 44 bits to 32 bits; a third stage reduces 33 bits to 24 bits, a fourth stage 22 bits to 16 bits and a fifth stage also reduces 22 bits to 16 bits; the "lost" bits in the mapping of some stages to lower stages can be picked up in the later stages. The final result is 16 bits, eight of which identify the character; the other eight bits can be used to indicate vertical or lateral displacement, type face, size, and the reliability of the recognition process.

Everyone who has some knowledge of maths will immediately ask: "Where has all the lost information gone?" The answer is that nothing has been lost because it wasn't there in the first place. Although 63 bits represent an incredibly huge number in binary terms, (9.22337204^{18}), in practical terms they can only represent a few hundred generally recognisable patterns. If we look at the way the chips are programmed in each stage, we will be able to see that the problem is not losing information, but sorting out the difference between valid information and that which is useless.

Assume that each of the first set of chips is programmed with the numbers 0 to 255 in sequence for 2048 bytes. The bit pattern repeats eight times in each chip. It is therefore possible to have eight different inputs on each chip which could give the same desired output. This duplication problem repeats itself at each stage until it reaches the final stage, which is programmed with what is being "seen", so a letter A would be programmed to be 0100 0001 (41H) and a letter a would be 0110 0001 (61H). Because of numerous duplications of numbers in the lower stages, there will be thousands of combinations which will also produce the same output. These unwanted combinations cannot be identified easily in advance, so a secondary process is needed to ensure that they have no effect; this process is, in essence, the reverse of the input process. The desired output is used to drive rams/roms to reproduce the matrix, which should cause the desired output.

This reproduced matrix is compared with the input matrix on a bit-by-bit basis. A 100% match is obviously desirable, but in the real world, a 90% match is likely to be more than sufficient to identify a wanted pattern. The ratios of the 1 bits and the 0 bits in the two matrices are compared and the reliability of the recognition is expressed as the proportion of bits which are correct. (63 true And gates are required, i.e. 0.0=1, 1.1=1, 0.1=0, 1.0=0.)

It can be seen that it is also possible to use precisely the same process for progressively larger numbers of "missing" bits in the reference matrix. For example, it is fairly easy for a human to recognise letters printed on a dot-matrix printer which doesn't print on one of its pins. It would be pointless to make a character recogniser which would reject a character which was printed with this fault because it would only have limited usefulness. This method of character recognition can be extended to cover larger matrices to allow larger, smaller and displaced letters to be recognised. An 18 × 14 matrix would permit a 50% displacement of a 9 × 7 character within its field of view in any direction, or deal with characters which are twice the size of the original.

The basic programming of such a character recognition unit would be done manually, but the rest of the variations – dots missing, size and displacement – could be handled by a microprocessor. As soon as *one* of these units has been made and programmed, the contents of the various ram chips can be copied into eproms or roms for the mass production of character recognisers.

Cognic processing

This is the term I have coined to refer to a processing method which uses an input system based on the principles of the character recogniser I have just described. For simplicity, I will continue to assume that the patterns to be recognised are characters, but any type of meaningful input pattern can be used, including sound patterns.

Word recognition

If a row of 80 character recognisers was made so that they covered an 8in × 1/6in rectangle, a whole line of typewriter type could be read at once. If a character recogniser identifies a letter with sufficient accuracy, it can produce an output bit which flags this fact and a group of adjacent recognisers which have set flags are assumed to have identified a word; a recogniser which identifies a blank area will set a "no character" space flag instead. In the assumption that ASCII code is being used to identify the characters, a word will consist of a number which is made up of the ASCII codes of its letters. A word could be of any length, but the number of positions on the line is limited to 80, one of which must be a space for a word end to be identified. It is therefore assumed that a word can have from 1 to 79 letters. The recognition of words uses a similar process to that which is used for letters; all the words on a line will be recognised simultaneously.

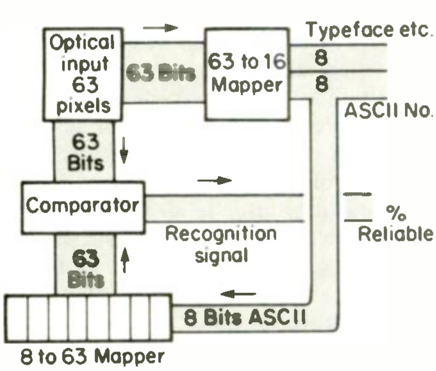


Fig. 3. Character recogniser unit, with reverse mapping to produce recognition signal. Reverse mapping can be used to identify any pattern input.

In an 80-letter line there can be no more than 40 single-letter words, since a word must be terminated by a space. In practice, provision would be made for up to 20 words on a line. The word recogniser used for any word is selected by the relative value of the position number of a word's terminating space character, which simplifies the switching needed to connect a group of character recogniser outputs to a word recogniser input. The process of reducing a large binary number to a smaller one which has a pre-defined meaning has been covered in the character-recognition process.

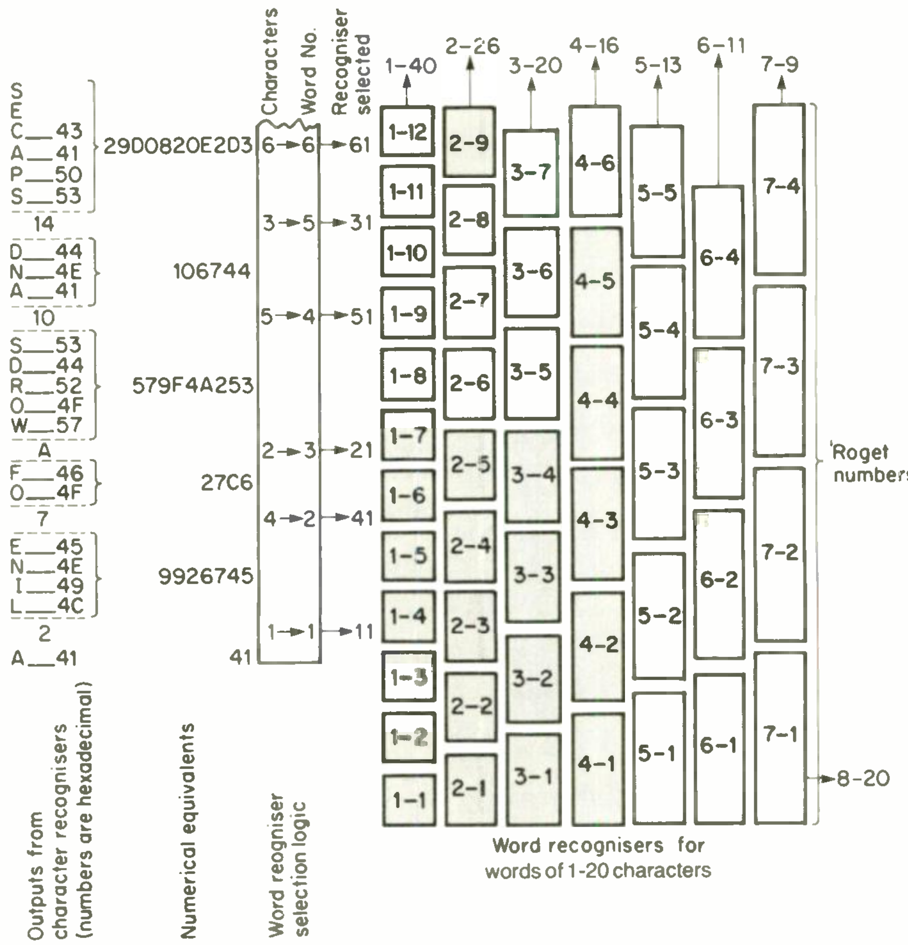


Fig. 4. Word recogniser identifies word endings by following spaces. Here, 7-bit ASCII codes produce numbers to represent words. Logic unit identifies word length and position on line, selecting next word recogniser available which matches word length.

Meanings of words

There is no universally agreed way of classifying words in order except alphabetically, but this order has no meaning and is purely arbitrary. One meaningful method of word classification is the one used in Roget's Thesaurus. For the purpose of explanation, Roget's numbers will be used.

There are just over 1000 classifications of words. Within each of these classifications all words which have similar or related meanings are listed,

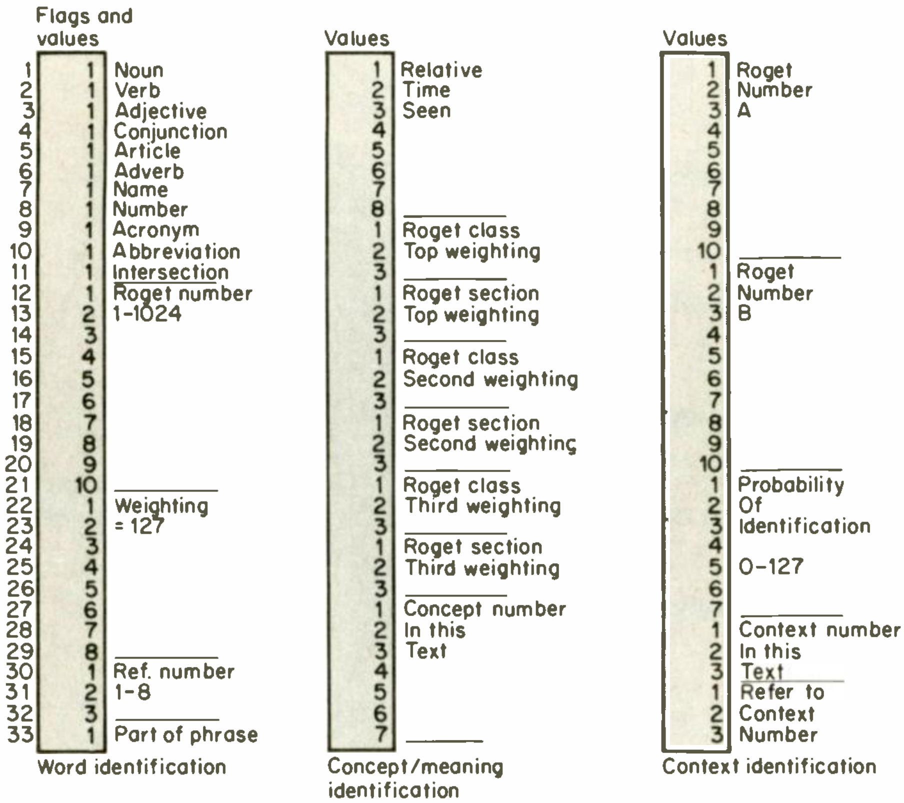


Fig. 5. Stages in "understanding" an input. First stage classifies word by grammatical type, "Roget" number, weighting within Roget class and arbitrary reference number. Flag indicates whether part of phrase or compound. Second stage records time marker and three Roget classes which include word. Concept in which word occurs given number to mark position in text. Third stage identifies two Roget class numbers which create suitable context identification number when combined. Probability of correct identification allocated and context sequence number generated. Reference to related context in text included. Number of bits used in each stage depends on application.

words within each classification varying in quality and degree. By some arbitrary method, each word can be given a weighting number which indicates the sort of classification which is appropriate. A typical list might be:

freezing	−9	stuffy	+1
icy	−8	warming	+2
cold	−7	warm	+4
chilly	−5	tropical	+6
cool	−4	hot	+7
cooling	−2	scorching	+8
temperate	0	searing	+9

There may be some argument about which numbers are allocated to certain words but the numbers I have allocated will show the principle. It is therefore possible to convert groups of letters into a set of agreed numbers which represent word meanings.

It is at this point that the next stage of recognition becomes harder to define. There is already a system in use which gives words meaning: every computer which uses a high-level language has an interpreter to convert character sequences into computer operations. This principle has been extended in computer-based dictionaries for foreign languages. An arbitrary numbering system is used to link pairs or groups of letter sequences.

The meanings of patterns

Individual patterns can only have meaning if they are part of a larger pattern structure, which can be either parallel or serial. This text was serially produced but it could be reproduced by the parallel method of photography. However, the pages on which it is written are each an entity which cannot be defined in a serial manner. The meaning of the text can only be arrived at serially, while the medium on which it appears has no meaning at all.

If I have written my description correctly, the reader will have stored a sort of summary of the abstract concepts which are contained in it; each concept is a recognisable pattern which has been described by the words I have used. These concepts have most of their meaning in the context of the other concepts, which are part of the even larger concept pattern which will be conveyed by the article.

The article can only be understood if the various concepts it contains overlay each other in a logical manner. Since it is in print, it has the advantage that the reader can re-read it if some vital point has been missed.

These comments are a description of a pattern which can be duplicated by using a further extension of the character and word recognition processes.

In context

The key aspect of this type of pattern is time; the meaning of the later parts of this article is based on what was written previously. Parallel input to the recogniser I have described must be flagged with the time the information appeared. Concepts of *begin, read, store, continue, until* and *end* are already incorporated in existing computer languages. It is therefore logical to use a serial processor to control the parallel recognition unit.

The higher level of recognition is based on a context comparison between text which is currently input and that which has been seen previously. Since every context can (by definition) be defined in words, a context number can be generated. Each change or development of context will also be flagged with its chronological position. As each context is identified it can be used to refer back to previous inputs to revise individual word meanings which could not be unambiguously recognised when they were first seen. Context recognition can use the same cues as we ourselves use when reading a text. Titles and headings are two examples of such context cues.

Final stage

I hope that the vague terms in which the previous section was expressed conveyed the idea of developing meaning/idea/concept from a collection of lesser concepts. The final in-built command of the cognic processor is to compare the knowledge gained, if any, with existing data. In the naive state, all input is new to the processor, so it is automatically stored. As time progresses, new input will either reinforce existing information or negate it. Stored information will thereby become more refined and reliable as a reference.

At a mature stage, the processor will be able to note that some new input is very similar to existing data, so only the differences need to be stored. If the data is exactly the same, only the facts that it has been seen again and when it was seen are stored. If the same data is repeated many times, only the first occurrence, the times of the first and last occurrences and the number of repeats are stored. Gradually the recogniser will need to store less and less as it becomes more knowledgeable.

The difference in meaning between command and data information is dealt with at an early stage, but the later stages of context analysis can alter the interpretation of what is a command and what is data. The processor will learn by experience.

Thinking

A machine which can think is almost unthinkable, but the cognic processor described can be made to emulate thinking. The input devices can be made to operate much faster than a human can; in consequence it is likely that the machine will have periods when no new input is available. A random number generator controlled by the serial (control) processor can then select pseudo inputs from different parts of the memory for comparison. Where common patterns are discovered, these are labelled with cross references to each other in a concordance, the cross references including the degree of matching and the contexts involved in the two sources. If the common pattern is well defined, a search can be started for more occurrences of the same pattern, which can be added to the concordance list. The possibilities for such a machine are almost endless. A biological version of such a machine has been used to write this article.

Notes on possibilities

One line of 80 character recognisers, which each cover a 14 × 18 matrix, produces 80 × 18 × 14 = 20 160 pixels or 2.5Kbyte. Using 2K types, about 32 chips would be needed to cover an 18 × 14 matrix in the way I have described. The word and context recognisers would use far fewer chips per stage, since they would have fewer bits to handle; about 500 chips would be needed to make a one-line reader/processor. A cognic processor made on this basis would produce an output from an 80-character input in less than 2μs using 120ns chips. This speed would be unaltered for all sizes of processor. A one-line cognic processor could read text printed at 6 lines/in, (and act on the input) at the rate of 1.315 mile/s. A typical 50 000 word book could be read and "understood" in 8.3ms.

If custom chips are designed to reduce the number of steps needed, the processing time would be correspondingly faster. A cognic processor which could read 1 000 000 pixels in less than a microsecond is conceivable.

Sound data is also formed in patterns which are received serially but processed after short-term storage in parallel chunks. Spoken language relies on the listener's ability to relate current input to that which has been received previously and our ability to understand a written text relies on the same processing system. This is why it is impossible to listen to one thing and read another at the same time, but it is easy to follow a written version of the spoken word even in another language (if you know both languages).

Since A-to-D sampling methods provide a satisfactory way of converting sound for digital storage, the data produced in, say, a 1s sample can be analysed in the same way as has been described for character and word patterns. There is no particular need to "know" how it is done; a cognic processor simply needs to be read to aloud at the same time as it "sees" the text. Its in-built cross-referencing system would enable it to relate one input to the other and it would quickly learn the rules of pronunciation for itself so that it could read to you or understand any spoken commands within minutes.

The system I have attempted to describe would deal with the equivalent of a line of type in 2μs. A fast human reader could read the same type in about a second. Such a machine could "learn" at least 500 000 times as fast as a human, if not faster. It would have to have the Asimovian Laws of Robotics built into it. ■

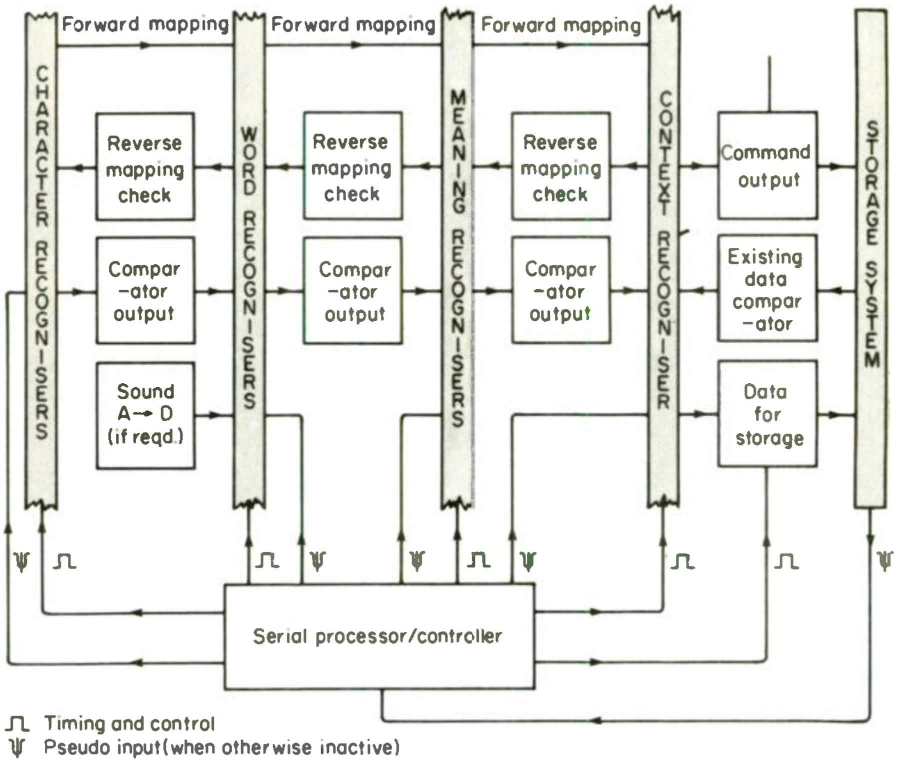


Fig. 6. Cognic processor. Each stage is a mapping unit which functions as parallel look-up table. Serial processor only controls timing and pseudo input generation for "thinking" process; it does not perform input processing. Only new data is stored.

The author
After serving in the RAF until he was 27, the author worked for various electronics companies until starting a degree course in computing and German at Hatfield Polytechnic, graduating in 1983 aged 50. He has been developing the ideas in this article for over 20 years, having become involved in the subject while designing artificial limbs using myoelectric input; at that time, he developed a novel type of memory using extremely fine glass fibres. He now works for Neosid.

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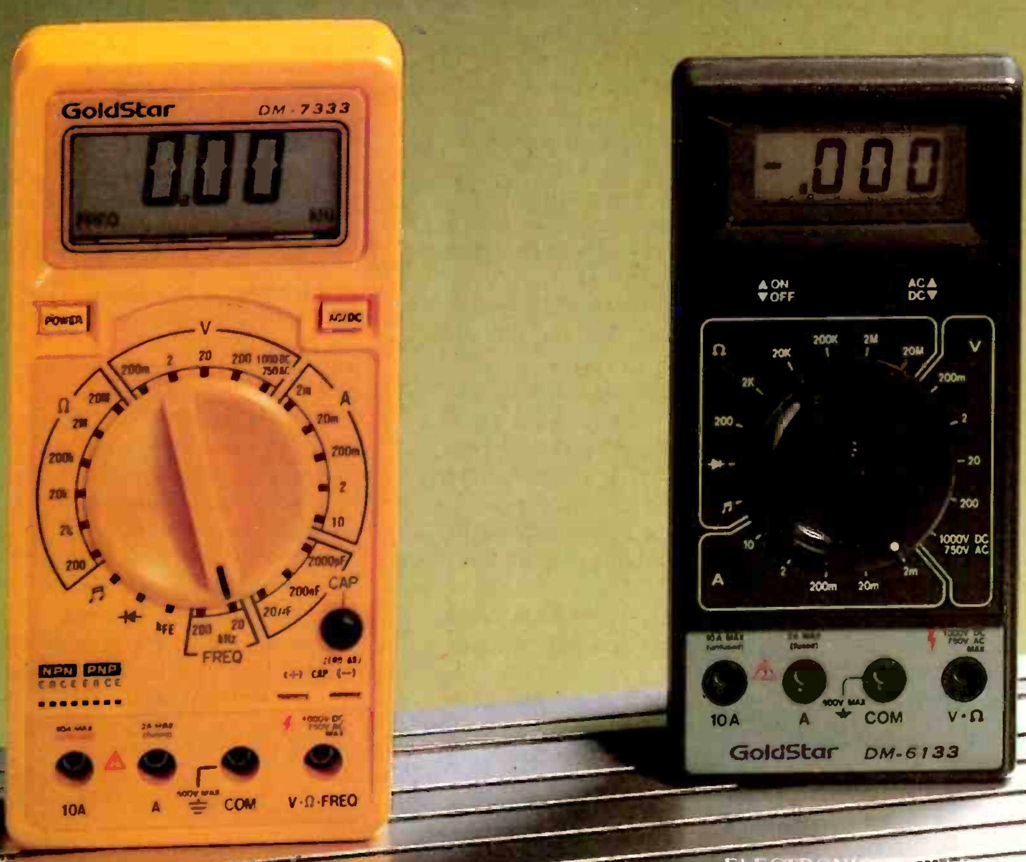

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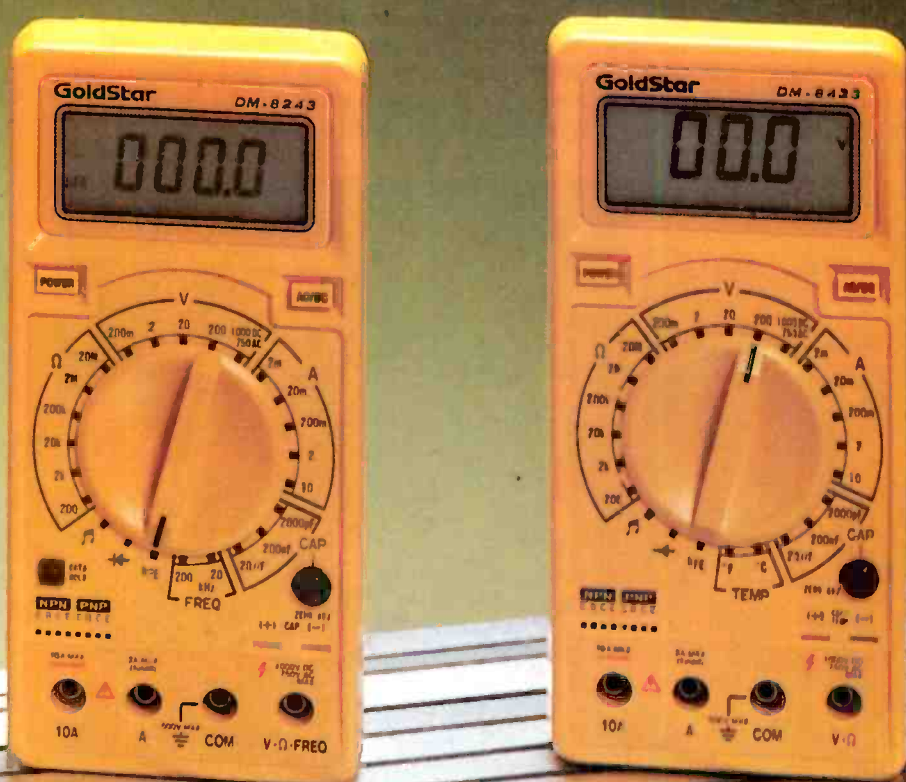


Telepoint firm hits back

One of the four Telepoint consortiums has hit back at claims that Telepoint is doomed because of the competing threat of personal communication networks (PCN).

BYPS, a combination of Barclays, Philips and Shell, claims that the decision by European PTTs to support the Common Air Interface (CAI) as the leading technical standard for Telepoint will be a boost to the UK's fledgling Telepoint industry.

Peter Wright, BYPS' managing director, said: "There has been a lot of comment in the press about the importance of PCN. Much of it has been confused and has led to the perception that the Telepoint industry will not flourish. Telepoint exists now. PCN is still a long way off." It took five years for the Common Air Interface (CAI) standard to reach its current position and it will take at least another five years for PCN to establish a common workable technical standard.

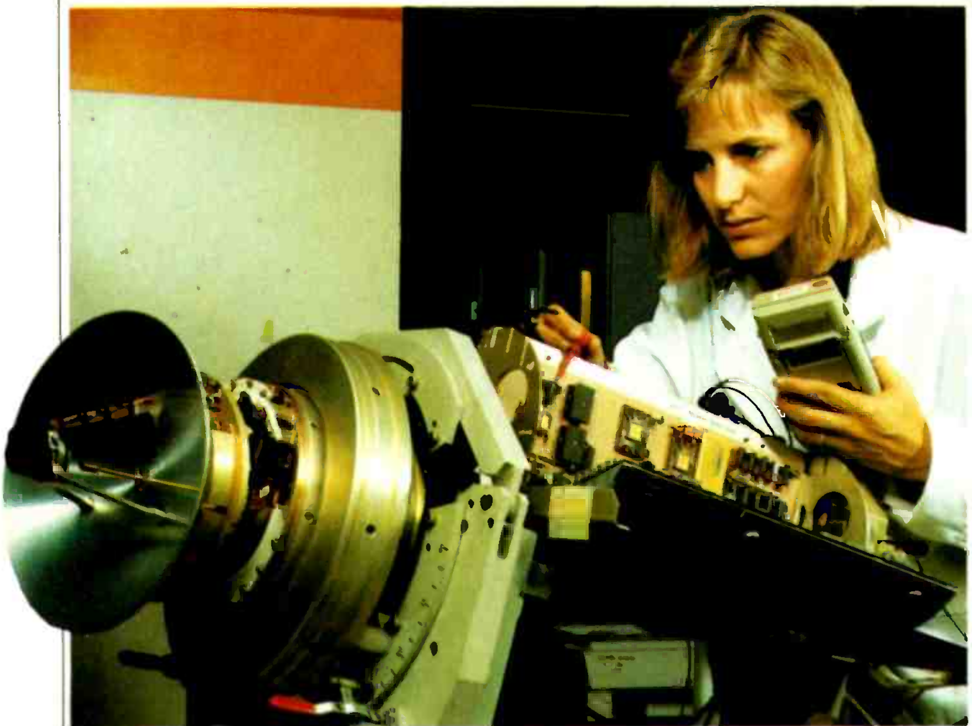
He said: "Telepoint will be the first mass-market mobile communication system and the CAI will be the technical standard which underpins its successful development. CAI will allow manufacturers and consumers to get the best from the cost-effective mobile communication which Telepoint can offer."

An independent report from CMA Research suggests that CT2 cordless telephone technology has a future that is not as bleak as some industry observers believe. Interviews conducted last year among potential users of Telepoint and CT2 found a high degree of confidence in CT2.

Carl Morris, Chairman of CMA, said: "The key to understanding the future prospects of CT2 technology is to appreciate that Telepoint should not be considered the main thrust of CT2." He said that Telepoint is just the first marketable service to use CT2 and pointed out that the next CT2 development after Telepoint is the wireless PBX.

He added: "The general belief among operators, manufacturers and opinion leading prospective users seems to be that CT2 technology will really take off when it is used in the office and business environment."

Hopefully rendered obsolete by the new politics: millimetre wave seeker for the Maverick air-to-surface missile. Millimetre wave radar, with its small system size and high resolution, makes autonomous target detection, acquisition and tracking possible in a missile-size package. This 9.6in diameter seeker was designed and built by Hughes to be evaluated by the US Air Force in captive and free-flight tests. The demonstration programme is being managed at the Elgin Air Force base in Florida.



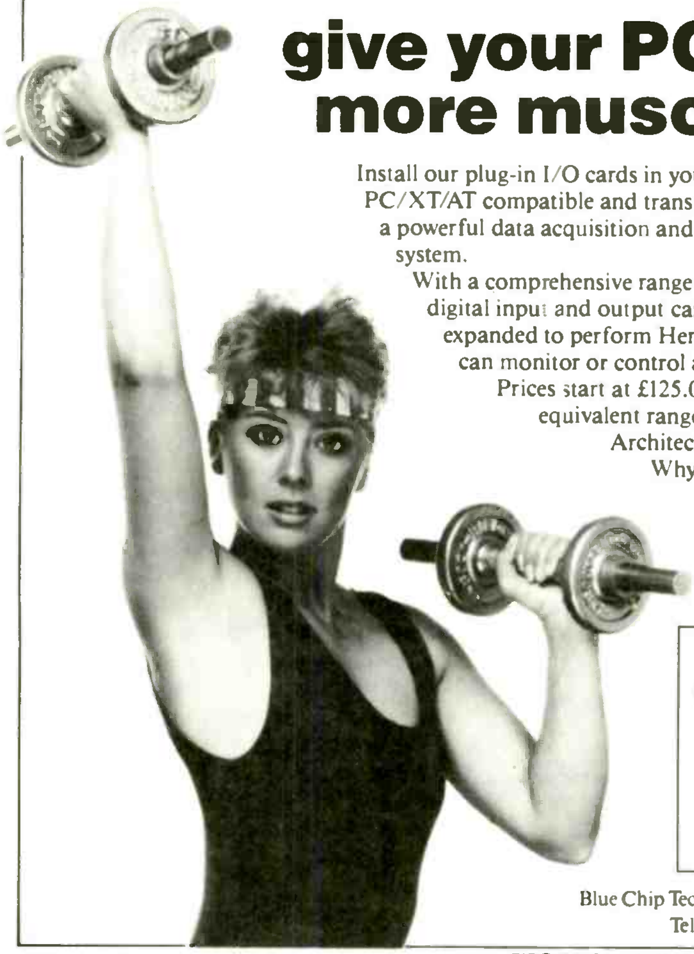
Computer shielding

Ugly metal shields to protect computer terminals from electromagnetic interference can be a blot on the landscape of a plush office complex.

A Kent firm may have the answer. Magnetic Shields has built a shield made of Mumetal sandwiched between two pieces of teak. As well as looking attractive, it cuts out crosstalk between adjacent terminals.

United Friendly Insurance in London is using them to block out electromagnetic interference from a nearby electricity substation. It can also help to stop rivals spying by remotely reading the data from the computer screen. Michael Eastland from Magnetic Shields said: "It does assist in stopping security tapping, but it does not stop it. It will make it more difficult."

The firm makes two sizes, the largest of which will hold most sizes of terminal, but the firm plans to extend the range to five in the near future. A space at the back of the shield allows access to sockets and ensures a free flow of air.



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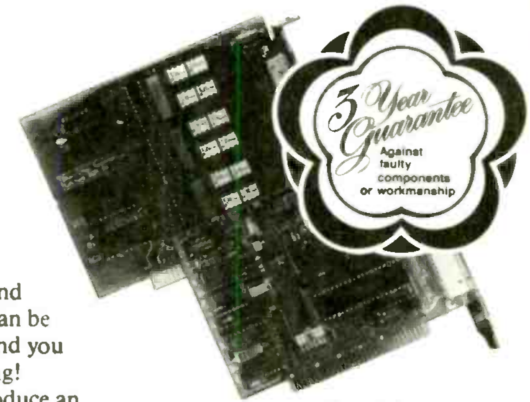

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Optical chip doubles capacity

A photonic IC has been developed with what is claimed to be the highest capacity in the world. Such devices use photons as well as electrons to process information.

The device, from AT&T Bell Laboratories, can process 2Kbit of optical information in parallel, twice that of other photonic ICs. It is a single GaAs chip with 2K elements. Each element is a symmetric self electro-optic effect device, (S-SEED), invented at Bell in 1987. An S-SEED can act as a logic gate, memory cell or switch.

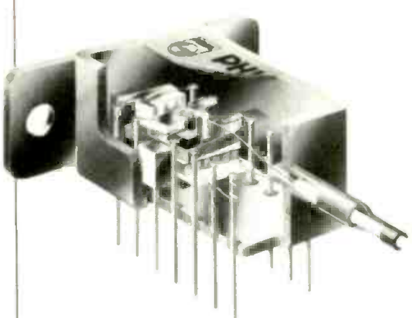
An S-SEED is cascadable and operates as a three-terminal device; it uses differential inputs and outputs. Switching speed is less than 1ns and initial results show that the optical switching energy per device is 2.5pJ. Holding power is 200nW per beam or 1mW for the entire array.

Prototypes of the new chip are being made and it is expected that it will be used in future optical computers and other optical systems. Edward Labuda, an AT&T executive director, said: "We're exploring the use of these ICs. We're a long way from development and delivery of whole systems using technology, but there is a lot of interest. We're happy to work with developers in other companies to design it into their systems."

The chips are 2mm square and come in a 32 × 64 element array in an open 24-pin package.

Laser diode for fast opticalcommunication

AveryfastInGaAsPlaserdiodefor high bit-rate optical-fibre communicationsincorporatesinternal electricalcompensationforoperation at up to 2.4Gbit/s, claimed to be a record for a dil-packaged device.



The Philips CQF60 has an LC compensation network that counteracts the effects of the inductanceandcapacitanceofthe encapsulation and feed-through connections,providesperfect50Ω impedance matching and avoids electricalreflections.Itcomesina14-pindipratherthantheconventional butterfly-style encapsulations.

Thediodeisoneofafamilycovering 1.3 and 1.55μm wavelengths that includesdeviceswithmultimodeand single-modefibrepigtailsandoutput powerlevelsfrom100μWto1.5mW.

Lasers with FP and DFP hetero-junction structures are available and some devices have integral TE cooling.

Patent grant for science students

The British Technology Group is to sponsor a course on intellectual property law for science and technology graduates.

The £2000 scholarship will be at London University's Queen Mary and Westfield College and it has been introduced as a response to a growth in British-generated technology.

An MSc in intellectual property law does not fall in the academic fields for which postgraduate research funding is generally available and often students have to finance their own studies. The college will decide which applicants receive the BTG grant. BTG hopes the grant will improve its links with the college, whose intellectual property law unit is highly regarded for teaching and researching patent, copyright, trademark and information law in the UK. BTG has one of Britain's largest patenting departments.

• Betronex, Hertfordshire based CAD/CAE system maker, has announced a scholarship programme for students of computer-aided electronic engineering. It will award two students £1000 grants towards tuition costs at a college or university of their choice.

Beware the ides of April

April could be a record month for nervous breakdowns among computer managers. A Friday the Thirteenth following so soon after Fool's Day is an ideal environment for computer viruses to flourish. The perpetuators of these software-wrecking bugs are unlikely to miss such a glorious opportunity.

The National Computing Centre has responded by putting out a fact sheet giving advice on prevention as well as telling you what to do if affected. Tony Elbra from the NCC's security department said: "The best way out of all viruses is by using back-ups."

But, if you haven't already started regular back-ups, it may be too late. The time-bomb viruses that are likely to hit in April may have been lying dormant for up to a year. Any back-up taken since the virus arrived will itself have the virus.

The golden rule if you are affected is not to panic. Do not switch the system off. Do not try using different data or different machines; this may just spread the virus. Contact a help desk for professional assistance. Some viruses can be easily cured if you know what you are doing.

Elbra said: "Most viruses are innocent. They are just a nuisance, such as a bouncing ball on the bottom of the screen. They are generally written by clever people with a warped sense of humour."

Fastest PNP transistor

Scientists have produced PNP transistors capable of switching at 25GHz, more than three times the speed of present generation PNP products, claims IBM.

Developed for supercomputer applications, the new device technology will allow complementary high-speed silicon technology rather than the all-NPN arrangements currently used at high switching rates. This will enable semiconductor makers to build low power chips without speed sacrifice. Although the advantage has yet to be demonstrated, the advent of complementary bipolar circuits "may revolutionize logic design in the same way that the combination of nmos and pmos devices in c-mos produced dramatic advances in mos technology". This will lead to larger, more complex IC systems, says IBM.

ATs get chip set boost

Intel has announced two chip sets based on the 386 SX and 386 DX microprocessors for use on IBM ATs and compatibles. They are claimed to be the only 16bit two or three component solution for the entire price and performance range of 32bit 386 microprocessor architecture.

They are called 82340 SX and DX and Young Sohn, an Intel marketing manager based in Santa Clara, said it "is the most flexible and cost effective solution for 386 PC AT systems available today, from entry level to high-performance computers."

The set brings down the total logic and TTL chip count for AT compatible computer systems to less than six components, compared to sometimes more than 25 components in comparable systems.

Samples are available now and production quantities are expected within three months.

• Sevenoaks based distributor Jermyn has announced ex-stock availability of Intel 80486 processors. They have previously been available to selected customers only.

Superchip can perform 200Mflops

Motorola and TRW have built a multi-million device superchip called CPUAX. It contains four million 0.5μm c-mos devices and can perform 200 million floating-point operations a second.

Dr Thomas Zimmerman, a TRW director, said: "The CPUAX is the computational equivalent of some supercomputers that fill an entire room, require elaborate refrigeration systems and weigh several tons."

The CPUAX measures 2.1in square and weighs 1.5 ounces. When used with a TRW-Motorola 36K-device satellite chip that can test, monitor and configure the on-chip assets of the CPUAX, the CPUAX can repair itself.

Zimmerman explained: "The self-repair abilities of the CPUAX make it possible to work around the inevitable flaws that occur during fabrication. Also they enable the CPUAX to repair itself should any failures occur on the chip during operation."

It is intended to function as the central brain of an advanced digital signal processing system in various air, ground and space based systems.

• Motorola has announced an 88000-based risc CPU that will power a high-performance multi-user system, from Norway-based Dolphin Server Technology. Motorola and Dolphin have a technology agreement which gives Dolphin access to the 88000 instruction set and gives Motorola access to Dolphin's processor technology.

BT has obscene headache

One in five telephone customers believe they get fairly or very bad value for money from British Telecom, according to a survey carried out by Oftel at the end of last year. Though bad, it is a slight improvement on the figures for 1988. While the figure for very bad value for money stayed the same at 4 per cent there was an improvement from 18 to 16 per cent who rated it fairly bad.

The best figures, though, were on customer satisfaction. Those who were fairly or very dissatisfied dropped from 15 to 9 per cent.

One of the main problems is the number of obscene telephone calls made to women, which is estimated at being more than ten million a year and there is evidence of substantial numbers of other types of nuisance calls. Sir Bryan Carsberg, director general of telecommunications, said: "I have asked BT to carry out a review of its procedures to deal with nuisance calls. I expect BT to be proactive in its efforts to protect customers from these calls, using the facilities provided by modern technology to the full."

Another problem is the number of unsolicited telephone sales calls being made, which has been rising steadily over the years. In a similar survey in 1985, 46 per cent said they had received such calls. The figure last year was a staggering 72 per cent. Sir Bryan said: "Telephone selling is extremely unpopular with telephone customers on the whole."

The good news is that in May last year BT hit its target of 95 per cent of call boxes in working order and this level has been maintained.

RSGB frets over proposed EMC law

A European Community directive and a DTI consultative document have been produced as a prelude to legislation on electromagnetic compatibility planned for mid-1991.

The directive tries to set standards for all marketed products covering radiation and immunity. Radiation refers to unwanted signals from equipment including toy trains, X-ray equipment, telephone exchanges and home computers. Immunity covers the ability of products to ignore the radiation from other devices.

The Radio Society of Great Britain is producing a response to the proposals and is seeking input from radio amateurs, short-wave listeners, amateur radio suppliers and associated bodies.

One of the RSGB's worries is that it could cost a company £5000 in testing before it could sell anything. Such a figure could be disastrous for small companies. Buyers of kits and second-hand equipment of all kind – not only amateur radio – could be badly hit, since it is proposed that this type of apparatus shall be covered by the legislation.

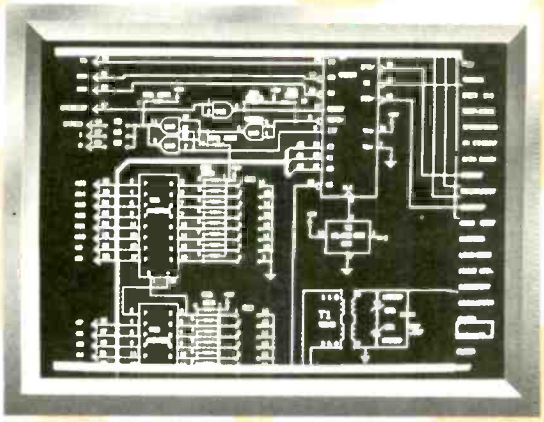
Flat year for industry

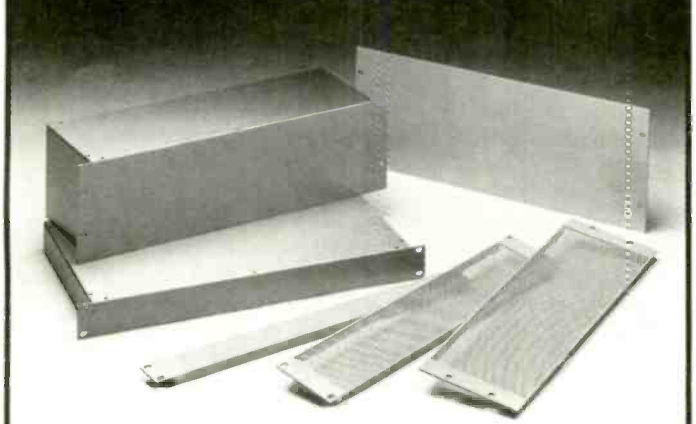
Little growth is expected in the electronics industry this year, but 1991 is looking good, according to a Dataquest survey commissioned by Semiconductor Equipment & Materials International (SEMI).

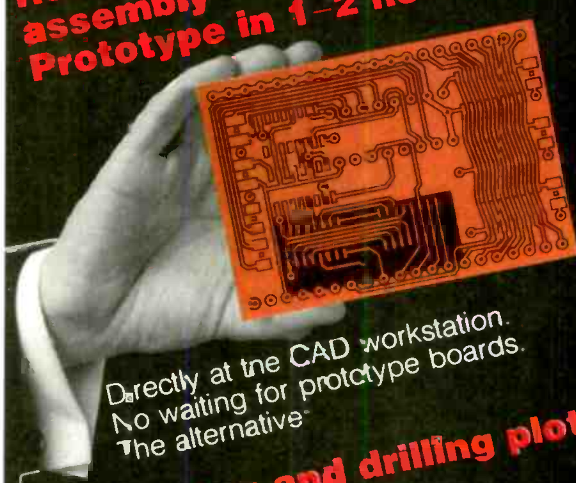
The survey adds that worldwide semiconductor production is expected to double in the next four years from $60 billion in 1990 to $120 billion in 1994. To meet this, more than 100 new wafer fabrication facilities are planned for the next two years, half of them in North America.

Paul Davis, SEMI's European director, said: "To support the expected increase in production, capital spending will have to increase simultaneously." And he added that Europe looks a likely target for expansion by Japanese semiconductor makers.

Significantly, equipment suppliers are expecting a 7% growth this year compared with only 3% for semiconductor device sales. Davis said: "This is very good news for our member companies which produce capital equipment for the semiconductor industry."







KILLING FIELDS

The microwave health hazard

The UK microwave exposure limits were originally determined by irradiating a body to the point where thermal tissue damage occurred, then backing off the power by a factor of ten. Our standards for safe exposure are still derived from this crude test. Meanwhile a number of associative studies have linked cancer and blindness to microwave exposure at power levels orders of magnitude lower. By Simon Best.

Epidemiological studies of RF/MW exposure are far less in number than those of exposure to ELF power frequency fields, perhaps for obvious reasons. Far less of the general population are directly exposed to such fields, at least at levels that current safety guidelines would lead one to think might be harmful, although some can be exposed to high fields occupationally.

Thus, some of the earliest studies have been of individuals exposed through a military or similar situation. Between 1953 and 1977 the Russians irradiated the US Embassy in Moscow on a more or less continuous basis, but at levels so far below the US MW exposure safety guideline of 10mW/cm^2 that the Americans could not believe they could be harmful.

A US Senate Report was finally produced on the irradiation[1], in which it detailed the irradiation and health studies performed during and afterwards. For example, from August 1963 to May 1975 the frequency of the beam ranged from 2.56 to 4.1GHz and the intensity remained at about 5μW/cm^2 at the strongest point of the beam. Other beams appeared in due course, boosting the intensity at times to 18 μW/cm^2. The irradiation stopped altogether in January 1979 but reappeared briefly in 1983 and again in 1988, when a frequency in the 9-11 GHz range was reported producing power levels of 0.01 μW/cm^2 inside the building.

Some of the health studies and results are difficult to evaluate and tended to be deemed inconclusive.[2] One study of lymphocytes used 350 Moscow personnel, two-thirds of them male, and a group of some 1000 foreign service personnel resident in the US as controls. Although mean lymphocyte counts among Moscow personnel were 41% higher than the control group's, they were present equally among those personnel who had arrived afterwards. They showed a sharp and sustained drop-off after August 1977, when they reverted to the control group's levels.[3]

The most extensive epidemiological study of ex-Moscow Embassy personnel was completed in 1978 by Dr Abraham Lilienfeld at John Hopkins University's School of Hygiene and Public Health.[4] It assessed the mortality and morbidity of all Moscow Embassy personnel and dependants from 1953 to 1976 and matched them with a control group of US personnel who had been stationed in other East European embassies, none of which had reported irradiation.

The analysis of the medical records of some 3100 Moscow personnel and 2336 dependants, 1468 of them children, yielded some provocative results. Although overall mortality favoured the Moscow group, females in the group showed a non-significant but higher than average death-rate from malignant neoplasms.

However, Moscow males showed a definitely significant raised rate of protozoal intestinal diseases, benign neoplasms, and diseases of the nerves and peripheral ganglia. Moscow females had a significantly higher rate of protozoal intestinal disease also, as well as complications of pregnancy and childbirth.

As a group, Moscow personnel suffered significantly more eye problems, psoriasis and other skin conditions, as well as depression, irritability, loss of appetite and difficulty in concentrating. And in the children four diseases – mumps, anaemic blood diseases, heart disease and respiratory infections – occured in significantly higher numbers.[4]

Although the evidence of a health hazard was very strong, the US State Department has continued to deny a radiation effect or liability, though it did try to appease by re-grading the Moscow post to carry a 20% extra salary. Three US ambassadors who served during the period have died of cancer and some former staff are still filing claims against the US Government.

If the microwave irradiation did wholly or partly cause the increased incidence of disease observed, then it was doing so at levels way below the 10mW/cm^2 safety guideline then (and still) in force, but at levels around the Russian standard at the time of 10 μW/cm^2.

US Navy personnel exposed to radar during the Korean War were studied by Robinette and colleagues[5] and Silverman[6] but no differences reaching significance were found between the high and low exposure groups for malignant neoplasms as the cause of hospitalization and/or death. But when the high-exposure group was divided into three sub-groups to provide a gradient of potential exposure, a trend did appear for increased number of malignant neoplasms in the sub-group rated as most highly exposed.

Recently, Dr Stanislaw Szmigielski, of the Centre for Radiobiology and Radioprotection in Warsaw, Poland, internationally known for his work on RF/MW radiation effects on the immune system, has reported on a five-year retrospective study of Polish military personnel exposed to RF/MW radiation over the period 1971-80 and their incidence of cancer. Typical exposure levels were estimated as 4-8 hours daily below $0.2mW/cm^2$ (the Polish 'safety zone'), although some, defying the safety rules, reported brief exposures to levels up to $20\ mW/cm^2$. Szmigielski summarised his findings in his contribution to the magnum opus *Modern Bioelectricity* (a book of over 1000 pages, with 48 contributors on virtually every area of bio electro magnetics[7], as follows:

* The risk of developing clinically detectable neoplastic disease was about three times higher for personnel exposed occupationally to MW/RF radiations. The highest risk appeared for malignancies originating from the haematolymphatic systems (morbidity about seven times higher). Other more frequent neoplasms were located in the alimentary tract and in skin (including melanomas).

* The highest risk factor of cancer morbidity related to occupational exposure to MW/RFs appeared for subjects at the age of 40-49 who had a 5-15 year period of exposure.

* Morbidity rates of neoplasms in personnel exposed occupationally to MW/RFs showed strong correlation with the period of exposure.

* Neoplasms of the same localization and/or type developed earlier (by about 10 years) in personnel exposed occupationally to MW/RFs than in those not working in the MW/RF environment.[7]

Referring to immunological effects, Szmigielski and his co-workers feel that research to date suggests that the immune system exhibits a 'bi-phasic' reaction to RF/MW radiation, with initial exposure stimulating the whole system, followed by a gradual suppression of the whole immunity with increasing exposure and/or power densities.

...Lester and Moore... reported an elevated risk of cancer close to (airport) radar installations. They observed that the highest cancer incidence tended to occur on leading terrain crests in the path of transmissions with the lowest occurring in the valleys...

In a recent communication on his current prospective study of the same population from 1986-90, Szmigielski reports that an analysis of the data to the end of 1988 'supports our earlier results from retrospective studies, although the differences between the exposed and non-exposed groups are somewhat smaller (although still highly statistically significant) than those found for the decade of 1971-1980'.[8] Preliminary results apparently indicated a doubling of the incidence of all forms of cancer among those exposed to RF/MW radiation.

Studies of those occupationally exposed in a non-military situation have also reported health effects. Vagero and Olin, in a study of cancer in the Swedish electronics industry, found a number of elevated incidences: for example, the relative risk for nasopharyngeal cancers in the radio and TV industry was 3.7 (CI 95% 1.0-13.5).[9] Milham, in a follow-up of a previous finding, found that a sample of 2,485 amateur radio operators showed a significant excess of deaths due to acute myeloid leukemia, multiple myeloma and non-Hodgkin's lymphomas.[10]

Zaret has observed a particular type of posterior, subcapsular cataract

(PSC) in microwave-exposed personnel, first identified in 1964 while studying radar maintenance men for the US Air Force.[11] Further studies[12], including air traffic controllers[13], led Zaret to describe a 'microwave cataract' which originates in the elastic membrane or capsule that surrounds the lens, as opposed to the other types of cataract (hereditary, metabolic and senile) that originate in the lens. According to Zaret, exposure to either thermal or non-thermal radiation can cause microwave cataracts, which can remain latent for months or years. Others have confirmed his findings, for example, Hollows and Douglas, who found a significant increase of PSCs in a sample of Australian radiolinemen versus controls.[14]

Studies such as the above led to the formation, in the States in 1976, of the Radar Victims Network, comprising a group (as many as 150 at its peak) of mainly ex-Forces personnel in Framington, Mass., which helped each other to obtain treatment and sue for damages for heath problems allegedly due to their employment. Out-of-court settlements were achieved, though the group is smaller and less active since the death of its founder, Joe Towne, in 1985.

Here, in Britain, considerable concern has been shown in the five deaths that have occurred at the Royal Signals Research Establishment at Malvern, all from brain tumours, giving an incidence rate 6.4 times the national average.[15]

The Ministry of Defence has not indicated what, if any, research it is doing on RF/MW irradiation; by contrast, Georgia Institute of Technology in the States is working with the US Air Force on a study of long-term pulsed MW irradiation of mice.

Another US occupational study has looked at the levels of exposure experienced by surgeons. Simulating a normal operation, Paz and his colleagues found that surgeons using electrosurgical units (ESUs), for cutting and sealing tissues, were being exposed to extremely high levels of RF radiation, especially around their eyes and foreheads which registered electric and magnetic fields as high as 9 000 000 V/m and 3.5A/m respectively, far about the current ANSI standard of 4000 V/m and 0.0025A/m for frequencies between 30 and 200 MHz.[16] An ESU may be used up to 100 times depending on the operation performed.

Turning to public exposure to RF/MW radiation, Lester and Moore, again in the US, reported an elevated risk of cancer with residence close to radar installations.[17] They mapped the geographical incidence of cancer mortality and morbidity between 1975-9 in Wichita, Kansas, against line-of-sight projections of radars from the local Mid-Continent Airport and McConnell Air Base. Cancer morbidity was found to be significantly related to the degree of radar exposure. They also observed that the highest cancer incidence tended to occur on leading terrain crests in the path of radar transmissions, with the lowest occuring in the valleys, shielded from the radar beams. They cited one residential building with 100 occupants, situated so that the upper levels were directly exposed to both beams, whose cancer morbidity rate was over six times that for a sample of six nursing homes in the city.

One study of lymphocytes used 350 personnel and a group of some 1000 controls . . . Mean lymphocyte counts were 41 per cent higher than among the control group . . .

In the second study, the researchers analysed the cancer mortality rates from 1950 to 1969 in areas surrounding 92 US Air Force bases containing radar, ([18]) using as controls the nearest county within the State having the most similar population size but lacking an Air Force base. They found that the former had a significantly higher incidence of cancer mortality for the period in question, though they conceded that other factors, such as noise, may have contributed to this finding. Their results were criticised as being due to incorrectly assembled data[19], but the authors showed that this was not the case and that re-analysis confirmed their original association.[20]

A further threat for those so irradiated is that the various scanning systems for the radar beams will produce ELF modulation of the microwaves. Such modulation, using 2.45GHz, has recently been shown to act as a co-carcinogen in cells also exposed to a chemical cancer promoter.[21].

In a very recent report, Chinese researchers compared 1170 students and soldiers living near radio antennae and radar installations for a minimum of one year with 689 non-exposed controls of the same grade, age, sex and education level, using field measurements and psychological and physiological tests.[22] Visual reaction time was delayed in the groups exposed to power densities from 10-42μW/cm^2, significantly so in the group of male soldiers exposed to 10-15μW/cm^2. The same groups also had significantly lower scores in the memory function tests, although the scores of the boys and girls in the low-intensity group (0-4μW/cm^2) were higher than those of their control groups. Phagocytosis (the ability of white blood cells to destroy bacteria, and thus a measure of immune function) was significantly impared in the highest exposure group (13-42μW/cm^2) and significantly increased at the lowest exposure level. For those exposed to AM radio frequencies, phagocytosis tended to increase in those exposed to relatively low levels (3-11V/m), while decreasing in the highest exposed group (22-23 V/m).

The Chinese findings seem to support Szmigielski's conclusion that the immune system exhibits a bi-phasic response to RF/MW irradiation, initial very low exposure acting as a stimulus, with higher intensities suppressing immune function. This bi-phasic response may also explain the results of the memory tests. The Chinese observations indicate that the cut-off level for this difference in reaction occurs at around 10μW/cm^2, the Russian MW exposure safety standard at the time of the irradiation of the US Embassy in Moscow and 1000 times below the current ANSI standard of 10 mW/cm^2.

The latter has been in the process of revision almost since its adoption in 1982.[23] It is based on limiting the wholebody average specific absorption rate (SAR) to 0.4W per kilogram of body weight for both public and occupational exposure. Reducing the maximum SAR to 0.04W/kg or below (equivalent to a power density of 100 μW/cm^2 or lower) has been suggested and debate continues over the evidence for thermal and non-thermal effects and their implications for introducing different standards for different frequency bands.

In the UK, the NRPB published its exposure guidance for frequencies up to 300 GHz in May 1989[24], although this is due for revision in 1990 according to its author, Dr John Dennis. For frequencies above 30 MHz the NRPB recommends 1, 2.5 x f (GHz), and 5 mW/cm^2 for the ranges 30-400MHz, 0.4-2.0GHz, and 2-300GHz, respectively. At its lowest the NRPB guide line is still 10 times above the 100μW/cm^2 level being considered by the ANSI revision subcommittee and approximately 100 times above the levels at which the above Chinese study observed significant differences in those chronically exposed to micro waves.

The Ministry of Defence also published its guide to the safe use of RF energy (from 10kHz to 300GHz) in 1989.[25] While not attempting to set any numerical limits, the MoD document summarily dismisses non-thermal RF effects in three sentences, without any discussion of specific studies, and endorses the ANSI 10 mW/cm^2 standard without giving any indication of the debate and revision currently in progress. Thus, its grossly biassed presentation of the state of research findings and debate conceals more than it reveals and gives the impression that there is no need even to research the health status for Forces personnel exposed to RF/MW radiation.

It is to be hoped that when the NRPB revises its Guidance this year a more positive and informed attitude prevails and that due consideration is given not only to all the accumulated evidence, epidemiological, animal and cellular, but also to the growing RF and MW sources in the environment – from radio and microwave communication systems, radar, cellular phone systems and increasing satellite TV 'footprints', and their complex possible interactions – that a large part of the population is now increasingly and chronically exposed to. ■

Simon Best is a medical journalist specialising in the biological effects of electric fields and co-author of the book 'Electromagnetic Man' together with Dr Cyril Smith. Simon Best holds a degree in psychology.

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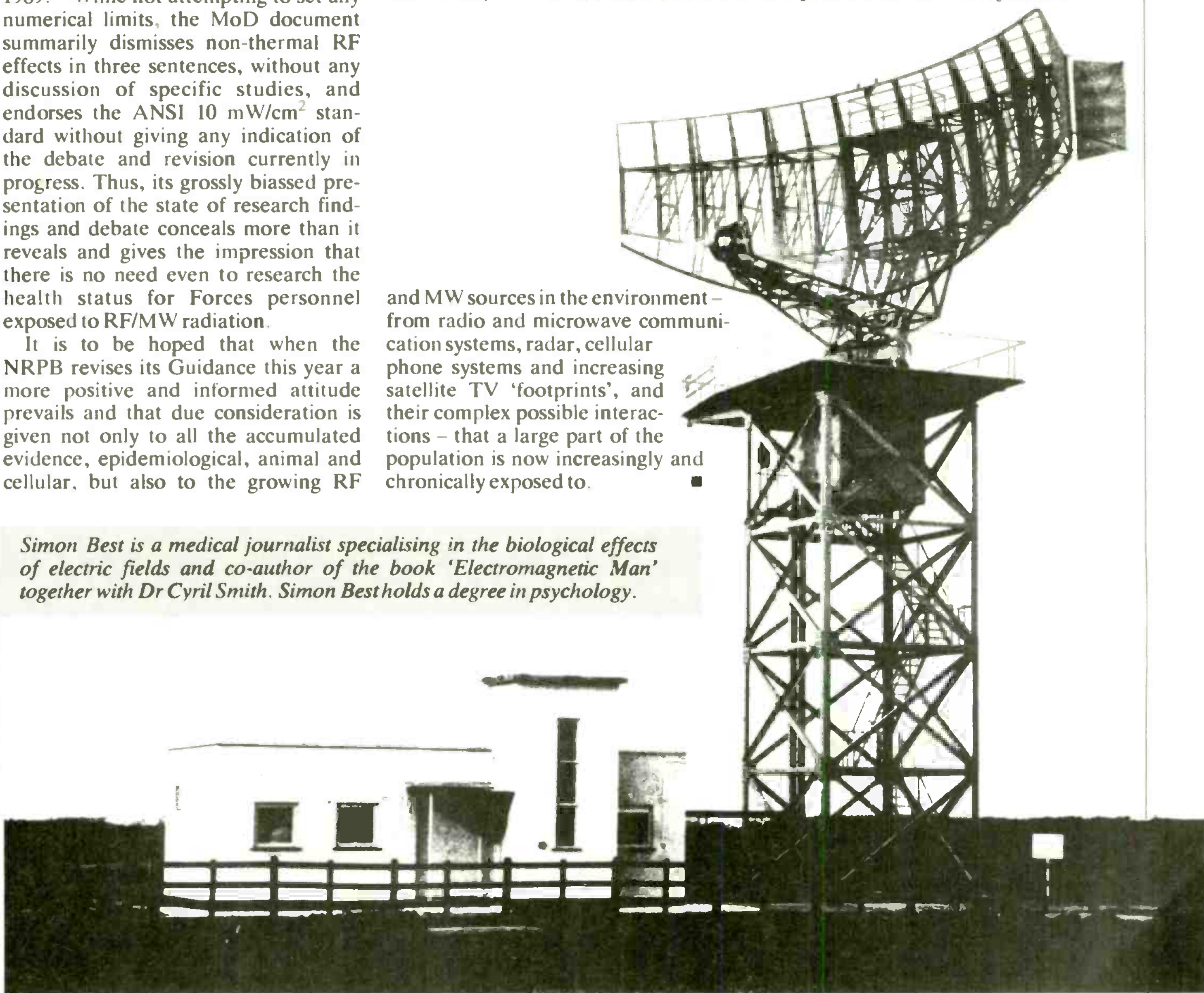
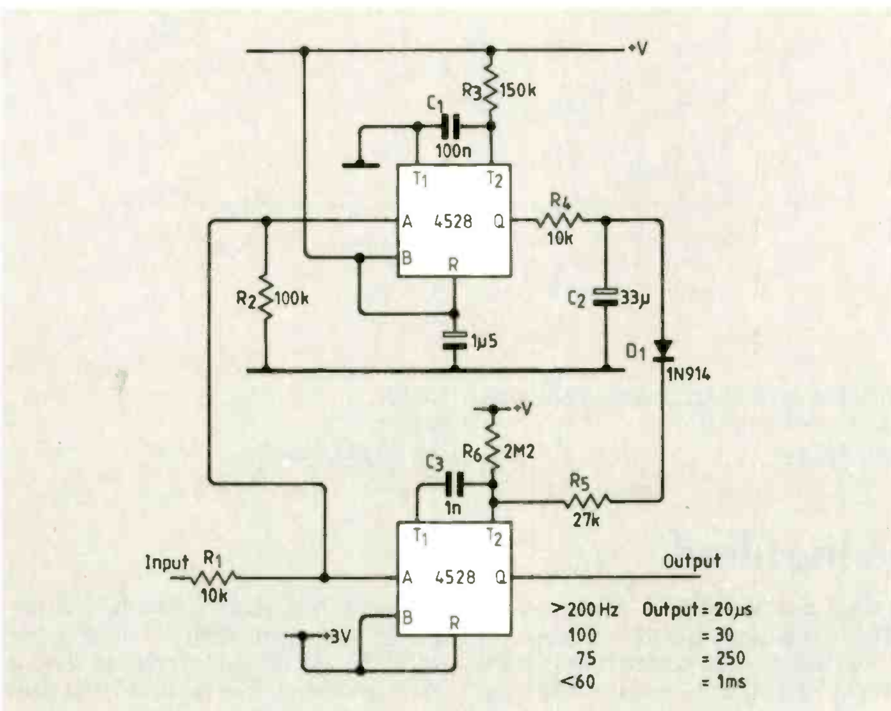


Observing short pulses at low PRF

While setting software time constants in a microprocessor-based system, it became apparent that low to mid-priced oscilloscopes are useless for observing input-port enable pulses of 1μs or less at a repetition of 30Hz or 300baud. This circuit, using a 4528 c-mos dual-monostable IC, should help.



MV1 produces 1ms pulses, while MV2 produces 5ms pulses. As the 4528 is retriggerable, the Q output of MV2 stays high at an input pulse rate of 200Hz or above. Below 200Hz, the Q output of MV2 produces a 5ms pulse waveform with a mark/space ratio that varies with decreasing frequency. This waveform is integrated by R_4 and C_2 to produce a varying DC, which is applied via D_1 to auxiliary timing resistor R_5.

Above 200Hz or 2000baud, R_5 is in parallel with R_6 and the output pulse from MV1 is 20μs. Between 200 and 60Hz, the output of MV1 varies from 20μs to 1ms. Below 60Hz, MV1 produces 1ms pulses.

The unit can be powered by two miniature alkaline cells (3V) or three miniature button NiCd cells (3.6V). The NiCd cells can be charged by applying 12V DC to the input connector.

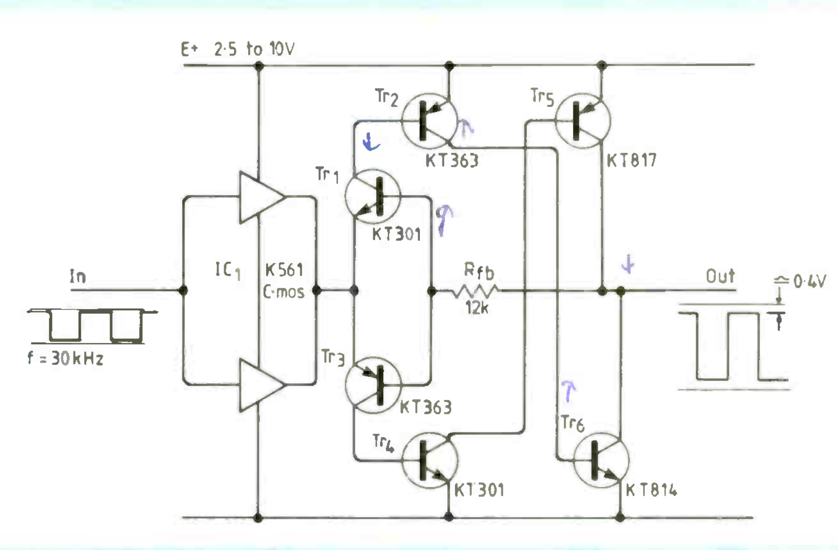
Darren Yates
French's Forest
New South wales

Low voltage switch

This switch for high-power applications has the advantages of a simple drive circuit, absence of simultaneous conduction, and a $V_{ce(min)}$ of 0.9V. It operates on 2.6V.

Transistors Tr_1 and Tr_3 work as comparators, Tr_2 and Tr_4 as regulators and Tr_5 and Tr_6 as power switches. Transistors Tr_1 and Tr_3 are equivalent to Russian part numbers KT301, Tr_2 and Tr_3 as KT363, Tr_5 as KT817, and Tr_6 a KT814. It should be acceptable to use standard p-n-p transistor equivalents.

Serge Khazanov
Leningrad
USSR



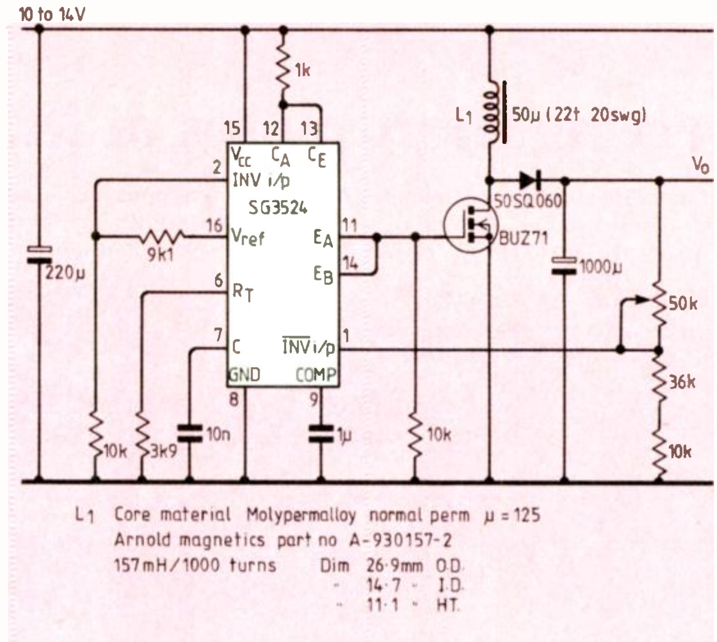
40W step-up DC/DC converter

This circuit lets a 12V car battery supply equipment requiring a higher voltage. It is a switch-mode design with a fixed frequency of 35kHz and uses a PWM method of providing regulation. Input is 10-14V; output from V_{in} to 24V using resistors shown.

As the output voltage is adjusted, the maximum available output current will vary to keep the output power product about 40W. Output regulation was about one per cent but there is a 35kHz ripple at full load of 200mV.

Most of the lost power is given up as heat in the mosfet switch and the output diode, so adequate heat sinking of the BUZ71 is needed.

Care should be taken to make sure the core for the inductor L1 can cope with the switching currents and the required output without saturation. The current limit facilities of the SG3524 have not been used because of the variable output voltage. But if a fixed output voltage is needed this can be brought into use by sampling the current in the drain of the BUZ71 and comparing it to a reference voltage using the current limit sense circuits on pins 4 and 5 of the IC.

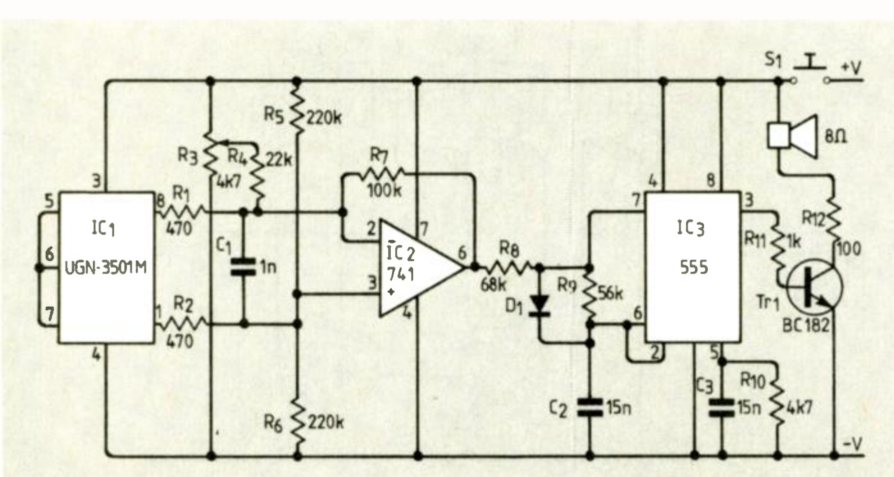


Anton Forte
Nirad
Antrim
Northern Ireland

Electronic compass helps the blind

This circuit produces an audible output with a varying pitch depending on its orientation to the earth's magnetic field. The accuracy is not high but it can be used as a hand-held compass by blind people. There are already commercially available compasses for the blind based on the traditional suspended needle. This though is unsuitable if the sense of touch is impaired.

The heart of the device is the UGN-3501M Hall effect sensor IC_1 which has a monolithic Hall cell and a linear differential amplifier with differential emitter follower outputs. Typical sensitivity is 1.4mV/gauss. It is unsuitable for measuring small fields such as the earth's since the drift is comparable with the signal. To overcome this, a flux concentrator in the form of a 6cm by 9mm ferrite rod is glued to each face of the IC.



The two outputs are fed into a differential amplifier IC_2. The output voltage for zero input can be adjusted by R_3. C_1 inhibits parasitic oscillations. The output of IC_2 is fed into a voltage-to-frequency converter based on the 555 timer IC_3. Its output drives the transistor in the grounded emitter configuration with R_{12} used as a current limiting resistor. An audible note is produced from the loudspeaker. The circuit draws a total current of about 50mA.

R_3 acts as a pitch control giving an output of about 1kHz. In the circuit shown the pitch varies by an octave as the orientation is changed from north to south.

W. Gough
Department of Physics
University of Wales
Cardiff

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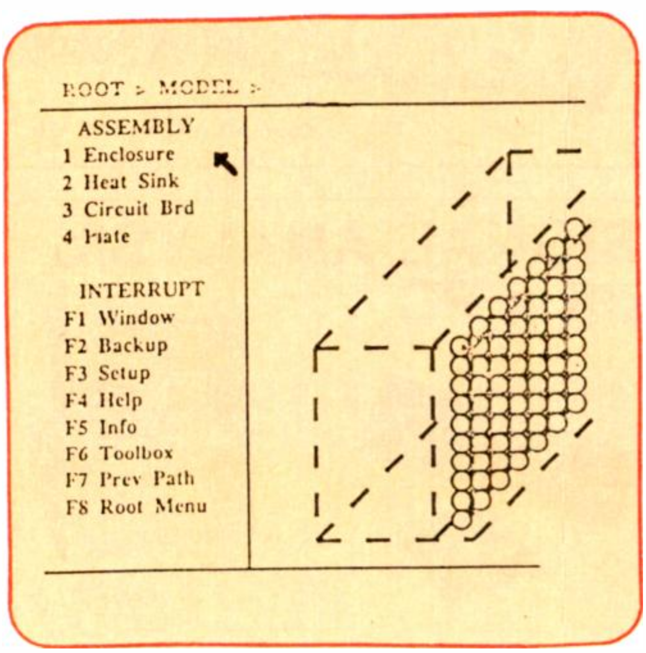

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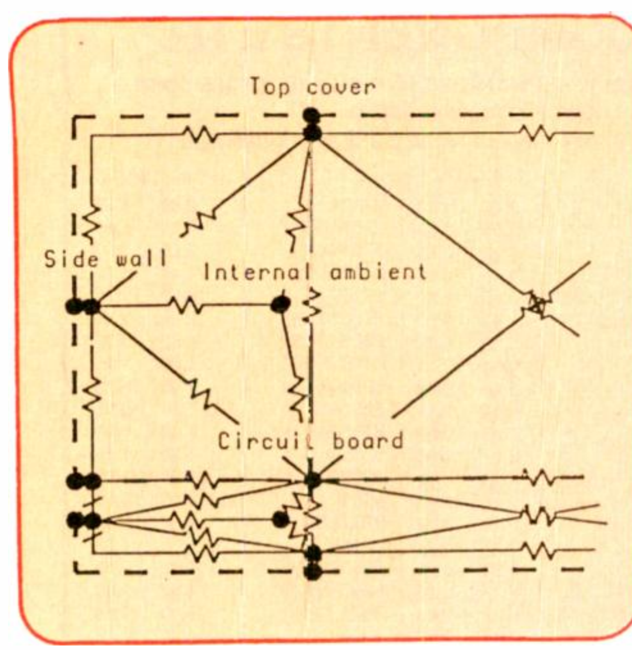

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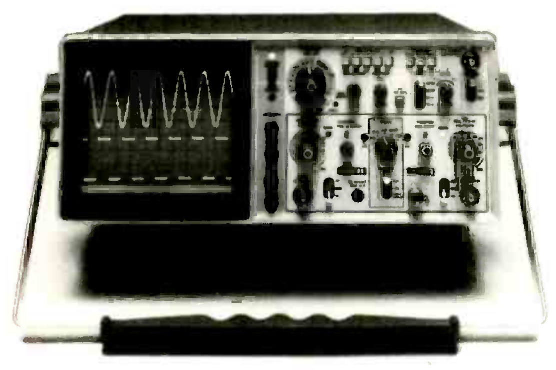

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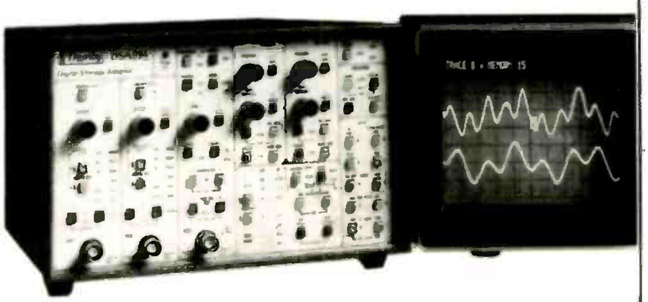

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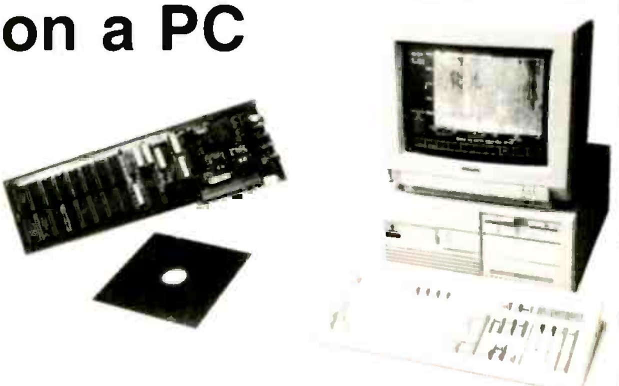

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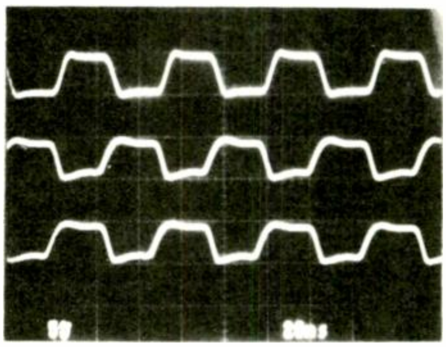
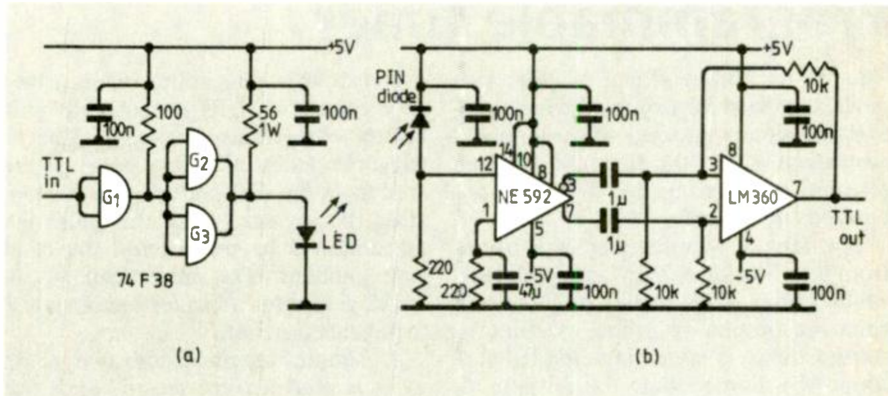
TTL compatible optical fibre data link

Off-the-shelf components can be used to make this 100bit/s to 40Mbit/s TTL-compatible optical fibre data link much cheaper than commercially available products.

The optical transmitter is based on the 74F38 quad open collector NAND buffer. Gate 1 reshapes and buffers the TTL data input and gates 2 and 3 connected in parallel drive the led. The





parallel design reduces each gate's output current by half. It also gives a faster led turn-off time because it halves the impedance that the led junction capacitor has to discharge through.

Using a low power led, the launched optical power in a 200μm PCS step-index fibre was about 60μW, giving about −12dBm. This was with a pull-up resistor of 56Ω and an led pumping current of 60mA. Optical rise and fall times were less than 6ns.

The optical receiver front end is made using a pin diode detector and a differential I/O video amplifier NE592 with an adjustable differential voltage gain from 0 to 400. The pin-compatible MC1733 amp can also be used.

The photocurrent from the incident light on the pin diode flows in the 200Ω resistor, generating a voltage at the amplifier input which is amplified with a gain of 100. Photodiode responsiveness is 0.5A/W giving an overall optical power to voltage conversion ratio of 5500V/W single ended.

Using the transmitter, the measured rise and fall times at the video amplifier output were 11.5ns, indicating a bandwidth of 30MHz and allowing digital transmission up to 40Mbit/s. The other input of the video amp is connected through a 220Ω resistor, bypassed by a 47μF capacitor to ground to balance the amplifier input bias currents and voltages.

The differential output of the receiver is AC coupled to an LM360 comparator via the 1μF-10kΩ capacitor-resistor combination, allowing for a minimum bit rate operation of 40bit/s. The use of a 0.1μF disc ceramic capacitor across the 1μF tantalums stabilizes the high-frequency operation. The comparator is driven differentially to reduce the effect of common-mode noise and its differential output provides the TTL data and data signals.

Successful operation through 1km of optical fibre (200μm PCS) has been demonstrated at 40 Mbit/s giving a better than 10^{-9} bit error rate.

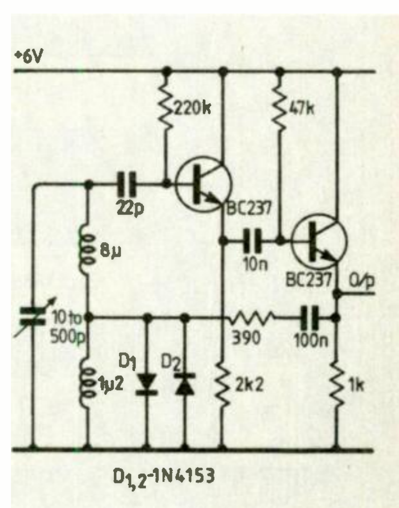
Z. Ghassemlooy
City Polytechnic
Sheffield; and
I. Darwazeh
UMIST
Manchester

LC oscillator

Maintaining a wide tuning range in an LC oscillator needs some controi to stop the output clipping. This circuit has no series capacitance but the approximate 30pF input capacitance of the emitter follower increases minimum capacitance.

With 100pF coupling the tuned circuit to the emitter follower, the effective tuning ratio is about 1:4 rather than the theoretical 1:7. Reducing the coupling capacitor to 22pF increases the ratio to 1:5.

The circuit works from 2 to 10MHz with essentially constant amplitude. The amplitude does, though, drop slightly at the end of the range. Replacing the first transistor by a decent RF device would improve the tuning range further.



Frantisek Michele
Brno
Czechoslovakia

Programmable timer

This 0 to 10min timer circuit was devised to control exposure times in a printed circuit process and its main advantage is that the time can be pre-set and, by pressing two switches, re-entered and started.

The tens of seconds digit will count from 0 to 5 using a 74157 data selector which either loads in the BCD switch value at pre-set or when a count is started. A fixed value of 6 is loaded at a count of 9 by decoding the outputs of the 74192 presettable up/down counter and loading the value 6 using Pin 11. The minutes and seconds count 0 through 9 and are only pre-set for start purposes.

Diodes detect zero count and IC_{1c} prevents further clocking down. To over-ride this zero count on starting a new count, a 74123 monostable pulls briefly the reset line high. This is triggered from the start pulse generated from the start button. When operating the pre-set switch this pulse lets the counters be pre-set and the clock gate enabled. The other half of the 74123 generates a buzzer enable signal to indicate timeout.

A simple toggle using two NAND gates is used for pre-set and start and the NOR gate allows either pre-set or fixed values to be loaded in the tens of seconds counter.

C.C. Clarke
Kenilworth
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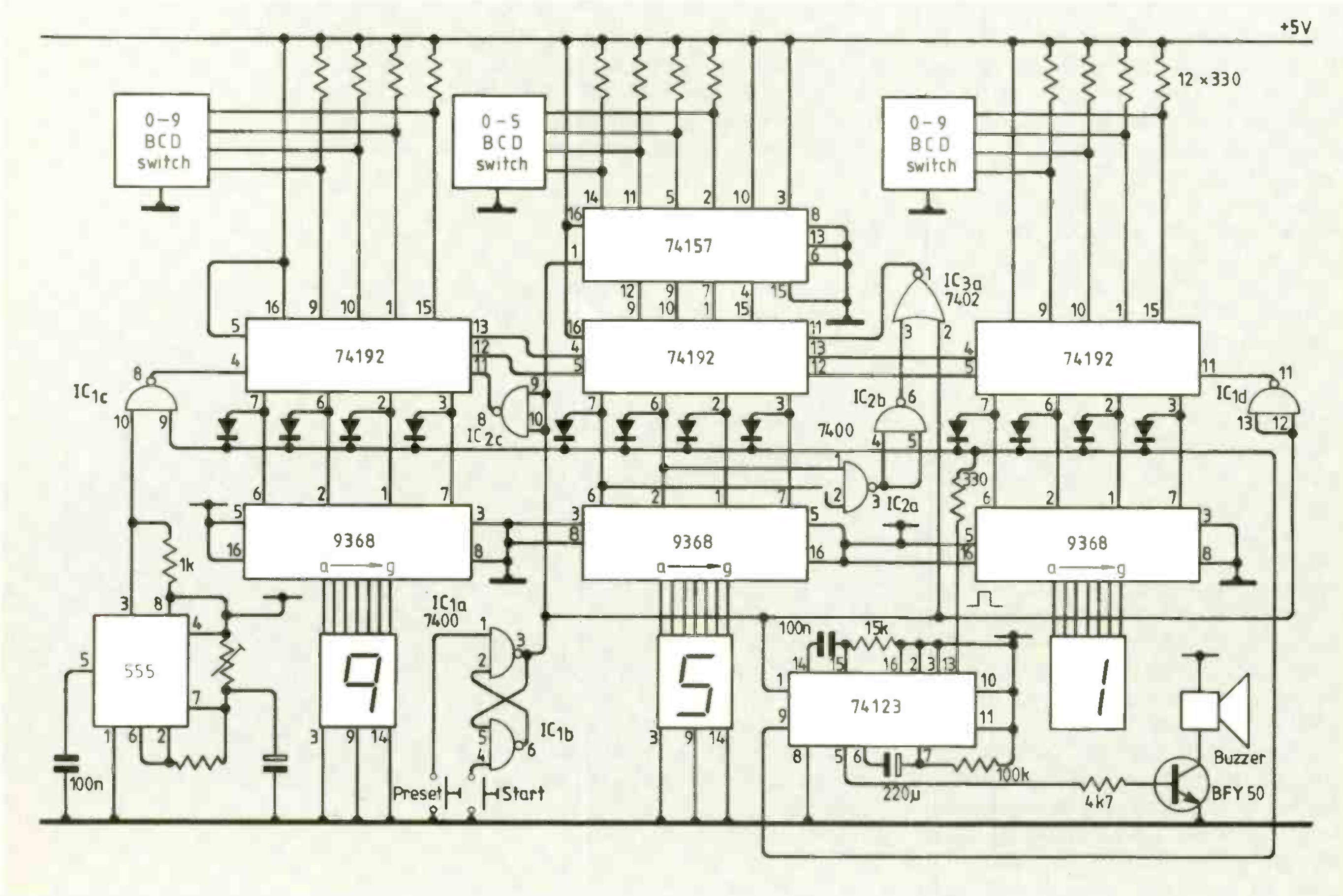

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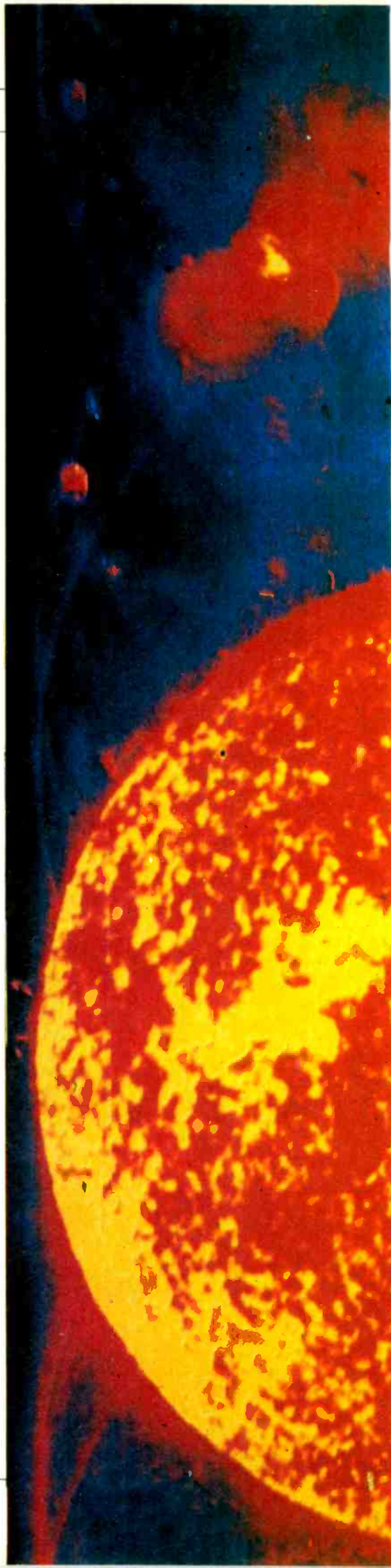


RIDING THE SOLAR STORM

Solar magnetic storms are the precursor of auroral ionization and deeply affect radio propagation. Although severe storms can induce power surges which have enough energy to knock out circuit breakers, we still have gaps in our knowledge about their origins and behaviour. Anthony Hopwood looks at the development of simple equipment which will measure the relative intensity of magnetic storms precisely.

A sensitive compass (magnetometer) will display the normal diurnal magnetic variation as a very small shift around zero, peaking to the west about 1300 UT, and to the east about 0700.

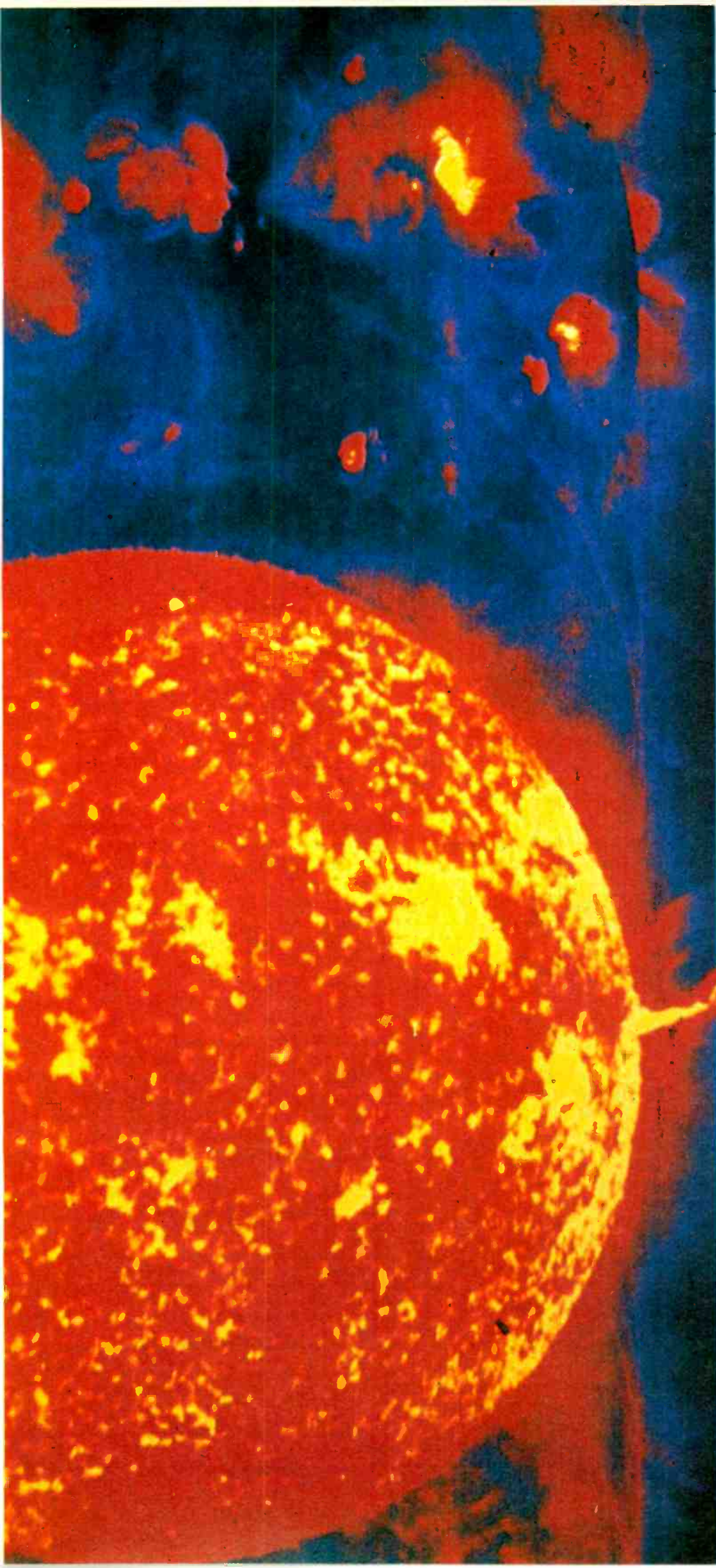
Unfortunately sensitive magnetometers do not tolerate normal domestic activity and react alarmingly to any nearby ferrous movement or domestic electrical activity.

A less pernickety detector of the magnetic storm triggering an aurora is an earth-current monitor. The variation of current in long wires earthed at both ends was noted as early as 1848 when Barlow presented a paper to the Royal Society on spontaneous current flow in the early earth-return telegraph lines. At times the current flowing between the earth plates along the telegraph line was strong enough to work the system without a battery!

Barlow's original observations were enlarged by the Rev. Lloyd who carried out a detailed analysis of the diurnal and sporadic variations of current in telegraph lines between Rugby and Derby and Derby to Birmingham.

His conclusions were published in the Proceedings of the Royal Irish Academy in 1861-2. In them he notes the correspondence between line current disturbances and deviations of the magnetic compass at the Dublin Observatory.

He also mentions that the French



False colour 30nm wavelength ultraviolet image of the solar disc showing a huge solar prominence as recorded by Skylab in 1973. Courtesy NASA/ Science Photo Library.

physicist De la Rive "ascribes the current variations to a direct electrical action emanating from the sun" – a hypothesis which he attempts to demolish in his own work. To date I have not yet pinpointed De la Rive's original reference which may well be the earliest intimation of what we now know to be the true origin of magnetic storm phenomena recorded over 120 years ago.

Updated monitor

To measure accurately earth currents, the whole system must be isolated from the local mains earth, otherwise leakage, transients and voltage drops from local domestic and industrial consumers will obscure the relatively small long period natural changes. It is possible to use a fet input DC opamp system running off batteries, carefully isolated from the mains, which will not introduce spurious mains borne signals. I tried another way . . .

A sensitive galvanometer will detect the effect without amplification. I used a 10mA FSD recording microammeter as a totally non-electronic earth current recording system. This, like the Victorian telegraph systems is totally floating and isolated from the local mains.

Text books suggest that the theoretical earth current PD is at least 1volt-kilometer on a NS axis. An activity graph is shown in **Fig. 1** (by R. Saunders). In fact using 6 × 2in copper foil electrodes buried on an EW and NS axis some 30m apart, currents of 1.5 and 4μA respectively were recorded between the pairs of plates once the chemical battery effects had been exhausted by shunting each couple with a permanent 2kΩ resistor.

The diurnal variation was very slight, being less than 0.1μA on the NS axis. There was one surprise – persistent long period wavetrains sometimes appeared on both input channels and to a lesser extent on the reference mechanical zero channel – they turned out to be the long secondary waves from distant earthquakes, recorded electrically and confirmed mechanically thanks to the inherent seismic sensitivity of the 6in long printing pointer on the galvo!

The plates did indicate magnetic storms too – when the recording was checked against RSGB reported auroral events – but at such a low sensitivity that the record was not very useful.

The problem was insufficient distance between the plates which were restricted to the boundaries of my garden.

Not wishing to forgo the simplicity and reliability of the recording galvo I decided to tap an unorthodox but accessible distant earth for the NS signal axis at the Upton-on-Severn telephone exchange – so I wrote to BT Engineering at Worcester . . .

They readily consented when they learned that I only wanted a few BT microamperes from the earth return line, and that there would be no mains earth link.

A line was strung from the junction box on the house gable to the lab, and a 22kΩ resistor was fitted in the box to set the earth current at about 3μA. The original earth plates were then linked together to make a distributed local earth to complete the circuit via the recorder.

The first magnetic storm logged by the system started about 1300BST on 20 October 1989 when the earth currents started to carry an intermittent wave of 15/20 minute period, and the magnetometer showed a slight deviation.

At 2000 a large earth current transient occurred (**Fig. 2**) accompanied by an initial westward swing of the magnetometer followed by a rapid excursion to the East.

A check on the short wave showed an HF fadeout extending down to 14MHz.

The night-time earth currents remained disturbed with an easterly deviation on the magnetometer of 1.5 divisions (6mm). Cloud prevented any visual auroral observation.

Next morning HF propagation remained poor with normally audible transatlantic stations blacked out.

At 0830 BST, the magnetometer and earth current recorder showed increased activity, with vigorous current and magnetometer swings reaching a maximum Eastward deviation of 2.5 divisions (10mm) at 1100.

Instability continued all day, with a further sudden large magnetometer and current excursion at 1915. (**Fig. 3**).

Still being under cloud, I decided to check for radio auroral activity. My own standard 'test' for this is the BBC World Service transmitter on the 49m band which comes in at S9 on the meter. During auroral conditions, the signal stays at S9 but acquires rapid auroral echo and flutter to such an

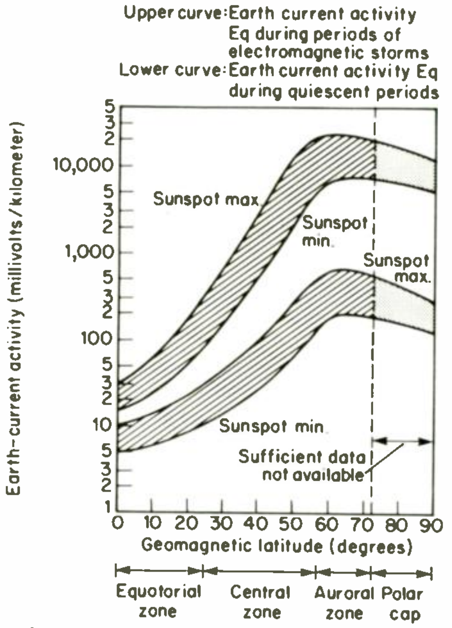


Fig.1. Activity graph of earth current levels with latitude.

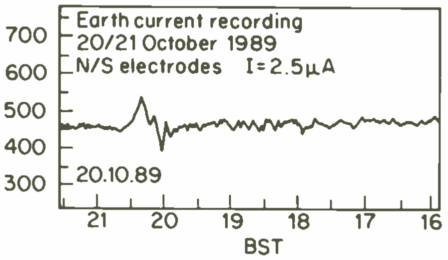


Fig.2. Evidence of the magnetosphere rebounding after a solar shock?

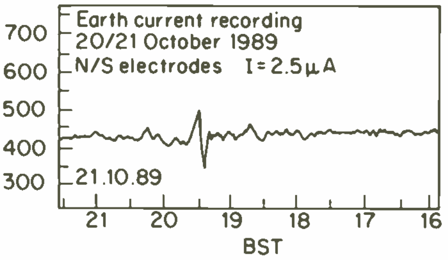


Fig.3. A subsequent transient was recorded with regular period on following days.

extent as to be unintelligible! This effect is due to the multiple additional propagation paths caused by auroral ionisation which play ducks and drakes with the signal on its short journey to my aerial . . . The magnetometer and earth currents remained disturbed until 0100.

Transient excitement

Next day there was still a slight 2.5mm. Eastward 'hangover' on the magnetometer (which decays over several days after any magnetic storm). My test for the 'end' of the storm is when the magnetometer returns to zero, and WWV from Colorado can be heard during the day on 20MHz.

Two features of the earth current recording which excited my curiosity were the large transients at 2000BST on 20.10.89 and 1915 on 21.10.89. The spacing seemed oddly coincident so a watch was kept on the earth current recording around 1830 on 22.10.89. This also showed a smaller but distinct isolated transient, with an even weaker but still distinct event around 1745 on 23.10.89.

A check back on the week's recording before the storm showed no earlier similar events, so what mechanism caused them?

It was time to consult an astronomer. I asked Michael Guest FRAS if the moon might have blocked the particle stream from the sun at those times? 'Unlikely' he said 'it was nearly at right angles to the Sun – Earth axis and it has no magnetic field'. The consistent 23.3 hour interval between successive transients certainly suggested a cyclic origin – but how?

The prime suspect was the moon, but this seemed even less likely when tables showed the lunar/terrestrial period to deviate more than two hours every 24 from the observed transient period.

The precession of the earth current transient from true rotation period is more likely to be due to the compression and recovery of the sun-facing magnetosphere and its internal shock wave structure in response to the incoming solar emissions. In that case the transient time may provide a rough indicator of the strength and velocity of the solar blast wave from a flare.

In any event it seems likely that any magnetospheric shock or standing wave effect that is big enough to induce surface earth current transients during a magnetic storm will have already been regularly observed by orbiting spacecraft, so we may not have to wait long for a full explanation of this intriguing observation. ■

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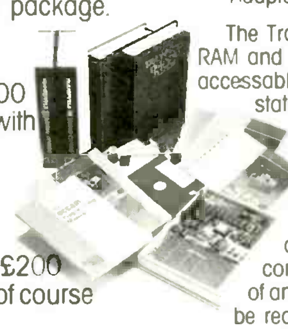

The Transputer Module houses a 15 MHz T414 with 256K RAM and is external to the PC, so that the hardware is fully accessable. The module includes a wealth of test points, 14 status LEDs, 16 I/O lines, EVENT input, independant power supply, prototyping area and four 15 way D connectors, which allow access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

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PC VOLTMETER BOARD

John Martin looks at an add-in board which can turn a PC into a four channel 6½ digit voltmeter

Software which is a joy to use completes the icing on the cake. The cake? An evaluation board which turns a standard PC into a high resolution voltmeter. The kit comprises the AD1175K 22bit A/D converter module mounted on the AC5005 evaluation mother board which plugs directly in the backplane of an IBM PC/XT/AT or compatible.

The 5¼in disk contains a colourful menu-driven program which exercises the functions of the converter. It lets the user view the voltages on the analogue input ports and change some of the system's configurations like gain and offset. Any changes to the configuration can be stored in the internal non-volatile RAM.

The disc also contains: the same program in Basic; the Basic program listing; a simpler Basic program to do conversions; and a help-screen file for use with the executable programs. A screen-shot of the main menu of the program is in **Fig. 1**.

The user guide is well written and presented, containing absolutely everything that a user could wish to know about the internal and external operation of the converter and its evaluation board including circuit diagrams and board layout. Clear explanations are given for setting the board's base address and for selecting 50 or 60Hz mains frequency.

The program's functions and menus are well described as are the connections to and from the board and the commands that can be used. In fact the documentation told me things about my PC that are not covered in its own user manual! For instance I did not know that the IBM I/O address map contains a reserved area for prototype boards starting at address 300hex. Although I did not need this information, as the AC5005 comes with a default address of 300hex preselected, it's still nice to know.

The converter is shipped separately from the mother board and needs to be plugged-in. This is simple enough but antistatic handling precautions should be observed. As mentioned, the base address of the board is factory set to 300hex but can be altered using the DIP switches on the board. Once installed, this setting can be changed using the supplied software.

The jumper link which selects 50 or 60Hz was factory set to 60Hz and so was changed to 50Hz. This is necessary

The converter is a high accuracy, autozeroing 22bit module using a mutlslope integration technique to provide 16 conversions a second, or 20 a second with a 60Hz mains supply. It has a high impedance differential input with a nominal range of ±5V. The digital inputs and outputs are LSTTL compatible for direct interfacing with a microprocessor bus. Its power requirements are +5 and ±15V.

The mother board accepts the AD1175K module which simply plugs into the board. It contains necessary address decoding logic, a four-channel analogue input multiplexer, a 5 to ±15V converter and links and switches to select the base address of the unit and whether a 50 or 60Hz mains supply is used. The board fits easily into an expansion slot of an IBM-compatible PC and provides the user with two 15-pin D-type connectors.

The male connector is for the analogue inputs but also provides access to the ±15V supplies and the internally generated reference voltage of +6.95V. The female connector provides an 8bit I/O port with flags for use in interfacing with external equipment for control applications and so on. Conversion may also be triggered using a pin on this connector.

Fig. 1. Main menu and selection of menu screens associated with the evaluation board. The software includes a Basic source code listing for customisation to individual specifications. There is also a help screen file for use with .EXE code, and a conversion program.

to ensure maximum supply-frequency rejection by the converter. The board fitted easily into the expansion slot of an Amstrad PC1640, leaving the D-type user connectors readily accessible at the side of the computer. Unfortunately, no mating connectors were supplied but they are common enough.

For testing, analogue channel #1 was connected to a variable power supply with a nominal output voltage of −4V; channel #2 was wired short-circuit and earthed; channel #3 was connected to an alkaline cell of nominal voltage 1.5V; and channel #4 was also wired as short-circuit and earthed. The evaluation program "AC5005.EXE" was run with the simple command "AC5005" and the "Work with analog port" option selected from the main menu. The results can be seen in the "messages" box in the screen-shot of the analogue menu in Fig. 2.

Inputs #2 and #4 should have been 0V but showed varying readings from 0V to as much as +7μV shortly after switch-on, reducing to a maximum of +5μV after a 45min warm-up period. Similar fluctuations occurred in the readings of channels #1 and #3. This noise is probably due to the electrically noisy environment inside the computer and the connections between the D-type connectors and the ADC module are PCB tracks of some length, also containing an analogue multiplexer. The noise quoted on the manufacturers data sheet is 5μV peak to peak.

A simple test of linearity used one channel of the system to measure the voltages of three constant-temperature 1.5V alkaline cells, first individually and then in series. The error between the arithmetic sum of the individual voltages and the actual series voltage was 0.001295%.

Although the analogue inputs are described as true differential, it should be noted that the cold leg of the differential pair is for remote ground sensing and should be within ±100mV of the analogue ground. This restricts the use of the kit if non ground-referenced voltages are to be measured, or if the kit is to be used with shunts for current measurement. However, OEMs may wish to design analogue front-ends to overcome this problem and provide input scaling.

The software was excellent and the supplied routines, with the documentary support, provide the basis of a useful instrumentation system for the display of voltages and their incorporation into PC-based data logging and control applications. Software snobs who abhor Basic are reminded that the conversion time of 40ms should allow even the most unstructured and sloppy program to make full use of the 16 conversions a second!

OEMs who wish to incorporate the AD1175K converter into a laboratory instrument are supplied with all the information necessary to access the ADC's 16 registers and interface the data to a microprocessor bus. Analog Devices are to be congratulated on producing such a user-friendly package, which is as important as producing a good product. ■

The AC5005 including software costs £350 plus VAT and the AD1175K £754 plus VAT. Both are available from Analog Devices, Station Avenue, Walton-on-Thames, Surrey KT12 1PF. Telephone: 0932 253320.

DISPLACED RADAR

Gift of second sight?

Separating transmitter and receiver avoids PRF anomalies and ground clutter and is more secure than monostatic types. Henry Hislop describes the advantages and disadvantages of the process.

Most radars use the same antenna to transmit and receive. Only a small part of the energy reflected by an aircraft is returned to that antenna; the rest is scattered in other directions. This energy can be received by other antennas in other places so that, in areas where radars are already operating, aircraft can be detected with no more than a receiver, in an arrangement known as bistatic radar.

Figure. 1 shows how radio amateurs living near Heathrow airport are able to locate an aircraft with nothing more than a simple receiver and a small omni-directional antenna. First, by measuring the time delay between a signal received directly from the radar and the same signal received after reflection from the aircraft, they can plot an ellipse on which that aircraft must lie. Then, by noting how the amplitude of the direct signal varies with time as the radar antenna rotates, they can estimate the position of the beam when the maximum signal is reflected from the aircraft. As long as the radar antenna is rotating at a constant speed, these two measurements provide all the information needed to determine the aircraft's position.

If the receiver is relatively close to the radar, the approximate position of aircraft detected in this way can be displayed on a plan position indicator by rotating the bearing line in synchronism with the radar antenna and using the pulses received directly from the radar to trigger the radial timebase. Such a display makes no allowance for parallax.

If the receiver is some distance from the radar, a more accurate display can be obtained by using a computer to determine where the transmitted beam intersects the ellipse on which the aircraft is known to be. The accuracy will depend on the angle at which the transmitted beam intersects the ellipse. It is greatest at long ranges and zero on a line joining the transmitter to the receiver. This problem can be overcome, as will be explained later.

Sensitivity compensation

Other things being equal, there is no reason why a remote receiver should be any less sensitive than one co-located with the transmitter. If, however, the antenna of a remote receiver is smaller or has a wider beamwidth than that of the radar, then the gain of that antenna will be less and the range at which aircraft can be detected with that antenna will be correspondingly reduced. If the simplest possible omni-directional antenna is used with the remote receiver – so that there is no need for the receiving antenna to scan – then the sensitivity of the remote receiving system is likely to be about 30dB less than that of a typical air surveillance radar. This will reduce the maximum range at which aircraft can be detected by a factor of 5.6; typically from 250 miles to less than 50.

The maximum range at which aircraft can be detected with a remote receiver can be increased by designing the receiving antenna to be omni-directional in azimuth but with the beam shaped in elevation to match that of the radar antenna. Further improvements can be obtained by rotating the receiving antenna broadly in synchronism with the radar antenna and using a beamwidth no wider than is needed to accommodate the angular errors caused by parallax and lack of synchronism. Very conveniently, the effect of parallax is greatest at short ranges where there is the least need for high antenna gain.

The antenna of a modern surveillance radar, which serves both transmitter and receiver. Picture by courtesy of Plessey Radar.

An interesting way of compensating for the lower gain of an antenna with a wide beam in azimuth is to reduce its beamwidth in elevation and use several narrower beams to cover the same total elevation angle. If each of these beams is connected to a separate receiver, not only is the sensitivity improved but the remote receiver can determine the height of an aircraft; a facility that may not be available at the main radar.

Bistatic by design

At this point, the perceptive reader will realise that a simple idea that formed the basis of an amusing toy is now leading us towards an ingenious type of sensor with many valuable features. So far, for example, we have assumed no co-operation from the primary radar and that it is detecting aircraft with its own receiver in its own way and in its own time. Much more can be achieved if the radar is designed from the outset to work with its transmitter and receiver in different places.

Removing the restraints of co-location gives a new degree of freedom. Cynics have said that the invention of the T/R cell (which made it possible for a radar transmitter and receiver to share the same antenna) delayed the development of air surveillance by forty years.

If more than one transmitter is used with the same receiver, there is no need to depend on a narrow beam to determine the exact position of an aircraft. From each transmitter, the signals reflected by an aircraft will be delayed by an amount which defines an ellipse on which the aircraft lies. From two transmitters, for example, the signals reflected by an aircraft will define two ellipses on which the aircraft lies, and the exact position of that aircraft must be where those ellipses intersect, as shown in **Fig. 2**. The accuracy with

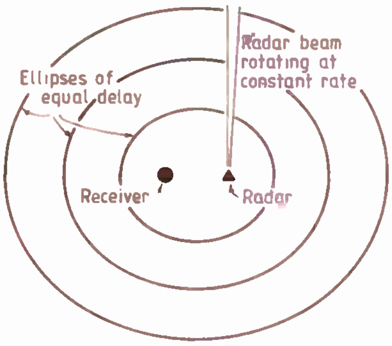

Fig. 1. Position of an aircraft can be determined using a simple receiver. Lines of equal time difference between reception of signal reflected from aircraft and that from transmitter form ellipses, on which aircraft lie.

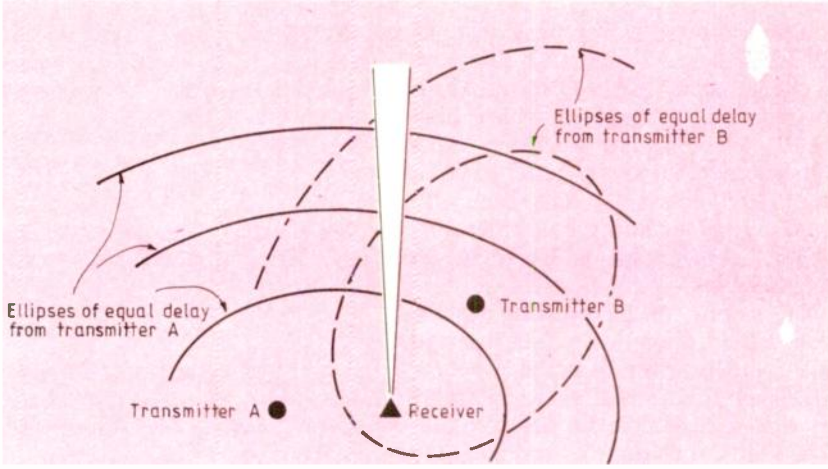

Fig. 2. Two transmitters form two sets of ellipses, crossing points locating aircraft more accurately.

which an aircraft can be located in this way is limited only by the range resolution of the system and can be much higher than is possible with a conventional radar.

A conventional radar distinguishes between aircraft and ground "clutter" by detecting the phase change between successive returns. The returns from a fixed object bear a constant phase relationship to the transmitted signal; the returns from an aircraft moving radially vary with time. With a conventional radar, therefore, it is difficult to distinguish between clutter and aircraft that are moving tangentially, but a receiver associated with two transmitters can detect aircraft moving in any direction.

With a conventional radar, problems arise if the interval between successive pulses is less than the time for a pulse to return from an aircraft at maximum range. A conventional receiver cannot distinguish between a pulse that has been reflected from an aircraft at long range and another pulse that has been transmitted later and reflected by an aircraft at short range. Both will arrive at the same time.

These ambiguities can be resolved if the transmitter and receiver are separated, because the returns from aircraft at long range are not received at the same azimuth angle as those from aircraft at short range. Freedom to use a higher pulse-repetition frequency makes it easier to distinguish between aircraft and ground clutter (for reasons that are beyond the scope of this article). Freedom to use a higher duty cycle makes it easier to transmit more power.

Keeping a low profile

Without prior knowledge of the position of a receive-only station, it is unlikely to be the victim of high-intensity jamming which, by definition, is concentrated in a particular direction. Pairs of receivers can locate self-screening jammers by triangulation so that they can be engaged at the earliest opportunity.

The antenna of a conventional surveillance radar presents a prime target for anti-radiation missiles. These relatively crude weapons steer themselves towards a radar transmitter just as a moth heads for a light. A radar with its transmitter and receiver in different places can be protected against these weapons by reversing the roles of the antennas, so that the large directional antenna is used at the receiver where it will not attract attention by radiating and the omni-directional antenna is used at the transmitter where it can be made very small and robust. The whole system then presents a much more difficult target. Moreover, with this arrangement, the transmitter power can be increased to offset entirely the lower gain of the smaller antenna.

Compromises

All design is compromise. The design of a bistatic radar is no exception.

For most applications, the receiving antenna should be as large as possible; a large antenna captures more of the energy reflected by aircraft and its narrow beamwidth minimizes the returns from clutter and power from offset jammers.

If a bistatic radar with a narrow receiving beam has a long baseline and transmits with a low duty cycle then, for maximum efficiency, the receiving beam must be moved to follow each transmitted pulse as it propagates outwards. This will demand that the receiving beam is steered electronically. If the radar transmits with a high duty cycle, or if more than one transmitter is used, it may be better to use a set of fixed receiving beams, each with its own receiver and signal processor. Either arrangement is likely to be expensive.

Whether or not the receiving beam is moved to follow each transmitted pulse, the receiver must be synchronized with the transmitter to an accuracy that depends on the range resolution. This can be done by receiving the radar transmissions directly, by passing timing signals via a wide-band link or by synchronizing both the transmitter and the receiver with some external reference. Whichever method is used must be protected against interference. A two-way link will enable the delay caused by the link to be measured and compensated but, unless precautions are taken, this may reveal the position of the radar receiver.

Given some method of synchronization, there is nothing to prevent the frequency, modulation, timing or beam position of the transmitter being changed in a pseudo-random sequence that is known to the receiver but cannot easily be predicted by a jammer. A two-way link will allow different sequences to be selected by the receiver in response to changes in the electronic environment. The speed with which this can be done will be limited by the delay introduced by the link but, for most applications, a delay of less than a millisecond is negligible. Opinions differ on the value of a faster response.

The cost and complexity of an efficient bistatic radar system will usually be more than that of a monostatic radar. For air-traffic control and strategic air defence, the important question is whether that extra cost is justified by the greater resistance to radiation homing, directional jamming and "stealth". For shorter range applications, the losses caused by transmitting a broad beam may be offset by the advantages of being able to use covert, low-consumption sensors.

The possibilities are endless. Perhaps one day we shall see a national network of radar stations; some receiving, some transmitting and maybe some doing both, but all co-operating to extract the maximum possible information about movements in the sky. For how much longer will the transmitters be earthbound? ■

REACTION FROM THE INDUSTRY

Comments from a radar manufacturer do not totally support the ideas put forward in this article.

It is pointed out that the advantages of bistatic operation are only realised when the distance between transmitter and receiver is long – perhaps 100km – which rules out simple synchronization of rotation, except at reduced gain. Compensation for lost antenna gain by increasing transmitter power is hardly attractive; 10dB of lost gain is equivalent to ten times the power.

The increasing complexity of radar waveforms, which is a response to the threat of jamming, would render synchronization difficult.

The view is expressed that, although the idea of bistatic radar is not new and has still not found widespread use, there might be an application for it in defence, for the reasons expressed in the article.

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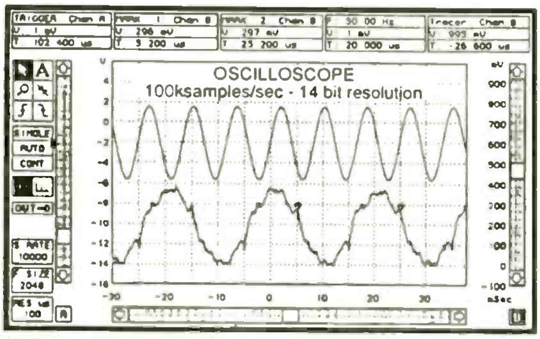

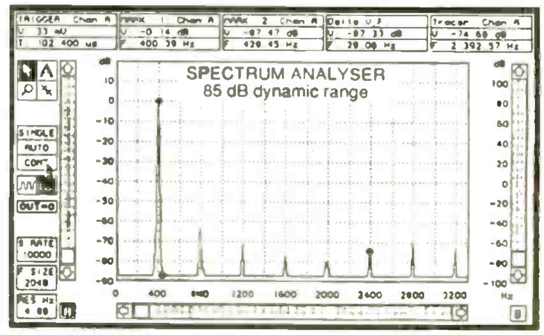

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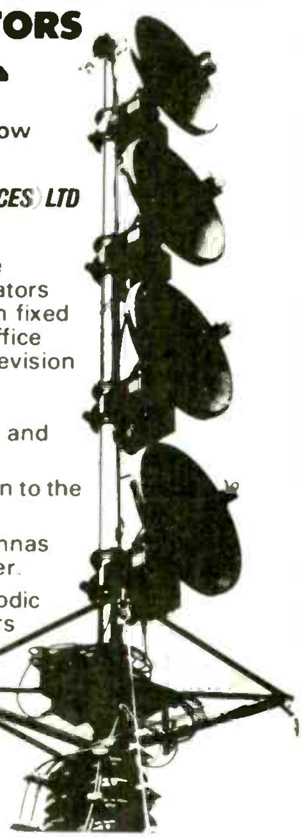

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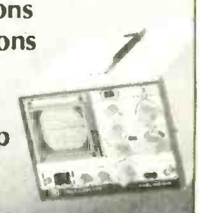

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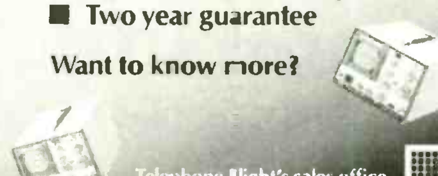

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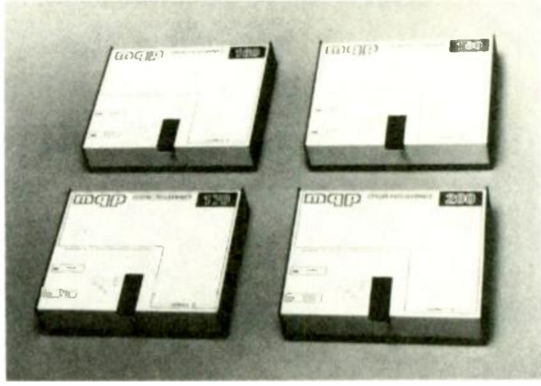

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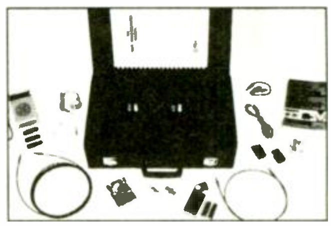

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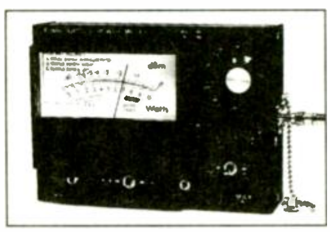

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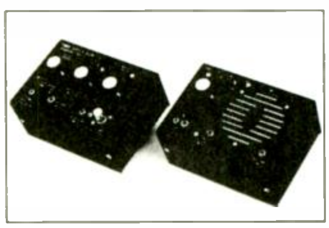

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Relative FSK

The profession of telecommunication engineer exists because there is noise. Without noise there is no telecommunication problem.

F.R. Connor in December *EW+WW* is undermining the profession. Noise is a paper tiger, he seems to claim. Telecommunication engineers always have overlooked how easy it is to defeat this enemy. You just have to transmit your information signal twice, once as an upper sideband signal and once as a lower sideband signal, using the same carrier frequency. At the receiver you make a sum signal and a difference signal. The sum signal contains the information signal plus noise. However, the difference signal is just noise! So apply the principle of negative feedback to cancel the input noise and there you are!

Mr Connor even modifies what he calls Shannon's famous equation. Famous, yes! But understood? How can he think that he can change a property of the channel, called channel capacity, with the construction of his receiver?

The editors of *EW+WW* are to blame. Let's forget this 'perpetuum mobile' of data transmission theory as soon as possible.

P. van der Wurf
Geldrop
The Netherlands.

I would like to make a point about F.R. Connor's article "Relative frequency shift keying" (*EW+WW*, December).

Take stereo radio. The originating signals are L (left) and R (right). These are combined to produce L+R and L−R. The received signals are L+R+N and L−R+N where N is the added noise.

Decoding these signals gives 2L + 2N and 2R, that is the right hand channel is noiseless mono from a stereo broadcast if L=R. So what is wrong with this theory?

N (left) and N (right) are not phase coherent and their subtraction or addition leaves the noise power unchanged. That is why Connor's hypothesis will not work.

E. Richards
Hitchin
Herts

In Hypothesis (*EW+WW* December 1989), the statement "noise voltages in the two channels are correlated prior to the detector" must be revised carefully. In the real world, they aren't. But if they could, many other systems could be designed to reduce or even eliminate the probability of error due to such noise. To tell the truth, I fell into this trap ten years ago.

Also the statement "amplitude noise is removed by amplitude limiting" is not complete. The limiting process in actual circuits introduces a time (phase) delay which depends on the input amplitude, even for a step signal. So the amplitude noise at a limiter's input (e.g. comparator) will be transferred to some degree to phase noise at the output, especially at relatively low input levels.

Finally, why do you still accept that DSB-SC and PSK are difficult to demodulate. You don't yet realise the real importance of my circuit idea "DSB-SC detector" (*EW+WW* August 1987) which is not just a mere idea. I have been using it for eight years in my personal links for privacy (the suppressed carrier at each transmitter is deliberately vibrating).

I will not be surprised to read one day on your pages the name of a company or person who will adopt it as happened a few years ago to my little idea "Voltage regulator", (*WW* October 1983) when it was seen again in November 1986 by Siliconix with a different output transistor.

It is not easy to be professional without being also practical and vice versa.

Kerim Fahme
Aleppo
Syria

The first thing that struck me about the "Relative frequency shift keying" article in the December issue was that, although the abstract claims that the system can approach the Shannon capacity, the equation $C \leqslant W_b \log_2 [1 + K^2_F(S/N)]$ bit/s indicates that the limit can be exceeded by an arbitrary factor just by increasing K_F, the gain of the feedback path.

The system transmits the same FSK signal in two adjacent channels. After filtering, the receiver multiplies the contents of the two channels together. The signals labelled sum and difference in Fig. 3, normalized to unit amplitude are:

Sum signal = $\cos[2\omega_o + \text{Ø}_u(t) + \text{Ø}_1(t)]$

Difference signal = $\cos[2\omega_1 t + \text{Ø}_u(t) \times \text{Ø}_1(t)]$

where $\text{Ø}_u(t)$ and $\text{Ø}_1(t)$ are respectively the phase noises in the upper and lower channels and $\omega_1 = \omega_s$ for logic 1 and $\omega_1 = 0$ for logic 0 in the information stream.

The idea is that the sum signal which contains only noise can be fed back to remove the noise on the incoming signal at the second IF. The problem is that feeding back any amount of the sum $\text{Ø}_u(t)$ and $\text{Ø}_1(t)$ will not cancel $\text{Ø}_u(t) - \text{Ø}_1(t)$ which is the phase noise on the signal component (difference signal).

There is no possibility of improving the signal-to-noise ratio in this way, so Shannon's capacity theorem lives to fight another day!

William Harrold
Harlow

The paper (*EW+WW* December 1989) by F.R. Connor is based upon a completely fallacious argument. The reference to relativity is irrelevant and that to Shannon, unhelpful.

The basis of the fallacy is the implied assumption that noise, as referred to a receiver's input, is correlated about a central frequency point. In particular, that noise in one band, say below the given point, is identical to that in another band spaced symmetrically above that same point. This assumption is not true, except for low frequency noises which modulate carriers and/or local oscillators.

Thus the common noise, consisting of the addition of two

Clash of symbols

I am sure that Michael McLoughlin and I (*EW+WW* December 1989) are really in close agreement. I do agree with him that an international language, at least for circuit symbols, would be good. The trouble is that the natives keep on speaking their own dialects. The great and the good of the International Electrotechnical Commission designed the language which comes to us in the shape of BS3939; do we or do we not try to speak it? I'm afraid that the answer is no, we prefer our own tribal versions.

Even the standards committees themselves sway in the wind. The 'wiggly resistor' is in BS3939 although it is a non-preferred form; the use of 'other symbols' for logic elements is not in contradiction with BS3939 although again not the preferred way.

In 1985 Texas Instruments published an interesting 'Explanation of new logic symbols' which was referring to IEEE 91 but they stated that 'the shape of the symbols is not significant'. Perhaps they have not yet updated all their data sheets but they do not appear to be totally convinced by the logic of their own arguments. Philips, a good European company, uses rectangular resistors and non-square gates in their current data books – so much for the common language.

The Zener diode symbol symbol (BS05-02-03), referred to by McLoughlin, represents a 'unidirectional breakdown effect'. Whether the American symbol was based upon the characteristic of the Zener I don't know but the BS/IEC version (05-02-04) represents a 'bidirectional breakdown effect'; both interpretations are I suggest as sensible as the American one.

L.P. Best
Fleet
Hampshire

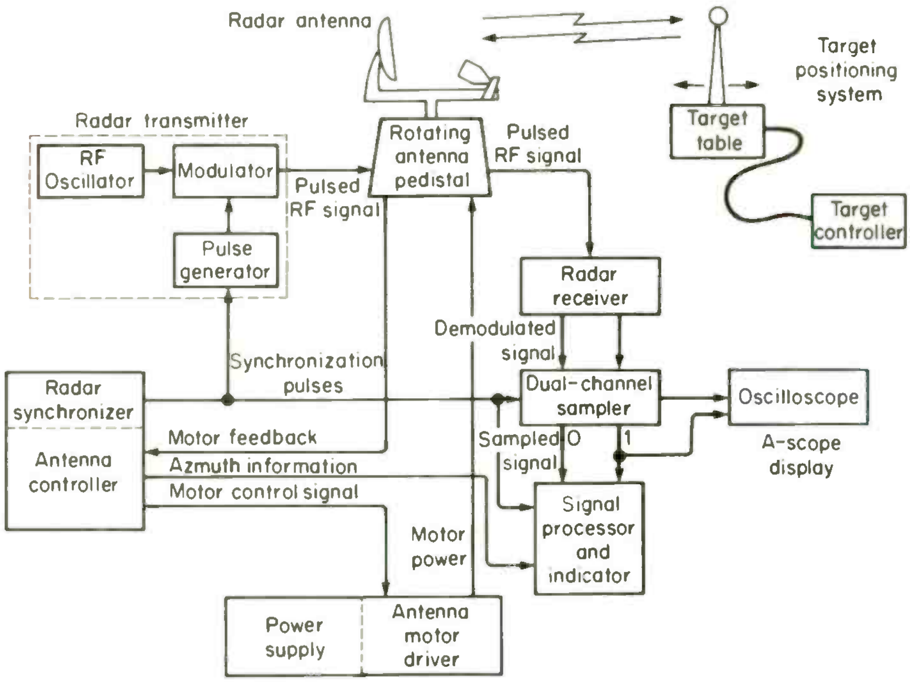


Fig.2. Short range radar system block diagram. A 10GHz source operates at a peak power of 2mW in either CW or pulse mode providing a variety of display types up to 30m range.

channels of the radar receiver in time. A repetitive pulse signal can be stretched in time by taking samples of this signal at different points of successive cycles, holding the value of each sample until the next one is taken.

Figure 1b shows an example of the signal that could be obtained by stretching in time the pulse signal shown in **Fig. 1a**. In this example, the stretched-in-time signal is only a rough approximation of the original pulse signal because a small number of samples are taken to reconstruct it. Nevertheless, the pulse width of the stretched-in-time signal is much greater than that of the original pulse signal.

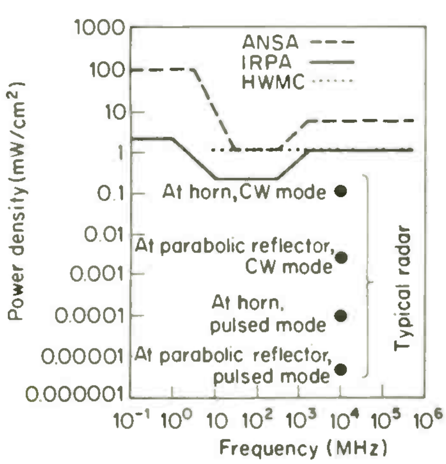


Fig.3. Power density for different operational modes with safety standard comparisons.

Fig. 1c shows the same signal stretched in time using a larger number of samples. This considerably increases the pulse width of the stretched-in-time signal (the time scales of (b) and (c) are not the same), and improves the resemblance of this signal to the original pulse signal.

By increasing the width of a pulse signal, the time-stretching process causes the bandwidth of this signal to be considerably reduced.

Safety

To protect people working with microwaves, various standards exist concerning the maximum microwave radiation levels considered to be safe. The standards are usually expressed in units of power density (Watts per unit area) at a given frequency. The power density of electromagnetic waves is equal to the emitted power per unit cross-sectional area normal to the direction of propagation. **Figure 3** shows three different safety standards and the power density levels associated with this training system: the maximum transmit power is fixed at 2mW. The aperture of the horn is $25cm^2$ and the area of the antenna reflector is $490cm^2$. In pulsed mode, the maximum pulse width is $5\mu s$, and the maximum PRF is $288\times 1024Hz$.

In CW mode, Power density at horn = radiated power/area = $2\times10-3W/25\ cm^2 = 0.08mW/cm^2$ which is within the most stringent limit.■

BOOKS

Optoelectronic line transmission, by Lt. Col. R.L. Tricker. The book is subtitled Introduction to Fibre Optics and, as that implies, is not confined to communications. A first chapter introducing optical-fibre communications and devices in a general way is followed by a chapter entitled Theory, which is somewhat overstating the case in that it is almost entirely descriptive.

The next section describes the types and manufacturing processes of glass fibres and two further chapters are devoted to transmitting and receiving devices – leds, lasers, PIN diodes and avalanche photodiodes – again a little on the cursory side; the section on receiving photodiodes only occupies five pages. A piece on waveguides, couplers, connectors and repeaters completes the hardware section of the book, which then goes on to communication systems, listing and describing several established installations.

As its sub-title indicates, this is a purely introductory text and in this, it succeeds. It is well illustrated and indexed. Perhaps Lt. Col. Tricker will follow it with a more detailed and exhaustive text. Heinemann Professional Publishing, 161 pages, £12.95.

Designing with linear ICs, by G.C. Loveday. Number 3 in the series The Successful Design of Electronic Hardware is concerned with the much curtailed, but still vital field of analogue design.

An introductory chapter deals with the classification, application and design of analogue circuitry in general, computer methods of design being briefly described. The three following chapters consider operational amplifiers, comparators and timing circuits, worked design problems forming a fifth section.

The book leans towards the practical, with many design examples. The Benchmark Book Company, 184 pages.

Newnes Radio and Electronics Engineer's Pocket Book, by Keith Brindley. The 18th edition of a book that has been around since 1940 manages to contain most of the factual information that any radio-oriented electronics engineer needs and often cannot remember. Who can hold in their heads all the 7400 series numbers, for example, or the frequencies in the microwave K band and in all four of the designation systems? About a hundred subjects are covered in impressive detail, including a 24-page glossary of electronics terms and a comprehensive section depicting BS symbols used on drawings and equipment. Heinemann Professional Publishing, hard back, 325 pages, £9.95.

Short range radar

The development of short range radar demo equipment turns up unusual design problems. Resolving the position of centimetre sized objects over just a few tens of metres calls for transmission pulse widths down to 1ns. Lab-Volt has developed a pulse multiplication system which reduces the bandwidth requirements.

The short range and high resolution required for operation inside a classroom or laboratory creates significant problems. A 15cm resolution requires a radar pulse width of 1ns and this, in turn, implies bandwidths in the gigahertz range. With high-speed electronics, the whole radar could theoretically operate with large bandwidths, but the cost would be astronomical.

At this point two major decisions were taken. The first was to design the receiver for direct baseband (homodyne) conversion. This eliminated the costly IF components and did not significantly reduce the instructional attractiveness of the system.

The second decision was to use a bandwidth reduction technique, similar to the one used in high-speed sampling oscilloscopes. The transmitted waveform is designed to repeat a certain number of times for each 'apparent' RF pulse transmitted. The bandwidth of the received signal reduces to a value where normal signal processing circuitry can operate. It was felt that this difference from a real radar would not affect the training potential of the system.

The T/R switch or duplexer design also caused problems. The ultra-short pulses involved did not permit conventional switching of the antenna between transmitter and receiver. A ferrite duplexer was selected to solve this problem. It couples the outgoing and incoming signals while reducing mutual interference.

Sampling technique

Pulsed radars transmit an RF signal in short bursts, at a constant rate. The shorter the duration of these bursts, the better the range resolution of the pulsed radar. Since the radar training system operates over ranges of only a few metres, the duration of the RF signal bursts must be in the order of 1ns to obtain an adequate range resolution.

Once received by the antenna, the RF signal bursts are demodulated in the receiver to extract their envelope. A repetitive pulse signal is therefore produced at the receiver output. **Fig. 1** shows an example of what the pulse signal from the I or Q channel of the radar receiver might resemble. The duration of each pulse can be as short as 1ns.

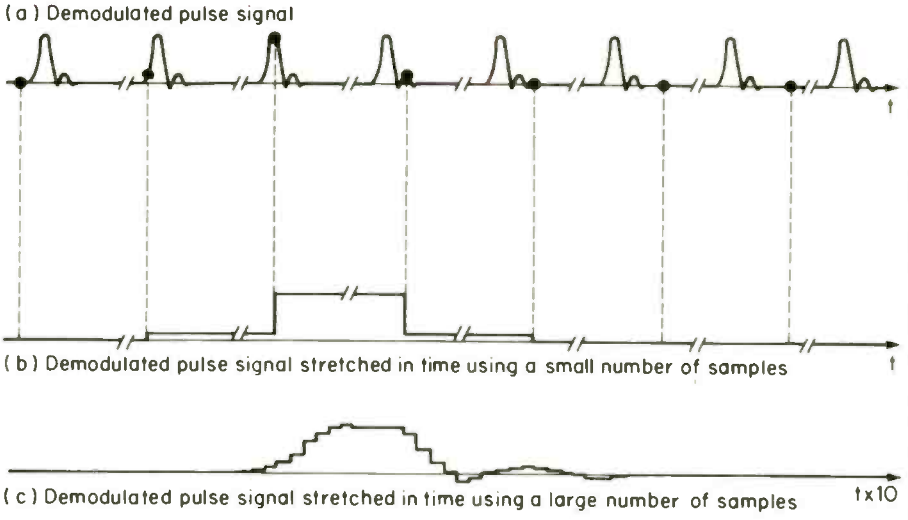
Such a pulse signal has an extremely large bandwidth. Therefore, the bandwidth of the circuitry involved in the processing of this pulse signal must also be extremely large. According to a rule of thumb currently used, the approximate bandwidth B required to process a pulse signal is equal to the reciprocal of the pulse width t of this signal. This is written

$$B = 1/t$$

Therefore, the bandwidth of the circuitry required to process the pulse signals from the I and Q channels of the radar receiver would have to be approximately 1GHz. Such processing circuitry would be complex and costly.

In the radar training system **(Fig. 2)**, this problem is avoided by stretching the pulse signals from the I and Q

Fig. 1. Nanosecond pulses provide the short-distance resolution while a pulse sampling technique reduces the subsequent signal processing bandwidth requirements.



uncorrelated packets of noise, can not cancel each separate one of these packets in their isolated upper and lower carrier forms.

If the assumption were true, communication over infinite ranges with infinitely small powers would be possible. Given uncorrelated noises, the performance will be limited by a near unity ratio of signal to noise power in the information band.

H.W. Hawkes
Winchcombe
Glos

Disgusted – Australia

I was surprised to receive an offer to resubscribe to your formerly excellent publication after letting my subscription lapse earlier this year. I can only hope that such an offer has been promoted by many lost subscriptions following the rape and engulfing of *WW* by *EW*.

Wireless World was an institution to me for more than 20 years and I and many others have learnt a lot from authors of the calibre of John Linsley Hood and innumerable others. It's probably unavoidable progress that our beloved *WW* has become a trade rag with articles about computer busses and news items about selling solar powered megabytes to Botswanaland.

I suppose some grey-suited marketing boffin has dictated that this type of magazine is appropriate to the times we live in. One can only hope that someone else will emerge with a journal that concerns itself with the elegant art rather than the state of the industry.

M. S. Odell
North Balwyn
Australia

You forgot to say if you want to resubscribe – Ed

Cross-field antenna

The CFA antenna (*EW+WW* March 1989) is not a fundamental alternative to dipoles and loops as implied in *EW+WW* November 1989. It consists of two separately fed aerials. One aerial is a short dipole with electric currents, the other consists of a loop with magnetic currents (i.e. a horizontal circular slot). Both are vertically polarized.

Each aerial generates its own separate combination of distant radiated, local inductive and local capacitive fields as described in standard text books. Both aerials have the same polar diagram, coincident phase centres and can be fed differentially in respect of phase and amplitude. The strong coupling, occasioned by the common phase centre, can cause feeding difficulties but can be exploited by an adjustment of phase and amplitude of each feed so as to tune and match the composite aerial.

It is advantageous for the tuning and matching to be via the aerial structure rather than externally in a smaller volume which could produce greater ohmic losses. A reduction of feed plus matching losses is of importance as a short dipole, with a given diameter, can then start to approach the effectiveness of a larger one; although the same level cannot be reached because of the inherent larger I^2R surface losses.

A dipole (particularly if of diameter comparable to the CFA) can also be resolved into electric plus magnetic currents that flow over the aerial surface (including the feed gap between the two dipole halves. However, because the feed is common, no extra tuning benefits are obtainable.

The above explanation based upon conventional aerial coupling is preferable to that of interacting Poynting vectors. Such interaction is not in the classic exposition of Maxwell's equations for transmission in a homogeneous medium. Indeed, if true there would be implications far beyond the aerial art as pointed out with clarity and impact in *EW+WW* Letters.

July 1989.

H.W. Hawkes
Winchcombe
Glos

I was most disappointed by C. Byron Well's article, "The cross-field antenna in practice," in the November 1989 issue. This drivel does little to clear up the mystery that surrounds this antenna.

Wells claims a number of successful contacts with British, Irish, and European stations. How does he define successful? Likewise, he says that, ". . . results were almost as good as both my double zepp and an 82M circumference vertical loop . . ."

Let's have some quantitative data here! I'd like to have signal reports from the stations he contacted as well as signal reports for the more usual antennas. In the same vein, "almost as good" doesn't support antenna performance either. Worse, measurements were made with a flashlamp and a neon bulb. Doesn't Wells own a field-strength meter?

Its performance remains in doubt until we have some quantitative data as well as the construction details on the balun, transmatch and multiband tuner used in Wells' research.

I'm very disappointed that you published such an article without any experimental details and without quantitative supporting evidence. After this editorial lapse, I cannot take you seriously.

J.R. Smallwood
Milford
USA

Mass confusion

Though John Ferguson (December letters) quotes correctly from an article in the June 1989 issue of *Physics Today* by Lev Okun of the Moscow Institute of Theoretical and Experimental Physics he does so in a totally misleading context. In fact Okun's article was a strong affirmation of special relativity. What he criticised were confused concepts of mass resulting from the use of the restricted classical version of the force equation which states that force = mass × acceleration.

The proper relativistically invariant equation states that force = rate of change of momentum. The mass of a free particle is a scalar constant, that is its value is the same whatever the particle velocity.

Okun said that while ideas such as those of transverse and longitudinal mass are in effect anachronisms, the idea of a mass which changes with particle velocity, widely used in teaching relativity physics, is in relativistic terms neither fish, flesh, nor fowl.

He particularly objected to the use of the equation '$E = mc^2$' which purports to relate the total energy of a free particle to its velocity dependent 'mass'. The correct equation is the superficially similar $E_0 = mc^2$.

However, in this equation m represents the invariant mass, while E_0 is the rest energy, that is the total energy of the particle in a frame at rest. Pauli bears some responsibility for propagating the notion of a velocity dependent mass, but in a 1921 encyclopaedia article, when special relativity was only 16 years old, and Pauli himself was only 21. In most respects that article has worn extremely well.

C. F. Coleman
Grove
Oxfordshire

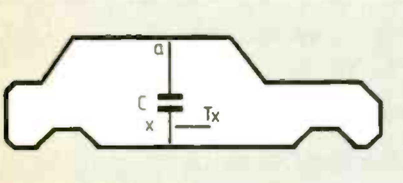
Tuned Vauxhall

The new car (a Vauxhall Carlton – Opel Omega) had its broadcast receiving aerial bonded to the windscreen and I wondered if it might be possible to drive part of a car body as an aerial, as in aircraft practice.

The whole body shell might resonate as a cavity, with radiation leaking out through the windows. Rough calculation showed this possible, and experiment confirmed the preliminary estimates.

The body shell (see diagram) is tuned to resonance by a capacitor between the centre of the roof (point a, the rear of the sunroof frame) and the transmission tunnel below it (point b). For 27.8MHz, C = 11pF. Due the high Q, around 100 at 27.8MHz, a simple J match connected between points x and b provides a good match to 50Ω. Over 27.6 to 28MHz, SWR remains below 1.5 if set at minimum (no perceptible meter reading) in the centre of the band. Polarization is vertical, of course.

The J match section C-a can be replaced by a small inductor, about 100nH, and the whole arrangement housed under the plastic console between the front seats.



Despite the low effective height, performance is comparable with that of a normal external aerial, certainly within 6dB. At 4W drive, the power density in the body is less than that adjacent to the aerial of a hand-held Tx, for which no health-hazard has been reported at these frequencies and powers. Due to the high Q, the voltage across the resonating capacitor is high. Thus a wide spacing between capacitor plates is necessary. For the same reason, the internal vertical rod a-b needs to be insulated.

Although SWR is affected by passengers and driver this is only a problem for distances of less than about 15cm.

Since the length a-b is less than the 165cm specified in the CB licence schedule, the arrangement is presumably legal.

The arrangement is also useful for HF reception, being tunable across most of the 3 to 30MHz band with a single capacitor. Maximum useful frequency depends on the car, but is unlikely to exceed 40MHz even for a mini.

Interference from the car electrics in the case of the Carlton was found to be no greater than for an external antenna, and perfectly acceptable. The internal rod a-b between the front seats can be a nuisance, but one soon gets used to it.

T.S. Christian
North Walsham
Norfolk

Inertia

Peter Graneaus' account of the Assis theory of inertia (*EW+ WW*, January) is interesting but it is surprising that there is no mention of the work of Prof. Jennison; see for example the article "What is an Electron", *WW*, June 1979. In the latter Jennison presents an elegant theory which, inter alia, accounts for the intertial property of matter while avoiding the need to invoke hypothetical interactions such as those which support the various ideas presented in Peter Graneaus' article.

If any theory depends on the introduction of presently unknown forces, fields, instantaneous interactions and so on then, at least, it is incumbent upon the theorist to explain what these are, where they come from and why they are there. In the absence of such explanations it would seem just as reasonable to support new hypotheses by the introduction of anything from magical dust to divine intervention!

Jennisons' work relied on down to earth theoretical reasoning involving known laws of physics. It would be interesting to have his views and to hear whether he has developed and/or changed his approach to the origin of inertia during the intervening years.

M.G.T. Hewlett
Midhurst
W. Sussex

CCTV for BATC

The November 1968 issue of *Wireless World* contained a survey of closed-circuit television equipment. Of the 21 manufacturers included only two – one British and one Japanese – are still actively involved in CCTV, and many of the 'great' British names have left the market place.

I am not aware of any museum which has saved any of this interesting but obsolete equipment, but some members of the British Amateur Television Club (founded in 1949 incidentally) are trying to save some of it. Could I ask anyone in a position to dispose of industrial CCTV cameras more than 20 years old to get in touch with me? We can arrange carriage, possibly even modest payment! Many thanks.

Andrew Emmerson
71 Falcutt Way
Northampton NN2 8PH
(0604 844130).

Audio power

J.L.L. Hood's article on evolutionary audio is good, but has three important errors. Referring to Fig. 9 (November), Hood says the compound emitter follower connection gives better quiescent current temperature stability than the conventional Darlington connection. This is incorrect, based on a false assumption that with the output transistor's base/emitter junction outside the inner bias loop the circuit is less temperature dependent.

Simple intuitive analysis of the circuit proves that the compound connection has the same temperature stability as the Darlington. The temperature stability of any compound connection is directly related to the g_m of the circuit, all things being equal, and if the g_m is the same, then the temperature stability will be the same. Considering the Darlington circuit, the total bias voltage would be $4 \times V_{be}$ and would have a $4 \times -2mV/°C$ temperature co-efficient, thus matching the total output and drivers against ambient changes.

Ignoring ambient changes or thermal tracking and considering the stability of a discrete Darlington circuit on its own with a fixed bias, for every degree rise in either driver or output device junction there will be a 2mV increase in potential across the emitter resistor, increasing driver and output emitter current and junction dissipation accordingly. Therefore the rate of increase of I_q with temperature is due to transconductance, which for R_e as 0.22Ω would be 5A/V.

Compare this to the first derivative from the Darlington

More audio?

I find articles somewhat removed from mainstream electronics and radio (such as the continuing Einstein debate) all that more interesting just because they are so removed. Long may *EW+WW* continue to be a forum in which the more heretical elements in engineering can air their views. The only thing on which I disagree with you is the magazine title.

Electronics World + Wireless World is a bit of a mouthful and I assume it is only a matter of time before the *+ Wireless World* bit is dropped. A title that has lasted 80 odd years will then disappear, presumably forever. That I find distasteful. I know I'm old fashioned but couldn't you leave the *Wireless World* bit in the magazine title, even if it's only on the inside title page; just as a sweetener to us old 'uns who remember when you didn't need a Towers guide to sort out one transistor from another. (I'm not that old, just halfway to my three score and ten.)

Can we also continue to have articles on audio and hi-fi? The article by Barry Fox was most welcome. I believe there is a growing disbelief in the subjective approach to hi-fi, but dissidents are effectively muzzled by the hi-fi press who seem unwilling or unable to criticise the more esoteric and not-so-esoteric offerings of hi-fi manufacturers. Yours is the only magazine open to us disbelievers with enough street cred to take on the hi-fi mags. Hopefully we can expect more articles like Barry's and indeed more by J. Linsley Hood and others of like mind and ability.

Philip Cadman
Dudley
West Midlands

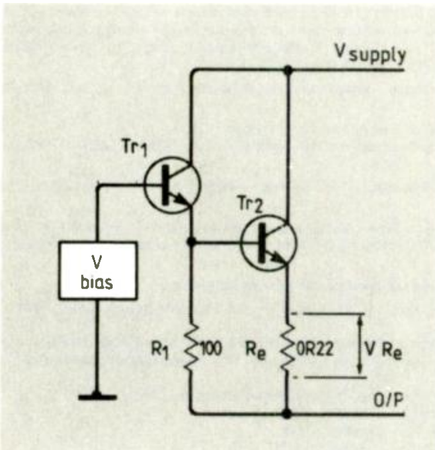


Fig 1

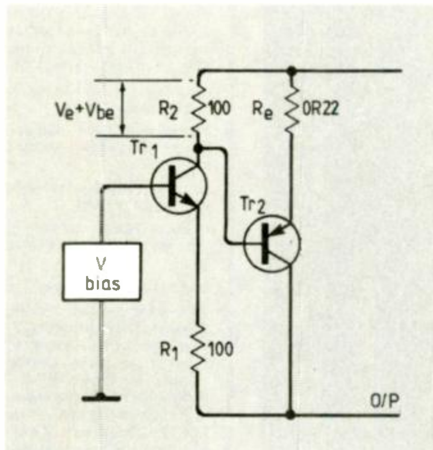


Fig 2

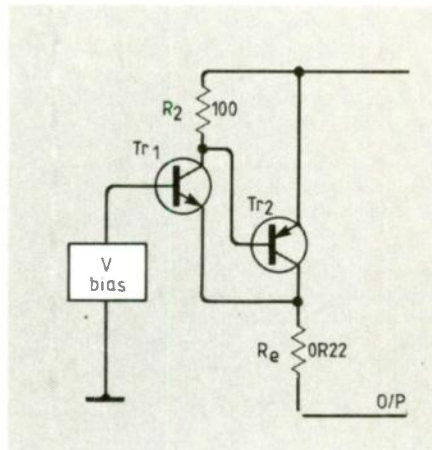


Fig 3

connection shown as Fig. 2, with the quiescent current V_e set the same as before. $V_e + V_{be}$ will appear across R_2. Since I_c and I_e for the driver are virtually equal then $V_e + V_{be}$ also appears across R_1. I_c is now a constant-current generator feeding into R_2. As I_c is considerably greater than Tr_2 base current, V across R_2 can be considered a voltage source to Tr_2. Every degree temperature rise in Tr_2 will cause 2mV increase in V_e. Similarly, for every degree rise for the driver, V_{R1}, V_{R2} and V_e will all increase by 2mV. So the circuit has exactly the same temperature stability as the Darlington. The only difference being the saturation voltage is now $2 \times$ V R_2 plus V_{be} (driver) compared to just V_{R1} plus V_{be} for the Darlington.

Short circuiting R_1 and moving R_e to the collector (Fig.3) as in Hood's circuit will reduce the saturation voltage to that of the Darlington. With I_q set as before, every degree rise in Tr_2 will cause its V_{be} to fall by 2mV, giving rise to a potentially large increase in I_q, again as before. As $I_c = I_e$ the increased I_q will appear across R_e thus subtracting from the bias, giving stability.

Even though Tr_2 collector effectively bootstraps Tr_1 emitter, the I_q stability is still the same as the Darlington. The transconductance (g_m) of the circuit is the same hence temperature dependance of I_q is also the same.

However, Hood has missed the most salient difference of the two circuits. The Darlington connection is used more extensively in commercial amplifiers because it is faster than the compound pair, and has better HF stability and lower distortion. The compound connection has the advantage that, with the circuit of Fig. 2, adding an additional resistor from Tr_1 emitter to ground will give some voltage gain. This allows for lower overall swing requirements on the preceding driver stages, allowing lower voltage faster transistors to be used (with the disadvantage of higher distortion and output impedance).

A further disadvantage is that at clipping the driver saturates, leaving an operational output device working as a grounded emitter rather than a follower. Thus phase reversal occurs, giving a step at the clipping point and some HF instability. This is termed by Hood as latch up; his suggestion of adding driver base resistors does not totally solve the problem; the true answer is to ensure the output device saturates before the driver using the Fig. 2 circuit.

The third false assumption relates to slew rate. Hood thinks slewrate is limited by the class A driver's collector current. This is false. It is simple to prove that, provided the driver I_c is greater than the differential input stage tail current, then, for any given stability phase margin, slew rate is a direct function of input stage tail current and transconductance only and independent of C compensation

Once this is appreciated it can be realised that the reason for asymmetrical slewing is not as Hood thinks but totally due to mismatch of the differential input stages collector currents (provided I_{driver} is greater than I_{tail}). The way to improve slew rate (as in the Supermos amplifiers) is to operate the input stage with a very low transconductance which also improves linearity, and use extremely fast output devices biased in class A and hence eliminate the need for compensation capacitors. The potential then exists for slew rates at least 20 times that of the Hood designs.

Les Sage
Sage Audio Electronics
Bingley, Yorks

Geocentric physics

I found your December issue particularly rich in thought provoking matter on the true basis and purpose of scientific theory. Not only were there challenging letters from Harrison and Lerwill, but there was a nice speculative dose of scientific puzzling over the origin and nature of pulsars.

The laws that govern physics and appear to control the cosmos are the distillation of millions of scientific observations reduced to a convenient shorthand for practical use. This is fine with something like the speed of light, because it can be demonstrated in a large number of ways or even realised as one of Grace Hopper's pieces of wire! The problems start when we try to explain fundamental forces like gravity and magnetism.

The complexity of particle physics leads to a myopic view of the universe, which is reinforced by our own terrestial prejudices.

Einstein and Newton produced basic laws to help explain things. We are now told they are so full of errors they wouldn't pass the Trades Descriptions Act! At the same time the entire state of the universe continues to be based on a belief that nothing can travel faster than light which is also constant, that zero is absolute and, worst of all, the red shifted light of distant galaxies proves that the more distant an object is from Earth, the faster it is receding.

I'm not saying the theory is wrong, I just want to caution against assuming our limited experience in one tiny corner of the universe holds good at the outer reaches.

Take the red shift. It works on Earth and can be demonstrated and used as a valuable yardstick in near space, but can we be certain that light coming from a galaxy thousands of light years away is not frequency shifted over such immense distances. Why shouldn't the speed of light vary with the age of the universe?

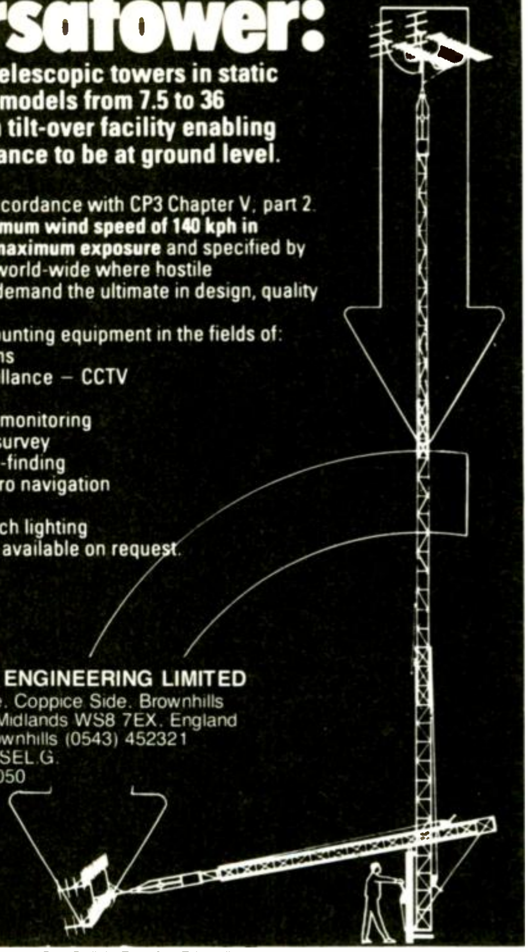
Take the pulsars in Research Notes – it's conveniently assumed that a pulsar emits two beams of radiation as it spins . . . why should it? We don't expect an oscillator to rotate to throw off electromagnetic waves. Why shouldn't a pulsar oscillate between different diameters, throwing off the surplus mass that makes it unstable as radiation? That would explain how the frequency decays with time until the pulsar turns into a neutron star, black hole or even a white dwarf – take your pick!

The truth is we are only making educated guesses, but our guesses may be too much conditioned by earthbound experience. One thing is certain – the true scientist keeps an open mind.

Anthony Hopwood
Upton-on-Severn
Worcester

Versatower:

A range of telescopic towers in static and mobile models from 7.5 to 36 metres with tilt-over facility enabling all maintenance to be at ground level.



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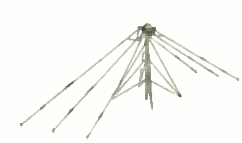

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CIRCLE NO. 157 ON REPLY CARD

PIONEERS

Alessandro Volta: the man who made electricity portable

It is well known that Volta invented the primary battery and in so doing moved electrical science into an age of electrodynamics. What is less well known is that he proposed a fundamental unit of electric tension some years before that invention, when scientists were still deep in the age of electrostatics. It is perfectly appropriate then that the unit for electromotive force (a term he introduced) is named after him. We may be thankful, though, that his original unit was never accepted; it is roughly equal to 13 350 volts!

Volta was already an established scientist with a reputation for experimental work when he announced the invention of the "Pile", the first electric battery. The importance of the invention was instantly recognised as being of the first rank and it opened new avenues of enquiry, including electrochemistry and electrodynamics. It quickly led to experimental electric light and industrial electroplating.

Volta was born in Como in the duchy of Milan in Northern Italy on the 18th February 1745 and died there 82 years later on the 5th March 1827. On his mother's side he came from a family with a leaning towards the law; his father's family was devoted to the church. One of his three paternal uncles was a Dominican, one a canon, and the third an archdeacon.

Alessandro, the youngest, was an active Roman Catholic and chose many clerics as close friends. His religion was important to him and he sought theological advice before his marriage in 1794. He was a large, vigorous man whom a friend once described as understanding "a lot about the electricity of women".

He was seven when his father died. When he was 12 one of his uncles took charge of his education, which began at a Jesuit college and nearly led to him becoming a Jesuit. His uncles decided they did not want that and so his education continued elsewhere. It was a wealthy friend, Giulio Cesare Gattoni, who provided the books and equipment which helped him to begin studying electricity.

The uncles had by now chosen his future career: the law. Somehow he avoided this path and continued to study what he termed his genius: electricity. Boldly, he wrote to leading scientists to discuss problems he encountered. One, Beccaria, recommended his own writings and also told Volta to experiment. So Volta began to develop his gift for making inexpensive but effective instruments.

Alessandro Volta; interpreter and emulator of Nature.

Slowly, from the mid-1760's he learned the science and practice of electricity and in october 1774 he received his first academic appointment, at the Gymnasium in Como. The next year he was appointed professor of experimental physics. About the same time he made his first important invention, the electrophorus, and followed that with the discovery of methane.

The electrophore was probably the most significant electrical invention since the Leyden Jar capacitor. After considerable experimentation, in June 1775, he announced his "elettroforo perpetuo". It was an inductive device for repeatedly charging a tin-foil covered shield which, in turn, was used to build up a large charge on a Leyden Jar capacitor. Whilst others had come close, only Volta produced a sturdy and usable instrument.

In 1776, he briefly turned to the study of gases and discovered a new gas which we know as methane. "Inflammable air" (hydrogen) had been isolated chemically ten years earlier and was known to exist naturally. Volta became intrigued by the "different kinds of air" and searched the countryside for the telltale bubbles until he found a new gas at Lake Maggiore. Hydrogen, however, was more explosive and it was hydrogen and air (oxygen), not methane, that Volta used in an "inflammable air pistol" which was fired by an electric spark. The pistol fired a lead ball, denting wood at 15 feet. From related experiments he concluded that about 20% of common air was oxygen. He narrowly missed synthesizing water, but his method was successfully used later by Lavoisier, Laplace and Monge in France.

His discovery of methane obviously enhanced his scientific reputation and his reward was a travel grant, which took him to Switzerland and Alsace. The grant came from the Austrian government which then ruled Northern Italy. Then came Volta's appointment to the professorship of experimental physics at the University of Pavia; his popular professorship there ran for nearly 40 years. In 1781/82 he visited France and England, and in 1784 he went to Germany. On such state-financed trips he bought new equipment for the laboratory at Pavia. Most of the instruments he built up were destroyed in a fire in 1899.[1]

Politically, Volta had much to be

thankful for to the Austrians, but in 1796 they were driven out of Northern Italy by the French, led by Napoleon. Volta was chosen in May of that year as one of a delegation to represent Como in honouring Napoleon. Later, he became an official of the new Government of Como but it was a position from which he soon resigned; his lingering loyalty to the Austrians, the damage done to his laboratory by French troops and his coldness towards the French led to his expulsion from pavia for a while. It did him no harm, however, when the Austrians retook the country in 1799: though they closed the university, Volta remained free.

Thirteen months later the French were back. The university was reopened, Volta was once again a professor and accepted his status as a citizen of the new republic. A trip to Paris to express the university's thanks to Napoleon became a triumph for Volta. The primary battery was by then well known and its chemical power had made scientific headlines. Even Napoleon attended his demonstrations at the French Academy and Volta was awarded a gold medal.

In many ways Volta's discoveries captured Napoleon's heart and he continued to be an admirer. A prize of 60,000 francs was announced for "whoever by his experiments and discoveries makes a contribution to electricity and galvanism comparable to Franklin's and Volta's". Volta was later given a pension, and made a count and a senator in the kingdom of Italy.

Volta's pile

The roots of Volta's invention go back to the discovery by his fellow Italian, Luigi Galvani, of frog legs fame. A full account was published in 1791 and caused great excitement amongst both physicists and the medical fraternity. The latter wondered if the "vital principle" had at last been found and pondered the possibilities for new treatments. Galvani was the second to report what we would now recognise as an electrochemical effect, the Swiss J.G. Sulzer having noted in 1762 that two dissimilar metals placed on the tongue gave a sensation of taste.

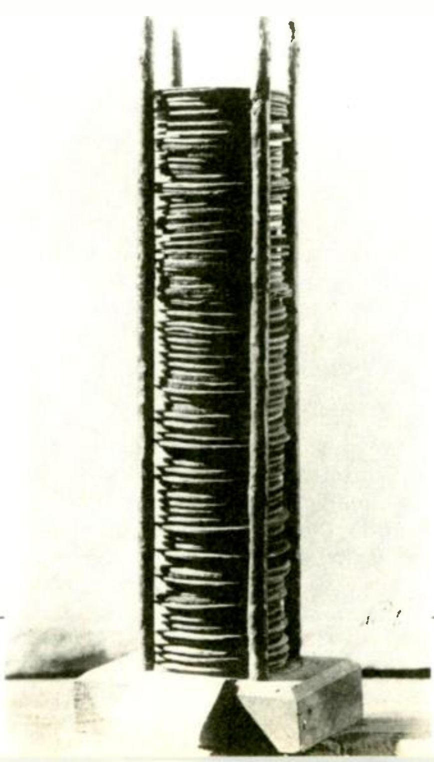
At first, Volta dismissed Galvani's reports as unbelievable. Pressed by colleagues, he at last investigated the phenomenon and, by the April 1 1791, had begun the series of careful step-by-step experiments which led him to the electric battery.

Galvani explained the excitation of the dead frog's legs as being caused by animal electricity, an explanation which Volta firmly rejected. Volta was led to believe that the current flow was caused by the contact of two different metals. In that he too was wrong. It was another Italian, G.V. Fabroni, who got the right explanation by pointing to a chemical action between the liquid, which always seemed to be present in both Galvani's and Volta's work, and the two different metals.

Volta repeated Sulzer's as well as Galvani's work. In one experiment he brought insulated zinc and copper discs into contact and found that they were charged on separation. By experiment he found that zinc and silver discs best suited his purpose and eventually he arranged pairs of them in a pile. Each pair was separated from neighbouring pairs by a piece of cardboard soaked in water or brine to provide, as he believed, a conducting path between the pairs. Letting all pairs touch one another, he knew, provided only the same effect as a single pair of discs.

The finished pile of discs and cardboard multiplied the effects of a single pair many times and he was able to receive a shock from his pile similar to that from a charged Leyden Jar capacitor. The vital differences were that Volta's pile did not need to be immediately recharged and could give a continuous current.

News of the invention was announced in a letter to the Royal Society in London: "The apparatus of which I speak," wrote Volta, "will doubtless astonish you." The continuous current almost appeared as perpetual motion, "but it is nonetheless true and real, and can be touched, as it were, with the hands."



Voltaic pile from the Wellcome Collection. This one appeared in the 1899 exhibition at Como and may have been used by Volta himself.

Volta's "crown of cups" – pairs of dissimilar metals with each end dipped into goblets containing brine.

Volta's pile, "as high as can hold itself without falling," consisted of 30, 40, or 60 cells. From such primitive origins grew today's huge international industry. As an alternative to the pile, Volta also used pairs of metals soldered together with each end dipping into water or brine contained in goblets; this arrangement he called the crown of cups. Again, 30 or more cells could be arranged to produce a battery of cells. The word battery had, of course, been used earlier, not only for a battery of guns but for a battery of charged Leyden Jars.

Improvements were soon made by others. For greater voltages more cells were needed in the pile, which increased the weight and squeezed out the electrolyte from the cardboard discs. In Germany, J.W. Ritter turned up the edges of his metal discs and obtained batteries which lasted for two weeks! A horizontal wooden trough provided an even better battery: zinc plates, for example, could be fixed vertically to a support and lowered into the trough between vertical plates of the other metal. This trough arrangement has been suggested as the origin of our circuit symbol for the battery.

Volta received many honours in his lifetime, including recognition by learned societies in London, Paris and Berlin. His financial rewards from his university salary were boosted in 1805 by the annuity he received from Napoleon and, in 1809, by his senatorial salary. For the last two decades of his life "he had the income of a wealthy man."[1] ■

Reference
1. Dictionary of Scientific Biography.

The volt was formally proposed as a unit of EMF in 1863 by a committee of the British Association for the Advancement of Science, although it may already have acquired some usage amongst practical telegraph engineers. It was adopted internationally in 1881.

ACTIVE

Asic

C-mos production process. ECPD-12 is the name of ES2's 1.2 micron dual-layer metal c-mos process, developed to offer die-size reductions for manufacturers wanting to integrate high complexity designs on a single chip in excess of 100mm². Asic designs prototyped by ES2 can be transferred for manufacture by Philips. European Silicon Structures, 0344 525252.

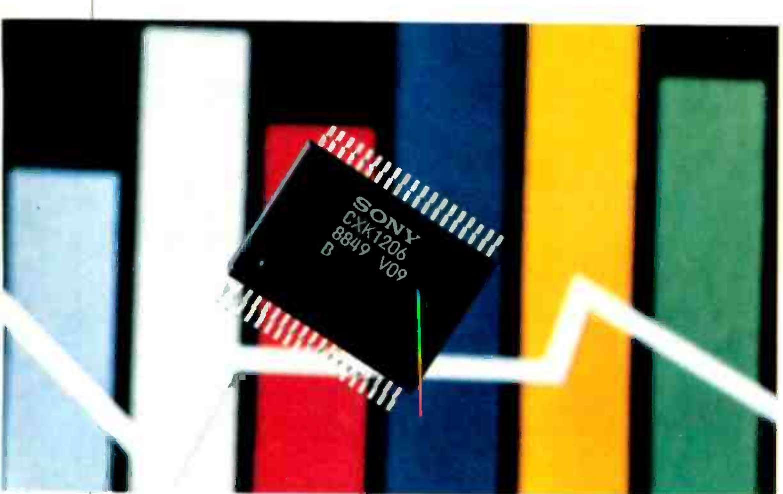
High density c-mos. 26 000 and 47 000 gates with over 70% utilisation are offered by Motorola's HDC026 and 027 high density c-mos micron arrays. The channel-less sea-of-gates architecture gives 300ps I/O delays, with a fan-out of 2. The 026 has 168 I/O pins and the 047, 212. Slew rate control macros provide two choices of output slew rate. Motorola, 0296 395252.

A-to-D and D-toA converters

Digital to analogue. The DAC-8228 has a voltage output and is a direct replacement for Celdis' AD7528/7628. It is a single-chip dual 8-bit c-mos device designed for outputs of 0V to +10V. Features include two integral output DACs, matched to 0.1%; 8-bit endpoint linearity; a write time of 50ns; and low power consumption. Available in 20-pin Cerdip and plastic packages. Celdis, 0734 585171.

Development and evaluation

State machine. The 125MHz CY7C361 high speed state machine sold by Ambar Cascom allows EPLD based logic design for systems with clock rates up to 66MHz. It incorporates an on-board clock doubler. Power consumption is 700mW. New PLD architecture has been used to improve performance over other PLD-based state machines. Production quantities will be available next quarter. Ambar Cascom, 0296 434141.



Sony 3-port video ram can store an 8-bit picture with two chips. Hakuto 0992 769090

Discrete active devices

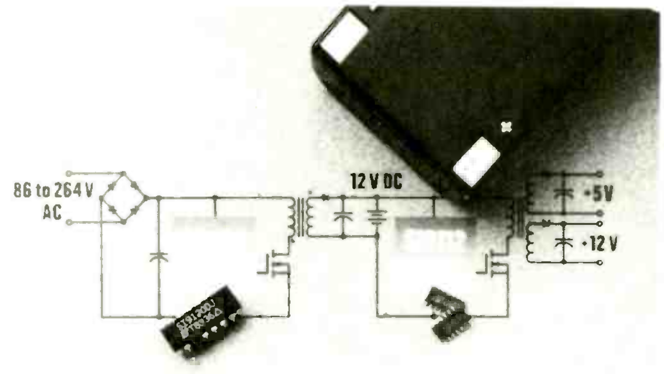
Barrier diodes. Hi-Rel III-V GaAs planar doped diodes, obtainable from Marconi, offer high pulse burn-out resistance, low local oscillator drive requirements, high tangential sensitivity, together with improved 1/f side-band noise performance. These combine to give good detection sensitivity and temperature stability. Marconi Electronic Devices, 0522 500500.

High performance semiconductors. Lower noise, better linearity, higher transition frequencies or reduced capacitance are the operational goals of Siemens latest RF silicon transistors. Its BFQ 82 noise level is less than 1.6dB (at 800MHz) with a gain of 17dB (at 1GHz) while its BAT 64 Schottky diode draws 200mA forward current, and has an overall capacitance of 6pF. Siemens, 0932 752323.

Mesfet for telecoms. Toshiba has announced a new mesfet designed to produce extra power for high frequency operations. JS8856-AS provides a power output of 33.5 dBm at 14.5GHz with a gain of 5.5dB. The 100² micron device has a thermal resistance of 9°C/W. Dimensions are 2.1mm by 0.53mm and Toshiba has increased the thickness of the chip to 70 micron. Toshiba Electronics (UK), 0276 694600.

General microprocessors

STD multiprocessing. ZT8832 single board STD bus multiprocessing computer with DOS extension can enhance performance, control, modularity and development facilities within control applications. 8MHz V40 chip ICP uses its own resources, not the system's. 800k on-board memory. SBX expansion socket, three parallel ports, two serial ports. Optional maths co-processor. Wordsworth Technology, 0732 866988.



Siliconix 9120 SMPS chip operates at mains input voltages; 9112 is intended for low voltage transverting. Siliconix 0635 309050

Processor. Primarily designed as a serial I/O module, the BVME775 6U VME card can be used as a general purpose CPU card or stand-alone single board computer. Its CPU is a 68000 or 68010 running at 12.5MHz and it has eight RS232/RS422 serial channels. It can be configured up to 0.5MB of 150ns dual port static ram accessible to local bus and VMEbus. BVM, 0703 270770.

Linear integrated circuits

Op amp. AD843 is said to be the fastest FET-input monolithic unit on the market. 135ns settling time of 10V steps to within ±0.01%, 34 MHz gain-bandwidth. The manufacturer also claims low cost and low power use as two of its features. Available in five temperature performance grades and also to Mil-Std 883B. Analog Devices, 0932 253320.

Operational amplifier. Optimised for a gain of 5, the Harris HA-2548 from Thame Components has a gain bandwidth product of 150MHz, a slew rate of 120V/s, a loop gain of 130dB and 300 V offset voltage. Settling time is 200ns to 0.01% (10V step). Available from stock in 8-pin cerdip and 8-pin can packages. Thame Components, 0844 261188.

Memory

C-mos eeprom. Seiko Epson has introduced a 512 bit device working at just 0.9V, obtainable from Hero Electronics. The SPM28C51 series is available in 8-pin SOP or DIP packages. They operate from 0.9V to 5.5V at the read stage with a supply current down to 40 A maximum at 1.5V. Design is 10 000 erase/write cycles per bit and a ten year bit retention time. Hero Electronics, 0525 405015.

Optical devices

Laser light sources. Two environment resistant lasers are now available from Lambda. Both are stabilised single mode sources. Model 7160 produces emission at 1300nm. 7170 emits at 1550nm. Units are portable – weighing 12lbs – held in water-tight heavy-duty militarised cases. Power is from internal 12V batteries. Features include adjustable level setting. Lambda Photometrics, 05827 64334.

Triac optocoupler. Siemens says its IL 428 is the first optocoupled triac delivering 2A at 55°C without additional cooling. Sensitivity is said to be so high that an input of less than 8mA (typically 4mA) is enough to switch up to 2A. A safety factor greater than 2 is promised with operation on 230V AC systems. Siemens, 0932 752323.

Oscillators and crystals

Miniature oscillator. The Ball-Efratom FRS time base oscillator, available from Racal-Dana, offers long term accuracy of 1 in 10^{-9} per year. Its dimensions are 2×3×4in and it may be installed directly on instruments or systems. The unit uses 10W at 24V DC and will warm up to the above accuracy in 6 min. Standard output is a 10MHz sine wave delivering 0.5V RMS into 50 ohms, with options. Racal-Dana, 0703 843265

Power semiconductors

Easy mounting transistors. Low on-resistance transistors in an industrial plastic package offering easier mounting can now be obtained from Siliconix. Nine devices are included in the range, based on the popular TO-220 package, and they do not suffer from the size disadvantages of the larger TO-3 packages. The devices also run cooler with greater reliability. Siliconix, 0635 30905.

PASSIVE

Miniature potentiometer. 10mm square, over 750 000 combinations all with conductive plastic elements to ensure low noise, the miniature Wilbrecht Electronics potentiometer can now be obtained from Radiatron. The model 400 has eight standard tapers and can be supplied in single or dual gang configurations. It is sealed for wave soldering. Radiatron Components, 0276 26466.

High frequency capacitors. The equivalent series resistance of Siemens' B45177 (axial lead) and B45187 (radial lead) tantalum electrolytic capacitors has been cut by over 50%. It now ranges between 45 and 330 mohms to meet the requirements of switched-mode power supplies. Capacitance values are 4.7μ to 330μF with current ratings of 1.1A to 4.6A. RMS. Siemens, 0932 752323.

Connectors and cabling

Cable ends. Contelec has extended its range of insulated cable ends to include types for use with stranded conductors from 0.25 up to 70mm^2 cross section. Standard and long versions can be supplied in all sizes and short and intermediate versions are available for most commonly used sizes of cables. Contelec Supplies, 0902 366556.

Cables and hoods. Thomas & Betts 300 series fully screened flat and round cables and associated hoods are being offered by Highland Distribution. Cable used is 28AWG stranded. Screening is with PVC-coated aluminium tape with additional braiding of tinned copper wire. External coating is flexible PVC. Eight versions are available. Highland Electronics, 0444 245021.

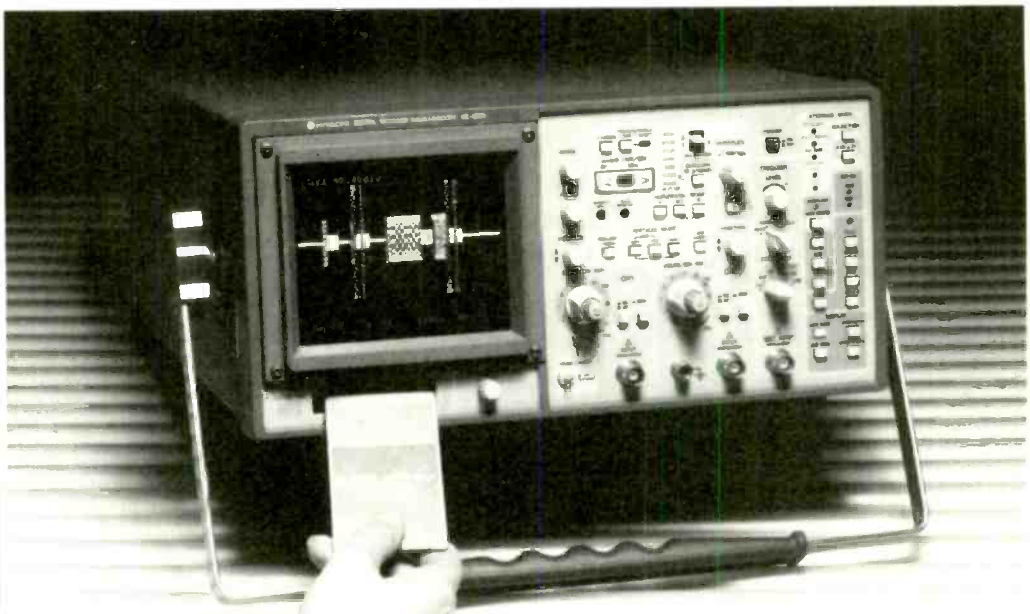
Displays

Rackable monitors. Use in hostile environments is the aim of this range of 19in rack mounting units, supporting all the common graphics standards including EGA and VGA, in colour and monochrome. All are encased in nickel-plated mild steel with a 6mm-thick Perspex screen to protect the monitor. Prices start at £480 for the mono version. Blue Chip Technology 0244 520222.

Small VGA colour monitor. 9in VGA screen units for mains-use with a maximum current consumption of 0.7A are available from Components Bureau. The Sony Trinitron tube used has a short persistence B22 phosphor, with high resolution to 640 × 400 on a display area of 140 × 100mm with a dot pitch of 0.26mm. Dimensions are 164×210×310mm. 5.2kg. Components Bureau, 0223 214949.

LED displays. A range of single digit seven-segment numeric LED displays from 7.62mm to 177.8mm, manufactured by Everlight Electronics, can now be obtained from HB Electronics. Colours include a choice of reds, green, yellow and orange. Each is equipped with a decimal point. HB Electronics, 0204 25544.

Colour terminal. ELF colour 14E terminal has VT220/VT320 compatibility with additional VT52, VT100, M2200 and Viewdata emulations as standard. All keys are programmable. Its high resolution screen has 0.31mm dot pitch and offers 16 colours. Graphics and character sets can be defined. Easydata says it is designed to be a low cost display, DEC compatible. Monotype Easydata, 0784 244277.



Hitachi digital storage scope uses an IC memory card with in-built data retention of up to three years. Reltech 0480 63570

Filters

Hex filter. MA6882 hex filter designed to consolidate filtering requirements in the dc to 8kHz range in multi-channel analog signals systems. Two 7th order lowpass filters, two 6th order bandpass filters and two 6th order notch filters are included on one monolithic cmos chip. All filters include anti aliasing circuits. Marconi Electronic Devices, 0522 500500.

Hardware

Eurocard backplanes. Double-sided uncommitted backplanes with four voltage rails, and jumper pins to allow any signal line to be committed to any voltage rail are now part of the Bicc-Vero Eurocard range. Power connections can be M3 studs or 6.33mm Faston tabs. Five sizes are available. Bicc-Vero, 0703 266300.

Data logger offers five basic recording modes across 12 channels with interchangeable data pods. Alpha Electronics 0942 872434

Instrumentation

Power surges. Elgal's modular system for testing power surges can now be obtained from Dielec. The EM101A is a transient generator system. 1044A series plug-in units provide test wave forms simulating lightning; 1011A and 1012A EXP series provide powerful pulses with fast rise time and exponential decay; 1020 provide damped sinusoid. Dielec, 0793 783137.

Function generator. The 5MHz GFG-8050 from Flight Electronics combines quality construction with low cost. The unit's frequency range spans 0.5Hz to 5MHz and it has multi-function output, sweep and gate burst operation. Waveforms include sine, triangle, square, pulse and ramp. There are six other units in the range. Flight Electronics, 0703 227721.

Digital storage oscilloscope. Grundig's SO 50 and SO 100 oscilloscopes have digital and analogue bandwidths of 50MHz and 100MHz respectively. Scanning frequencies up to 40Ms/s with storage capacities up to 4K produce optimum recording of signals in the digital mode. Real time sampling or sequential sampling can be selected. Grundig Electronic.

Battery dual trace oscilloscope. Hitachi's V209 mini portable unit is now available from IR Group. The DC-20MHz bandwidth instrument measures 215 × 110 × 350mm, weighs 5.3kg, and offers a sensivity of 1mV/div at 10MHz and sweep times of 50ns/div. It has a built-in TV sync separation circuit with selectable TV-v and TV-h modes. IR Group, 0753 580000.

Digital phase meter. Feedback meter type DPM609 will display the difference in degrees between two signals of the same frequency. 3.5 digit fluorescent display will show 0° to 180° in 0.1° steps. Its frequency range is 10Hz to 100kHz. Two symmetrical channels accept signals from 10mV to 10V RMS "sine" or 1V to 30V pk-pk for "logic" waveforms. Resolution 0.1°. STC Intruments, 0279 641641.

Literature

Power supplies. 1990 catalogue now available. 76 pages covering linear supplies, switched mode supplies, eurocassette supplies, DC-DC converters and laboratory burn-in supplies. Companies represented include Computer Products, Danica, Elco, Electronic Measurements, HC Power, International Power and Schafer Electronics. XP, 0734 508179.

Materials

Ferrite cores. Steward's soft magnetic type 28 material is the basis for a range of ferrite cores now offered by Ramp Electronics. It is particularly suitable where applications involve frequencies of 1kHz or greater. Cores may be specified to meet intended functions of wound components. Configurations include E or U shapes for power applications. Ramp Electronics, 0703 260161

Production equipment

Removal of surface mount components. CPE's system 1000 portable rework station can desolder and resolder using directed hot air blowers. Though designed for surface mount components it can also remove 0.3in (6-20 pin), 0.4in (22 pin), 0.6in (24 pin) DIL components and now PGAs. Boards up to 24 × 16in can be

NEW PRODUCTS CLASSIFIED

accommodated. Circuit Plating Equipment, 0635 33656.

Component preformer. French manufactured Loupot CK machine, introduced to the UK by John Minister, is suitable for preforming axial components at up to 20,000/hr – ideal for small to medium batch runs. It can handle most bandoliered forms and cutting and banding is adjustable within 0.1mm. Compact design produces easy changeover and low set up times. John Minister Automation 0303 56816/7.

Wire twister. Rush's model WT20 is an improved version of its WT12 and incorporates an LCD pre-settable read-out and special wire clamping mechanism. It is particularly useful for twisted pairs and can twist two or more wires, up to 16AWG, of any length up to a speed of five twists/sec. Rush Wire Strippers, 0264 51347.

Power supplies

Compact supply. Acdc's JF201 2000W switchable power supply, from Astec UK, provides 2 or 5V DC output at 400A, with other outputs of 12, 15, 24, 28 and 48V DC. Dimensions are 5×8×10in – a power density of 5W/in^3. 208/230V AC or 300V DC input with full output at typical efficiencies of 80%. Switching is at 100kHz. Two forward converters are used. Astec UK, 0246 455946.

Capacitor charging unit. Series 5000 modular power supply is a low profile 19in rack mount with a charging rate of 600J/s. Voltages are 1, 2.5, 5, 10, 20 and 30kV with regulation and resolution figures of 0.5%. Maximum repetition rate is 10 pulse/s though other voltages and rates are available. Hartley Measurements, 0752 344606.

Selectable requirements. Astec MS series supplies from Thame Power are rated at 1200W and can provide any combination of 5, 12, 15, 24 or 48V outputs. Configurable AMPSS modules can be factory or customer selected for particular requirements. Overall efficiency is 75%, with a 500kHz switching frequency. Dimensions are 8×5×11in. Thame Power, 0494 442266.

Dual laboratory power supplies. The Twinpack power supply 4000/2 from Weir gives a total of 120W from two identical, isolated, 0-30V, 0-2A sections. True constant current/constant voltage operation and output protection diodes allow series/parallel connection, also giving 0-30V, 0-4A and 0-60V, 0-2A. Simultaneous monitoring of each rail is possible. Weir Electronics, 0243 865991.

Switches and relays

Sub-miniature switches. LIMA A6 series switches are designed for surface mounting and are fully sealed to allow wave and flow soldering. Resistive ratings with silver contacts are 250V AC at 2A, 125V AC at 5A. Gold contacts give 5V AC/DC and 10 A minimum or 20V AC/DC at 0.4VA maximum. Insulation resistance is at least 1000MΩ. Electric strength is 1KV for 1 minute. Arrow-Hart (Europe), 0752 701155.

Light load relays. Standard and high sensitivity relays have been made available by Devlin in its M3 series for PCB mounting. At resistive load the contacts maximum switching current is 1A AC/DC. Maximum switching power is 30W DC 60VA AC with maximum switching voltage of 60V DC 120V AC. Devlin Electronics, 0256 467367.

SIL relays. A relay 3.7mm wide, 15.1mm long and 6.6mm high, claimed to be the smallest currently available, has been introduced by Pickering. Its series 109 requires half the board needed by some other SIL relays. Switches are rated at 10W 200V and 0.5A maximum. 5V, 500Ω and 12V 1000Ω coils are available. Pickering Electronics, 0255 428141.

Transducers and sensors

Photodetector. Centronic's OSI35 series of devices has a photodiode mounted together with an amplifier in an hermetically sealed TO8 package with a low profile cap. Simplified system design should be possible through elimination of a head amplifier. Four versions: uv (250-400nm) visible (400-900nm); IR (600-1100nm) and eye response are available. Centronic, 0689 42121.

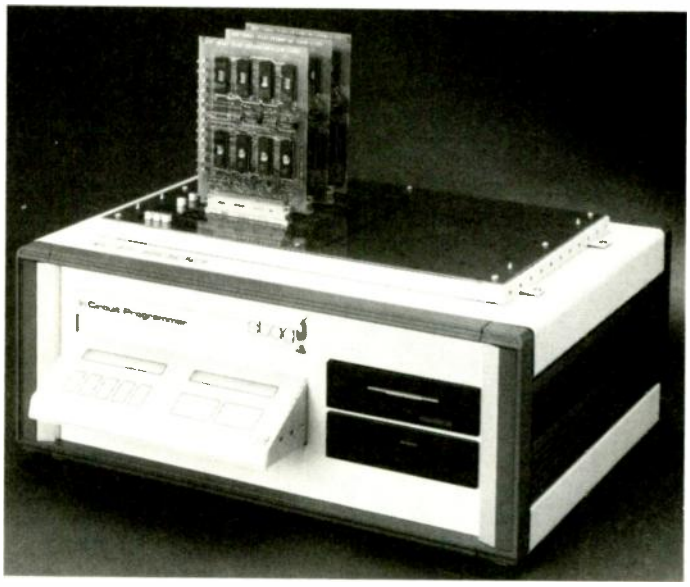
COMPUTER

Data communications products

Communications controller. Celdis has extended its range of Zilog microcontrollers with its type 16C30 – delivering 4x transmission rate of current 2-channel industry standard SCCs. It operates at a data rate of 10MB/s which Celdis says is the fastest available. Bus bandwidth has been improved to 12.5MB/s. The device can operate two protocols simultaneously. Celdis, 0734 585171.

Signal processing codec filter. Siemens SICOFI-2 for ISDN switching systems can process two channels on one chip. An IOM-2 interface should avoid compatibility prolems and programmable filter coefficients will enable matching of national standards. Power consumption is maximum 5mW for both channels in power-down mode. Siemens, 0932 752323.

ICP series of dedicated on-board eprom programmers. Stag Microelectronics 0707 332148



Software

PCB design. RUN Electronic Design System for the Apple Macintosh, can deal with surface mounted devices on a multilayer board, and PCBs up to 32×32in with up to 50 layers can be created with an internal resolution of 0.0005in. Autoroute algorithms included, and up to 24 signal and power layers. Prices from $1000 to $9500. Formula GmbH.

Image processing. Real time display, full image set-up, acquisition and analysis control are the features of MetraByte's MV-RMAC designed for use with PC/XT/ATs and compatibles. Systems must be equipped with MetraByte's MV1 frame/line grabber board. Menu selection should allow inexperienced users to access all features. Keithley Instruments, 0734 861287.

PC-based network management. CMS Nucleus 200 is network software for PC/XT/AT PS2 and compatibles which Racal-Milgo says offers the benefits of mini-computer systems, but at lower cost. It will control up to 512 devices. Operator training is minimised through mouse control and windows/menus. Facilities include monitoring, testing and database management. Racal-Milgo, 0256 763911.

PCB design. Cadstar Professional, running on PC AT, PS/2, Compaq 386 or compatibles, will help with design of large, complex, multilayer PCBs encompassing surface mount and fine line technologies. This enhanced version of the standard Cadstar package will cope with 5400 connections and over 50,000 segments. It has blind and buried via capabilities over all 16 permitted layers. Racal-Redac (UK) 0684 294161.

Back-up utility. SitBack from Roalan is a memory resident utility especially useful for users who forget to back up their files. At defined intervals SitBack will back up created or changed files without disturbing normal use of the PC, and without user intervention. Uses 13k system memory and costs £99. Roalan International, 0202 861512.

Interfaces

Parallel DMA link. Ikon 10092 card provides a high speed parallel DMA port between Versatec or Centronics-type hard copy devices and IBM compatibles. It can be used in any AT-compatible or with a peripheral device adapter such as that provided with Apollo DN3000/4000 workstations. Taking up a single AT slot it allows a 6MHz PC/AT system to transfer data at up to 425 kB/s. GMT Electronic Systems, 0372 373603.

DMA parallel interface. Compatible with DE DRV11-WA, Q-bus, MicroCax II and 18-bit and 22-bit backplanes, the GT370 DMA board features 16-bit input and output ports, used to transfer parallel data to and from the Q-bus under program control or DMA. For heavily driven I/O or DMA driven the unit contains a jumper throttle allowing selectable interleaving on and off the bus. Lighthouse Electronics, 0825 68849.

I/O controller. The IO 186/070 analogue and digital I/O board for Multibus II systems manufactured by Concurrent Technologies is available through Rapid Silicon. It has a 10MHz 80186 CPU, six analogue outputs (employing 12-bit D/A converters and amplifiers), 16 single ended or eight differential analogue inputs (0 to +10V and 0 to −10V) and 48 digital I/O lines. Rapid Silicon, 0494 457267.

In-circuit emulator. Reduced program download time – typically 4s for a 16k object and symbol file – is one of the advantages of Nohau's 68HC11 emulator. Nohau claims this is the first emulator to be PC resident rather than stand alone. High sample rate, through eradication of the usual serial link, is another plus. Nohau UK, 0962 733140.

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EL84	0.95
EL84 MULLARD	4.50
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3A4	1.50
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3AT2	3.35
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3E29	39.50
3EJ7	1.95
3H	0.40
3J 170E	1450.00
3L	0.40
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6BK4	6.50
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6BN8	3.95
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6BR7	4.95
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6BW6	5.35

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12AT7	1.50
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33A/158M	19.50
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35L6GT	2.00
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42	6.95
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75C1	4.50
80	4.50
83	8.50
83A1	7.50
85A1	6.50
85A2	2.95
90AV	17.50
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91AG	9.00
92AG	25.00
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Audio current conveyor

A recently introduced integrated circuit could be the answer to the harshness in sound that has been a common criticism of compact disc players. The device uses a current conveyor configuration to give low-distortion and wide-bandwidth functions such as gain blocks, inverters and virtual ground inputs without the global negative feedback required by most other circuits such as operational amplifiers. It is therefore inherently free of dynamically induced distortion.

Global feedback techniques can introduce dynamic distortion such as transient intermodulation (TIM) and slewing induced distortion (SID). Many audio signals are band limited and therefore may not contain the fast edges needed to generate this type of distortion but there are notable exceptions. For example, the dynamic characteristics of op-amps in the D-to-A stages of digital recording and compact disc equipment must be considered carefully to eliminate distortion.

The new IC could be the answer. It comes in two versions, PA630 and PA630A, and each has two unity gain buffer amplifiers, a current mirror, and a current conveyor block. The PA630 is a 16-pin device and the PA630A has two extra pins to give more flexibility in interfacing.

Each unity gain buffer amplifier (**Fig. 1**) consists of four emitter followers and two current sources. The quiescent operating point of each can be set independently with an external resistor. This arrangement produces a fast unity gain buffer that uses only the local feedback inherent in the emitter follower configuraton.

The current conveyor consists of two complementary cross-coupled current mirrors and an output transistor. This arrangement produces a virtual ground without the global negative feedback needed in op-amp type circuits. One mirror can set up an opposing reference current to define a net output current of zero at one of the pins for any desired input current. This combination of a current conveyor and opposing current mirror lets many useful function blocks be realised.

The on-chip circuitry consists of a connection of Wilson current mirrors, an emitter degeneration compensation scheme to optimise the transient response and stability of these mirrors, and an output mirror arrangement to improve output impedance.

The nature of the high impedance current output allows for some interesting applications. Since the input reference (ground) and output reference (cold end of the load) can be independent, signals can be level shifted between any two voltages in the common mode range. This could be used to isolate two grounds in a system while still retaining DC coupling. In audio systems this could help eliminate noise caused by ground loop circulating currents.

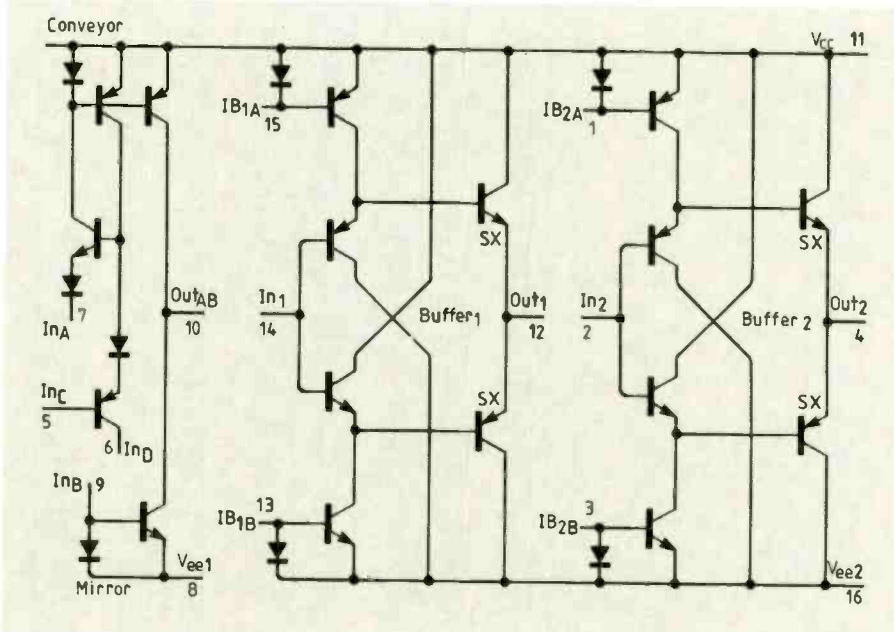


Fig. 1. Functional schematic of the PA630

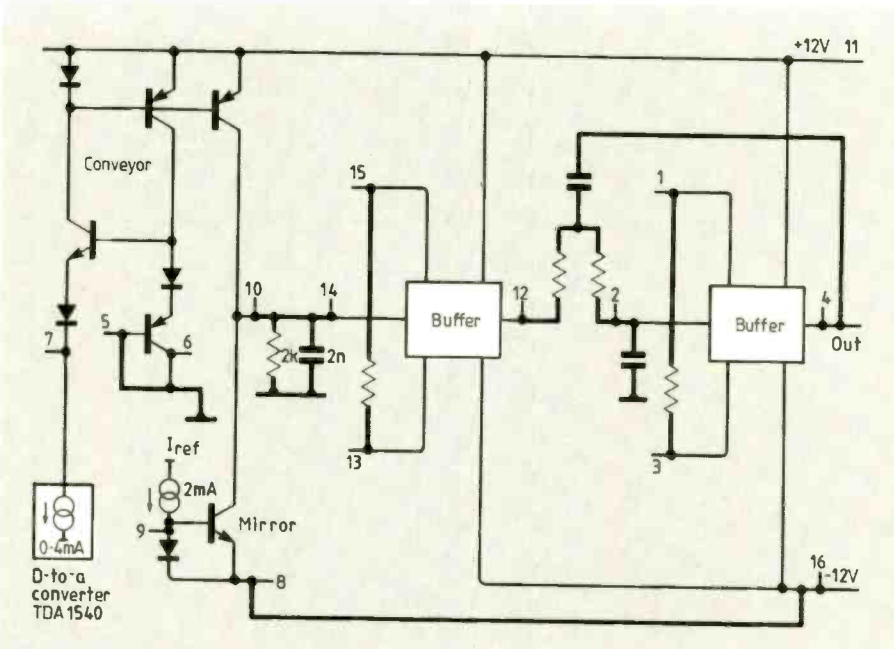


Fig. 2. The output from the CD player

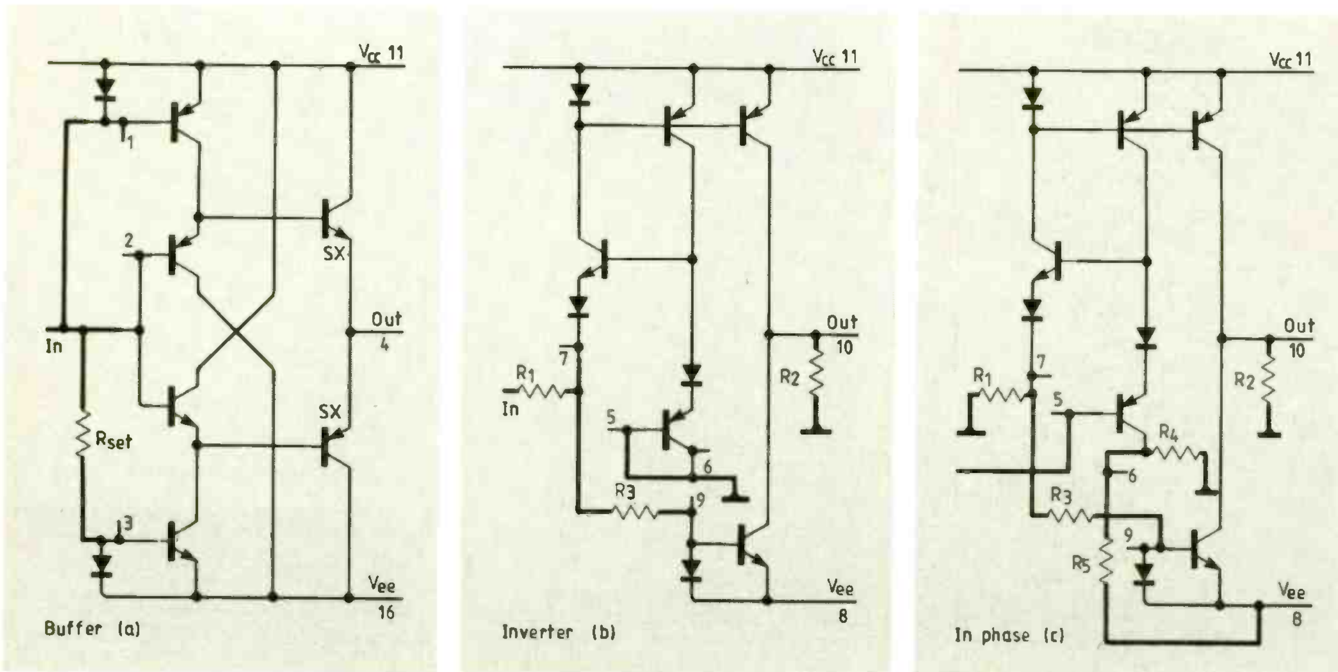
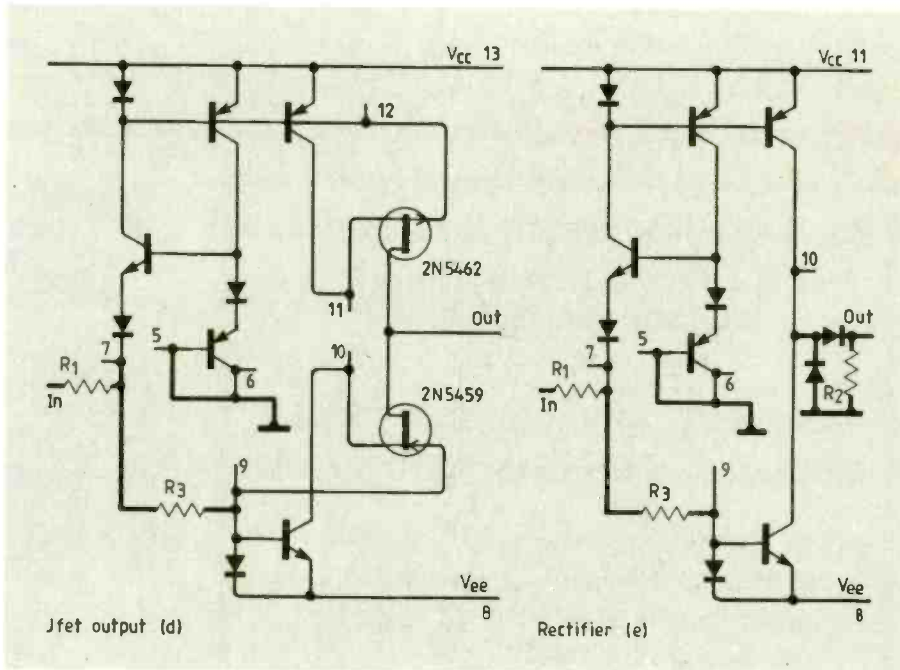


Fig. 2 shows the PA630 used in a typical compact disc player where the current output of a D-to-A converter, which must drive into a virtual ground, is opposed by a 2mA current to establish the zero reference for the audio signal. The current conveyor together with a buffer section provides the virtual ground and performs the I to V conversion with a high frequency roll off. The filter is a Salen and Key second order linear phase based around a buffer connected as a unity gain op-amp.



Conveyor configurations: (a) butter; (b) Inverter; (c) in phase; (d) jfet output; and (e) rectifier.

Operation

Each unity gain buffer amplifier consists of four emitter followers and two current sources as shown in (a). The quiescent operating point of each can be set independently with an external resistor (Rset) connected as indicated. Pin 1 and pin 3 may be left open to save current if this buffer is not required, but since the other buffer provides internal bias, it must be powered up with an output stage current of no less than one tenth of the conveyor quiescent current. As the current sources are actually Wilson mirrors (2 Vbe), and the output devices are five times larger than the input transistors, the quiescent current in the output stage can be calculated as:

$5[V_{cc} + V_{ee} - 2.8V]/R_{set}$.

The current conveyor block consists basically of two complementary cross-coupled current mirrors and an output transistor. Referring to (b) if pins 5 and 6 are shorted to ground, and current is sourced from pin 7, then to a first order, equal currents are sourced into the ground and pin 10. Of particular interest is the fact that pin 7 will be driven to a virtual ground potential, regardless of the current levels being sourced. Conversely, pin 10 becomes a high impedance output. Current is therefore conveyed from pin 7 to pin 10 unaltered, except for impedance level. This arrangement produces a virtual ground without the global negative feedback required in op-amp type circuits.

By using both the conveyor and the current mirror, the inverting gain block of (b) is produced. Since pin 7 is a virtual ground, and the mirror is a Wilson (2 V_{be}), R_3 sets up a quiescent current around the loop equal to:

$[V_{ee} - 1.4V]/R3$.

If V_{IN} is left open or connected to ground, pin 10 will also be at ground, since all currents balance. The gain of this block is R_2/R_1 and it is bi-directional up to the level of current set by R_3. It should be noted that both the

input and output are actually currents that are converted to voltages by resistors R_1 and R_2 respectively. By eliminating one or both for these resistors, many current mode applications can be addressed.

A non-inverting configuration of the circuit is shown in (c). The gain is R_2/R_1 and R_3 sets up the quiescent current as before. By making $R_4=R_1$ and $R_5=R_3$, transistor output impedance errors are minimized.

The additional pins on the PA630A can be used to interface with two external jfets which buffer the output, as shown in (d). This provides high output impedance, improved accuracy, and lower distortion.

The precision rectifier circuit (e) provides glitch free performance up to 1 MHz due to the diodes being current driven and no feedback. Even fast opamps (30 V/μs, 20 MHz) will produce distortion spikes well below 100 kHz when used as precision rectifiers, due to the slew rate limitations from having the diodes inside the feedback loop.

Tape head amplifier

The voltage level at the output of the playback heads is too small to be useful without a large amount of low-noise preamplification. The preamp should have enough open loop gain so that the correct equalisation curves can be produced in the feedback networks of the amplifier.

The NE542 dual amplifier provides a matched pair of gain blocks that minimise amplifier noise and maximise the signal-to-noise ratio. Each of the two amplifiers is independent with individual internal power supply decoupler-regulator. Open loop gain is 104dB from two stages of voltage gain and one stage of current gain.

When designing low noise devices special care must be focussed on the input stage. If different topography is used, the stage should be designed so that one of the differential transistors is turned off. This reduces the noise by a factor of 1.4 since only one transistor is producing noise. Current sources and mirrors cannot be used for biasing loads because active elements will contribute more noise. The first gain stage of the NE542 allows this (see **Fig. 1**).

Although the differential input configuration degrades the noise performance slightly, using differential inputs has the advantage of higher input impedance letting smaller capacitors and larger resistors be used.

The second stage, also shown in Fig. 1, is a common-emitter amplifier Q_5 with a current source load Q_6. The Darlington emitter-follower Q_3-Q_4 provides level shifting and current gain to Q_5 and the output current sink Q_7. The voltage gain of the second stage is about 2000 making the total gain of the amplifier typically 160 000 in the differential input configuration.

The non-inverting input has been internally biased from a 1.4V internal voltage source. From the zero differential rule, the output voltage will be set by the R4 and R5 resistor feedback network in **Fig. 2**. The base of Q2 needs 0.5μA bias current. Hence R5 should pass at least 5μA for stability.

DC amplifier gain is defined by the ratio of R4 and R5. Open loop AC gain can be regained by adding a shunt capacitor across R5. The low frequency 3dB corner is then defined by the capacitor-resistor break point.

Design of a preamplifier starts by determining the gain and output signal amplitudes in reference to the standard 800μV input signal level. The NE542 is used to achieve a 100mV output at 1kHz following a 7.5in/s equalisation curve. The closed loop gain becomes 32dB at the highest frequency.

The NAB equalisation curve is achieved by adding frequency-selective AC feedback as shown in **Fig. 3**. Resistors R4 and R5 select the DC gain. Lower corner frequency 0.159/(C4 × R4) gives a C4 of 0.0047μF.

The upper corner frequency is similarly fixed by the reactance of C4 and R7 and is equal to 0.159/(C4 × R7).

Midband gain is fixed by (R6 + R7)/R6. Solving for the 1kHz gain of 42dB gives a value of 88Ω for R6. The final calculation of the low frequency cut-off of the preamp determines the size of C2 from C2 equal to $0.159(f_{cut} \times R6)$.

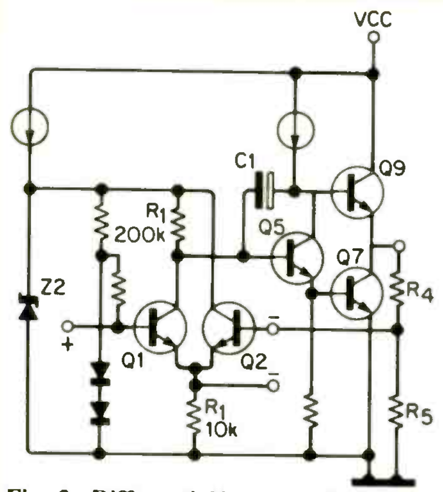


Fig. 2. Differential input biasing NE542.

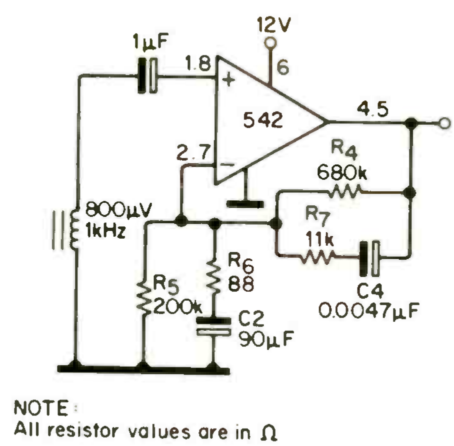


Fig. 3. NAB response amplifier.

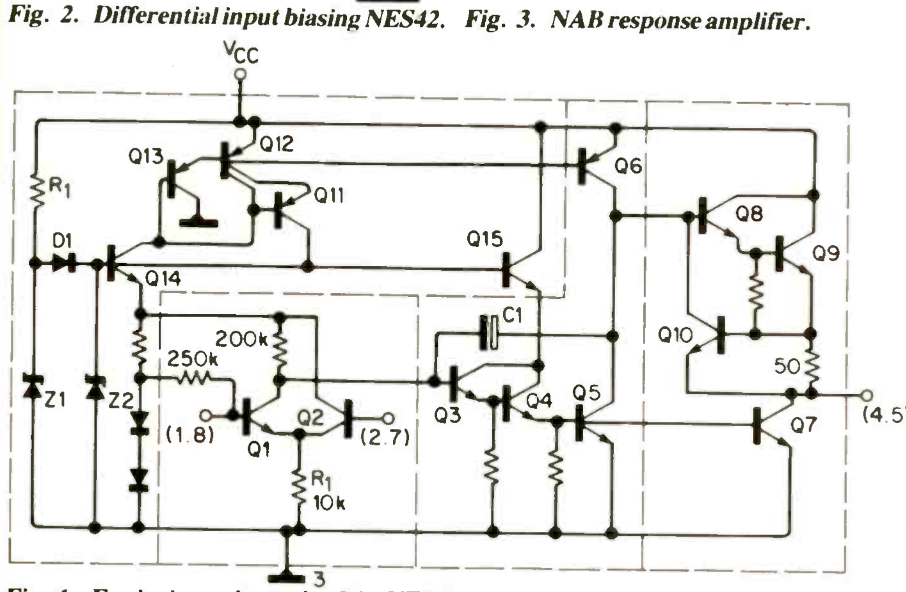


Fig. 1. Equivalent schematic of the NE542.

CFA EXPERIMENTS

Bryan Wells* reports on further experience with the barrel-shaped crossed-field antenna

**G3MND representing an amateur radio experimenter's group.*

A major difference between this article and its predecessor in the November issue is that, as an amateur radio group, we have become convinced, since that article was written, that the CFA does indeed work effectively. We are now concerned with its performance and the potential for further development.

The question of whether the theory expressed in the original article by Hately, Kabbary and Stewart in the March 1989 issue is the correct explanation for the practical results we have experienced, we must leave to others better qualified to judge. However, we feel that whatever opinion may be expressed in this context, the authors have produced what appears to be some entirely original thinking which ought to be acknowledged as such.

Matching the feed

Since my previous article, I have made efforts to achieve a matched feed system for the CFA – for two reasons. Firstly, a matched system with more or less "flat" lines might avoid the criticism that all we have been doing is using the combination of the feed lines, the CFA and a matching unit to create a resonant system in which most of the radiation is from the feed lines.

The second and more important practical reason for a reasonably matched system is to obtain correct phasing; Hately confirmed that the required phasing between the plates and cylinders of the CFA is the 90° shown by our experiments.

The next step was to use a noise bridge to check as carefully as possible the approximate impedance of the plates and cylinders of the present version of the barrel-shaped CFA. (Previously I had obtained some very doubtful results, suggesting a very high radiation resistance and of course a substantial X_C.) Eventually, repeated measurements suggested that the impedance for both plates and cylinders in the R + jx form was of the order of 10Ω and 100Ω. Because of the difficulty of making accurate low-value resistance measurements with the noise bridge, these figures were checked by substituting with 1% 8-12Ω carbon resistors. It seemed that the resistance values might be overstated, but only slightly.

An obvious way, neglecting reactance effects, of matching 12Ω to 50Ω co-ax, seemed to be a one-to-four, balanced-to-unbalanced transmission-line transformer that could be effective over the range 3-30MHz. I constructed this transformer along the lines shown in **Fig. 1**, only to find that although it behaved perfectly well with a pure resistance load, its transformation ratio varied widely with even a slightly complex load and did not provide even a reasonable match for the transceiver. I put this down to its inability to cope with the inherently high capacitive reactance of the CFA, together with my use of ferrite core material of unknown specification. Attempts to cancel out the reactance with a conjugate inductive element did not achieve the desired result.

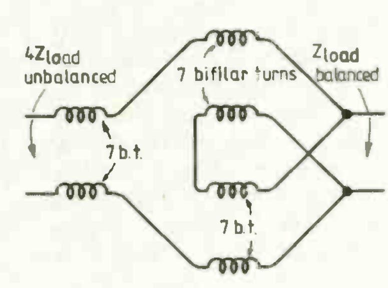


Fig. 1. Impedance matching to 50Ω line. A 1:4 balun by Goanella, taken from Transmission Line Transformers, published by ARRL. Each element wound on 0.5in diameter ferrite rod of Q1 material. It is reputed to give 4:1 ratio from 50Ω unbalanced to 10-15Ω balanced over 1.8-15MHz.

Series-section matching. My next thought was to try series-section matching and wrote a simple Basic programme so that I could vary the line-impedance values to see which combination could provide a match and also be of the shortest possible length. I eventually settled on the

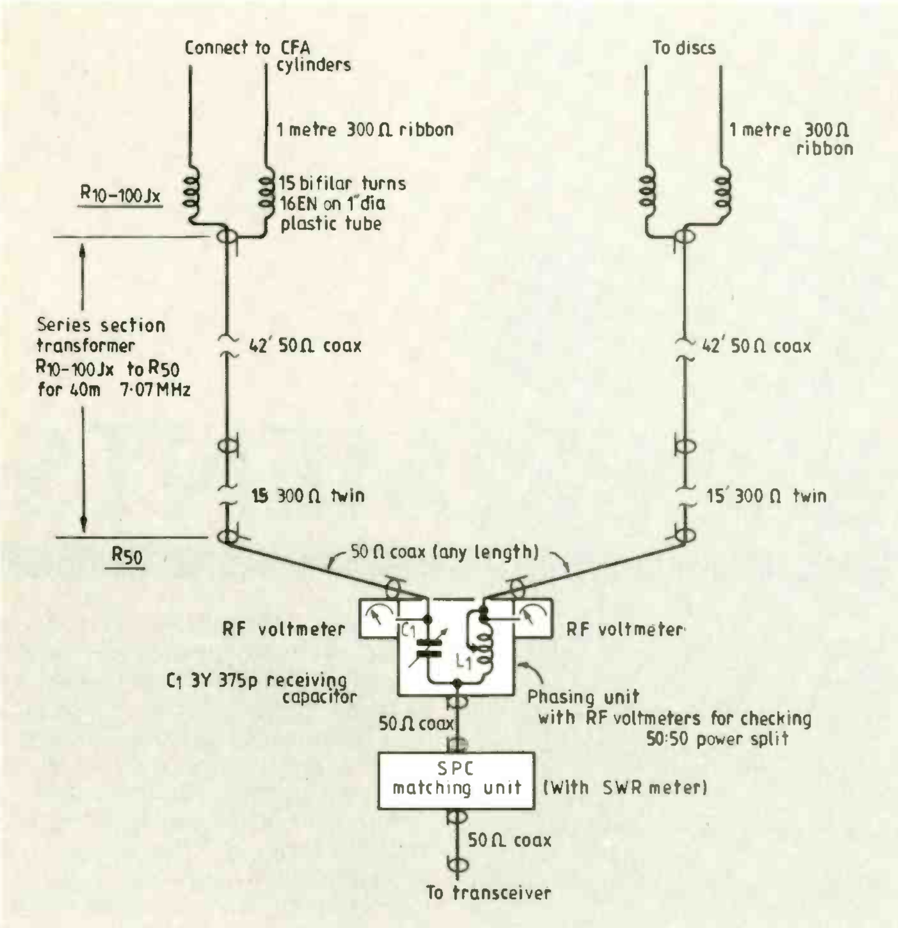


Fig. 2. Series-section matching. Phasing unit design appeared in CQ August 1989, p. 30.

rather clumsy and complicated looking system indicated in **Fig. 2**. A 1m length of 300Ω ribbon makes the balanced connections to the CFA, and is immediately followed by a bifilar-wound line transformer in the form of a sortabalun. (A balun of this kind is intended to provide a transition from balance to unbalance without necessarily forcing balance to earth).

A second series of impedance measurements was now required at the transceiver side of the sortabaluns for use in the final series-section calculations. The sortabaluns did not appear to affect the resistance values, but their inherent inductive element counterbalanced some of the CFA capacitive reactance. The impedance finally used for the series-section calculations was R=10 and X_c=100 with 50Ω co-ax. as the main line and 300Ω ribbon as the series-section. Mixing balanced and unbalanced lines in this way is not very elegant, but seemed to be the only practical way to achieve the required transformation. Figure 2 also includes a very simple and effective phasing system drawn from a recent article in *CQ Magazine*, August 1989.

Operating experience with this system has shown that the phasing method works well and has produced the best CFA results so far on 40m, for which the series-section matching was designed. Without altering the matching sections, the system also gives acceptable results on 20m – I managed a contact in Western Connecticut in relatively poor conditions, using 350W PEP to maintain a Q5 signal. The CFA is located about 25 feet above ground, inside the roof space of my house.

Perhaps the most surprising and puzzling results of all with this 40m matching arrangement is that it has produced even better results on the 80m band, where it has, at times, equalled the 272ft-circumference horizontal loop at 35 feet that I normally use.

These results on 80 and 20m caused me to question exactly what was happening in the series-section matching. It seems that one way of interpreting Fig. 2 is that it places plate and cylinder lines in parallel at the phasing unit, which suggests that the matching system has fortuitously provided a transformation to 100Ω on each line and a

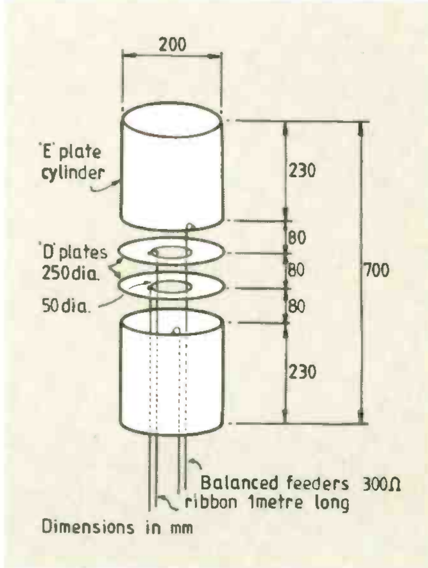


Fig. 3. Dimensions of CFA.

50Ω load for the transceiver.

To check this possibility I used a PL259 T connector to submit the plate and cylinder series-section "matched lines" directly to the transceiver without any other intervention; the result – a perfect match and 1:1 SWR.

Further measurements showed an impedance at the end of each line of 100Ω and a small inductive reactance. Reintroducing the phasing circuit made no difference to the 1:1 SWR once it was correctly adjusted to give equal RF voltage readings in the two feed lines to the CFA. I think it is important to stress that a perfect match was available without any additional tuning or matching unit over the whole 40m band, so the series-section match was working, but in an unpredicted way.

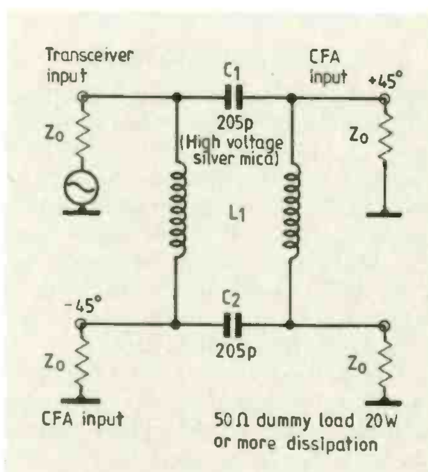


Fig. 4. Alternative 90° phasing method, adapted from ARRL Antenna Compendium Vol. 1, p. 67. L_1 consists of 7 bifilar turns of 32-strand insulated wire on Amidon T200 Red Mix iron powder toroid.

Hybrid combiners. Meanwhile, my attention had been drawn to an article in the ARRL *Antenna Compendium*, Volume 1, p.67, on phasing four 40m vertical antennas by means of hybrid combiners. The initial combiner, a four-port device – all ports presented with 50Ω loads – produces two of its outputs at ±45°. If my matching to 50Ω had not been shown to be flawed, this would have been a more or less ideal way to provide single-band phasing for the CFA, particularly since it was a broad-band device.

The "Twisted-wire Hybrid Combiner" was not difficult to construct as illustrated in **Fig.3.** Despite the mismatch with 100Ω plate and cylinder lines, I was delighted to find it worked well over the whole 40 metre band with a direct match to the transceiver and an SWR of about 1:1.3 without a matching unit. It may be slightly down, less than an S point, in comparison with the tuned phasing system. Again the hybrid is supposed to exhibit heavy dissipation in the dummy load if not presented with the correct 50Ω to each port. This did not seem to amount to as much as 5W: probably accounted for by, at least the two antenna lines are about equal at 100Ω.

The question of why I failed to produce the designed 50Ω transformation with the series section intrigued me; running the computer programme again, I discovered that I had been working at the limits of what a 6:1 series-section combination could achieve.

Slotted 300Ω ribbon. If the CFA impedance had a resistance of less than about 8Ω, the series section would not work. In fact, its length approaches the length of the main line and the total becomes more than a half wavelength. This made me think that I might try out an electrical half-wave length of slotted 300Ω ribbon as the feeder to plates and cylinders. On 40m this would mean that whatever impedance existed at the antenna would be repeated at the opposite end for any measurement purposes. I could also use the two sortabaluns to provide balance transition from the transceiver end of the 300Ω ribbon and use the *CQ* tuned phasing system and a final matching unit for the transceiver's 50Ω needs. This arrangement would also provide multiband operation. This arrangement is now in use and works well on 80, 40 and 20 metres.

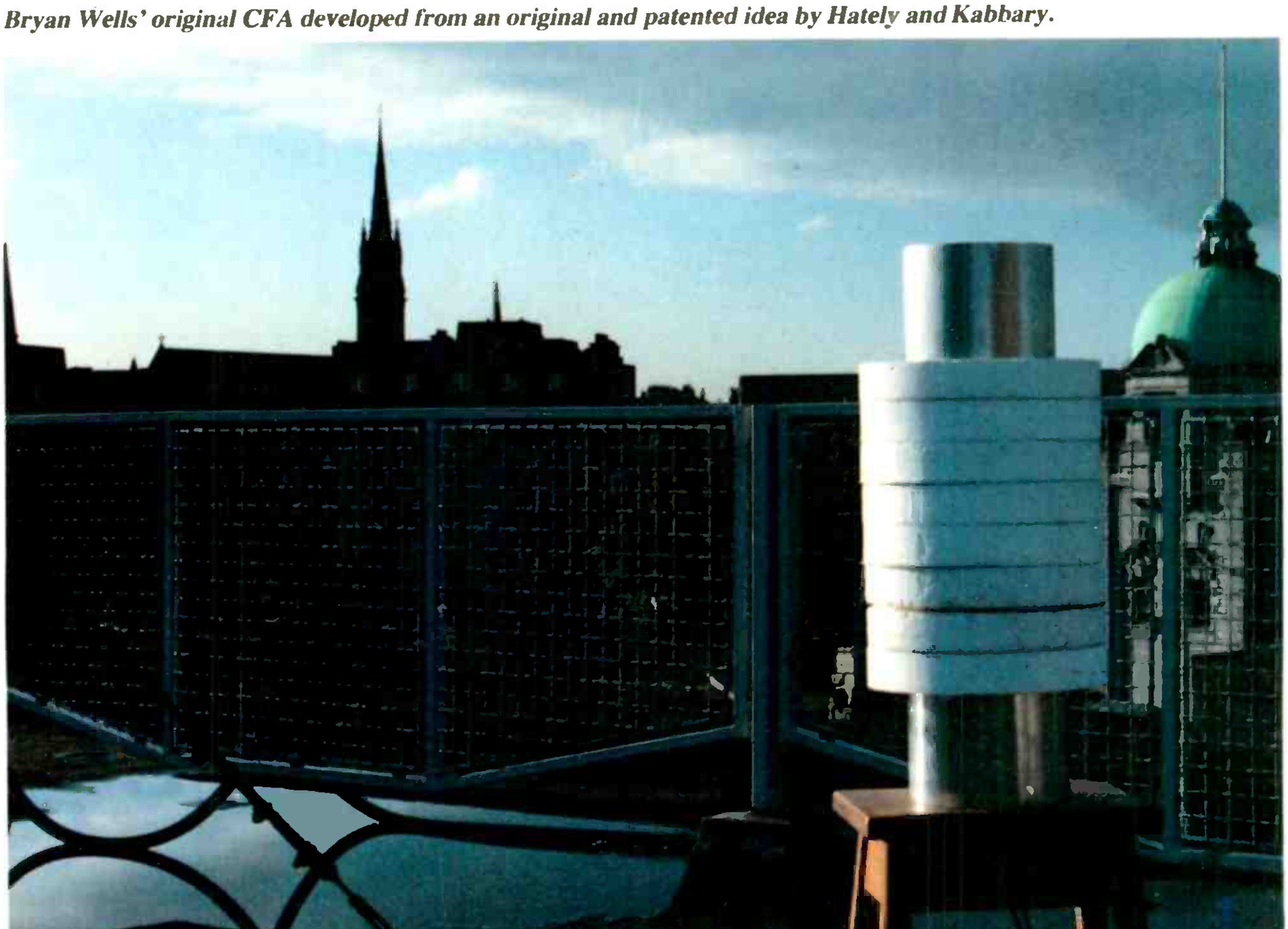
All the effort with the series-section experiment had been useful experience and did provide matching of a kind which, so far as I could measure, eliminated most feeder radiation.

In making all the measurements that have been described, resistance values of somewhere between 7 and 12Ω have been encountered from the CFA at 7.07MHz. These values are much larger than any DC resistance values, even if the circuits were closed. Does this confirm that the CFA does create a radiation resistance element as required for antenna operation? If not, where does this apparent resistance come from? ■

The crossed-field antenna was described by F.M. Kabbary, M.C. Hately and B.G. Stewart in the March, 1989 issue of *Electronics and Wireless World*. It is intended to synthesize directly the Poynting vector S=E.H from separately stimulated E and H fields and one result of the development is an extremely small and compact design which is independent of the radiated wavelength.

There have been criticisms of the design, some correspondents saying that it cannot possibly be practicable, but Bryan Wells has made models which appear to work well. He described some initial experiments in the November 1989 issue.

Bryan Wells' original CFA developed from an original and patented idea by Hately and Kabbary.



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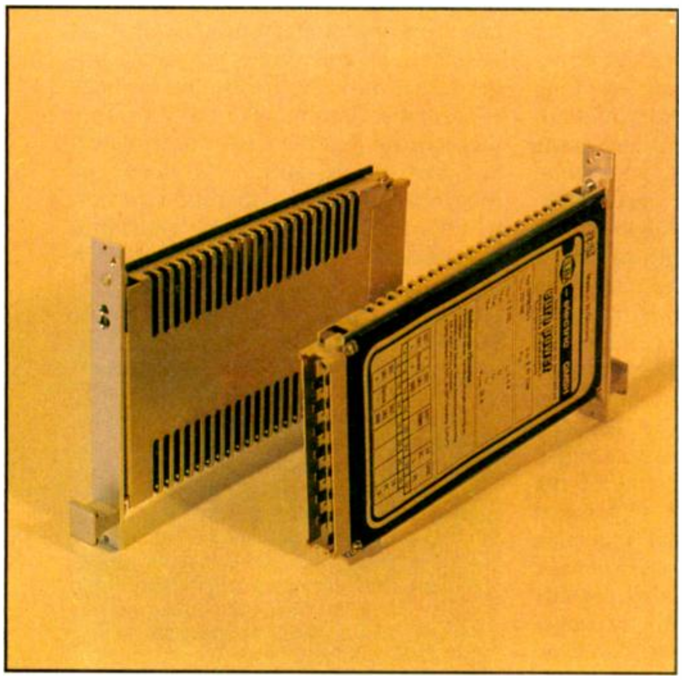

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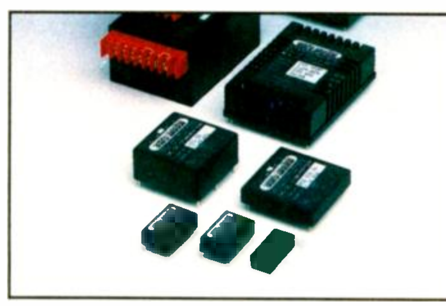

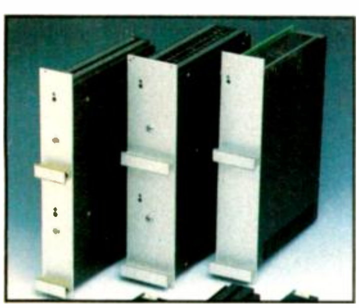

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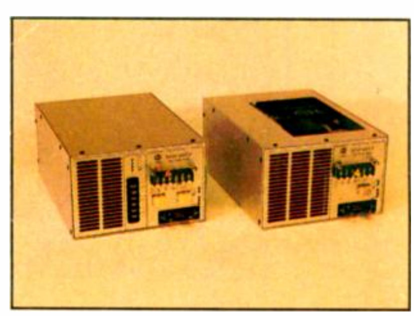


CIRCLE NO. 154/155 ON REPLY CARD

PC Oscilloscope add-in

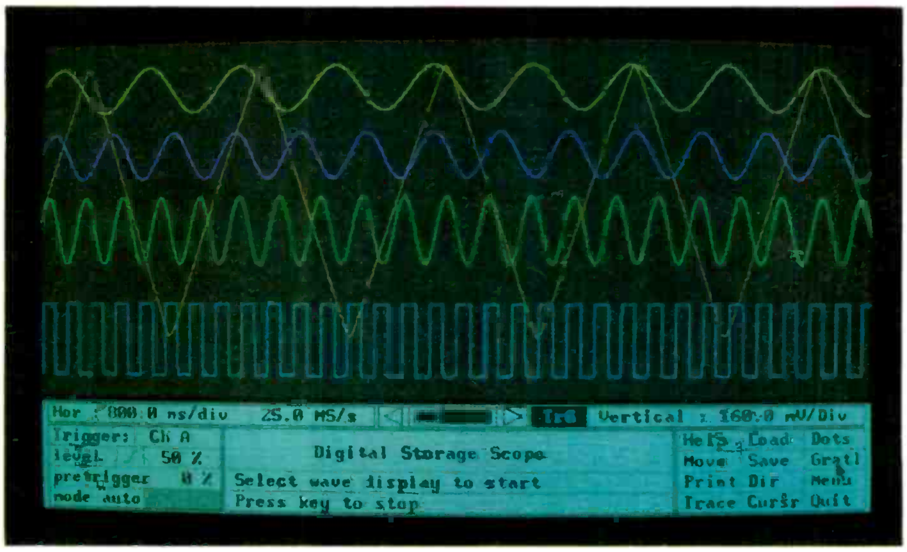
Allen Brown reviews an IBM compatible backplane card which converts a personal computer into a 25MHz sampling digital oscilloscope.

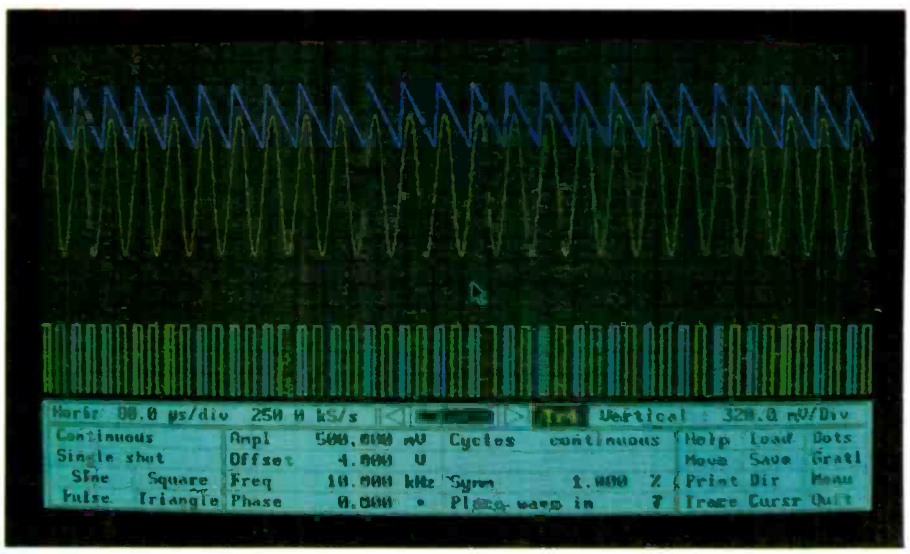
IBM PC architecture is hosting an ever growing variety of I/O expansion cards. The PC99 card from Amplicon converts a typical business machine into a dual function instrument: it acts as a 25MHz sampling oscilloscope with storage and, secondly, it provides a two channel waveform generator.

The electronics takes the form of a full length card with an 8-bit ISA bus which can also be accommodated in an IBM AT (clone) or 386 based machine. The PC99 can produce two output analogue signals as well as sample two input analogue signals. To make the card convenient to use, there is an additional module which fits into the D connector of the card providing two input BNCs, two output BNCs and a fifth BNC for a trigger signal.

A set of software drivers accompany the card and produce a rather attractive mouse driven screen display. It will run under the Hercules, EGA and VGA display formats. However when used with a VGA on an OPUS VI, the results were a little disappointing – only two thirds of the screen was occupied by the display.

The input waveforms can be frozen and stored to disc for recall and display at a later time. When operating in its





storage mode, the PC99 can display up to seven waveforms at any one time, five recalled from storage and the two live inputs. as seen from **Fig. 1**, the display is well laid out and the seven different colour attributes of each waveform adds to display clarity.

The use of the mouse contributes to the usefulness of the package and this enables easy switching between waveforms, triggering levels and the instrument options shown on the bottom right of the display.

Oscilloscope

The PC99 signal inputs pass through anti-aliasing filters and lead to separate ADCs. The ADCs are 8-bit devices with sampling frequencies of 20MHz. The effective bandwidth of each channel, is therefore at best 10MHz. When operating as a 'scope, in its storage mode, the two channels can be displayed with a maximum time base setting of 25MHz.

Despite the attractive screen presentation, the PC99 has three outstanding oversights in its design. Firstly, it is unable to cope with input waveforms with negative voltages. When an AC waveform is fed into the card, the negative half cycles are chopped off. An extraordinary characteristic for any oscilloscope, it could conceivably be useful for looking at the unbiased outputs from square law detectors.

Secondly, the user has no screen control over the input signal gain. This deficiency necessitates external attenuators or amplifiers on the input signals.

Thirdly, the input voltage range is limited to between 0V and 2.5V.

Although these specifications are laid out in the rather poor user manual, they render the board as almost useless as a general purpose oscilloscope. However if there is a requirement to analyse only positive waveforms, not exceeding 2.5V which are band limited to below 10MHz, then the PC99 will serve the purpose well.

Waveform generator

The second mode of operation of the PC99 is for waveform generation (see **Fig. 2**). Four types of waveforms can be generated, sine, square, triangle (with adjustable symmetry) and pulse (single or continuous). Once the waveform has been specified by the user then it can be channelled through one of the digital to analogue converter outputs.

Two independent waveforms can be produced simultaneously by the PC99 card and these can also be displayed on the screen. This feature is attractive, but does not offer anything more than a standard waveform generator apart from two independent outputs. It is a great shame that this facility is so limited, since this type of unit could offer extensive options for waveform synthesis, for example five tone waveforms or FSK signal generation with varying degrees of added noise.

The final analysis

It's all very well having I/O expansion cards for PCs but unless they offer distinct features and advantages over conventional instrumentation, their value must be questionable. I can see no benefit of having the PC99 installed in a PC when the service provided by a modest priced scope and signal generator is considerably better. The PC99 cannot be recommended as a practical, general purpose 'scope because of the severe limitations it imposes upon the input waveforms. This limits potential applications to very tightly specified input conditions. It may be useful for highly sanitised demonstration purposes. ■

PC99 costs £699 plus VAT and consists of the card, manual and software. an advanced wave processing software package is now available, for an additional £195 plus VAT, which enables further mathematical manipulation, such as spectrum analysis, integration, differentiation and statistical operations.

The package is obtainable from Amplicon Liveline Limited, Centenary Industrial Estate, Hughes Road, Brighton, East Sussex BN2 4AW. Telephone 0273 570220.

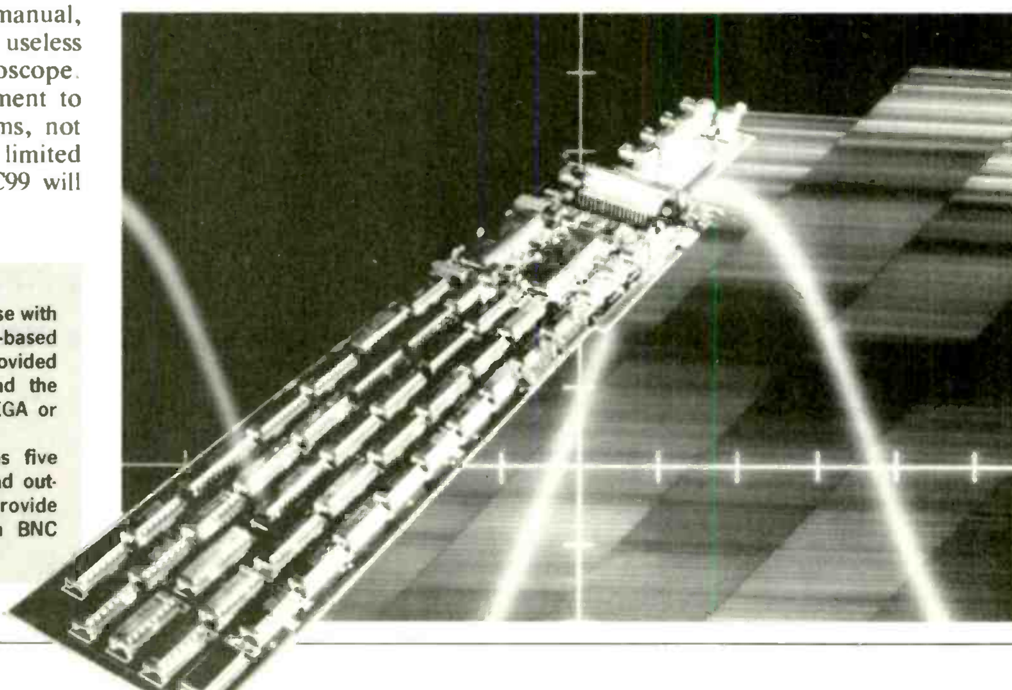
Amplicon says it is well aware of the limitation on input mentioned by our reviewer, but points out that the package was designed primarily for, and in consultation with educational establishments, who are prepared to use their own input signal conditioning with a view to keeping the price of the package as low as possible.

Nevertheless, the company has plans to produce a signal-conditioning package to provide a more flexible input requirement.

Operating environment

PC99 takes the form of a card for use with an IBM AT or clone, or a 386-based computer. Software drivers are provided to allow the use of a mouse and the display format can be Hercules, EGA or VGA.

An additional module provides five extra BNC connectors for input and output and the user is expected to provide his own oscilloscope probes with BNC connectors.



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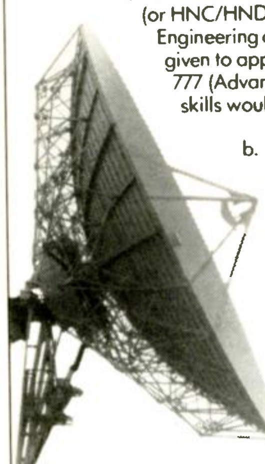

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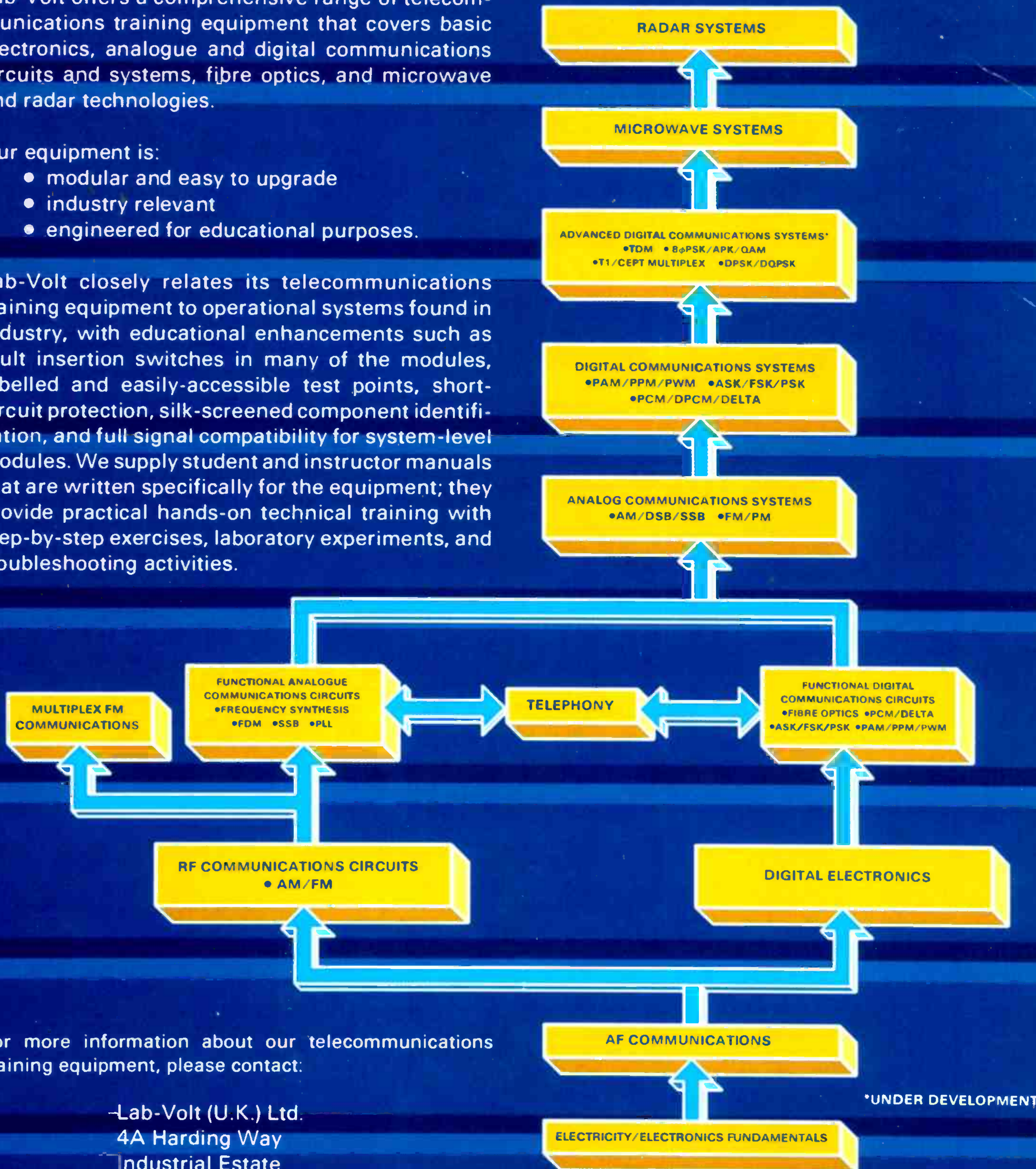

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