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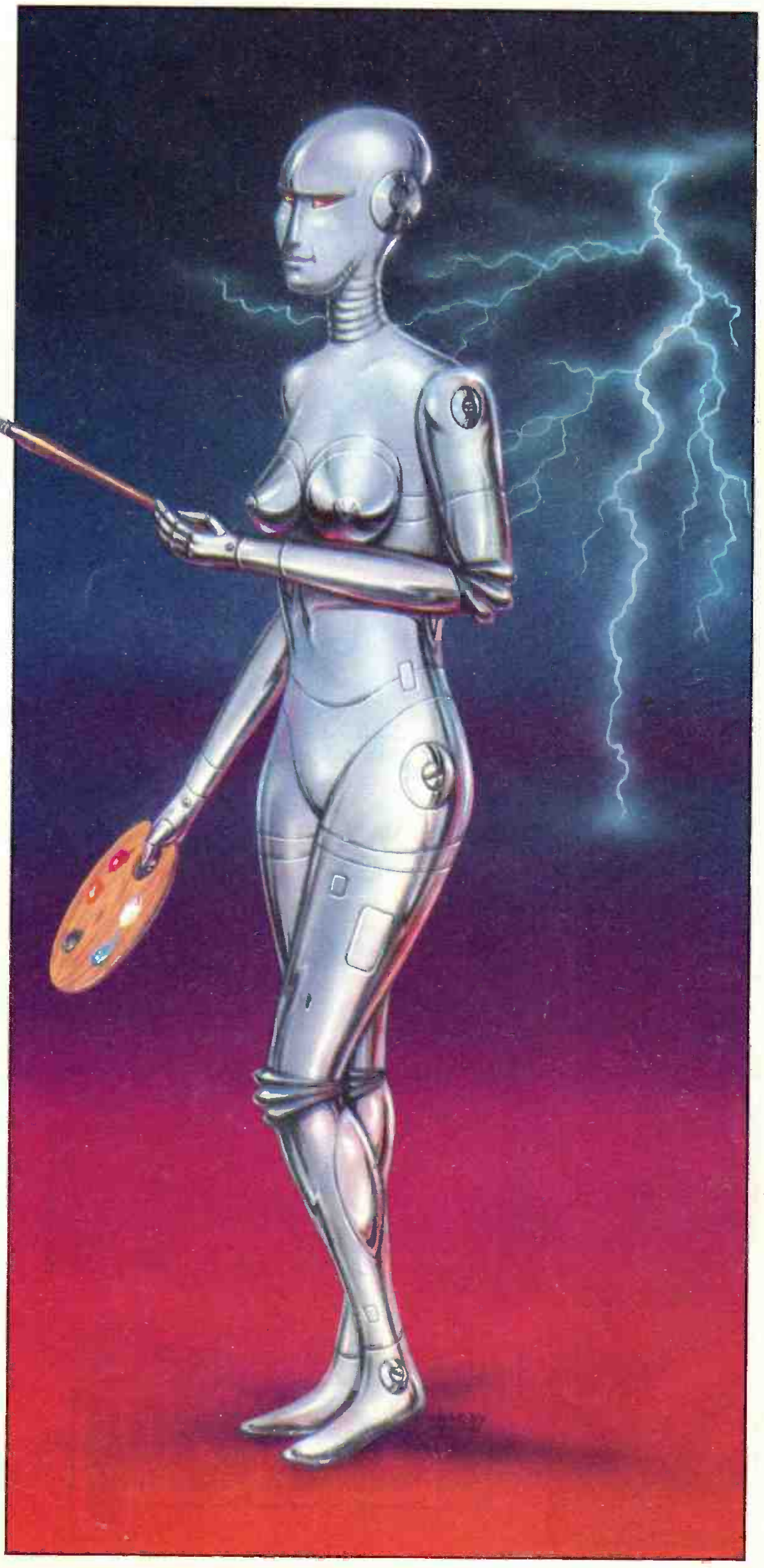

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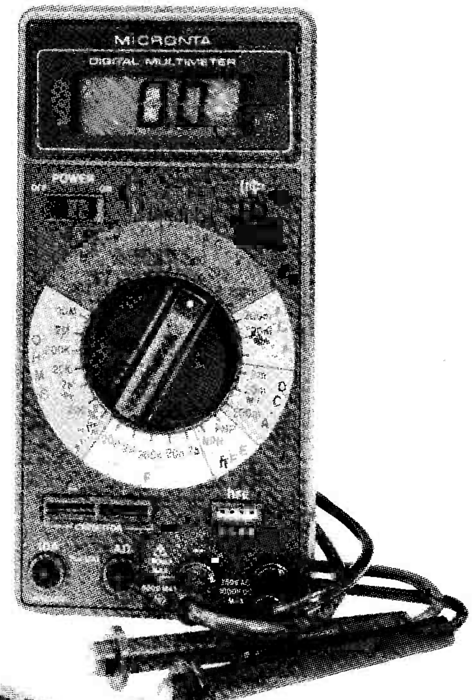

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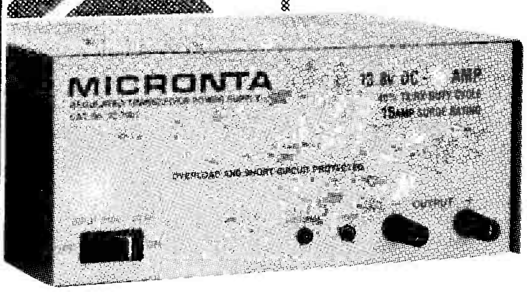

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PRACTICAL ELECTRONICS

VOL 26 NO 4 APRIL 1990

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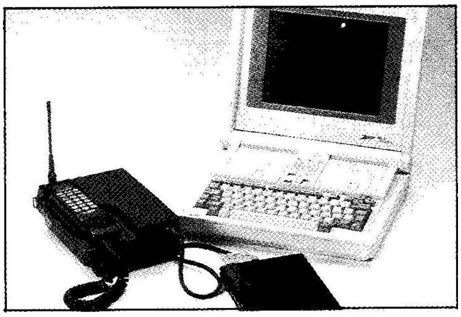

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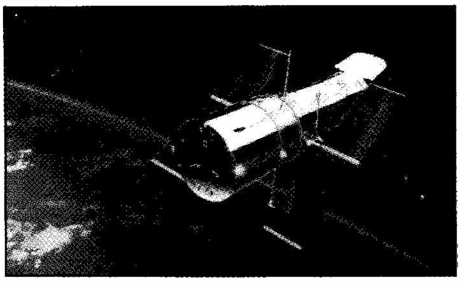

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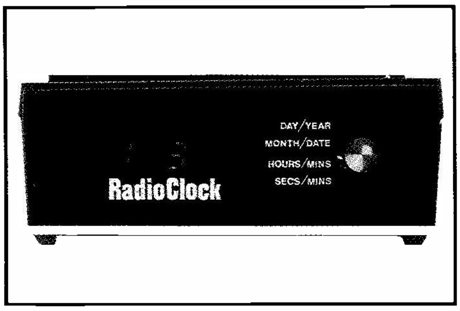


NEXT MONTH

With a new family of alphanumeric liquid crystal displays now more readily available, we taken an in-depth look at one of them and show you how to build and use your own lcd message-maker. For all constructors addicted to microprocessor projects we've an automated deluxe programming unit which caters for practically any type of eprom. Communications buffs can extend their inter-computer talk-back facilities with our baud rate converter. We'll have more on robot car building and another episode in the Basic Electronics series, plus, of course, our usual top-line features.

★ SPRING INTO PRACTICAL ACTION
★ WITH OUR GREAT MAY 1990 ISSUE
★ ON SALE FROM FRIDAY APRIL 6TH

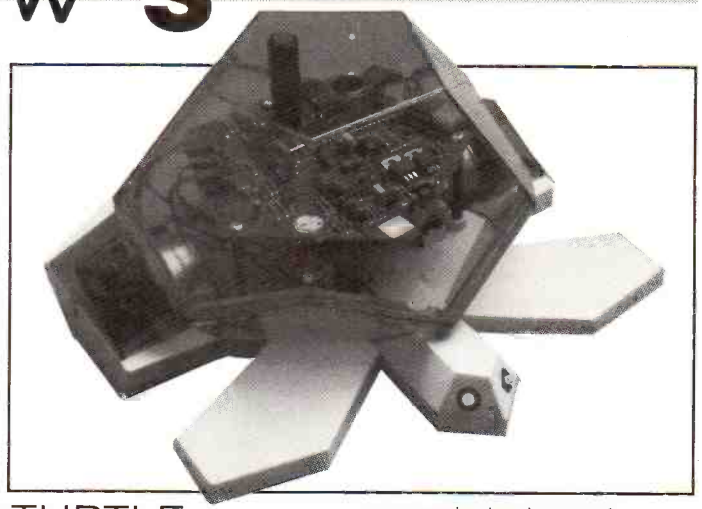
ROBOTICS FEEDBACK

At the recent British Educational and Training Technology exhibition in London were a number of companies whose electronic products will be of interest to PE readers. Among the companies was Feedback Instruments who specialise in several areas of teaching systems and one of whose products interested me in particular.

Unless I am very much mistaken, one of their robot arms has an ancestry that is PE related. Some of you may recall that in 1985, PE published a series of articles on robot arms designed by someone with a name relatively similar to your Editor's. Those robots set a certain company upon the road to many cybernetic applications products. Involving a story too complex to be told here, some of the products were recognised by Feedback as having good market potential and were acquired by them. The subsequent history of those machines is less well-known to me, but I would like to think that, even if the hydraulic robot arm in Feedback's current catalogue is not the original model with which I was familiar, it still owes its genealogical line to a PE-published ancestor.

In addition to the hydraulic arm, Feedback have several other robots which will have great appeal to anyone wishing to teach or learn about automation. Among them are a servo motor robot arm, some SCARA robots with work cells, as well as some low cost CNC machine tools. The catalogue also covers teaching systems relating to basic electricity and electronics, digital systems and computing, telecommunications and weather satellite receivers, control and instrumentation, and electrical power and machines.

For your copy of this catalogue of really interesting products write or phone **Feedback Instruments Ltd,** Park Road, Crowborough, East Sussex, TN6 2QR. Tel : 0892 653322.



TURTLE TURNING

Also at the BETT show was a favourite robot that must surely appeal to anyone of any age who finds enjoyment from mobile models. It was the Valiant Turtle.

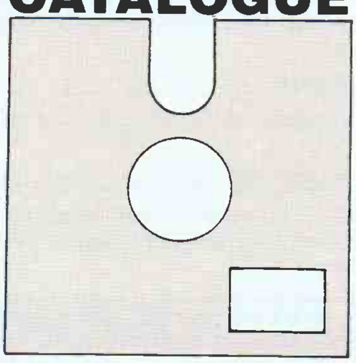
First introduced in 1983, the function of the Turtle is just as valid for the 1990s as it was seven years ago. Valiant say that this remote controlled robot was designed to be accurate and safe, and that it has brilliantly passed the test of time. Approved and purchased in large numbers by most UK LEAs, Turtles are the key to mathematics, computing, problem solving and programming in primary and secondary schools. They unlock understanding of abstract ideas through the computer language which controls them, Logo.

The Valiant Turtle is known for its delightful and distinctive turtle-like shape and precise performance, and provides an unforgettable experience in geometry for anyone controlling or watching it as it glides across a floor.

Many different computers are capable of use with the Turtle, including Acorn, Apple, Commodore, IBM, Research Machines and ZX Spectrum.

For more information contact **Valiant Technology Ltd,** Gulf House, 370 Old York Road, Wandsworth, London SW18 1SP. Tel: 01-874 8747.

CATALOGUE DATABASE



Continuing our browse through advertisers' literature

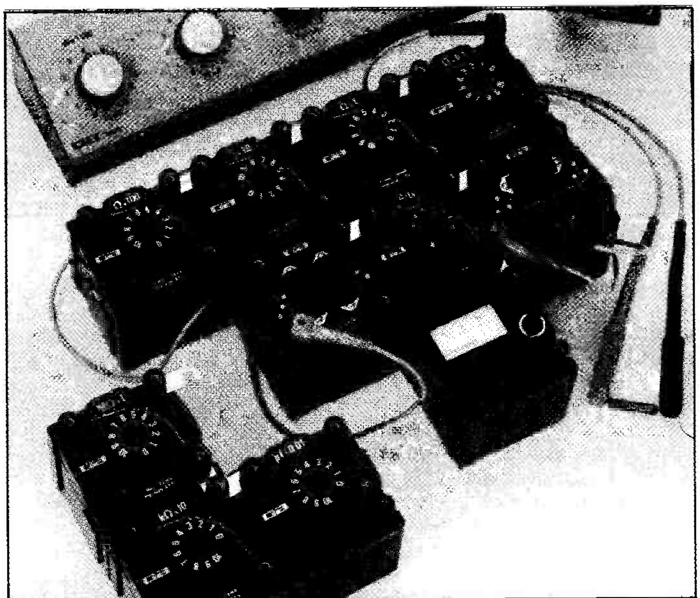
Alpha Electronics have sent their **1990 electrical product guide**. You've undoubtedly seen mention of their products on PE's news pages from time to time, mainly relating to **meters of various types.** The new product guide colourfully illustrates how wide that range is, covering insulation and continuity testers, tachometers, thermometers, lux meters, phase indicators, cable location and fault testers, portable appliance testers, and many other interesting varieties. Also included are details of Alpha's **repair, calibration and hire facilities**. For your free copy contact **Alpha Electronics Ltd**, Unit 5 Linstock Trading Estate, Wigan Road, Atherton, Manchester, M29 0QA. Tel : 0942 873434.

Maplin's professional supplies division has issued a new product catalogue (an "encyclopaedia", in Maplin's words). Dave Scoad, the Sales Director at MPS, points out that the catalogue is the biggest yet and is packed with **lots of new products at "super bargain prices** - some reduced by up to 50%!"). Right across an enormous range of products, if you're looking for a **professional supplies source**, you will find this catalogue worth studying. It is illustrated in colour and gives a variety of price breaks in tabulated columns, clearly showing how much more you can save the more you buy. **Speed of order fulfilment has also been increased** since the opening of Maplin's new Northern distribution centre. **Maplin Professional Supplies** head office is at PO Box 777, Rayleigh, Essex, SS6 8LU. Tel : 0702 552961.

Cirkit's 1990 catalogue will find favour with any PE reader looking for electronic **products of practically all varieties**. Over 300 pages which are well illustrated and in a comprehensible layout. Cirkit's Managing Director, Richard Bulgin, says that the new **catalogue has undergone a complete redesign** and that it is their biggest, most carefully thought out and best yet! Among the new lines he draws to our attention are **more communication coils and filters** from Toko, an extended crystal range, and new filters and counters. There are new waterproof switches, **new ranges of Cirkit multimeters**, and much more. Another appeal of the cat is the improved **keenness of the many price structures. Cirkit's** distribution headquarters are at Park Lane, Broxbourne, Herts, EN10 7NQ. Tel : 0992 444111.

ICS have just released a new full colour catalogue covering their **product range which will interest anyone** looking for amateur radio, data communications and weather monitoring equipment. A number of new products have been included and are intended for both **amateur and professional radio communications**, as well as weather satellite monitoring, weather fax reception, wind monitoring, radio telex. Slow scan colour tv computer software is also featured. ICS request that you write for their free catalogue. **ICS Electronics Ltd,** Unit V, Rudford Industrial Estate, Arundel, West Sussex, BN18. Tel : 0903 731101.

NEWS



MEASUREMENT TEACHING

A recently received catalogue jointly supplied by E&L Instruments and Global Specialities features a range of measuring instruments specially for teaching and training purposes.

The products are manufactured by the French company Chauvin Arnoux and cover a variety of instruments whose robustness should be the match for any high-spirited classful! Among the instruments are numerous multimeters of different types, watt meters, temperature meters, frequency meters and light meters. I was particularly interested to see that some less-usual products are included, such as a stroboscope, a thermo-anemometer, and an x-y potentiometric chart recorder.

A product range that especially appeals to me, though, consists of a wide selection of decade boxes. Most of you must be familiar with the more-conventional decade box which is self contained and allows switched selection of, for example, different values of resistor, or capacitor. Chauvin Arnoux's boxes go a stage further; they are still self contained, but have been designed in modular form so that they can be strapped together. From the photo you will see a conventional decade box alongside the modular form. Each module has a single control and can be switched to select one of 11 modes for a specific value range of component. What also appeals to me is the way that the boxes can be interlinked and coupled to probes and leads at various strategic points, and that a meter can be coupled into the configuration as well.

This must surely be the type of product that will not only teach children the elementary facts about components and measurement, but also offer a fun element as well by allowing experiment with visually appealing building blocks.

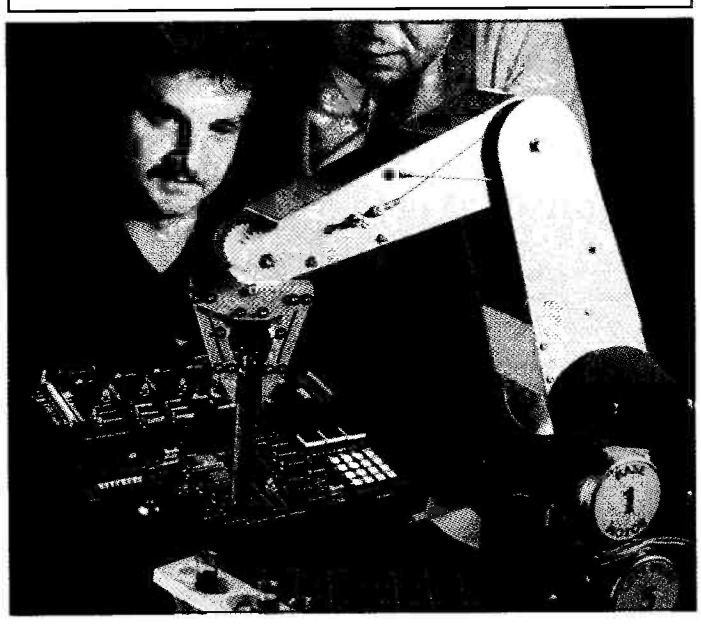
E&L Instruments and Global Specialities are at Rackery Lane, Llay, Wrexham, Clwyd, LL12 0PB. Tel : 0978 853920.

STATE-SIDE ROBOTS

Another brochure from the BETT exhibition is concerned with the American company Lab-volt Systems' involvement in robotics training systems. The brochure highlights the company's educational program which, they say, represents a modern approach to robotics and robotics training. The program is designed to provide entry level job skill training or career awareness training related to a specific training or curriculum requirement.

Included in the program, which deals with both concepts and applications, are a student laboratory manual, instructor's guide and pre and post testing in the single instructional module. The latter is supported by the robot arm and microprocessor, trouble shooting and robot interface trainers.

The company has several offices world-wide, but most readers will find it easiest to obtain further information by contacting **Lab-volt (UK) Ltd**, 4A Harding Way Industrial Estate, St Ives, Cambs, PE17 4WR. Tel : 0480 300695.



ADVERTISERS AWAKE!

Don't let your competitors steal all the glory of PE News Page Publicity - have YOUR interesting new products highlighted here as well as theirs! Send us concise details plus a good photo and we'll do our best to publicise them.

First come, first served, and it must be interesting. It's up to you to keep us all informed!

If you are organising any event to do with electronics, big or small, drop us a line, we shall be glad to include it here.

Please note : Some events listed here may be trade or restricted category only. Also, we cannot guarantee information accuracy, so check details with the organisers before setting out.

Mar 7-8. Laboratory 90. G-Mex Centre, Manchester. 0799 26699.

Mar 9-10. London Amateur Radio Show. Picketts Lock Centre, Edmonton, North London. Advance ticket sales and trade enquiries to The Secretary. LARS, 126 Mount Pleasant Lane, Bricket Wood, Herts AL2 3XD. 0923 678770.

Mar 28-29. Laboratory, Science & Technology Show. Kelsey Kerridge Sports Hall, Cambridge. 0799 26699.

Apr 4-5. Drives, Motors, Controls. New Century Hall, Manchester. 0799 26699.

Apr 9-11. Cable and satellite exhibition and conference. Olympia, London. 01-486 1951.

Apr 24-26. British Electronics Week. Olympia, London. 0799 26699.

May 27. Plymouth Radio Club annual radio and electronics fair. Plymstock School, Church Road, Plymstock, Plymouth. 0752 340946.

Jun 26-28. Infrared Technology. Wembley Conference Centre. 0799 26699.

Sep 25-27. British Laboratory Week. Olympia, London. 0799 26699.

NEWS

ROBOTS AT COLLEGE

The great importance of training students in automation has been further recognised by the North West Kent College of Technology at Dartford, Kent. In collaboration with Kent County Council, the College has recently completed three years of strategic planning for more integration on the syllabus of automation and allied technology.

As part of that plan, the college recently installed a new multitasking robotics training system. Costing around £22,000, the system represents a significant capital investment for the college. "The intention of installing this equipment is to train B-Tec and HNC students in the automation skills required by local industry," said Ian Goodwin, Head of the Faculty of Technology. "We have many large companies in the area, such as the Wellcome Foundation and AEI, who draw their technologically trained workforce from the college. It is essential to train students in the skills needed to meet the requirements of these and other companies."

Under Dave Budden, the Section Leader of Technology, students are already receiving training in many areas of automation control, such as pneumatics, hydraulics, and CAD. The new system is compatible with existing facilities and will enhance the college's ability to simulate the operations performed by larger industrial control systems. It will, additionally, assist in the college's general science training, providing practical examples of how electro-mechanical components work, and of the design criteria which they have to meet. With the addition of these new facilities, the college expects to considerably increase its annual student intake.

British company Cybernetic Applications of Andover are the manufacturers of the installation. Managing Director Richard Becker emphasised the importance of training tomorrow's control engineers in suitably equipped colleges, but commented, "It is a need well understood by many countries abroad, and Cybernetic Applications has a healthy export market for these systems. In Britain, though, colleges are slower in responding to meet industry's needs for appropriately trained technology students."

It is good know that a British company is satisfying overseas demand for automation control training systems. But why is British education allowing other countries to gain and excel in technological skills which we are equally capable of acquiring? Let's have more colleges in Britain following the example set by the one in Dartford.

As a footnote, you'll be interested to know that this robot system has ancestry rooted in the Neptune robots published in PE 1985. The picture shows R. Becker, one of the students to benefit from the robot system, and I. Goodwin.

For further information, contact **Cybernetic Applications**, Portway Industrial Estate, Andover, Hants. Tel : 0264 50093.

REWARDING

The 1989 Young Woman Engineer of the Year Award has been won by Anne-Marie Carter, a Principal Communications Trials Engineer with Siemens Plessey Defence Systems of Christchurch, Dorset.

At a recent ceremony, 24-year old Anne-Marie was presented with a cheque for £250 and an inscribed rose bowl by Sir Trevor Holdsworth, President of the Confederation of British Industry.

The award, sponsored jointly by The Institution of Electrical and Electronics Incorporated Engineers (IEEIE) and The Caroline Haslett Memorial Trust (CHMT), aims to promote electrical and electronic engineering at Incorporated Engineer level as a challenging and exciting professional career for women.

AMBITIOUS ENGINEERING FACULTY

The first phase of the most ambitious engineering complex to be launched in a British university since the 1960s was opened on January 16th by the Secretary of State for Wales, the Rt Hon Peter Walker MP.

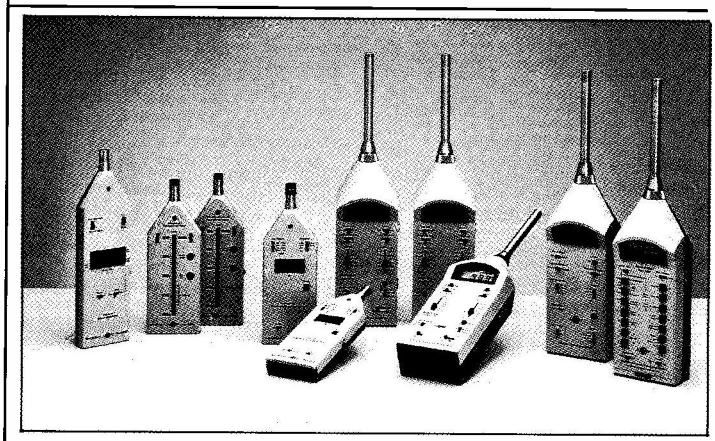
The £27.5 million five-phase development at the University of Wales College of Cardiff is expected to help combat the serious nationwide shortage of trained engineers. When completed in 1993 the complex will cater for 1100 students in the Schools of Engineering, including Electronic and Systems Engineering. Among the facilities provided are extensive ones for computing, including three terminal classrooms, plus computer aided design and engineering labs.

"Britain will inevitably decline as a manufacturing economy if we don't educate, and retain, more engineers," said Professor Roy Evans, Head of the School of Engineering. "We have the expertise, courses and facilities for Cardiff to be recognised as a major engineering centre."

The new development has been named after the Cornish mechanical engineer and inventor Richard Trevithick, a man who should have achieved greater fame than history accords him. Born in 1771, he was described by his school master as "disobedient, slow and obstinate". However, although he remained scarcely literate throughout his life, he had an extraordinary talent for solving problems that perplexed educated engineers, and his technical achievements in harnessing high-pressure steam were an important factor in the rise of the Industrial Revolution.

In 1803 he constructed the world's first steam railway locomotive at Samuel Homfray's Penydaren Ironworks in South Wales. In 1804 the engine won a wager for Homfray by hauling a load of ten tons of iron and 70 men along ten miles of tramway.

Trevithick, though, was entirely lacking in business sense. He left for South America in 1816 and returned in 1827, penniless, to find that in his absence other engineers, notably George Stephenson, had profited from his inventions. He died in poverty in Dartford, Kent, and was buried in an unmarked grave, in 1833.



HEADACHE CURE

Employees, does your boss know about the new regulations relating to noise at work? If you work in a noisy environment perhaps you should inform the boss that he can decrease your headache potential by asking Bruel & Kjaer about their seminars, literature and instruments relating to noise measurement.

B&K has embarked upon a programme of seminars and literature releases to educate employers as to the measurement task involved and to clarify the choice of measurement systems. While the wide scope of the available specifications may seem baffling, say B&K, the choice is quite simple and is determined by the nature of the noise and the work pattern in each workplace. Again, while it may be tempting to go for the cheapest solution on the market, employers should bear in mind that remedial work, and maybe even claims for compensation for hearing impairment, may be determined by the accuracy of the measurements.

A range of sound level meters is manufactured by B&K, each of which has its niche in environmental noise assessment. The ideal solution for each set of circumstances depends on whether the noise level is steady, fluctuating or impulsive, and on the predictability of the employees' working patterns.

So, if you've got a working headache, make noises at Those Concerned and shout the praises of B&K and their noise abatement aids. A quiet letter or phone call could then work medicinal wonders if addressed to **Bruel & Kjaer UK Ltd**, Harrow Weald Lodge, 92 Uxbridge Road, Harrow, Middx, HA3 6BZ. Tel : 01-954 2366.

LONGEVITY AND THE 68000

Motorola have recently announced that 34 computer system and board manufacturers have endorsed the 68040 microprocessor as a platform for future products. The 68040 is the latest addition to Motorola's 68000 family.

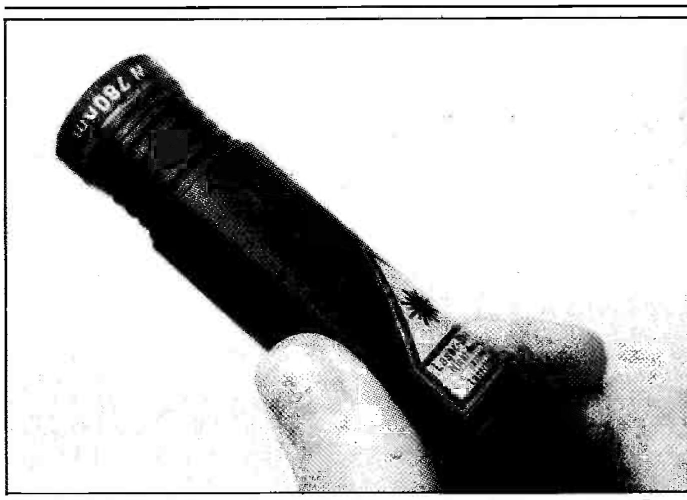
With the rapid progress of ever-improved electronic devices casual observers might be forgiven for forgetting that each improvement owes its origin to products introduced many years ago. The 68040 can trace its ancestry back at least 15 years. Motorola introduced the 6800 microprocessor in 1975, following it with the 6801, 6805, 6809 and 68000 by 1979. Since then numerous mutations to the evolutionary tree have come about, and the variety of Motorola microprocessors and microcontrollers is wide, with many of the parallel branches of development still producing fresh fruit.

Among the companies endorsing the 68040 are Apple Computer, Bull, Commodore, Hewlett Packard/Apollo, Nixdorf, Philips and Unisys. Additional customers worldwide are expected to endorse the 040 later this year.

Clive Gay, manager for the 68000 family in Europe, comments, "Customer endorsements of the 68040 microprocessor further demonstrate the longevity and versatility of the 68000 family. With 20 mips of performance, the 040 gives these companies a powerful solution, both in terms of hardware and software, to deliver to the end user."

The 040 is the most sophisticated microprocessor on the market, with more than 1.2 million transistors incorporated on a single piece of silicon. This integration includes multiple execution units that enable the 040 to deliver 20 mips (million instructions per second) of performance, outperforming Intel's 80486 and several RISC implementations. The 040 provides an average 3.5 million floating-point operations per second (Mflops), making the chip ideal for graphics applications, computer simulations and financial analysis.

For more information contact The Manager (68040), **Motorola Literature Centre**, 88 Tanners Drive, Blakelands, Milton Keynes, MK14 5BP.



LENGTHY LASERS

A new inexpensive range of solid state lasers has become available from Spindler and Hoyer. The lasers offer a nearly unlimited lifetime and cover wavelengths from visible light to the near-infrared, 670nm to 820nm, and with power outputs of up to 40mW. The outputs are adjustable, and low voltage versions are also available. These compact units incorporate a laser diode complete with collimating optics and control electronics in a single package.

The longer wavelength units are ideal for such applications as speckle interferometry, while the others will find wide uses in holography, positioning and alignment, non-contact surface measurement, liquid level control and medical techniques.

Long wavelength models have a guaranteed coherent length of greater than five metres and small wavelength drift, typically around 0.2nm/°C. Despite their relatively low cost, all models incorporate power stabilisation using a monitor photodiode plus feedback control electronics. Very low divergence (0.3mrad) is another feature and all models are easily modulated from an external source at frequencies up to 150kHz.

For more information contact **Spindler & Hoyer UK Ltd**, 14 Tonbridge Chambers, Pembury Road, Tonbridge, Kent, TN9 2HZ. Tel : 0732 770800.

CHIP COUNT

TLC1078/9 PRECISION MICRO-POWER OPAMPS

Texas Instruments have sent us an update on the state of the art in their LinCMOS opamp series, specifically regarding the new TLC1078/9 precision micro-power opamps.

LinCMOS opamps were first introduced to satisfy the requirements for low power products optimised for single supply operations, typically 3V to 16V for the standard TLC27x family. Recent product introductions, say TI, have seen reductions in the offset voltages and supply voltage. However, the latest addition to the family offers unprecedented performance.

The TLC1078/9 are dual and quad precision opamps designed to operate from supply voltages down to just 1.4V. With supply currents as low as 2 microamps per amplifier, they can operate from a single silver oxide battery for up to two years. The designs have also been optimised for precision: the TLC1078 has a maximum offset voltage of just 450 microvolts and is therefore ideal for accurate systems. TI comment that, unlike competing products, these devices maintain their precision even with low supply voltages.

The devices have been optimised for battery powered and portable equipment. The low power consumption and excellent precision make them ideal for measurement equipment requiring an interface to high impedance sensors or transducers.

The main features are:

Supply voltage range : 1.4V to 16V.
Low supply current : 2µA per amp at Vcc = 1.4V.
Low offset voltages : 450µV max for TLC1078; 850µV max for TLC1079.
Low Vio drift : 1µV/°C and 0µV mnt typ.
Low bias current : 600fA
Slew rate : 47V/ms typ.
I out : ±20mA at Vdd = 10V.

Both devices have extremely low bias currents (fA means femto amps) and in applications requiring the low power dissipation offered by these opamps, bias currents must always be considered.

PCB61C65 ULTRA LOW POWER SRAMS

Philips have announced the introduction of a new byte-wide sram, the FCB61C65, which is a high performance 8K device and the first of its type to be offered by the company.

The device features ultra low power consumption, down to 1µA, both in the 5V standby and in the battery back-up mode (Vdd = 3V). Normal and low power versions are also available and speeds range from 55ns to 70ns.

Double-metal 1.2µm technology, together with the full cmos six transistor cell design, account for the new sram's low power consumption, very low sensitivity to alpha particles and a wide operating temperature range.

The sram operates from a single 5V supply, and its inputs and outputs are ttl and cmos compatible. Two chip-enable pins are provided for maximum flexibility, easy memory expansion and controlling the standby mode. The address activated devices feature combined data input and output interfaces and can also be tri-state controlled with a separate output-enable pin.

MANUFACTURERS' ADDRESSES

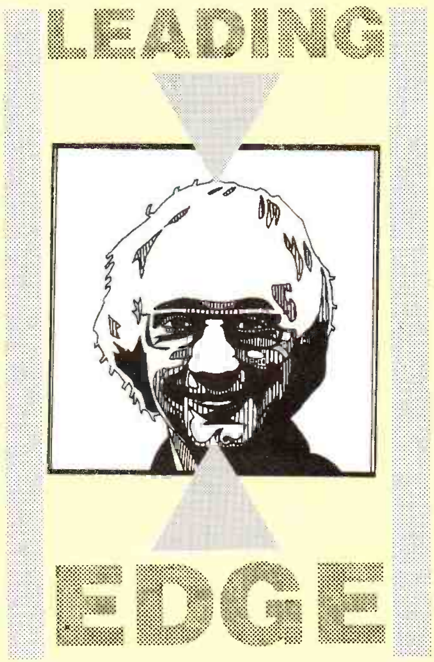
Philips Components Ltd, Mullard House, Torrington Place, London WC1E 7HD. Tel : 01-580 6633.

Texas Instruments Ltd, Manton Lane, Bedford, MK41 7PA. Tel : 0234 270111.

SQUARING UP TO JAPAN

BY BARRY FOX
Winner of the UK Technology Award

Japanese management ethics can maximise electronic production with a minimum but dedicated British workforce.



At the end of February business executives from the European electronics industry were invited to gather in London for a conference jointly sponsored by the Confederation of British Industry, the Electronics Industry Weekly. The executives were to pay £250 each to hear their counterparts in Japanese companies NEC, Sony and Matsushita lecture on the manufacture of electronics equipment and components.

In 1979 Japan had 23 production facilities in Western Europe, five of them (mainly tv manufacturers) in the UK. There were 42 in the US. There are now over 40 Japanese-owned factories in Europe making consumer electronic equipment, more than 20 making industrial electronics and well over 30 producing electronic components. Britain has the lion's share, with over 30 Japanese factories making electronics equipment and components. West Germany is now fast catching up. In North America (the US and Canada) the total number is now well over 100.

Western firms now rely on Japanese expertise to produce equipment which native manufacturers cannot make. By neat irony, the conference chairman was to be Sir Trevor Holdsworth, who is both president of the CBI and chairman of British Satellite Broadcasting. Wearing his CBI hat, Sir Trevor Holdsworth promotes British industry. But BSB recently had to admit defeat and place an order with Japanese company Matsushita for the supply of flat plate aerials or "squarials".

BSB had proudly unveiled a small and cheap squarial in August 1988 and promised them in bulk for BSB's scheduled broadcasting launch in September 1989. But the squarial shown to the trade and press turned out to have been only a dummy and after sixteen months BSB had still been unable to find a British manufacturer to deliver the promised design. Matsushita came to rescue with a larger and higher priced unit based on proven technology which Panasonic has been selling in Japan for two years.

Those with long memories will remember what happened in May 1977, when visitors to Hitachi's suite at the Cumberland hotel in London during the annual consumer electronics trade show found themselves facing 200 banner-waving workers picketing against Hitachi's plans to set up a tv factory in the North of England. Leaflets were handed out arguing that if the government allowed Hitachi to move into the UK, the British tv industry would lose around 5000 jobs. At that time only Sony and Matsushita (maker of National, Panasonic and Technics equipment) had tv factories in Britain.

Lord Thorneycroft then chairman of the British Industry Council and later president of the British Radio and Electronic Manufacturers Association, BREMA (which ironically now relies on Japanese firms for support) wrote to the Secretary of State for Industry expressing "immense concern" at the Hitachi plan.

Hitachi was dubbed "the hit man" and the company's Japanese head office promptly scrapped the plan. Late in 1978 Hitachi signed a joint venture agreement with GEC to manufacture tv sets at Hirwaun in South Wales. After 8000 redundancies, the shop floor workforce of 1200 was still making an annual loss of £5 million. Hitachi bought out GEC and still quietly runs the factory from Japan. Toshiba has had striking success with factories once owned by Rank in Plymouth. The story of "Tosh" in Plymouth is a microcosm of Japan's ability to prosper where the West flounders.

True blue British company Rank Radio International made tv sets and audio equipment under the Rank, Bush, Murphy and Arena brand names. In 1978 RRI was employing 3000 people at factories in Plymouth and Redruth Cornwall; Rank was the biggest private employer in Plymouth and producing 175,000 colour tv sets each year. But the products were behind the times and sales fell off.

In November 1978 RRI signed a joint venture deal with Toshiba. Rank would provide the factories, then valued at around £7 million, and local management. Toshiba would provide £3 million in cash plus access to Japanese colour tv technology. The joint venture company, to be called Rank-Toshiba, would make 350 000 tv sets in 1981, of which about 40% would carry the Toshiba brand name. The British Government even chipped in with nearly £2 million as a goodwill gesture.

In October 1980 Toshiba and Rank admitted defeat and started to wind down production. On March 20, 1981 the joint venture closed and all the staff were dismissed. No-one was even sure how many people were employed or how many different types of tv sets were being produced. It depended on how you counted. Toshiba estimated that 2600 people were on the payroll, represented by seven unions, and making 62 different models.

On Bank Holiday Monday May 4 Toshiba Consumer Products, or TCP opened. Japanese parent Toshiba paid £3 million for one of three factories in Plymouth. Toshiba employed 260 people, all ex-Rank employees, but vigorously vetted. Within a few weeks the 260 people represented by one union in one factory were making eight models, all for home markets. Even with literal decimation of the workforce Toshiba still aimed for 100,000 sets a year.

TCP demanded total flexibility from the bottom up, as in Japan. Everyone had to be prepared to do someone else's job at a moment's notice. All job applicants were shown a film which warned:

"We want enthusiasm and idealism - do these words frighten you? We want people who are absolutely and utterly committed, not doing their best. If you have someone who depends on you and you don't have a parent or friend who can help you cope when your child has a snivelling cold, you should think again about coming to work for TCP. We are a lean and hungry company and we need everyone here, all the time. We want this factory to run like clockwork. Some people may not like the idea of a factory that runs like clockwork. They should think again about coming to work here".

In February 1989 Toshiba installed a completely new Japanese production line. It cost £2 million and was opened by the Lord Mayor of Plymouth. Although the line saves labour, it does not lose jobs. Toshiba now employs 750 people in Plymouth, 590 on tv and video recorder production and 160 making microwave ovens - all in old Rank factories. But all the old Rank Toshiba lines have now been replaced. The millionth tv set was made in October 1986, the two millionth in May 1989.

One of Toshiba's managers, who used to work at Rank as a design engineer, remembers how things were. "We worked in a laboratory, we didn't visit the factory. We had a marketing brief, not a manufacturing brief. We just designed things and left someone else to engineer production." PE

Just as I was about commit this month's comments to the cpu, on the virtues of building and programming robots, a copy of an article from another magazine was placed before me. It was captioned "The Death of the Hobby". I'm not sure from where it originated, and the author's name is indistinct.

Reading through, I became increasing astonished and appalled that the author should appear to be expressing views which to me are both negative and fallacious. To quote: "Like the *Eagle* comic and football rattles, hobbies now have an aura of post-war nostalgia. Our fathers had hobbies. When we were younger, we had hobbies too. ... I have an image of a man with hobbies. He wears a kagoul and spongy Polyveldt shoes. In the spare room, his hobby lurks like an unmentionable perversion. ... A hobby today is guilty secret."

Already filled with indignation, I read on and there was worse to come: "And several of the traditional hobbies have been made redundant by the passage of time. 'Electronics' once meant fiddling around with crystal radio sets, in the days when Clive Sinclair sold DIY stereo kits." Shear heresy! Neither hobbies in general, nor electronic hobbies in particular have been consigned to the attics of antiquity.

What do the dictionaries say about 'hobby'? The consensus amounts to: "a spare-time occupation done for pleasure". Ok, and what is one the aspects of the late 20th century from which many of us are said to benefit? It's increased leisure time.

So how do we make use of this spare time? For a start there is a whole industry

PRACTICAL
ELECTRONICS

HOBBY HORSE

that is devoted to offering us ways of filling it. At the passive end we have tv and video, and no doubt some of the population find viewing to be the only spare time activity they need. I believe, though, that a much larger proportion prefer not to become 'couch potatoes' but to find greater fulfilment from more active pursuits. Look at the number of sports centres that have opened up around the country over the last few years. The author acknowledged these facilities but denied that they are hobbies. I disagree. Anyone who seriously makes use of these facilities is, within the word's definition, pursuing a hobby. So too am I when scuba diving, cycling, computer programming or building electronics. Similarly, those who go to evening classes, studying languages, doing arts and crafts, and so on, are pursuing hobbies, as are those who delight in collecting items of various sorts. These activities are not dead.

Consider two more aspects of usefully pursuing some hobbies: you learn from doing them, and they could be the key to enhanced career opportunities. An enterprising person could well find that sufficient knowledge and interest is gained though a hobby subject to justify seeking further training in it, so offering a greater chance of employment.

This is especially true of electronics, which can be pursued at the hobby level both as leisure time fulfilment, and as a means to acquiring a good grounding in a subject highly relevant to the 90s. To consider electronics as hobby that died with crystal radios is the height of folly and implies a failure to understand how we all depend heavily on technology and those who are trained in it. The products of electronic technology, whether for computing, communications, medicine, leisure applications, or whatever, do not yet invent themselves; they still require human intervention. Many of those involved in electronic design, manufacture and research started off by becoming interested in electronics as a leisure pursuit - as a hobby. That is still the case, and will continue to be so for decades hence.

Only those who lack the desire or intelligence to make better use of their lives will ignore the value of hobby activities. To the rest of us, the majority, the hobby is definitely not dead.

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BUILDING A ROBOT CAR

Alan Pickard begins a series of articles that will inspire your interest in robotics and encourage you to build a robot car.

Part One
Basic Operation

Although robots are now being used more and more in the engineering industry, they are not yet commonplace in the hobbyist area. This article is intended to provide sufficient information and inspiration to enable readers to experiment with simple robotics in the form of a microprocessor controlled vehicle. Further articles will cover more advanced practical hardware and software aspects.

The control computer used is the BBC Micro, but any micro with a suitable user port or interface can be used instead.

DEFINITIONS

The word robot is derived from the Czechoslovakian word *robota* which means forced labour, and is now used to refer to a man type machine which performs any task without compunction. In this article the word robot will be used to refer to the simplest of mobile machines acting in an 'intelligent' manner. *(I briefly discussed the origins of robota in my editorial of April 1989, concluding that the source could also be Latin, Ed.)*

The word robot conjures up different meanings to different people. Although the literal meaning is defined as forced labour or slave worker, it is more usually defined as being a machine which carries out preprogrammed tasks under the direction of a computer. Almost by definition, a robot must be re-programmable, and if under the control of a computer this will be the case, whether in a hardware or software sense. Therefore, for the purpose of this article, a machine which is *manually* controlled is not a robot.

A robot is thus defined as a machine which is connected to a computer, or has an on-board control computer.

Fig.1 illustrates the basic requirements for a computer controlled vehicle.

Continuing with definitions, the machine which under the control of a computer comprises a robot is described as follows. The machine is either mobile (wheeled) or performs mechnanical action relative to a base (eg, robot arm).

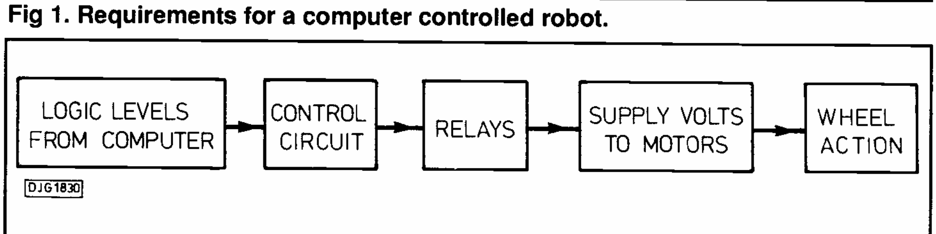
A robot arm may be considered to be a0 complete robot, even if it is fixed to a non-mobile base, providing it is capable of being programmed and re-programmed).

A robot arm is classified by the number of degrees of freedom it posesses, ie, each separate axis provides one degree of freedom. the arm is described as having waist, shoulder and elbow movements. The end of the robot arm is usually equipped with a 'wrist' mechanism. The unit also has three joints, or axes of rotation. The movements possible are called yaw (sideways), pitch (up and down) and roll (rotational). A robot arm capable of all of these movements is said to have six degrees of freedom. (A simple object has three degrees of freedom).

Practically speaking, a simple robot can be considered to be a wheeled vehicle driven by transistor operated relays which enable a motor to drive one or more wheels in a forward or reverse direction. The control circuit is switched on and off by the 'host' computer, which may be either a remote or 'on board' unit, as in Fig 1.

Although the control computer used in this series is the BBC Micro (Model B), any micro with a suitable 8-bit user port or special interface can be utilised. Even a very basic micro operating directly in machine code via a hex keypad can be employed.

Fig 1. Requirements for a computer controlled robot.



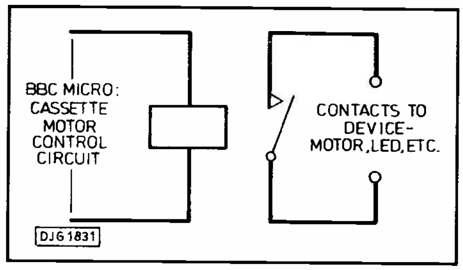
SUITABLE VEHICLE

A suitable vehicle consisting of a chassis and a pair of wheels each driven by a separate motor could be constructed or obtained by 'conversion' of a cheap radio controlled car (such as those obtainable from Tandy). By removing the radio receiver pcb an instant chassis, wheels and battery compartment (s) remain. Such a vehicle would probably have only one motor and some crude front wheel steering via a 'floppy' wheel. Although individual driving of each separate motor is more desirable, this vehicle is a useful starting point for experimentation with hardware and software.

Once a suitable test vehicle (or motor assembly) is obtained, a very simple experiment in robotics can be performed. By connecting the relay contacts of the cassette motor control circuit (pins 6 and 7 on BBC DIN socket) to the motor (Fig. 2), it can be switched on and off either from the keyboard or via the simple test program shown in Fig.3. The contacts are suitable for a voltage of around 9 volts at up to 100mA.

The test program in Fig.3 illustrates how to switch the motor on for a specific time period and then off for a period. The GOTO statement in line 70 enables the cycle to be repeated indefinitely until the program is stopped.

Fig 2. Typical connection to cassette motor control circuit.




```
10    * MOTOR 1
20    FOR T = 1 TO 2000
30    NEXT T
40    * MOTOR 0
50    FOR T = 1 TO 2000
60    NEXT T
70    GOTO 10
```

Fig 3. Simple test program.

Now that we have experienced/caused mechanical movement using some simple software, we can get down to the real thing, ie, interfacing an external 'machine' to a microcomputer such that two-way communication can be achieved (input and output).

INTERFACING

A typical home computer usually communicates with the outside world via one or more user ports. A user port usually

	PORT B BITS								
REGISTER VALUES	7	6	5	4	3	2	1	0	ACTION
DDB at &FE62 = &03	0	0	0	0	0	0	1	1	PB0, PB1 set to OUTPUT
DRB at &FE60 = &03	0	0	0	0	0	0	1	1	Logic level 1 sent from PB0, PB1 to interface circuit

Fig 4. Relevant VIA register components.

consists of 8 at least lines, each of which can be programmed as either an input or an output. An example of use of this port would be to dedicate (or program) two lines as outputs, such that a logic level appearing on one line would activate a transistor control circuit to operate a relay which in turn switches on a motor. Similarly, a logic level, eg, logic 1, could operate another relay. By using these two lines it will be seen how we can switch on a motor for forward motion and then reverse its direction.

By setting another line as an input, the operation of a remote switch can provide information to the computer, which could then act on it. A simple example of this would be the fitting of a microswitch to the chassis of a robot such that on collision with an object, an input signal is received by the computer and appropriate action taken, eg motor direction reversed.

The user port is connected to the central processor unit via an input/output interface chip such as the 6522 Versatile Interface Adaptor (VIA). This ic is used by the BBC Micro, Acorn Atom, Oric and Electron. A data sheet which goes into its operation in great detail concerning its hardware and software facilities can be obtained from many retailers.

For the purposes of this article, the 6522 provides two 8-line user programmable ports and various registers. In addition, it contains a number of on-chip timers. The BBC, Atom, Oric and Electron all have one port dedicated to printer (output) operation, which only leaves one port which is fully programmable. This is quite adequate, leaving room for expansion beyond the scope of this article.

The 6522 is said to be memory-mapped, ie, each register is treated by the cpu as a memory location.

The registers we are concerned with are the Data Direction Register (DDB) and the Data Register (DRB). the DDB Register defines which lines are inputs and outputs. As a port has 8 lines (or bits) the highest number which can be stored in the memory location associated with the register is 255 or FF. That is, an 8-bit byte provides a maximum binary value of:

1 1 1 1 1 1 1 = 1+2+4+8+16+32+64+128 = 255

VIA OPERATION

On the BBC Micro, DDB (Data Direction Register associated with Port B) is allocated to memory address &FE62. Therefore, if the binary value 11 is placed in this location, the VIA is programmed with lines PBO, PB1 as OUTPUTS. Similarly, DRB (Data Register associated with Port B) is allocated to memory address &FE60. Thus, if the binary value 11 is placed in this location, then the VIA sends logic level 1 to each of the output lines, which could enable forward motor motion (see Fig.4).

Programming of the VIA is possible using the BBC Basic equivalent of POKE, ie, ?&FE62 = &03, and ?&FE60 = &03.

The VIA defines individual output lines (set to input by default) and also supplies data logic levels to these output lines.

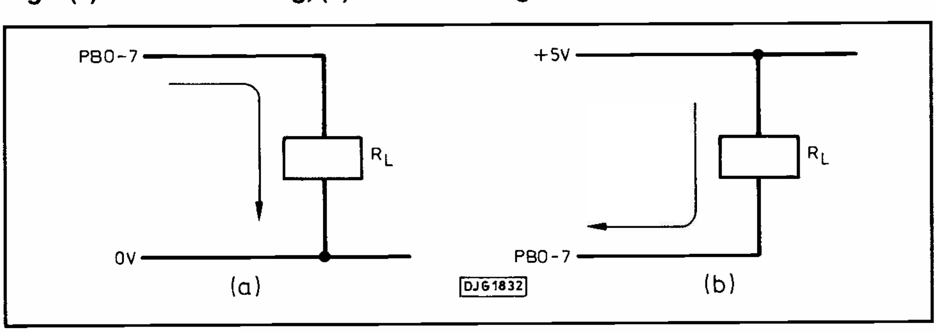
It is most important not to get these two registers confused (even if they are awkardly named), especialy when their data values are different (not the case in this particular example).

Also, care must be taken to ensure that attempts are not made to input into the VIA when a particular line has been programmed to output, and not to accept input. It is possible to cause hardware damage by careless software programming! (Connecting input to input will not cause damage and in fact on reset, all lines default to input).

Further information can be obtained from the 6522 data sheet or data sheet of a similar device, but the principles of programming will be the same.

Before moving on to a practical circuit, a note about connection to the user port and sinking and sourcing. If a resistor is connected between an output line and 0V, a logical level 1 (5V) at the output results in a current flowing from the interface adaptor (VIA) as shown in Fig.5a. The microcomputer, or more correctly the interface adaptor, is said to be 'sourcing' current, ie, it is providing a source of current to the load device, RL. If a resistor is connected between the +5V supply and an input line (Fig.5b), current flows via RL into the interface when the appropriate logic level is present on the input line. In this case, the VIA is said to be 'sinking' current, ie, current is drawn from the micro psu into the VIA. Typical currents in both cases are of the order of 1mA.

Fig 5 (a). Current sourcing, (b) current sinking.



PRACTICAL CIRCUIT

The simple circuit shown in Fig.6 demonstrates how a logic level 1 can turn on a transistor which in turn operates a relay, led or other device. As mentioned before, current is provided from the interface circuit (VIA) and is sourced through the transistor. This provides base current to the transistor, which then turns on and collector current flows through the load. The load current I_L flows through the transistor when it is switched on via the appropriate logic level (1).

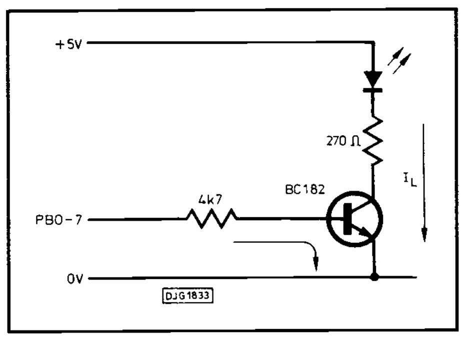


Fig 6. Transistor switching circuit.

Such a circuit is suitable for driving a single motor (such as that on an ex-radio controlled car). Two port lines would be used to provide a logic level output to each of two transistor circuits which drive a separate relay. The relay then operates a changeover switch which can facilitate the operation of a motor in a forward or reverse direction, as can be seen from the full control circuit shown in Fig.7.

CIRCUIT DESCRIPTION

The switching circuit operates as follows. If PB (output) line is at 0V, D1 is forward biased and therefore current flows from the +5V connection through D1 and into the VIA. Thus for a logic 0, the transistor is off and therefore the relay is not energised. When a logic 1 appears on PB, D1 is reverse biased and current then flows through D2 and into the base. Thus a logic 1 is required to provide relay operation and subsequent motor action. The logic truth table in Fig.8 can be produced by arranging the wiring such that a logic 0

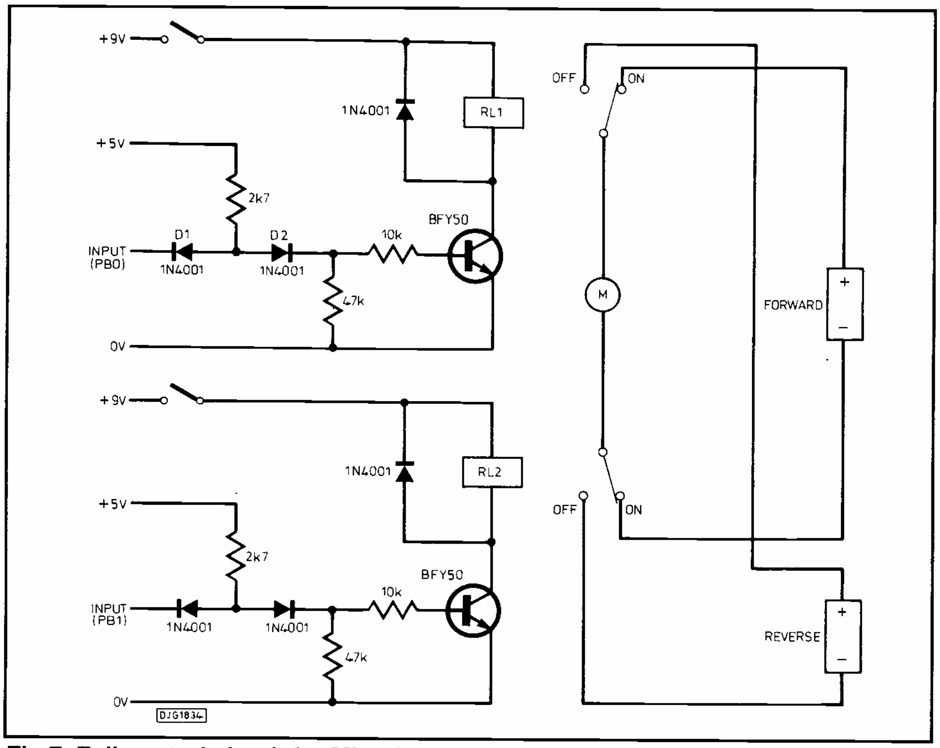


Fig 7. Full control circuit for Microbe 1.

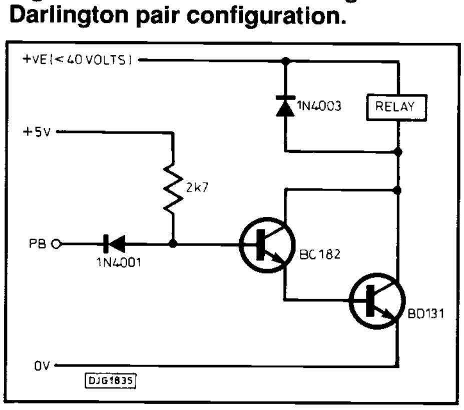
produces an open switch contact and a logic 1 a closed contact.

When both relay 1 contacts complete the motor/battery circuit the motor will go forward. If contacts 2 are both made, then the motor direction will be reversed, as the battery contacts are now transposed. Each relay is operated when a logic level 1 appears on PB0 and PB1 respectively. For the relay contacts to be in the default position, a logic level 0 must be present on PB0 and PB1. This will result in the battery connections being reversed and of course the motor direction. Non-operation of the motors is achieved by opposite logic levels being present on each pair of output lines, as in the table, Fig.8).

RELAY 1	RELAY 2	BINARY VALUE	ACTION
ON	OFF	1 0	STOP
ON	ON	1 1	FORWARD
OFF	OFF	0 0	REVERSE
OFF	ON	0 1	STOP

Fig 8. Logic table for relay combinations.

Fig 9. Motor drive circuit using Darlington pair configuration.



For larger current applications, two transistors can be employed in the darlington configuration as shown in Fig.9. For convenience darlington drivers are available in sets of 7 or 8 within one ic package. These are used in a later article, in connection with Microbe 3.

A typical supply voltage for the control circuitry is provided by, for example, a PP3 9V battery, and one HP7 1.5 battery to drive the motor. A BFY50 or equivalent npn transistor should be able to handle the relay current. 5V and 0V logic connections are normally available from the user port connector.

TEST PROGRAMS

The program listing in Fig.10 consists of a sequence of instructions from the cpu to enable the robot motor to go forward, then stop, then reverse direction and finally stop again.

Test Program 1

Line 60 sets up lines PB0 and PB1 as outputs. Lines 100, 170, 240 and 310 provide the data register with appropriate hex codes for forward, stop, reverse, stop conditions. The four sections of programs relating to forward stop, etc, contain a sound statement which provides an audible indication following each function, with a longer duration sound at the end of the cycle (line 340). A FOR....NEXT loop provides a time delay between functions.

A loop (line 380) enables this procedure to be repeated unti the program is stopped (eg, by pressing ESCAPE). This results in a two-wheeled, one motor vehicle travelling backwards and forwards. (This vehicle,

```
10 REM MICROBE 1 Test Program 1
20
30
40
50
60 ?&FE62=&03
70
80 REM FSRS LOOP + SOUND
90
100 ?&FE60=&11
110 PRINT
120 PRINT "FORWARD"
130 SOUND 10,-12,20,1
140 FOR T=1 TO 2000
150 NEXT T
160
170 ?&FE60=&01
180 PRINT
190 PRINT "STOP"
200 SOUND 10,-12,20,1
210 FOR T=1 TO 2000
220 NEXT T
230
240 ?&FE60=&00
250 PRINT
260 PRINT "REVERSE"
270 SOUND 10,-12,20,1
280 FOR T=1 TO 2000
290 NEXT T
300
310 ?&FE60=&01
320 PRINT
330 PRINT "STOP"
340 SOUND 10,-12,20,5
350 FOR T=1 TO 2000
360 NEXT T
370
380 GOTO 100
```

Fig. 10. Test program for forward and reverse.

incidentally, is designated "MICROBE 1".) Such a vehicle with a 'floppy' wheel at the front would go backwards and forwards in a mad 3-point turn fashion! On the BBC Micro, using the user programmable keys manual controls can be employed (eg, *KEY 3 ?&FE60 = &01 IIM, etc).

Software adjustments can provide different time delays between functions, sound effects and visual comments can be displayed on the screen.

Any micro with a suitably protected user port or interface can be programmed to 'drive' this simple circuit, and as an example Fig.11 shows a machine code program for the early MK14 micro which utilises the INS8060 cpu, with the INS8154 as the I/O interface ic. The INS8154 is similar to the 6522 VIA, in that it has two 8-bit user ports.

COLLISION DETECTION

Now that the vehicle can obey simple instructions from the computer under program control we can move on to sending information from the robot to the micro. This can be acieved by fitting a microswitch in a strategic position on the vehicle such that a collision closes the switch momentarily.

ADDRESS	MACHINE CODE	OPERATION PERFORMED
0F 20	C4 0A	INITIALISATION
0F 22	85	
0F 23	C4 00	
0F 25	31	
0F 26	C4 FF	SETTING OF
0F 28	C9 23	DATA DIRECTION REGISTER
0F 2A	C4 01	LOADING OF BINARY VALUE
0F 2C	C9 21	FOR 'FORWARD'
0F 2E	C4 FF	TIME DELAY
0F 30	8F FF	
0F 32	C4 FF	
0F 34	8F FF	
0F 36	C4 00	LOADING OF BINARY VALUE
0F 38	C9 21	FOR 'STOP'
0F 3A	9C F8	JUMP TO START OF PROGRAM

Fig 1.11 Example of machine code test program for MK14 micro to drive microbe 1

The circuit in Fig. 12 shows the switch connected to a port line (PB2) and a 1k resistor limits the flow of current into the VIA. When the switch closes, the input line is set to 0 (0V). In Basic, two statements, such as:

110 IF (?&FE60 AND 4) = 0 THEN PRINT "OUCH!"
120 IF (?&FE60 AND 4) = 4 THEN GOTO.........

provide responses to two conditions. An instruction following the keyword THEN in line 120 could be ?&FE60=&03 which places the binary value 03 in the data register, resulting in the motor direction being reversed. Thus an external event can be 'reacted' to by the robot under computer control and then remedied!

The program is Fig.13 provides the robot with forward motion until collision occurs which then results in the motor being reversed for a specific time, and then driven forward, subject to further collision.

TEST PROGRAM 2

This program incorporates the use of three user programmable keys which enable manual operation of the vehicle. Line 180 sets the Data Direction Register and lines 200 and 340 provide the register with forward and reverse hex codes. Line 240 consists of an IF.....THEN statement and uses the logical operator AND. This program line tests whether bit 3 (decimal value 4, hex 100) is set or not. If a collision occurs, line 290 provides a jump to line 240 where the conditions are tested again.

Fig 12. Collision detection circuit.

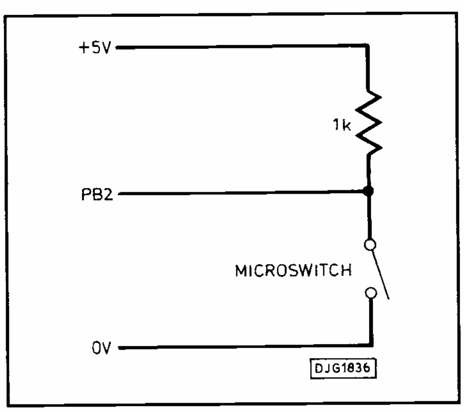


Fig. 13. Test program for collision detection.

```
10 REM MICROBE 1 Test Program 2
20
30
40
50
60 ?&FE62=&03
70
80 REM MANUAL CONTROLS
90
100 *KEY 3 ?&FE60=&11 IM
110 *KEY 4 ?&FE60=&01 IM
120 *KEY 5 ?&FE60=&00 IM
130
140
150
160 REM FCR LOOP
170
180 ?&FE62=&03
190
200 ?&FE60=&01
210
220 PRINT "FORWARD"
230
240 IF(?&FE60 AND 4) =0 THEN GOTO
                                340
250
260 REM COLLISION OCCURRED
270
280
290 IF (?&FE60 AND 4) =4 THEN GOTO
                                240
300
310 REM NO COLLISION
320
330
340 ?&FE60=&02
350 PRINT "REVERSE"
360 FOR T=1 TO 2000
370 NEXT T
380 GOTO 200
```

This routine can be inserted into the first program for completeness, but collision detection will only occur if the robot collides at the appropriate time in the execution cycle! A more satisfactory method would be to utilise the interrupt facility of the CPU, and this will be covered in a later article. This problem could also be overcome by software, but it can be seen that this simple vehicle and a suitable micro can provide the means of experimenting with both hardware and software.

The two test programs can be improved, extended, and even combined, but care must be taken to ensure that hardware wiring matches up with software!

FURTHER POSSIBILITIES

If a simple robot is powered by batteries (taking into consideration weight and slight inconvenience of recharging) this could eventually enable the umbilical cable to be dispensed with and a radio, infra-red or sonar link established. A more substantial vehicle would have a motor for each wheel giving better control and resonably accurate steering. This vehicle is designated "MICROBE 3" and will be discussed in a moment.

On-board intelligence could be supplied by means of a separate micro circuit complete with rom and ram. The robot could then operate independently, albeit in a limited way, or could also receive downloaded programs from the remote micro's ram.

Once a basic vehicle is established, a whole range of electronics systems can be employed = D/A, A/D, sound and light sensing, sound output, telemetry, radio, etc. The robot then becomes a 'vehicle' for ideas, interfacing experiments and software development, with the only real limitation being the imagination.

MICROBE 3

So far we have looked at simple examples of robotic control, using hardware and software. We can now put those experimental activities on to a more practical footing in the form of a simple and relatively inexpensive robot system. The word system is used because from the outset the machine is designed with expansion in mind.

As before, the robot is defined as being a microcomputer controlled vehicle, and is designated "MICROBE 3".

APPROACH

A useful vehicle having at least three or four wheels would require two wheels to be driven in either direction to provide full circular movement, eg, forward (both motors forward), reverse (both motors reverse), left turn (left and right motors driving opposite) and vice versa for a right turn. Immobility is, of course, achieved with both motors being inactive!

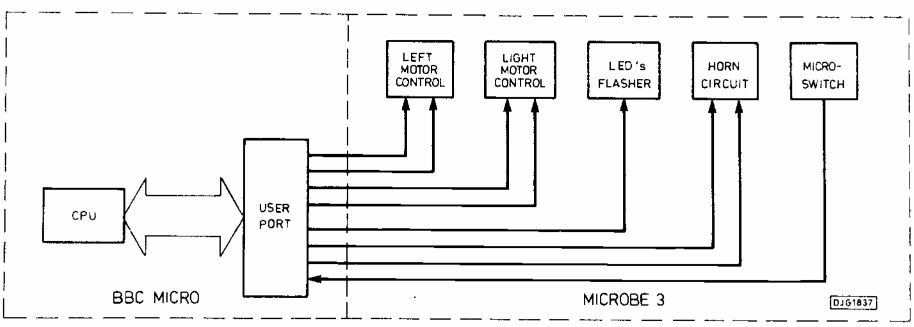


Fig 14. Simple block diagram of micro-controlled robot.

Various possibilities for a basic chassis exist, such as metal, wood or plastic. Kits of Lego or Meccano are worth considering, but may be of limited application and tend to be expensive. Alternatively, any custom built unit comprising wheels and motors with the provision for electronics and mechanical hardware to be added, would be suitable.

Consideration should also be given to motor and control pcb power supplies. If independent operation is desired, batteries will be required for motors and also the control electronics.

Once a suitable vehicle has been established, the facilities required by the robot can be summarised, preferably allowing for expansion at a later stage.

SPECIFICATION

The practical robot discussed now is required to do the following:

Drive two separate motors (left and right) independently in the forward or reverse direction, and also remain stationary when required; activate a loudspeaker by the application of two different tones; turn on an led pair; receive an input via a microswitch.

In addition, the supplies to the motor are to be derived from one set of batteries, and the control pcb from another.

Initially, the robot was required to be connected to an external micro, via a 10/12 way ribbon cable, but from the outset was designed with an alternative communication link in mind, eg, infra-red, radio, serial cable, etc. See Fig. 14 for block diagram.

CONTROL UNIT

As with Microbe 1, the control computer used is the BBC Model B, but any micro having a suitable 8-bit user port would be suitable, providing interfacing precautions are taken, and programming of interface circuitry is possible.

The BBC Micro has a readily available user port (Port B) with eight data lines (or bits) and also two control lines CB!,CB".

MOTOR RELAYS

Four data lines (PBO-PB3) were allocated to two pairs of relays to enable combinations of 4-bit words to switch battery power to the motors as shown in Fig.15. Fig.16 shows the circuit details of a single darlington stage. This provides an alternative to individual transistor switching circuits.

Four bits (or lines) provide up to 16 possible combinations (0000 to 1111), but as can be seen from the table in Fig.17, several combinations are duplicated and therefore redundant. Use of these four lines enables each motor to be either driven forward, reversed or stopped, providing complete manoeuvrability of the motor / wheel unit.

For a slow right turning action, the left wheel is driven forward, pivoting on the stationary right wheel. The opposite is achieved by driving the right wheel about the left wheel.

Increased speed (power steering!) when turning is achieved by driving both wheels in opposing directions.

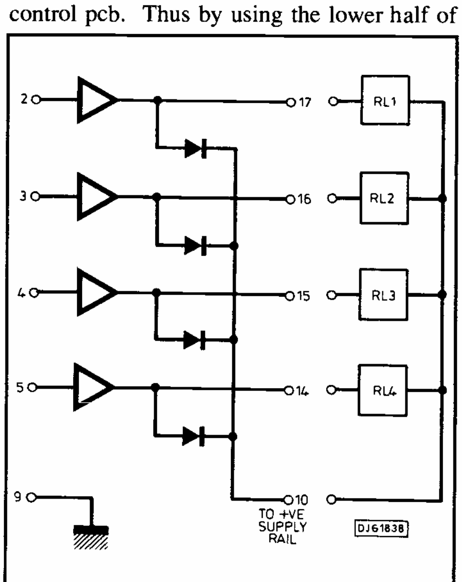
By simply poking hex values into the appropriate memory mapped locations in ram, relays can be energised (or not) depending on whether a logic level of 1 or 0 is sent to the control pcb. Thus by using the lower half of the Data Register byte, (binary) combinations can result in the direct operation of the relays. It is then a simple matter to send hex values to the relay drive circuit to effect relay contact switching.

For example, the combination 1111 = 70F (hex) would result in all four relays being energised such that each motor drives in the forward direction. Logically, 0000=&00 would produce reverse movement (both motors reversing). Combinations such as 0101 would produce no movement, whilst combinations such as 1101 would produce a turning motion, as one motor would be driving forward (11) and the other would be stopped (01). An alternative method of producing rotational movement would be to have motors turning in opposite directions (clockwise and anti-clockwise) thus providing more power and therefore a faster turning action.

Incorporating these values into a Basic program could provide a simple test routine or loop such that the robot travelled forward for a short time, stopped for a short time, reversed and finally stopped.

The Versatile Interface Adaptor (VIA) could be interfaced to the drive relays via a transistor circuit or via a dil darlington driver ic containing up to eight separate stages.

This section of the circuit can be tested before proceeding to the other sections, without actually connecting the motors/batteries to the relay contacts. Relay operation can be visually observed, using a simple program such as that listed in Fig.18 (see 'Testing' in the next article)



ON-BOARD SUPPLIES

Practical experiments indicate that eight AA size rechargeable batteries provide a suitable supply voltage (about 11 volts) for the relays and remainder of the control circuit, and also a reasonable current/time capacity.

Ordinary dry cells (D-size - 2 x 2 x 1.5V) were used for the motor supplies, but rechargeable batteries would be more suitable for heavy continuous use.

TWO-TONE HORN

Two further lines of the VIA, PB5 and PB6, are allocated to the oscillator section of the control circuit.

The oscilator in Fig.19 is based on a 555 timer ic configured as an astable multivibrator.

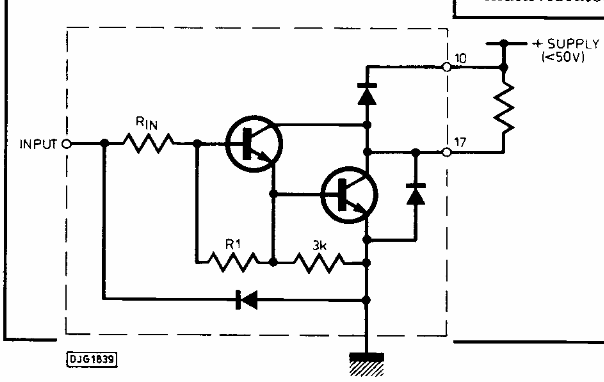


Fig 15. (above left). Relay drive circuit using four stages of darlington driver ic.

Fig 16. (left). Single darlington driver stage schematic.

HEX &	BINARY R	BINARY L	M2 R	M1 L	M2 R	M1 L	ACTION PERFORMED
00	00	00	ON	ON	R	R	REVERSE
01	00	01	ON	OFF	R	S	
02	00	10	ON	OFF	R	S	
03	00	11	ON	ON	R	F	RIGHT TURN (FAST)
04	01	00	OFF	ON	S	F	
05	01	01	OFF	OFF	S	S	STOP
06	01	10	OFF	OFF	S	S	
07	01	11	OFF	ON	S	F	RIGHT TURN (SLOW)
08	10	00	OFF	ON	S	R	
09	10	01	OFF	OFF	S	S	
0A	10	10	OFF	OFF	S	S	
0B	10	11	OFF	ON	S	F	
0C	11	00	ON	OFF	F	R	LEFT TURN (FAST)
0D	11	01	ON	OFF	F	S	LEFT TURN (SLOW)
0E	11	10	ON	OFF	F	S	
0F	11	11	ON	ON	F	S	FORWARD

Fig. 17 Motor action codes

TR2 switches on when PB5 is at logic 1, thus connecting pin 1 to earth through the transistor. This causes an oscillation of about 500Hz. If PB6 also goes high (logic 1), the frequency of oscillation increases to 1 kHz.

Thus, a binary combination of 00 on PB5, PB6 would produce no tone, 01 a tone of 500 Hz, while 11 would produce a tone of 1 kHz. Possible combinations are summarised below:

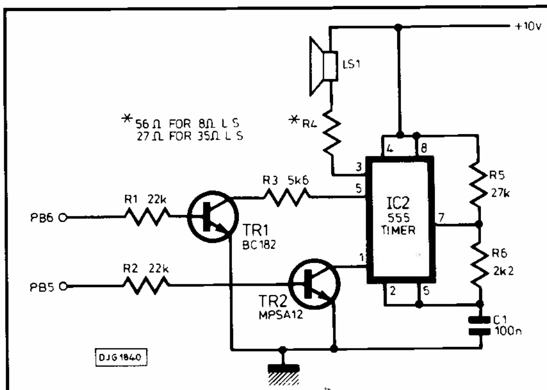
00 = no tone
01 = tone 1 (500 Hz)
10 = no tone
11 = tone 2 (1000 Hz)

Thus 01 and 11 select tone 1, tone 2 respectively.

To be continued next month when we shall look at a full control circuit and software designing considerations. PE

```
10 REM MICROBE 2.5
20 REM MANUAL CONTROLS
                    (MOTORS)
60 ?&FE62=&0F
70 ?&FE60=&05
90 *FX4,2
110 *KEY 11 ?&FE60=&05IM
120 *KEY 12 ?&FE60=&03IM
130 *KEY 13 ?&FE60=&0CIM
140 *KEY 14 ?&FE60=&00IM
150 *KEY 15 ?&FE60=&OFIM
```

Fig. 18. Manual controls (motors) program.



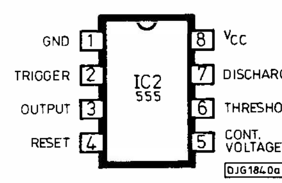


Fig 19. Two-tone horn circuit and 555 timer connections.

PC INTERFACING

Robert Penfold shows that designing add on cards for PCs is not quite as hard as it looks.

Although the IBM PC series and their innumerable clones are the standard business computer, and seem to be widely regarded as unsuitable for anything else, they are very versatile computers indeed. They fill an "all things to all men" role, and are well suited to home computing as well as specialised applications. They are certainly well suited to do-it-yourself add-ons. Physically interfacing to the expansion slots of an IBM PC or compatible is perhaps a bit awkward, with a double-sided board being mandatory, and a reasonable amount of precision being called for if everything is to fit into place properly. From the electronic point of view, and provided nothing fancy like the use of interrupts is required, interfacing to a PC is more straightforward than you might expect.

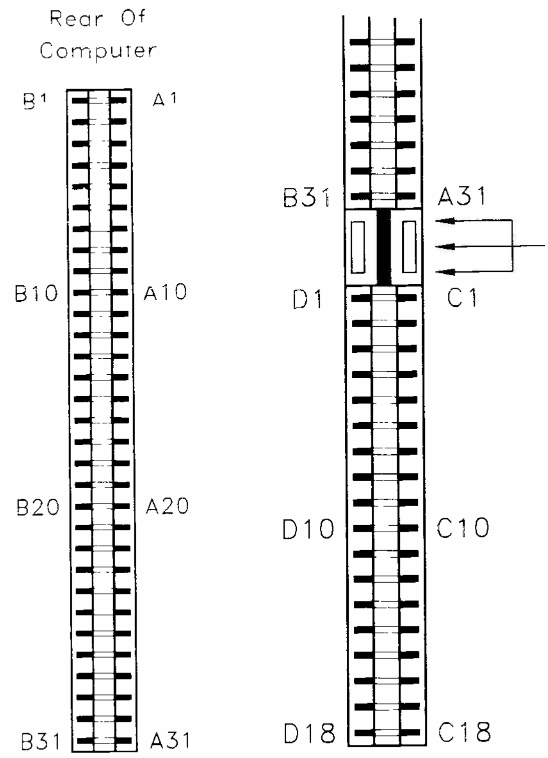


Fig 1. (Far left). Numbering system used for the PC expansion connector. It is a 2 x 31 way 0.1 inch pitch female edge connector. Fig 2. The additional connector of the 16 bit AT bus as a 2 x 18 way type, numbered as shown here.

SLOT MACHINES

What makes the PCs such an attractive proposition for the home constructed add-on enthusiast is their expansion slots. Typically there are eight of these, but some are occupied by essential cards such as disk controllers and a display card. A typical PC having a hard disc, one or two floppy drives, a parallel port and two serial ports would have at least three spare expansion slots. With many PC expansion cards being of the multi-function type these days, most PCs seem to have about four or five expansion slots free before any extra serial/parallel ports or more exotic cards are added. You can therefore have several of your own add-ons fitted in the computer and ready for immediate use, without any need for unplugging and plugging in, or external bus expansion units.

It is important to realise that there are two types of expansion slot. These are the 8 bit type of the original PCs and the later PC XTs, and the 16 bit type of the AT style machines. The original PCs and the XTs are based on the 8088 microprocessor, which is a 16 bit type having an 8 bit data bus and increased operating speed, but computers of this type invariably seem to use some electronic trickery to permit the use of a standard 8 bit expansion bus.

AT style computers are based on the 80286 which has a 16 bit data bus, the 80386 which has a 32 bit data bus, or the 80386SX, which is an 80386 having a 16 bit data bus. These computers have a 16 bit expansion bus which actually consists of the original 8 bit bus plus an additional connector which has the eight extra data bus lines, plus some further address and control lines. There are 32 bit expansion buses, but as yet there is no true standard for these. For most user add-ons the ordinary 8 bit expansion bus will suffice. In general, 8 bit boards are usable in AT type computers. About the only exceptions are the 8 bit hard disc controller cards. The incompatibility occurs with these simply because they have a built-in rom bios, whereas AT machines utilise the bios on the motherboard. The problem is therefore one of firmware incompatibility rather than bus problems.

The expansion slots on the motherboard are ordinary 0.1 inch pitch female edge connectors. The basic 8 bit slot has a 2 by 31 way connector, with the two rows numbered from A1 to A31, and B1 to B31 (see Fig.1). The 16 bit expansion slot additionally has a two-by-18 way female edge connector, with the two rows numbered from C1 to C18, and D1 to D18 (see Fig.2). This additional connector is mounted in front of and in-line with the 8 bit expansion bus connector.

Do not confuse long and short expansion cards with 16 and 8 bit types. Either type of card can be the maximum length available, or some shorter length (usually about one third to half full size). With some computers the disk drives obstruct some of the expansion slots, and short cards are all that these can take. Most home constructed cards will probably only need to be of the short variety.

RIGHT LINES

Table 1 towards the end of the text is a list of all the lines on the 8 and 16 bit expansion buses. Apart from supply lines a minus ("-") sign indicates that a line is negative active.

These are the functions of the AT expansion bus - a few of the terminals on the 8 bit bus have slightly different functions on the PC and PC XT machines (-REFRESH is DACKO on the PC bus for example). In general these few differences are of no importance as they are little used by expansion cards, and are unlikely to be needed for user constructed cards.

The input/output lines break down into the usual address, data, and control buses, plus power supply lines, clock signals, interrupt, and dma (direct memory access) lines. We will concentrate here on the basic 8 bit bus, since this is all most users will be interested in initially, and is probably all most users will need for the foreseeable future.

DATA BUS/ADDRESS BUS

D0 to D7 form the standard bidirectional data bus, while A0 to A19 are the address bus outputs. These provide a one megabyte address bus range. The 16 bit bus has extra address lines which give a 16 megabyte even when run on 80286/80386 based machines. This is due to these microprocessors running in an 8088 emulation mode in order to run MS-DOS software. The extended memory can only be used indirectly via disc cache and ram disk programs, or with the aid of special DOS extender programs. The 8088 series of microprocessors do not have input/output devices memory mapped, but have a separate I/O map. This used 16 of the ordinary address lines, giving a 64K address range. However, in the PCs only the lower ten address lines are used, giving some 1024 port addresses. Of these the lower 512 are reserved for internal circuits, leaving the upper 512 addresses for cards fitted to the expansion bus. Many of these addresses are reserved for specific functions such as display adaptors and disk controllers. This is a subject we will consider in more detail later.

ALE (ADDRESS LATCH ENABLE)

This is an output which provides timing information that can be used for synchronisation purposes for events that must be synchronised to bus cycles. This is not needed by most home constructor add-ons.

AEN (ADDRESS ENABLE)

Another output, and one which indicates whether processor or dma bus cycles are in progress. It goes low during normal (ie processor not dma) bus cycles. It is a line that must normally be taken into account by the address decoder circuit of any add-on card.

CONTROL BUS

There are four lines making up the control bus, MEMR, MEMW, IOR, and IOW; these are forms or read and write lines. The first two are the read/write lines for memory accesses, while the second pair perform the same function during input/output accesses. They are all active low. Thus, for example, during a write operation to memory, MEMR goes low while the other three all remain in the high state. IOR and IOW are obviously important lines which would normally need to be decoded by any user add-on.

DMA LINES

These are the four input lines, DRQ1 to DRQ4, outputs DACK0 to DACK3, and TC (terminal count) output. Since it is unlikely that user add-ons will make use of the advanced dma facility, we will not consider these lines further here.

INTERRUPTS

IRQ2 to IRQ7 are standard active high interrupt request lines. IRQ0 and IRQ1 are not available on the expansion bus as they are used for the time of day clock and the keyboard. Some of these lines are likely to be used by standard expansion cards such as the serial and parallel ports.

CLOCKS

There are two clock signals on the expansion bus. These are OSC - a 14.318 buffered crystal controlled oscillator signal, and CLK - the 4.77MHz processor clock signal which has a 2 to 1 duty cycle. The OSC signal is primarily intended to act as the clock signal for the colour graphics adaptor board. Although the original IBM PC and PC XT machines (plus some early clones) use a 4.77 MHz clock frequency, most of the more recent compatibles can operate at higher speeds of between 8 and 15MHz. AT style computers operate with clock signals of between 6MHz and 33MHz. This clock signal will be at whatever clock rate the computer is using, and in most cases will not be 4.77MHz. This makes it a non-standard signal which is of limited usefulness as a result.

POWER SUPPLY

Supplies of ±5 volts and ±12 volts are available on the expansion bus. The maximum current from the ±5 volt rail is 4 amps for the original PCs, but is upwards of 11 amps for more recent PCs and clones. This is the total available to all the expansion cards, including essential ones such as disk controllers and display boards. However, in any reasonably recent PC there should be several amps to spare, which should be substantially more than any user add-on or set of user add-ons will require. The ±12 volt output has a rating of 2 amps on early machines, or about 4 amps or more on recent ones. The negative supplies have much lower current ratings of 0.3 and 0.25 amps for the -5 and -12 volt outputs respectively.

IO CH RDY (I/O CHANNEL READY)

This is an input which can be used to insert wait states if a slow device is used on the expansion bus. Some user add-ons might need this facility, but it obviously makes things easier if it can be left unused.

IO CHCK (I/O CHANNEL CHECK)

This is another active low input line, and it is pulled low in order to indicate a memory or input/output parity error. This generates a non-maskable interrupt. This feature is not normally required for user add-ons.

PROPERLY ADDRESSED

The first decision that has to be made when designing a PC card is just where in the input/output map it should be placed. As explained previously, only 1024 of the 65536 possible input/output addresses are available on a PC, and the lower 512 addresses are reserved for the computer's internal hardware. Much of the upper block of 512 addresses is reserved for essential and standard expansion cards such as serial ports and display adaptors. For the record, this is a full list of the PC input/output map allocations.

System

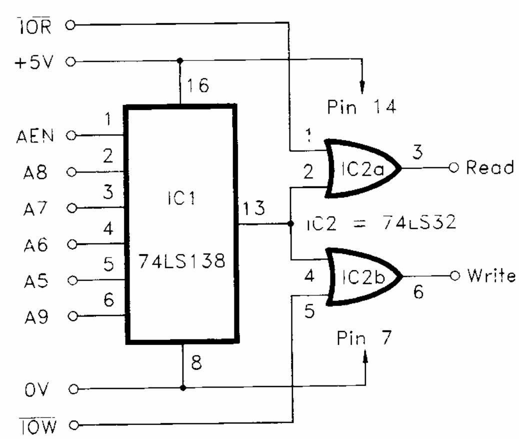
Hex Address Range	Function
000-01F	DMA Controller #1
020-03F	Interrupt Controller #1
040-05F	8254 Timer
060-06F	Keyboard Interface
070-07F	Real Time Clock
080-09F	DMA Page Register
0A0-OBF	Interrupt Controller #2
0C0-ODF	DMA Controller #2
0F0	Clear Processor Busy
OF1	Reset Processor
0F8 - OFF	Arithmetic Processor

I/O Channel

Hex Address Range	Function
1F0-1F8	Fixed Disk
200-207	Games Port
210-217	Expansion Unit
220-24F	Reserved
278-27F	Parallel Port 2
2F0-2F7	Reserved
2F8-2FF	Serial Port 2
300-31F	Prototype Card
320-32F	Fixed Disk
360-36F	Reserved
378-37F	Parallel Port 1
380-38F	SDLC Bisynchronous #2
3A0-3AF	Bisynchronous #1
3B0-3BF	Monochrome Display/Printer Adapter
3C0-3CF	Reserved
3D0-3DF	Colour Graphics Adapter
3F0-3F7	Floppy Disk Controller
3F8-3FF	Serial Port 1

GAP EXPLOITATION

Although the I/O channel addresses range seems to be rather crowded, there are actually a few gaps that can be exploited. Also, the address range 300 - 31F is explicitly for prototype cards, which would presumably embrace user add-ons. This gives some 32 addresses, which should be sufficient for most purposes, even if two or three home constructed cards are to be added. Apart from exploiting any gaps in the allocation map, it is of course quite acceptable to use one of the allocated address ranges if you do not have that particular hardware installed. The SLDC



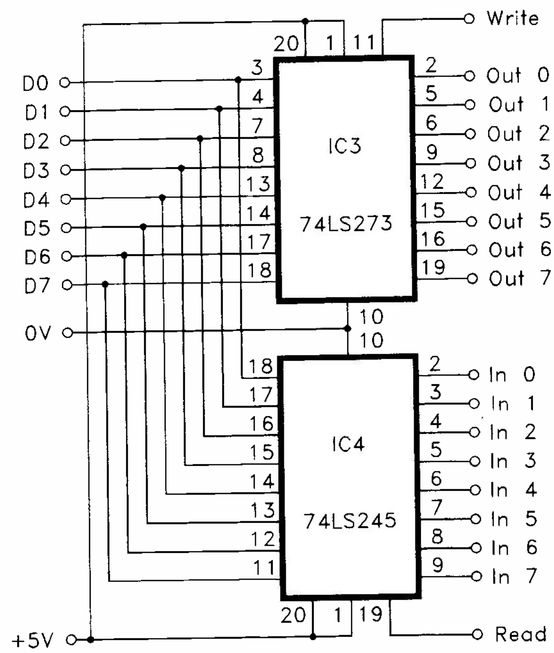


Fig 3 (above). An ultra-simple address decoder for PC add-ons.
Fig 4 (right). The additional circuitry needed to provide basic 8-bit input and latching output ports.

or games port address ranges could be used, for example, provided you do not have the relevant cards installed, and do not envisage fitting them at some later stage. Obviously this type of thing should be avoided if you are designing cards that will be used by others, and you do not know for certain what cards will be fitted in their computers.

Another system that can be very successful is to utilise the upper address lines (A10 to A15). On the face of it this is unacceptable, since these address lines are not decoded by either the system hardware or any expansion cards. These items of hardware will therefore respond to "echoes" of their base addresses, making addresses above 3FF unusable. However, this problem is avoided if you only use addresses that are "echoes" of the 300 to 31F address range of the prototype card. By decoding one or more of the upper address lines as well as the lower ten address lines, these 32 addresses can effectively be used over and over again, with one set of hardware using the base address range, and each additional piece of hardware using a different "echo" address range. This gives what should be more than enough input/output addresses to satisy even the most prolific expansion card builder.

DECODING

The bit pattern on the lower ten address lines for address &H300 is as follows:

A0	A1	A2	A3	A4	A5	A6	A7	A8	A9
X	X	X	X	X	0	0	0	1	1

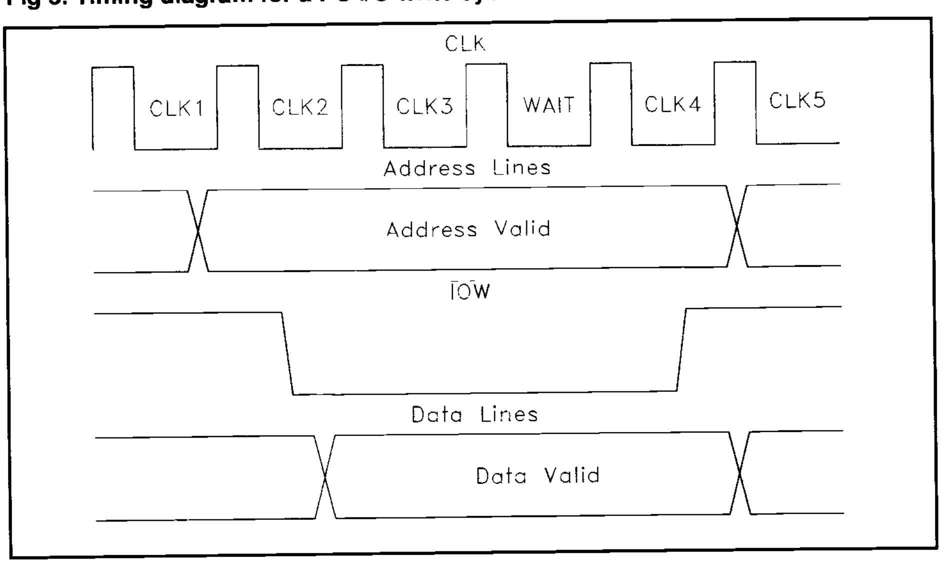
The "X" for the five least significant address lines indicates that their state is unimportant. For the base address of &H300 they should all be at zero. However, if several addresses in the available range of &H300 to &H31F are utilised, then these lines must be properly decoded for each address that is used. For a very basic port that requires just a single address they can simply be ignored. The port can then be accessed at any address in the &H300 to &H31F range. A complex peripheral chip that has a number of registers at different addresses will have address inputs that will effectively provide decoding for some of these address lines.

For the moment we will concentrate our attention on the upper five of these address lines, which must always be decoded. Also, the address decoder must process line AEN, which is high during dma cycles, and low during processor cycles. Therefore, any normal add-on must only be activated when AEN is low. Some peripheral devices are intended for operation on an 8088 type bus structure, and have inputs that can be used to process the IOR and IOW lines (the 82** series of chips have suitable read and write inputs for example). In other cases the address decoder must also process these lines, so as to produce separate read and write outputs.

There must be countless ways of decoding AEN and A5 to A9 correctly, but the most simple method that I could devise uses a single 74LS138 3 to 8 line decoder to decode all six lines. Fig. 3 shows how this is achieved. A9 is connected to the positive enable input, while A5 and A6 are connected to the negative enable inputs. This leaves the three normal inputs of the device free to process AEN, A7, and A8. Output of ICI pulses low when an address in the range &H300 to &H31F is accessed. If the decoder is used with peripheral devices that have suitable read and write inputs for IOR and IOW, then output 2 of ICI can directly drive a negative chip select input (or a positive type via an inverter). If not, then a couple of OR gates (IC2a and IC2b) are needed in order to decode these lines and provide separate negative read and write outputs.

Fig. 4 shows the additional circuitry needed in order to give basic 8 bit input and latching 8 bit output ports. IC3 provides the outputs, and this is an octal D type flip/flop connected here to act as an 8 bit latch. The data inputs are fed from the computer's data bus, the Q outputs provide the latching outputs, and the write output of the address decoder drives the clock pulse input. The timing of a write bus cycle is shown in Fig.

Fig 5. Timing diagram for a PC I/O write cycle.



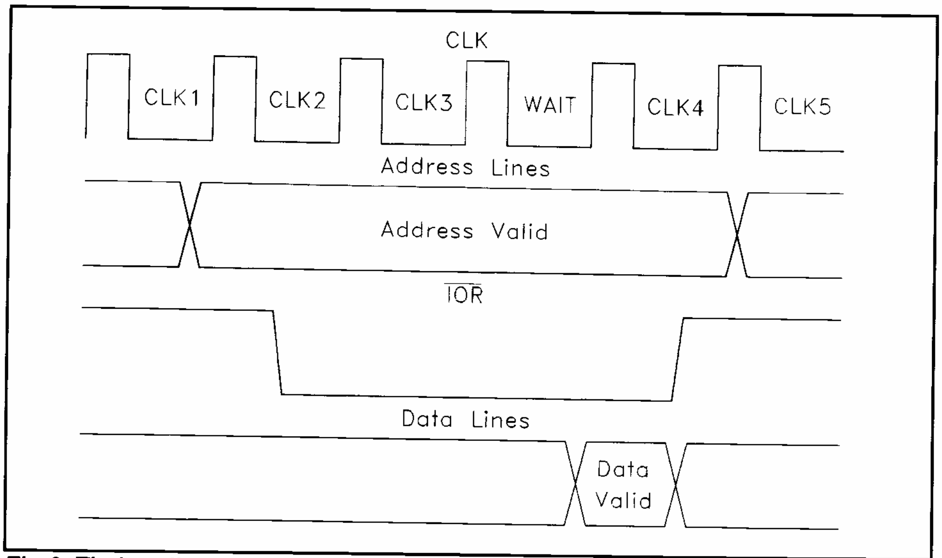


Fig 6. Timing diagram for a PC I/O read cycle.

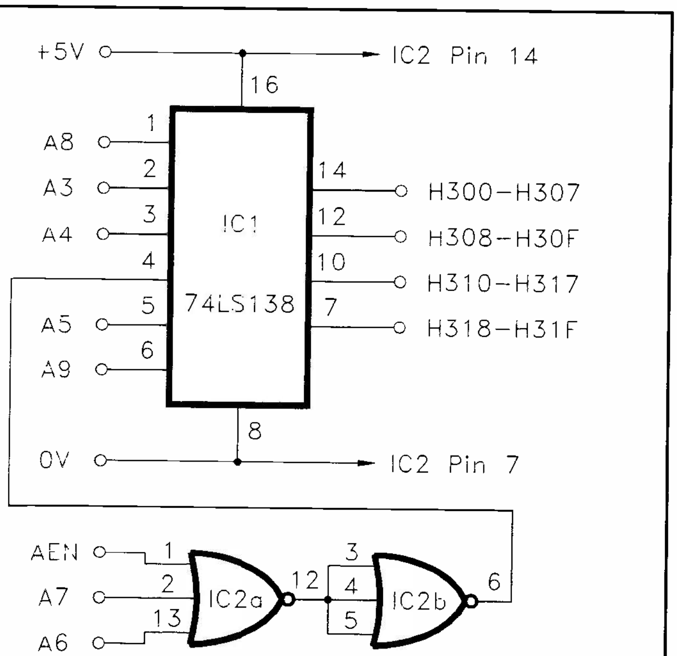
5. IOW returning to the high state ends the negative output pulse from the address decoder, and this latches the valid data on the data bus into IC3's flipflops.

The 8 bit input is provided by IC4 which is an octal transceiver. However, in this circuit its direction input is permanently wired to logic 1, and it operates as what is really just an octal tristate buffer. A read pulse from the address decoder activates its outputs and places the input data onto the data bus. Bus timing for read operations is shown in Fig. 6. There is no difficulty in using many computer peripheral chips with the 8088 bus of the PC, but note that it is not well suited to all peripherals. In particular, using 65** and 68** series peripherals with 80** processors (or vice versa) usually requires some trickery in the address decoder and the control bus in order to obtain satisfactory results.

If more than one device is to be placed in the &H300 to &H31F address range, some of the lower address lines must be decoded. A simple method of splitting this block of addresses into four blocks of eight addresses is shown in Fig. 7. This is based on the decoder circuit of Fig. 3, but the AEN, A6, and A7 lines drive one of the negative enable inputs of IC1 via a three input OR gate. This is actually a three input NOR gate followed by a second gate connected to give an inverter action. Ideally there should be as few devices as possible decoding each line in order to give a minimal delay in the operation of the circuit. Also, simple devices such as gates and inverters are preferable to the more complex and slower ones such as 4 to 16 line decoders. In this case the extra inverter is necessary as a suitable ttl OR gate does not seem to be readily available.

Using the extra gates result in two of the normal inputs of IC1 being left available to process A3 and A4 of the address bus. This gives the required splitting of the address range into four blocks, with a separate output of IC1 being used for each one. With an extra gate or two it should be possible to leave all three normal inputs of IC1 unused, and available to decode A2 to A4. This would give eight decoded outputs, with each one covering four addresses. Do not forget that unless the peripheral devices have inputs for IOW and IOR, these must be processed with the outputs of IC1 using two input OR gates. Even if a home constructed expansion card does not require more than one decoded address output, it is still worth using a decoder such as the one shown in Fig. 7. By using just one block of eight addresses, this leaves some 24 addresses free for any further expansion cards you may wish to build later. If you use the entire &H300 to &H31F range on a single card it is still possible to find other niches in the input/output map for additional cards, but you would be making life difficult and limiting your options.

Fig 7. An address decoder giving four outputs, with each one covering eight addresses.



EXPERIMENTING

For anyone who is at all familiar with computer interfacing it should by now be clear that the PC is relatively straightforward from the electrical point of view as far as basic interfacing is concerned. In fact it is more simple than many 8 bit computers, which often indulge in slightly non-standard methods of interfacing. This sometimes makes them difficult to use with what should be ideally suited peripheral devices!

The PCs are a bit awkward as far as the mechanical side of things is concerned though. Having interface cards actually inside the computer is in many ways a very convenient way of handling things, but it can make it difficult to develop prototype circuits, and the final product must be produced with a fair degree of precision. Fig. 8 shows the correct size and shape for a full length PC expansion card. A short card would normally be about half the length of a full card (ie about 6.6 inches), but there is no standard in this respect. The short cards in my XT compatible range from about 4.2 inches to 6.8 inches. If a card needs to be much more than about 7 inches, then it would probably be better to make it a full length type so that the front end is properly supported, and is not left flapping around. There is no standard height for PC cards, but it is best to keep the height to not much more than about 4.2 inches. Most PC cases can accommodate taller cards, but some recent low-profile types cannot take some of the high-profile expansion cards.

BRACKETS

If a card is less than full length, it is always the front end that is "trimmed off" as it were. The rear end is fitted with a metal bracket which fits into the space vacated when the blanking plate for the slot in question is removed. Making your own brackets is quite difficult, since they are quite a complex shape. Where possible it is probably best to use a blanking plate removed from the computer. Most users soon add one or two ready-made expansion cards, and will have a couple of "spares" which can be used for their add-ons. Some computers seem to be supplied with a set of eight blanking plates, but with some expansion cards being needed for a basic configuration, this obviously leaves some of these plates unused.

Certain types of expansion card are supplied

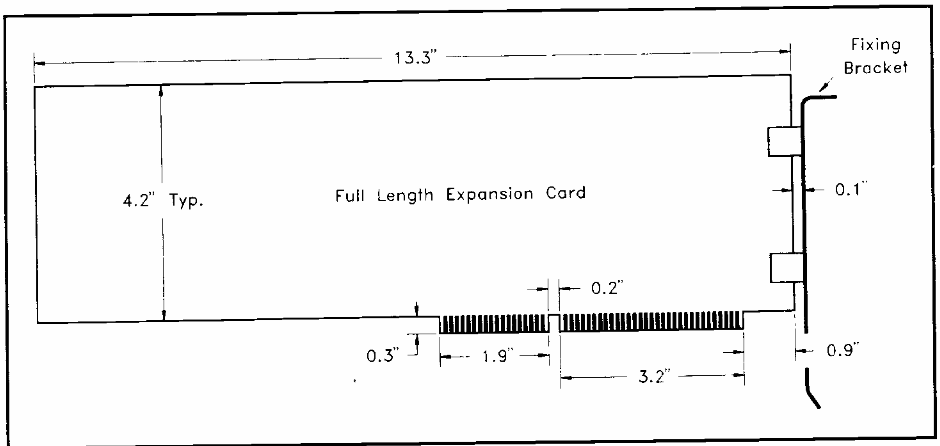


Fig 8. Dimensions for a full length PC card. Short cards are usually about five inches in length.

SLOT NUMBER	FUNCTION	SLOT NUMBER	FUNCTION
B1	Gnd	A1	-I/O CH CK
B2	RESET DRV	A2	D7
B3	+5V	A3	D6
B4	IRQ2	A4	D5
B5	-5V	A5	D4
B6	DRQ2	A6	D3
B7	-12V	A7	D2
B8	OWS	A8	D1
B9	+12V	A9	D0
B10	Gnd	A10	-I/O CH RDY
B11	-MEMW	A11	AEN
B12	-MEMR	A12	A19
B13	-IOW	A13	A18
B14	-IOR	A14	A17
B15	-DACK3	A15	A16
B16	DRQ3	A16	A15
B17	-DACK1	A17	A14
B18	DRQ1	A18	A13
B19	-REFRESH	A19	A12
B20	CLK	A20	A11
B21	IRQ7	A21	A10
B22	IRQ6	A22	A9
B23	IRQ5	A23	A8
B24	IRQ4	A24	A7
B25	IRQ3	A25	A6
B26	-DACK2	A26	A5
B27	T/C	A27	A4
B28	BALE	A28	A3
B29	+5V	A29	A2
B30	OSC	A30	A1
B31	Gnd	A31	A0
D1	-MEM CS16	C1	BHE
D2	-I/O CS16	C2	LA23
D3	IRQ16	C3	LA22
D4	IRQ11	C4	LA21
D5	IRQ12	C5	LA20
D6	IRQ15	C6	LA19
D7	IRQ14	C7	LA18
D8	-DACK0	C8	LA17
D9	DRQ0	C9	-MEMR
D10	-DACK5	C10	-MEMW
D11	DRQ5	C11	D8
D12	-DACK6	C12	D9
D13	DRQ6	C13	D10
D14	-DACK7	C14	D11
D15	DRQ7	C15	D12
D16	+5V	C16	D13
D17	-MASTER	C17	D14
D18	Gnd	C18	D15

Table 1. Itemised lines on 8 and 16 bit expansion buses.

with plates that are ready drilled to take D connectors. This is where the card needs (say) three input/output sockets, but there is only room for two on its fixing bracket. The third socket is mounted on the extra plate, which is then fitted into position behind a vacant expansion slot. A cable connects the expansion card to the extra socket. Most PC cases, including standard size horizontal AT and XT types, have mounting holes for extra sockets in the rear panel, just to the side of the expansion slots. Where possible it is best to utilise these, leaving as many expansion slots as possible completely free. This also leaves the blanking plate free for use in your own cards. Always keep any left-over items of hardware such as this, as they can often prove invaluable when indulging in some PC diying. A standard method of fixing an expansion card to the blanking plate is via a printed circuit mounting D connector. This is simply soldered to the board in the normal way, and bolted to the mounting bracket. If you use this method make sure that the position of the socket on the board is such that it brings the fixing bracket the correct distance away from the rear edge of the card.

COMMERCIAL HARDWARE

There are various items of commercial hardware available which can be used to assist with the production of prototype PC cards. These include full length cards fitted with breadboards on which circuits can be developed, and cards with built-in address decoders plus a "prototyping area" on which circuits can be built up in stripboard fashion. There are also units which allow for prototyping of circuits on breadboards etc, outside the computer. The two main problems with these units are that many of them are difficult to obtain in the UK, and they all seem to be quite expensive. In fact the most expensive PC prototyping systems seem to cost more than the cheapest PC computers!

It should be possible to produce home constructed prototyping systems, and one of these will be featured as a future PE project. *(Robert, I await your offering - asap! Ed)* A simple method of testing simple add-ons that I have found useful is to build an edge connector to fit into a PC expansion slot, and to connect this to an ordinary breadboard unit via ribbon cable. A suitable edge connector design is shown in Fig. 9. This only provides connections for the essential lines, which are in three groups (data bus, address bus, and control bus/power rails). Obviously the board could easily be modified to include further lines if necessary. It is advisable to implement the bare minimum number of lines, as this lessens the risks of mistakes. An essential point to keep in mind if you try this method is that long cables to the breadboard are not acceptable. I found that with cables about 700 millimetres long that results were only reliable with the non-turbo 4.77MHz clock speed, and if extensive supply decoupling plus a few noise filtering capacitors were used. Cables about 300 millimetres long are much more satisfactory, but might not be usable with very high clock frequencies.

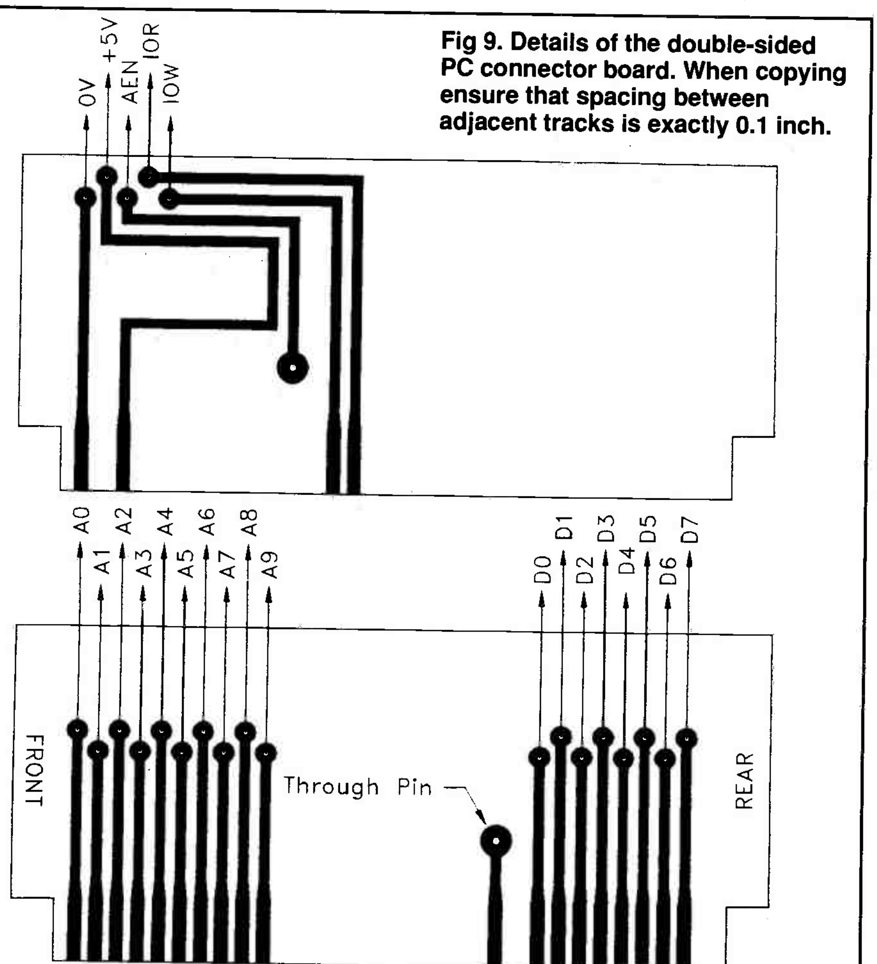


Fig 9. Details of the double-sided PC connector board. When copying ensure that spacing between adjacent tracks is exactly 0.1 inch.

FINALLY

This article should provide those who are experienced at computer interfacing with sufficient information to enable them to design add-ons to suit their requirements. It is hoped that some PC projects will follow in future issues of PE. Those who would like to know about the finer points of PC interfacing, such as using interrupts and adding wait states are recommended to obtain a copy of "Handbook off Software and Hardware Interfacing For the IBM PCs" by Jeffrey P. Rover, and published by Prentice-Hall (ISBN 0-13-381849-7). You are not exactly spoiled for choice when it comes to PC interfacing books, but fortunately this one tells you clearly and concisely what you need to know.

One final point that has to be made is that interfacing to the buses of computers is not something that can be recommended for beginners at electronics. Mistakes will in most cases not damage the computer, but there is certainly the potential to do a lot of expensive damage. Even with a low cost PC there is the possibility of being faced with a large repair bill if things go wrong, and with AT computers the cost of repairs can be more than the price of a good home computer. The inexperienced should gain the necessary skills and knowledge before tackling PC interfacing, and those with the requisite experience should still proceed with due caution. Producing PC add-ons should then be a very interesting, rewarding, and low cost experience. PE

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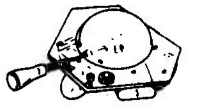

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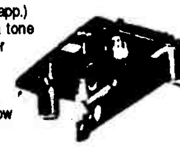

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ARTIFICIAL INTELLIGENCE

Richard Mishra considers how AI advances our understanding of perception gradually as we work at it.

Artificial Intelligence (AI) as far as the average disinterested observer is concerned is usually a source of anxiety. Its purpose is seen as to undermine humanity by explaining and then replicating intelligent behaviour. Not only is this a spiritual oppression, ousting us from the top of the intelligence tree, but a real threat to our worth and livelihood. The normal response usuals betrays the feeling that AI is studied because the real stuff is not quite good enough.

Despite this, the source of such anxiety is not the arena in which AI works. It is fair to say it is a poorly understood concept,, mainly because it is used to describe an immense range of attitudes and activities. However, the overall picture that is emerging from the first fifteen to twenty years of work suggests quite strongly there is more even to animal intelligence than direct, clear cut methods of perception, planning and action. The attitude to intelligence as a behaviour decribable by analogy with current computer technology has not produced anything that could be considered cognitively significant.

METHODOLOGY

At its most prosaic, AI describes a methodology for computing: one that is distinct from traditional 'numerical computing' and is based on the use of symbols to encapsulate and manipulate knowledge. This is referred to as the 'symbolic paradigm'. The main tools for this are logic and inference rules: rules of the form 'IF some state THEN some action'. The main products are Intelligent Rule Based Systems (IKBS), inappropriately, but more widely known as Expert Systems. Such systems become useful when situations are not precisely defined and there are no directly applicable mathematical solutions to the problems. Otherwise, traditional numerical computing could be employed with greater confidence and less programming effort.

Roughly speaking, an IKBS should have three elements. Firstly there is the knowledge base: a large number of inference rules that would have been established by the experts in the field. There has to be a method of extracting and using the knowledge from these rules to answer questions about specific situations described to the system. Finally, a good system should have a way of explaining its reasoning process in a meaningful way. This is rare, mainly because there are many different types of explanation and it is not always possible to know what is required or how to generate the appropriate explanation. The situation is further complicated by uncertainty. Both the descriptions of the situations and the expert's knowledge can be uncertain to some extent. These uncertainties have to be represented in the system and propagated through the reasoning process. It is not clear how this should be done.

Getting the information from the expert is a far from trivial process in itself. The business of finding experts, getting enough of their time, allaying their fears over redundancy and then getting them to express their knowledge coherently are all problems that are largely beyond the training of computer scientists who first set out to create such systems. Since then more appropriately trained people, psychologists and cognitive scientists, have been having greater success. It may turn out that the problems with IKBS are not so much elicitation, as has been thought, but more with the representation of knowledge. Certainly, knowledge elicitation, representation and manipulation are key concerns of AI, so much so that AI in some, mainly commercial circles, is considered to be synonymous with IKBS.

ROBOTICS

So much for the prosaic. Another general feature of AI can usefully be gathered together under the heading of 'Robotics'. This is possibly the most emotively charged aspect, evoking visions of autonymous machines unleashing amoral social havoc. It is also the aspect of the subject that has most underachieved. The key concerns for AI at the moment are those of perception and planning.

The idea of perception as a pattern recognition process is probably the grandfather of AI. The aim is basically to extract the significant features from a signal and then combine them to form recognisable entities. The assumption is that semantically meaningful entities can be constructed from their composite features alone. Unfortunately this assumption turns out to be false. Extracting features only gets you some of the way to perceptions because the context of the particular perceived feature is very important. For example, if someone is fetching you a gin and tonic from a pub and they turn to look at you across a crowded and noisy bar, mouthing a single syllable word and looking expectant, the chances are that you will correctly interpret the gesture as 'Ice?' without hearing the word. Much of what we perceive is determined by expectation but the relationship between expectation and feature extraction has yet to be formulated, let alone solved.

LINGUISTICS

A similar problem occurs in another major field of AI, that of natural language understanding. Parsing well formed sentences can generate syntactic and some semantic information. To get access to the full, unambiguous meaning of a sentence, which in normal circumstances will not always be grammatically correct, the contextual information is vital. Simply working on the words of a single sentence will not give access to the natural language underlying it, although language constrained in form and applied to a specific domain can be analysed in this way. In both the cases of perception and natural language processing progress has been slow. There appears to be a need for a more general understanding of cognition from which an understanding of the relative roles of context and features can be established.

PLANNING

The other aspect of robotics that concerns AI is planning. This describes the process of establishing what actions need to be taken in order to get from a particular initial situation to another one in which certain goals have been achieved. It turns out to be very difficult to plan in even simple 'toy' environments; processes have to be generalised, a hierarchy of goals has to be established and conflicting goals have to be resolved without undermining previously established ones. It is difficult to produce any plan to achieve the goals, let alone an optimal plan. In environments where there many be several active systems and where temporal constraints become necessary, the planning process is intractable.

In order to create robots, the issues of planning and perception have to be brought together and combined with actuators to provide movement. This is primarily of concern to industries working in hostile environments; the nuclear industry is a good example. The mechanisms of grasping are now being established and there is even a computer controlled pogo stick that will happily bounce along without losing its balance.

CONNECTIONISM

An alternative, or at least complementary, strategy to the symbolic paradigm has emerged recently and has been grasped by the AI community with open arms. This is the 'connectionist paradigm' and has become very fashionable because it is seen as a way round the impasse in which symbolic AI seems to find itself. It is particularly appropriate to perception problems, but is also being applied to other areas including IKBS.

The connectionist paradigm, more precisely known as Parallel Distribute Processing (PDP), emerged with the study of mechanisms of the brain. It basically assumes that if we are to mimic cognitive behaviour then we ought to use methods that are analogous to neural systems. Such artificial systems are often referred to as neural networks, though this is rather presumptuous; the variety and complexity of neural operation has yet to be determined. It is still not clear what kind of functions the individual processors in a network should possess, or what the overall network structure should be.

The main feature of a PDP system that marks it out from symbolic processing is that it allows the same kind of freedom to be precise that is found in natural cognition. For example, if the input is an image of an alphabetical character, the output should indicate the correct character even if the input image varies in size, font or orientation. Obviously there are limits to this tolerance. On the whole, if we cannot recognise a character, there is not reason to expect a machine to be able to do so.

PHILOSOPHY

An important aspect of AI is that its methods and conclusions, like any endeavour, are subject to philosophical inspection. The issues of induction, representation, intentionality and so on are central issues in the philosophy of the mind that also impact directly on the expectations and design of AI systems (see D. Dennett '*Brainstorms*', Harvester Press, 1978). It may well be that it is the absence of such considerations at the level of systems design that is holding back progress in constructing useful, cognitive-like systems.

Finally, AI can be taken as being a kind of philosophy of science and mind in itself. The idea that science is an absolute structure built on absolutes has been giving way this century, but the case for it being able to produce an ultimate understanding of the universe is made even weaker by an AI attitude. It is clear that the universe is not being analysed by a pure and unbiased observer, but that the universe develops through the interaction of the physical universe and the structures of human cognition. The latter has its own peculiar capabilities, biases and limitations that are not just of any individual, but fundamental to cognition itself. The universe is likely to be more than the structures of human thought can represent and it is these structures that are part of the studies of AI. The fun really starts with the realisation that AI, being a science itself, is limited by these same structures it is trying to establish. In this way AI can be seen, at one of its limits, as an important bridge between science and philosophy, a new 'natural philosophy'. PE

Richard Mishra is currently researching into some of the philosophical issues in AI at Cambridge University.

COMPUTERS

Part Three

Mike Saunders concludes his over-view of computer whys and wherefores.

In writing a program in assembly code, four columns or fields are used. Field 1 is the label or title eg Start. Field 2 is the operation required, eg LOAD. Field 3 is the operand, e.g, the register (say B) to be loaded and the value (say FF in hex). Field 4 is the comments column so that someone else can understand the program and even the programmer may not understand it some months later if the comments have been ommitted. The following example should summarise the fields.

Field 1	Field 2	Field 3	Field 4
START	LD	A,FF	Brief description of program.

It can be seen that Fields 1 and 2 are the most important from the point of view of the computer.

ORG (origin) tells the computer where the main program starts and END is obvious but just as important. Most assemblers are of the two pass type, ie the program has to be run through twice since a label can be met quite early and makes sense only later in the program. A cross-assembler is an arrangement to assemble on one machine and run the program on another machine.

HIGH LEVELS

Instead of writing a program in mnemonics, one could use a high level language (hll). These use full English statements but still keep within the syntax or grammatical rules of the particular language. The languages are written for special applications, eg Basic for mathematics, Fortran for science, Cobol for business and commerce, Algol for military applications, Focal for control purposes, etc.

An example of hll statements would be:

```
READ N

PRINT N
```

A computer cannot read such statements. A compiler or interpreter is required to convert these statements to machine code. A compiler converts the whole program to machine code, whereas an interpreter reads and converts each line, each time the program is run. This means that an interpreter is slower but the program can be changed easily.

If a compiler is used and the hll statements are altered, then the program needs to be recompiled. This has its advantage - it prevents the users from getting their grubby fingers on the program, altering it to do fancy things and then complaining to the programmer that it does not work!

To sum up then, machine code is ok for small programs up to 1K for a fixed purpose or where speed is essential, eg a fast computer game. Assemblers are used where timing is critical and an efficient code is required. High level languages are used where there are a lot of unskilled programmers or where a very large program is being written which might require constant or even drastic alterations.

On the subject of programming, the terms macros or macro instructions may be encountered. A macro is a group of program steps like a subroutine It's a bit more complicated than that - it's possible to alter the variables within the macro, and loops within the macro have to be defined as local loops otherwise the program would never stop!

So the choice between using macros and subroutines is an individual one. Both have ardent disciples. In general if the program is longer than twelve bytes and a subroutine is used more than ten times, then less code is generated if a macro is used. However this should not stop a programmer using subroutines if it makes things clearer or reduces the chance of error in writing the program.

SUPERCOMPUTERS ONWARDS

Supercomputers are sometimes mistaken for fifth generation computers. Supercomputers are simply the most powerful, the Mr. Universe of their day. So the EDVAC and Colossus were supercomputers of their era.

Today a supercomputer costs about $15 million and can perform 100 million operations per second. There are only about forty such computers in the world and they are used for geology, defence and weather forecasting. The Cray-1 and CYBER 205 are in the present day supercomputer class and are built by Cray Research Inc and Control Data Corporation respectively.

Every three or four years the speed of these large computers doubles. This is due to developments in technology. For instance, the cycle time in a computer using discrete transistors was 100ns; with integrated circuit this has been reduced to 1ns.

Sometimes one does not have to wait for technology to advance, a simple alternative is more effective. For instance, signals travel at three tenths the velocity of light in copper wire but at nine-tenths the velocity of light in coaxial cable, so the CYBER 205 uses coaxial cable.

When the possibilities have been exhausted, one has to get back to basics. Do things have to be done the way they have always been done? For example, one processor can be used to fetch and another to execute in order to save time. Does a program have to be performed in a sequential manner? Vector computers use the pipeline concept, ie a job can be broken down into parts complete in themselves. Considerable time can be saved in running a large program if the discrete tasks are performed simultaneously and the results combined in the right order.

TIERED MEMORY

All large computers have the satellite processors, mentioned earlier, to take some of the work load off the cpu. And, of course, for number crunching exercises they need large memories to hand. The memory can be arranged in three tiers:

a. The register set consisting of several hundred words and accessible in one machine cycle.

b. The main memory holding the data and program

c. Rotating magnetic discs holding 77 million words each and a total capacity of over a billion 64-bit words. These discs can be accessed at a peak rate of half a million words per second.

Some machines have a buffer memory of several thousand words between the register set and main memory.

Thanks to integrated circuits, today's supercomputers do not have to be the size of the Empire State Building. Although small may be beautiful, integrated circuits have their heat dissipation problems. The Cray 1 uses 300,000 chips all packed into a space of less than 100 cubic feet. Since it is necessary to use fast bipolar logic consuming 5 watts per chip, that's a lot of sweaty chips and freon refrigerant is pumped through cooling pipes.

GENERATIONS

Computer generations up to the present day may be categorised as follows:

First generation: Valve types like the Colossus.
Second generation: Transistor types like the IBM 1401.
Third generation: Integrated circuit types like the IBMs S/360 and ICL 1900. At this stage high level languages were well established.
Fourth generation: Very large scale integration, eg the IBM 3081.

The fifth generation of computers has a target date of 1991 and is expected to use revolutionary new designs in terms of hardware and software. It would need to if it is expected to see, hear and speak! Whether these objectives will be met remains to be seen.

On the hardware side components that are durable and stable will probably emerge, as will fabrication of materials besides silicon to achieve higher speeds and greater immunity to temperature, radiation and vibration.

Programming languages will have to move away from high level languages to others based on logic and symbols, like Prolog and Lisp.

A.I.

In general, the drift of fifth generation computers is towards artificial intelligence (AI), ie an ability to make inferences and therefore solve problems. The learning process is part of AI. For example, given a situation involving trial and error, the program should analyse failures, look for a general trend in the failures and add it to a file of traps to be avoided.

Research on speed recognition and speech synthesis is underway. The accent is on sentence understanding rather than word understanding and concentration on a vocabulary of 5000 words, which is that of an average human. Speech recognition like handwriting recognition is a daunting task for a machine. In addition to all the regional accents there are colloquialisms. Besides this, humans convey some of their messages with eyes and gestures.

However, if you can remember you are talking to a machine and keep the sentences simple and precise, voice control can be extremely useful in an industrial environment. For instance, where the worker must keep his eyes on a display or hands on controls, or where the worker has to move around yet activate machinery.

EXPERT SYSTEMS

Expert systems (ES) are a subclass of artificial intelligence. These already exist, though most of them are in the USA. They are more than just a huge data bank. Although they do not undertake a learning process, they do undertake a reasoning process to arrive at a conclusion. They are believed to be of the level of 'intelligence' of at least a good graduate in the field.

Some of the expert systems that have been developed are Prospector for geology, Secs and Dendral for chemical analysis, Mycin and Internist for medical diagnosis. In 1982 Prospector made news by informing geologists that there was molybdenum in Washington State. It was fed the same information that is available to geologists and though the experts disagreed with the finding, Prospector was proved right.

Some people think that the definition of an expert system should be extended slightly: that an expert system should be able to explain how it arrived at its conclusion in a way that is understandable to the person interrogating the expert system.

CONCLUSIONS

Mankind has always been a sucker for exploiting technology. But if he does not watch out, computing is the one technology that could get the better of him, whether it be in the form of personal records held on data banks or a horde of intelligent robots actually walking around homes and offices.

The development of intelligent robots within the next human generation is not as laughable as it seems. In 1982, Cubot, the American robot equipped with a computer for a brain and camera for an eye, solved any combination of Rubik's cube in less than four minutes using his mechanical fingers.

Other robots have been built. Reckitt Industries have built one to dust furniture and polish floors. As early as 1977, Quasar Industries built a robot to mow the lawn, cook simple food and mop floors.

The Japanese have not been idle. All the big names, including Kawasaki, Hitachi, and Yashukawa, have used robots for purposes other than motor car assembly. Robots using vidicon cameras for eyes have been used for arc welding, transistor die bonding and inspection of nuclear plants.

Robots can boldly go where no man has gone before: near dangerous industrial processes and in deep space probes. Next time someone tells you he saw a spacecraft in a meadow with robots disembarking, don't laugh at him.

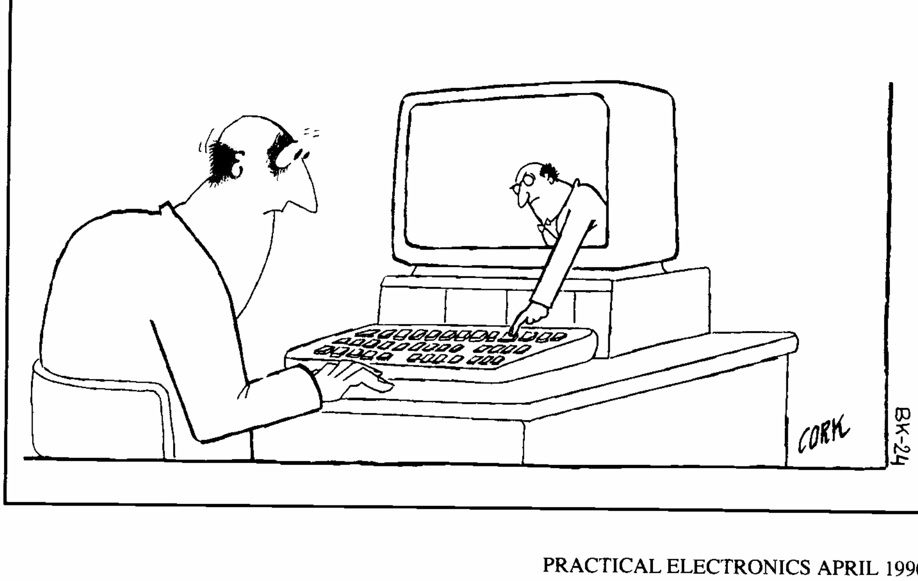
What is the most valuable commodity in the world? Did you say gold, or plutonium? If you said silicon chips, you would probably be right.

MICRO-GLOSSARY

ALU	arithmetic and logic unit
Ascii	American Standard Code for Information Interchange
Cmos	complimentary symmetry metal oxide semiconductor
CPU	central processing unit
EArom	electrically alterable read only memory
Fifo	first-in first-out
HLL	high level language
Ice	in-circuit emulator
Lifo	last-in first-out
Pipo	Parallel-in parallel-out
PLA	Programmable logic array
Prom	Programmable read only memory
Ram	random access memory
Rom	read only memory
TTL	Transistor transistor logic
ULA	uncommitted logic array
Usart	universal synchronous/ asynchronous receiver transmitter

PE

...an expert system should be able to explain how it arrived at its conclusion...



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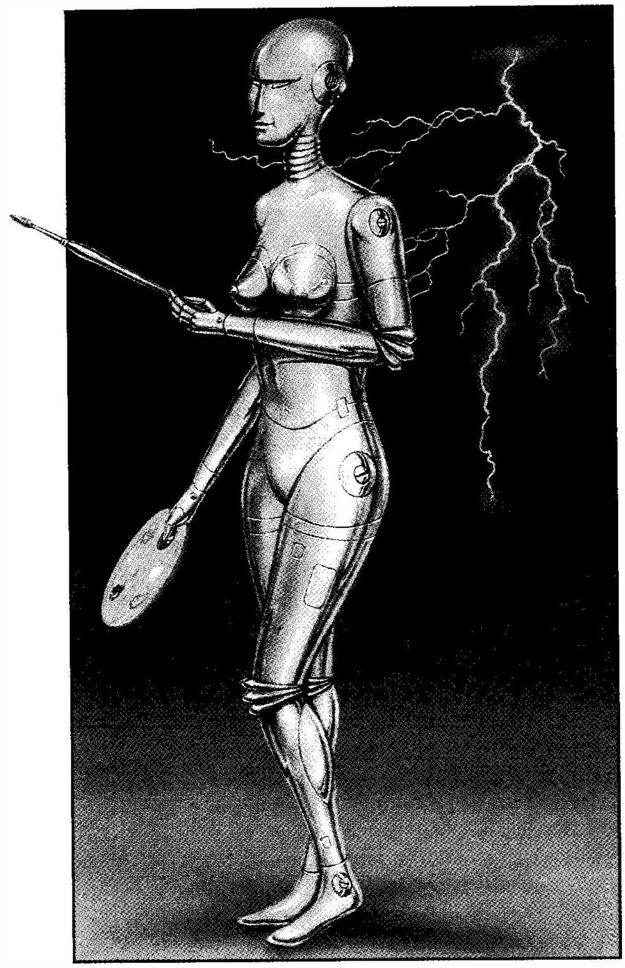

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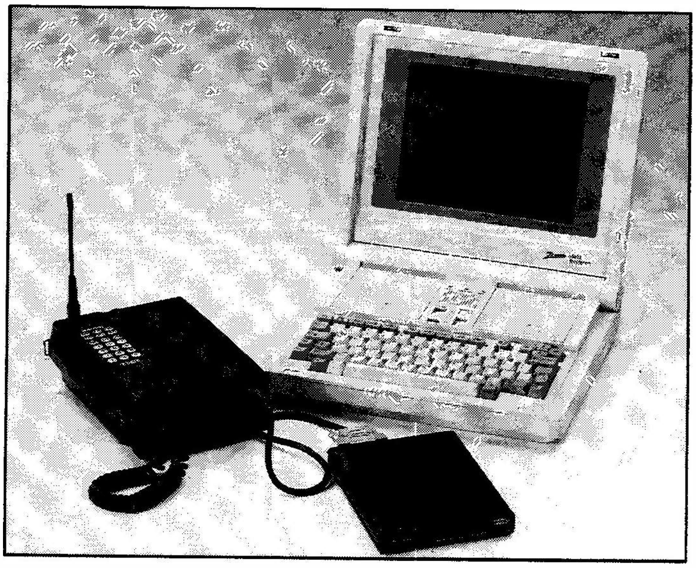


HOME-BASE

John Becker hosts the first of a series of reports in which are highlighted some of the interesting new products for use at home, or the office, or even the office at home. Communications, perhaps not surprisingly at the start of this decade, dominate the scene and this column (even the car alarm can be regarded as a communicator!)

CELLULAR MODEM

The first product I highlight is one which might even be for use by those of no fixed abode! It's from Racal-Vodata, and they have taken the concept of the portable office and developed it into reality, by introducing a new cellular modem. By combining one of their latest compact Vodafones with a lap-top computer and a Vodata CDLC modem, they have made it possible to create an office in a briefcase which incorporates comprehensive voice and data communications facilities.

The modem weighs only one and half pounds and offers full autodial/autoanswer facilities. Its low power consumption means that the 'talk-time' of battery-powered transportable Vodafones is not noticeably reduced.

Cellular Data Link Control (CDLC) is a protocol developed by Racal-Vodata to ensure reliable data transmission through the hostile environment of a cellular network. Under normal cellular reception conditions, the advanced forward error correction techniques used in CDLC provide user data rates of up to 2400 bps (bits per second), full duplex. (Duplex was discussed at some length in the PE Modem project of Feb 90.) Even under severe reception conditions, data throughput is typically 1200 bps, full duplex.

To complement CDLC, the company introduced their Vodafone Mobile Access Conversion Service (VMACS), which allows subscribers to access a wide variety of computer systems and data services using a common equipment configuration. Via VMACS, a CDLC modem and lap-top terminal can access the BT Packet Switch Stream, Mercury 5000, IBM's Managed Network Service, Istel's Infotrac, a number of private data networks and any computer system connected to the public phone network.

RETRIEVING CD-ROM

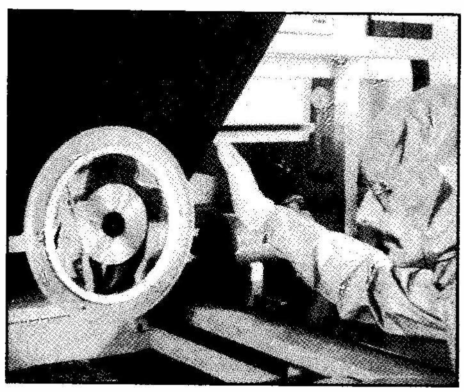
The future growth and effectiveness of cd-rom technology recently received a major boost with the announcement of a new index and retrieval software package, Romware.

Nimbus Information Systems, the cd-rom division of Nimbus Records, are the company responsible for Romware. They have developed it exclusively for cd-rom, and claim that it performs faster and more effectively than any other search and retrieval system available on the market.

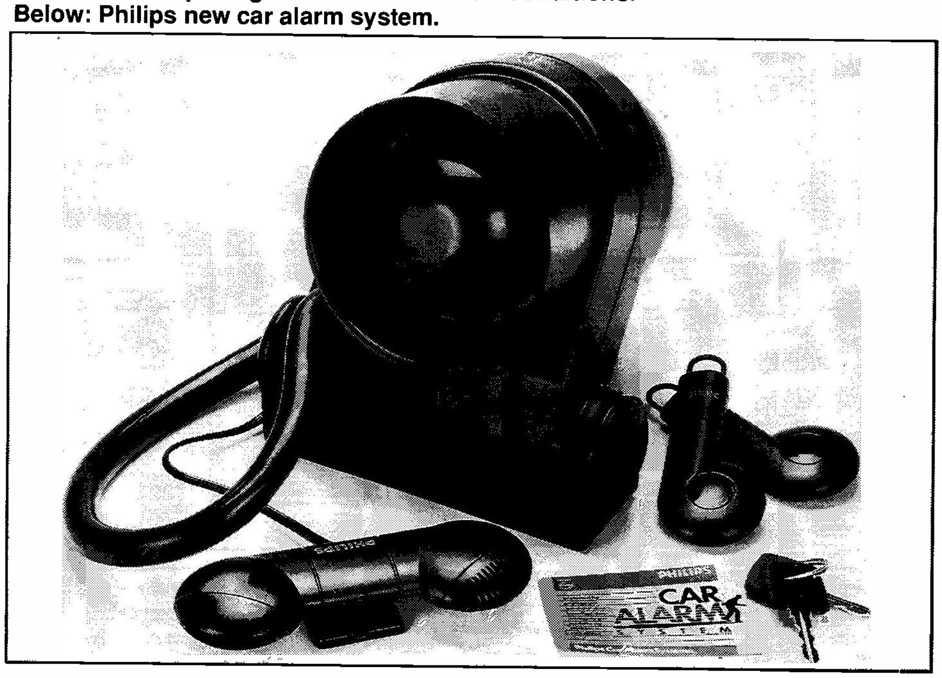
Romware offers a range of high quality functions. The build and indexing capabilities are simple, powerful and fast. For example, it took Nimbus just under 20 minutes to complete the indexing of the Bible, which contains approximately one million words, into retrieval format. But speed of retrieval is the software's key asset, locating terms requested by the user almost instantaneously.

Regarding Romware with high esteem, Nimbus say that the introduction of such a package, which works effectively and meets the standards required by industry, will stimulate the market and encourage the expansion of cd-rom.

"We know Romware to be an excellent and economic software package," comments Gerald Reynolds, joint managing director at Nimbus Records. "Alternative packages on the market, offering equivalent features to Romware, cost three to five times as much. We have priced Romware competitively with the aim of significantly improving the ease with which companies and organisations can design databases and author cd-rom discs in-house."



Above: Master plating CD-ROM in clean air conditions.
Below: Philips new car alarm system.



RAISING THE ALARM

There was a spate of thefts from cars in my district not so long ago. Eventually, the thieves were apprehended, but the in-car entertainment systems pinched were not recovered. Philips have now taken active steps to make their in-car products less appealing to would-be thieves, and are offering total vehicle protection with their new range of car alarms.

By launching in-car units featuring Philips inventions such as Security Code, and also retractable models which can be removed stored safely, the company has established a proven track record in the prevention of radio theft. The experience they have gained has been used to develop the new alarm range, which includes two models, the switch-activated PH100, and the radio key or remote control model PH200.

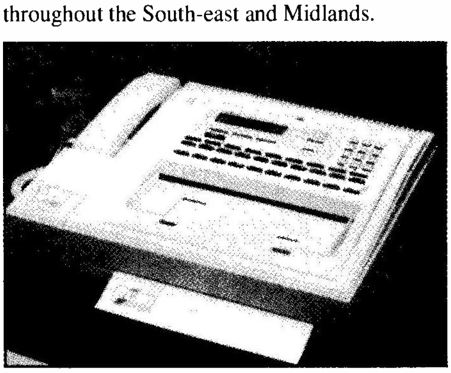
The PH100 is armed by a hidden switch and allows 30-45 seconds exit delay, and six to seven seconds delay for re-entry. The PH200 is armed by a radio key remote control which allows 40 seconds exit delay, but no re-entry delay.

On setting or disarming the alarms the hazard warning lights flash, and model PH200 has additional led indicators to show when it's armed. Both models are triggered by a voltage drop from opened doors or direct earth switches to cover boot and bonnet. Once activated, the alarms flash the hazard warning lights with the PH100 sounding a 114dB siren for 30 seconds, and the PH200 a 120dB siren for a minute, followed by automatic reset. A vehicle immobilisation circuit is featured on both alarms which includes a safety circuit to prevent it cutting in while the engine is running. An ultrasonic detector is available as an optional extra.

One of my neighbours ought to look at this new range. He installed an alarm after his car radio vanished, but it keeps going off at odd hours. I caught the culprit at 2.30am the other night - a cat who uses the car as a stepping stone between wall and pavement, triggering the alarm on landing! I feel sure Philips have designed against such trigger-happy eventualities.

FAX FLOODGATES OPENED

Amstrad has concluded an agreement with Ryman, the office stationery and equipment suppliers, to sell the new Amstrad FX9600T fax machine in 65 Ryman high street stores throughout the South-east and Midlands.



Ryman has invested significant resources on training its business machines staff to sell and support the FX9600T, which can be linked with a personal computer so as to send fax messages directly from the PC without first printing them out.

Ryman's marketing manager for business machines, Bob Thrower, commented, "We believe this machine breaks new ground at this price point and represents excellent value for money. It is ideally suited to both home and office use and our high street stores are the best possible outlet into the market for Amstrad."

OKI'S EXCEPTIONALLY OK

Around 1 million has been spent in promoting a new portable phone. It's the CDL 700E from Oki, and Martin Dawes Communications (MDC), the company who promoted it, say that the investment is paying off handsomely. Apparently, dealers and end users alike have found it to be a runaway best seller, praising it as the smallest, lightest phone listed at under £1000.

The selling price is, in fact, £699 excluding vat, and the phone is exclusively marketed by MDC. They say it is the biggest-selling phone handled by them to date.

"Customers know the price of the Oki and where to get it through our extensive advertising", comments MDC director Jack Holland. "And the dealer is making money, so everyone is satisfied."

COINING IT OUT

British Telecom is to phase-out 2p and 5p coins from its public payphones from June. The move is intended to further improve the reliability of payphones by reducing the number of faults associated with mechanical handling of coins. "The 2p and 5p coins represent only a small percentage of the value of coins used by our customers, but the volume of these low-denomination coins increases the likelihood of faults due to coin mishandling", said Graham Hanson, Manager of BT's national payphones service.

News of greater reliability of BT's public phones is always welcome. Welcome, too, is the news that BT has launched the best freephone service in Europe. Advanced LinkLine is a highly versatile service which, claim BT, will mean that no call to a Freephone 0800 number need go unanswered, whatever the day or time.

The service has been made possible by new technology in which BT has invested, and is the first implementation outside North America of the "intelligent network" concept.

OPTICAL CAR COMMS

Battelle are researching into the potential reliability of using optical fibre multiplexing networks for data transmission in vehicles.

Multiplexing permits transmission of several signals simultaneously on the same circuit or channel. Optical fibres reduce levels of electromagnetic interference allowing error-free signal transmission.

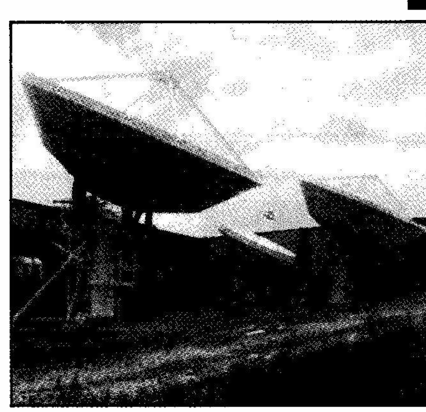
The programme should benefit manufacturers of vehicles, wiring harnesses, semiconductors, and optoelectronic component equipment. And drivers too we hope!

BSB UP AND COMING

Hot in from BSB as we go to press is confirmation that their tv satellite is in safe orbit and that all's well for their programme launch in the spring. The picture shows the BSB transmitting dishes at Chilworth.

BSB had intended to launch in September, but due to slippage in the development of the ITT D-Mac descrambling chip, they felt that too much time pressure would have been put on the systems integration phase of the project to achieve a polished autumn launch. The view was taken that it was better to be right than quick, and that the launch should be professionally done.

The company is now in discussion with McDonnell Douglas to bring forward the launch of its second satellite. The second rocket and satellite package is identical to the first and will provide 100% redundancy on all five BSB channels. PE



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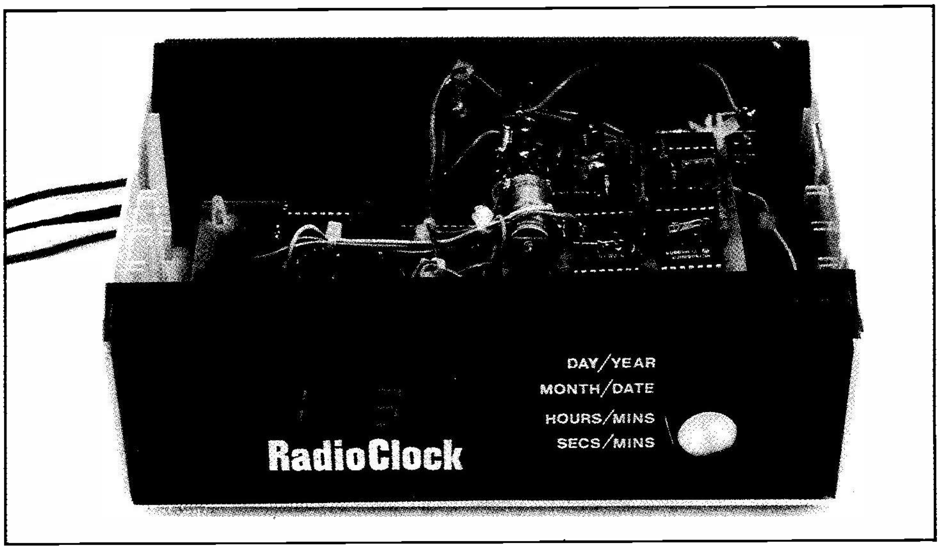
RADIO CLOCK

Part Two:
How, with the aid of a computer, some logical analysis and a few shifty considerations, John Becker registers and regularises Rugby time codes, and gives an insight into a designer's design techniques.



With the optional machine code program I gave last month, it was the computer which assessed the pulse length and determined whether it represented logic 1 or logic 0. In electronic terms, a similar function can be performed by using a monostable circuit whose period is set somewhat longer than the short pulse, but shorter than the long pulse. We can then examine the state of the pulse source at the end of the monostable period. If the source is low, then a short pulse has been received, conversely, if the source is still high then it's a long pulse being received.

DUAL MONOSTABLE

In fact, I use two monostables in the pulse length extractor, as you will see in Fig.13. The first, around the twin NOR gates IC3a and IC3b, serves as a gate to allow only one pulse to be reacted upon for the duration of its active state.

The high going pulse from IC2c comes into IC3a whose output is then triggered low producing a negative-going pulse across C12. In response, the output of IC3b goes high, as does the second input of IC3a. Consequently, further changes in the signal from IC2c will have no further affect until IC3b reverts low at the end of the set period. The rate at which C12 recharges via R15 determines the period, and in this instance is set for around 500ms. Once the level on C12 rises above the threshold point, the output of IC3b will revert to its normally low condition.

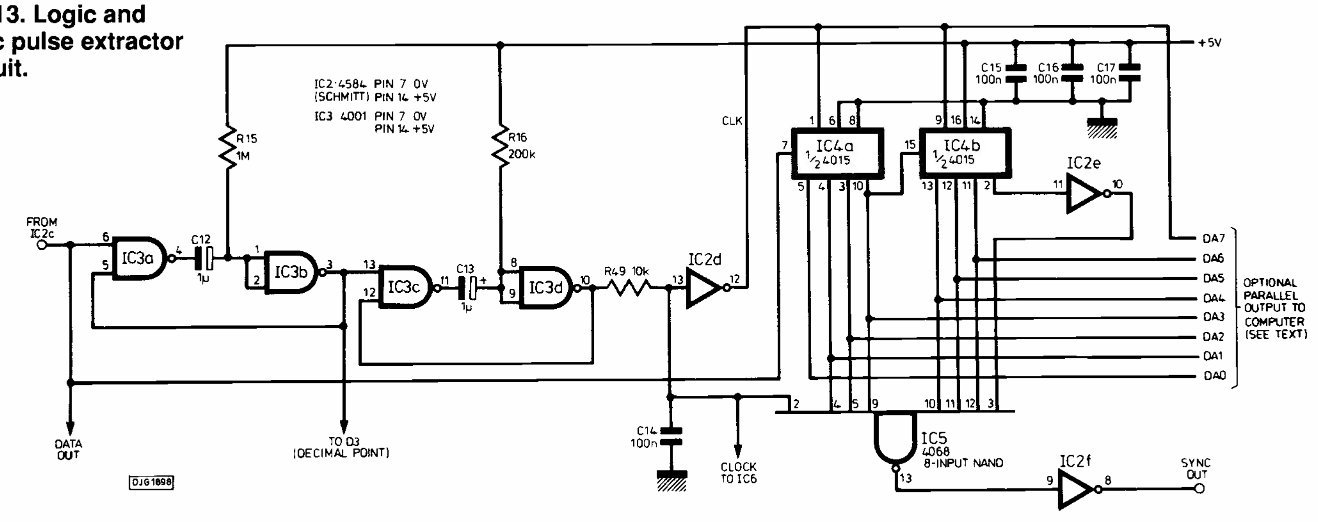
Simultaneously with the initial pulse triggering IC3a/b, the monostable around IC3c/d is similarly triggered. From that moment the action of the second monostable is independent of the first one. The timed period on this section is set by C13 and R16, to about 150ms. This period is selected to be longer than the 100ms duration of a short pulse, but shorter than the 200ms of the long pulse.

The output from IC3d is now used as the clock signal controlling subsequent decoding operations. First, it is passed to the Schmitt inverter IC2d via R49 and C14. The latter two components were found to be necessary to eliminate an occasional, and undesirable double pulse generated as the second monostable reverted to its normal state.

SYNC SHIFT REGISTER

Two 4-bit shift registers, IC4a and IC4b, are coupled together in the first stage of detecting for the sync pulse marker. The data signal is the pulse taken direct from IC2c to IC4a pin 7. When the output from IC2d reverts high after the end of the timed period, and at the moment of transition, it triggers the clock inputs of both shift registers. Each stage of the registers takes on the logic state of the prior stage, which in the case of the input at pin 7, is that of the data line. If the data is high at the moment the register is clocked, logic 1 is fed in; if it's low, then logic 0 is registered.

Fig 13. Logic and sync pulse extractor circuit.




```
100 DIMA(100),T(100),M$(12),N$(16),S$(70):PRINT"♥"TAB(5)"RUGBY CLOCK PROGRAM"
110 IN=59457:DRT=59459:POKEDRT,0:DN$="SQQQQQQQQQQQQQ"
120 A$="21152515260130073203361539074103451548075215"
130 FORA=1TO44STEP4:B=VAL(MID$(A$,A,2)):A(B)=VAL(MID$(A$,A+2,2)):NEXTA
140 N$="0123456789":FORA=1TO10:N$(A-1)=MID$(N$,A,1):NEXTA
150 C=0:FORA=0TO6:FORB=0TO9:S$(C)=N$(A)+N$(B):C=C+1:NEXTB:NEXTA
160 M$="???JANFEBMARAPRMAYJUNJULAUGSEPOCTNOVDEC"
170 D$="SUNMONTUEWEDTHUFRISAT???"
180 B=0:FORA=1TO39STEP3:M$(B)=MID$(M$,A,3):B=B+1:NEXT
190 B=0:FORA=1TO24STEP3:D$(B)=MID$(D$,A,3):B=B+1:NEXT:GOTO240
200 B=A:A=PEEK(IN):K=K+1:IFK>99THEN220
210 IFA=BOR(AAND128)=0THEN200
220 D=D+1:PRINTDN$TAB(20)S$(D):K=0
230 IFA<>254ANDD<>60THENT(D)=AANDA(D):GOTO200
240 PRINTDN$TAB(5)"TIME    "N$(T(41))N$(T(45))"  "N$(T(48))N$(T(52))
250 M=T(26)*10+T(30):IFT(39)>7THENT(39)=8
260 PRINTLEFT$(DN$,8)TAB(5)D$(T(39))"     "N$(T(32))N$(T(36))"  ";:IFM>12THENM=0
270 PRINTTAB(10)M$(M)"     19"N$(T(21))N$(T(25))
280 IFD<>60THENPRINT:PRINTTAB(5)"SIGNAL ERROR":D=0:R=R+1:PRINT"S"R"■ ":GOTO200
290 PRINT:PRINTTAB(5)"                    ":D=0:GOTO200
```

Fig 14. Experimental Rugby decoding program written in Basic

The sole function of IC4 is to shift the data through, feeding its outputs to an 8-bit NAND gate, IC5. During the entire Rugby transmission sequence, it is only the minute marker that can ever produce a code of 01111110, decimal 126, and it is this code for which the sync gate must look. However, the NAND gate must receive binary 11111111, decimal 255 before its output responds. To achieve this condition, outputs 2 to 7 of IC4 (pins 4, 3, 10, 13, 12 and 11, respectively) are used as the potential source of the six logic 1s. Output 8 (pin 2) is inverted by IC2f so that the final logic 0 is seen by the gate as logic 1. The remaining bit required by IC5 is the positive going level of the clock pulse via R49.

At the moment IC5 recognises decimal 255, its output goes low, causing the output of inverter IC2f to go high. As you will probably notice, the transition occurs at the start of second number zero. It is to this instant that all remaining functions are synchronised.

We have now reached another crossroads at which we have a choice of action, that of either using the decoder and display circuit yet to be described, or of using a computer and a control program written in Basic. Before we examine either option, let's see what essential decoding requirements have to be met.

DECODING REQUIREMENTS

Understandably, those who established the protocols for the Rugby time data transmission chose to keep the number of bits transmitted to a minimum. The number of bits and their timed order were shown last month and you will have seen, for example, that the month units require four bits since all decimal numbers from 0 to 9 need to be expressed, from binary 0000 to 1001. The tens of months, though, only need one bit, expressing either zero tens or one ten, represented by 0 or 1 in both decimal and binary. Also, whereas year, month, date, hour and minute require two data blocks, one for tens and one for units, the day of the week only needs one block to represent all days from 0 (Sunday) to 6 (Saturday). These inconsistencies of block counts and lengths make decoding a little more complex than it would be if all parameters were all the same.

As some of you may have gathered from analysing the earlier machine code program, one way of extracting the data and catering for the inconsistencies, is to count each pulse following the sync marker, and use individual memory locations in which the data is assembled. There are 11 groups of data to be detected and thus 11 memory locations are needed. As each count is received, the associated data is allocated to the relevant memory location. In the machine code program the data was progressively built up at each location by shifting the previous data left by one place and then OR-ing it with the new data. All locations would be set to zero at the start of each minute cycle, thus containing binary 0000. Then, for example, for the tens of years relating to 1990, (ie, decimal 9, binary 1001) at count 17 the associated memory store would be shifted left (ASL) and OR-ed with the data received, in this case logic 1. The memory then contains binary 0001. At count 18 we shift left and OR with the next data, in this case 0, resulting in 0010. Similarly at count 19, resulting in 0100. At count 20, logic 1 is received, resulting in 1001 after ASL and OR. At count 21, the second memory location relating to year units is used, and a similar process follows. And so on through the full cycle.

DEFERMENT

If we were making use of the Fast Code referred to last month, the data would be decoded so rapidly that we could immediately show the results on some sort of display module. With the Slow Code we are using here, though, it takes a full minute to receive all the data and if we were to display it immediately it was received we would see any data change occurring long before the sync point, which could be highly confusing when quickly glancing at the display. Consequently, we need the display to show the data received prior to the last sync marker while we build up the new data currently being received. We thus need two sets of memory locations, one for data build up, and the other for data display. At the sync point, the contents of the temporary memories are transferred to the display memories, and the former reset to zero.

DECODING WITH BASIC

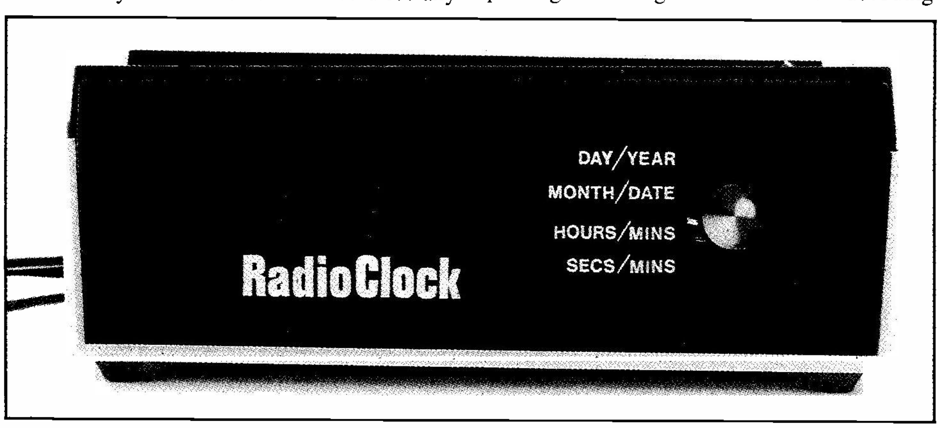
Last month's machine code program is fast enough to do all the logic level detection, data build up and transfer by tapping in to the primary data line from IC2c. A program written in Basic, though, is unlikely with most computers to be fast enough to perform the same functions. However, now that we have a pulse length extractor, around IC3, and a hardware OR function in the form of the shift register IC4, we can write a Basic program that is fast enough to do the remaining decoding and display. Fig.14 shows such an example.

As with the machine code program, the Basic program was written for a computer with a parallel in/out port having its input register at decimal 59457, and its data direction register at decimal 59459. These location numbers will need changing to suit your own machine. Minor Basic dialect differences may also need to be catered for, in particular DN$ which represents "clear screen" followed by 13 "cursor downs" for vertical tabbing purposes.

After having first set up the various parameters, the program then simply loops and reads the output of the shift register, looking for changes on line DA7, the clock signal, and for decimal 254, the sync marker. Each time the clock signal changes, the shift register data is stored in memory at the allocated temporary address. On receipt of the sync signal, the data is then transferred to the display memories, in this case the screen itself.

HARDWARE INTERPRETATION

Both programs were written largely for my own intellectual amusement (!) but also served a practical secondary purpose, of proving the logic behind the decoding



requirements. Following that proof, the next thing I considered was how to use dedicated electronics to perform a similar function to the computer routines.

When designing any circuit there are usually many ways in which the job can be accomplished, and Rugby decoding is no exception. In excess of 20 methods were apparent and which were committed to paper as theoretical possibilities. There were four design criteria that I wished to meet: the circuit should be readily understandable by the majority of PE readers; it should be capable of comparatively easy checking, stage by stage, so also giving it wider readership appeal; the readout should be on four multiplexed led displays, thus minimising the cost of the displays, and also keeping down power consumption; the components should be readily available and relatively inexpensive.

For more experienced constructors, the use of a microprocessor would be the obvious

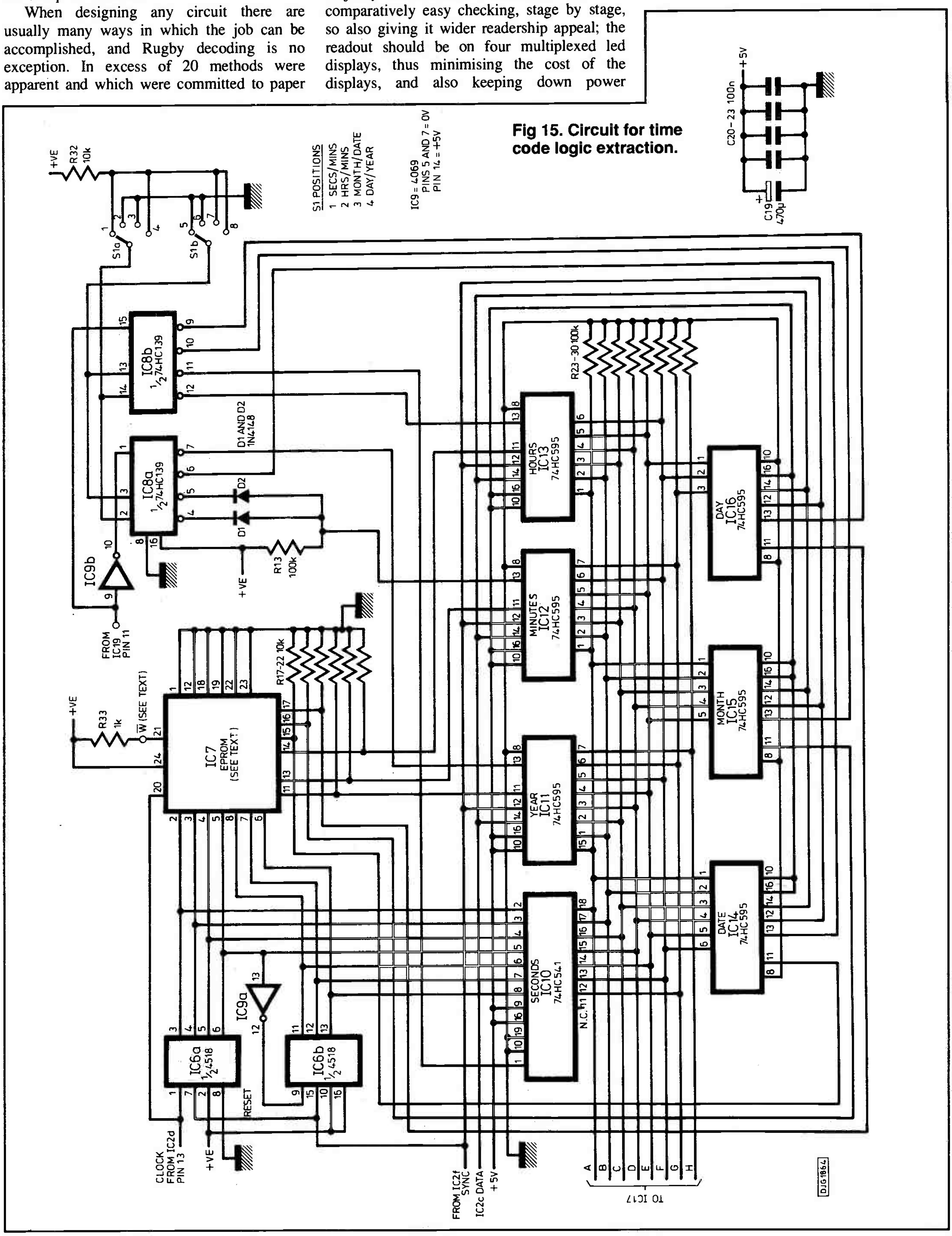


Fig 15. Circuit for time code logic extraction.

choice. This method, though, was decided against so as to give those readers not yet familiar with microprocessors the opportunity to also build the clock. Of the other options available, I examined various methods for temporarily storing the received data followed by transferring it to display memories. In several of these, two or three counters and two or three sets of memory locations were required, and the overall synchronisation needs made them less easy for inexperienced constructors to check. Apart from sync problems, the main area of thought was with regard to an easy method of separating the inconsistent data blocks into forms readily suited to multiplexed control.

The options were whittled down to two: to use several shift registers in series, clocking all the data through the chain, padding with extra zeros where appropriate to provide regular block formats; or to use several shift registers in parallel, accessing them each only during relevant moments of the count. This latter option is, of course, the one used in the programs described. (I had also written another program in order to check out the logic requirements of the serial technique.)

DECODING CIRCUIT

Fig.15 shows the final logic decoding circuit based on the parallel technique. In essence, it uses six shift registers, an eprom programmed to open and close them, a counter to control the eprom, and a multiplex controller selecting and routing the register outputs to a subsequent display stage. There is an additional stage (IC10) which allows the counter data to be fed to the display to show the seconds count.

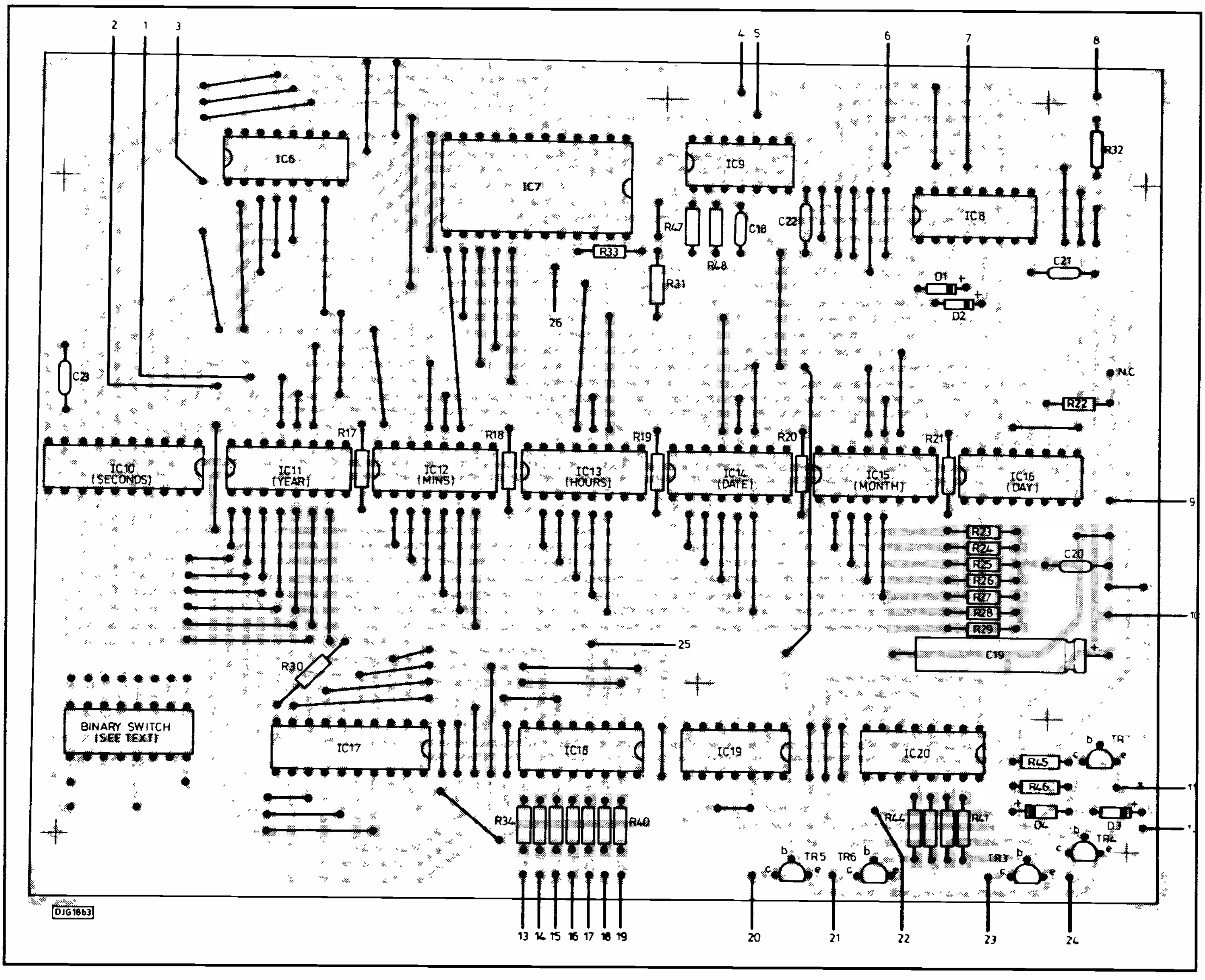
The controlling counter is IC6. It is a dual binary coded decimal (bcd) counter which is triggered by the clock pulse from IC2d. Its outputs become the source of the seconds count data display, and the address lines for the eprom. On receipt of each sync marker, the counter is reset to zero.

One shift register is used for each aspect of the time code: year, month, date, day, hour and minute. IC11 to IC16 are the registers and they operate in fashion similar to that for the sync detector IC4 in that they clock the serial data through, bit by bit, at each clock pulse from the eprom. However, unlike IC4, the resulting parallel output data is stored internally and is not passed to the output lines until a sync pulse is received. On receipt of this pulse the output lines take the internal data and hold it available for immediate output, and it remains unchanged until the next sync pulse. Between sync pulses, the internal data can be repeatedly changed without the output lines being aware of it. An additional function available on the registers used is that they have an output enable control. This allows the outputs to be opened or closed as required. In the closed condition they are at a high impedance and have no affect upon any other chips on the same connection lines; an obvious importance for multiplexing techniques.

EPROM CONTROL

The eprom is programmed so that each of the first six output lines controls one shift register, producing a positive-going pulse (logic 1) which clocks data into the register. Logic 1 is programmed to appear at the relevant output line corresponding with the register required at the particular point in the count cycle. The pulsing effect is achieved by

Fig 16. Component layout on the logic decoder and display driver pcb.



using the eprom's output enable control. When enabled, all the eprom output lines are opened, but when disabled the lines are held at high impedance. In order that the registers see this state as logic 0, the lines are held low via the grounded resistors R17-R22.

Each time the clock pulse from IC2d goes high, it triggers the counter forward one step, which sets a new address for the eprom. While the pulse is high, the eprom is disabled and all registers see logic 0 on their clock pins. When the primary clock pulse goes low, the eprom is enabled and any output line programmed for logic 1 goes high, triggering the corresponding register.

REGISTER OUTPUT MULTIPLEXING

We shall be using four led displays to show the data from two halves of two selected registers. We shall also be using only one binary to 7-segment decoder to process the four groups of data. As you will see, though, all the registers, plus the seconds count buffer (IC10), are all connected to the same eight data output lines. Thus we need to automatically and alternately switch open the outputs of either one of two registers.

I have arranged the routing so that the displays show seconds and minutes, or hours and minutes, or month and date, or day and year. The data routing is controlled by S1 and IC8, the latter being further controlled by an oscillator to be described shortly.

IC8 consists of two 4-bit data routing switches. Any one of the four outputs of either section can be selected, depending on a binary code presented to their control inputs. Either section can be turned on or off, again depending on another logic code.

S1 is wired so that one of four binary codes can be selected, in order of 10, 00, 01, 11. To select the month/date option, for example, S1 is switched to position 3, resulting in the selection of binary 01. This selects IC8 output lines at pin 6 and pin 10. The oscillator clocking signal is brought to the inverter IC9b; the non-inverted clock controls IC8b, and the inverted clock controls IC8a. Each section of IC8 is turned on by a low clock level, and off by a high one. Since the sections are controlled by opposite phase clock signals, they switch on and off alternately, so switching between the month and date registers.

Pins 4 and 5 of IC8a are taken via D1 and D2 to the minutes register IC12, so allowing minutes to be displayed in two switch modes.

DISPLAY MULTIPLEXING

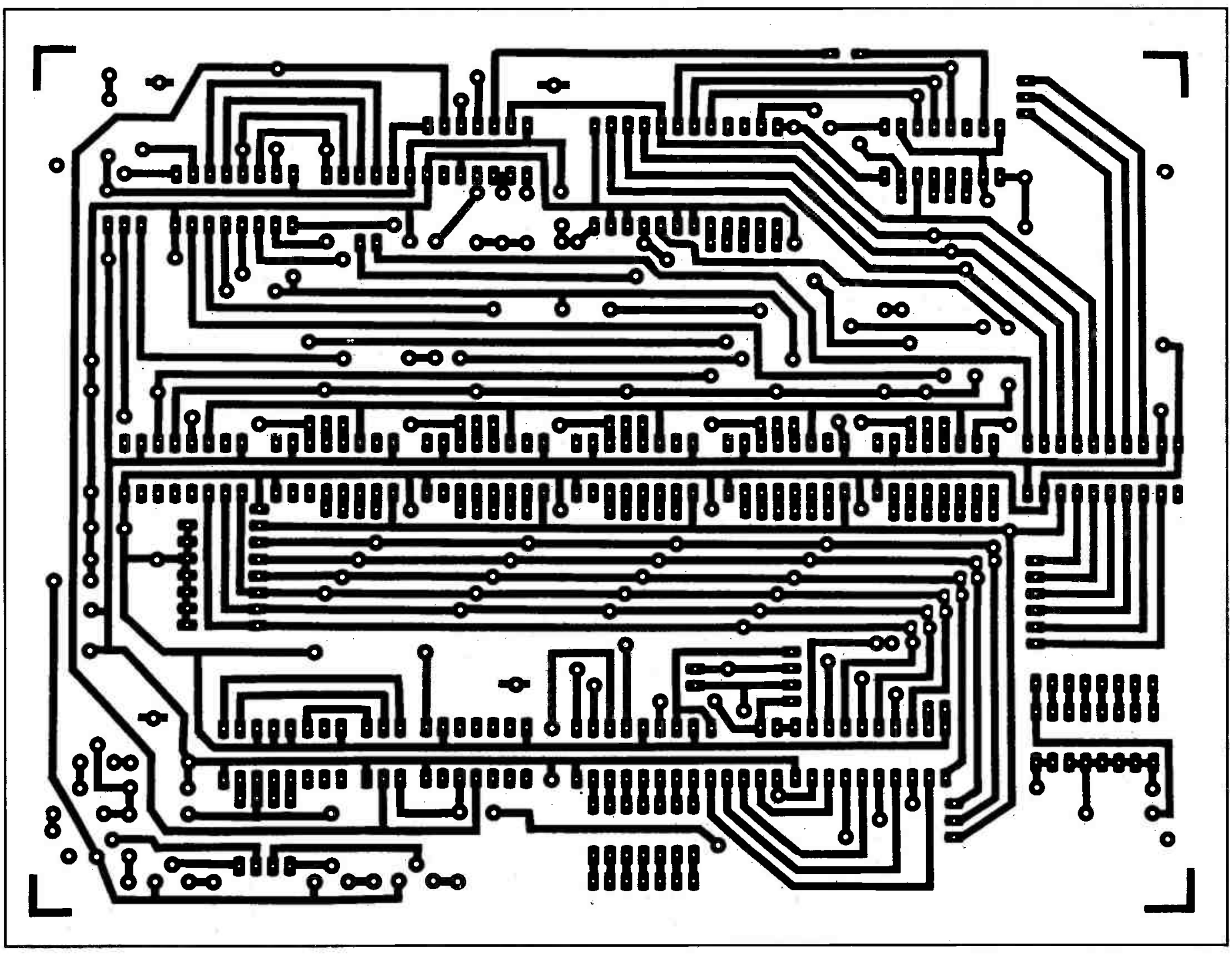
From the last example we now have the month's tens and units from IC15 alternating with the date's tens and units from IC14; four groups of data which we want to see displayed. Fig.18 shows the circuit that sorts out the visuals.

The display consists of four 7-segment led displays bought as a complete module, and arranged by the manufacturer for multiplexed viewing. The multiplexing allows for each 7-segment led to be turned on and off consecutively, so minimising the amount of power required, to about one quarter of that required to drive all four displays simultaneously. With a sufficiently fast rate of sequential switching, the eye is fooled into believing that all four displays are on at the same time.

The multiplexing also means that just one chip is needed to provide the necessary decoding from binary to a code suitable for driving the seven segments. IC18 is the decoder which takes a 4-bit binary-coded decimal input from which it produces an equivalent 7-bit output.

However, the data from the shift registers is in 8-bit format, consequently it has to be

Fig 17. Track layout for the decoder pcb. When copying ensure that IC pin spacing is 0.1 inch.



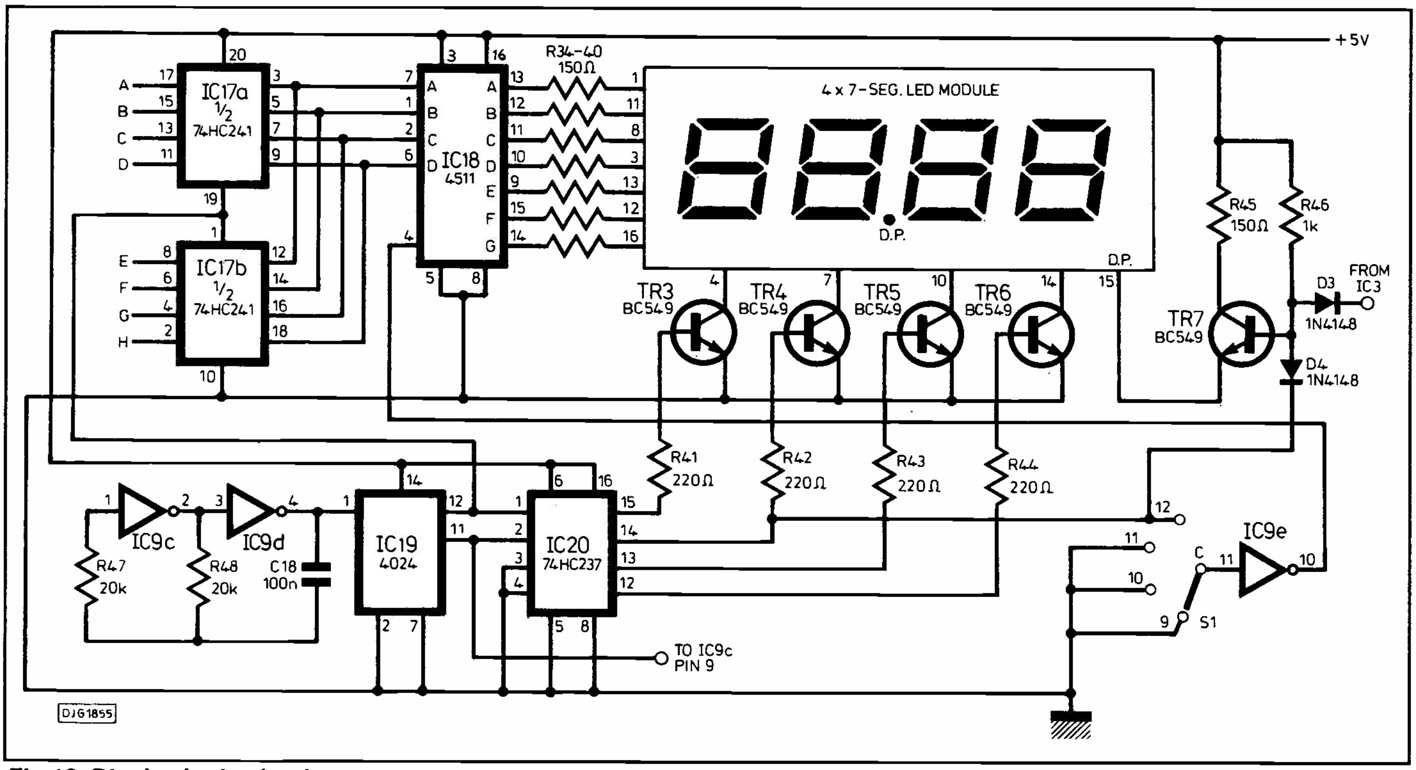


Fig 18. Display logic circuit.

split into two groups of 4-bits in order to be usable by IC18. IC17 is used for this purpose and consists of two 4-bit gates which can be opened or closed separately. Similar outputs from each section are coupled and feed into IC18. The input groups of IC17a and IC17b each take four bits of the 8-bit register code. The control inputs are designed for ready alternate switching, one requiring a high level, the other a low one, so they are coupled together and driven by the same clock signal.

MULTIPLEXING OSCILLATOR

The clocking oscillator is formed around the twin inverters IC9c/d, with the frequency determined by R48 and C18. The precise frequency is irrelevant as long as the eye is deceived by the rate at which the displays are switched. The oscillator is the source for clocking the led displays, the switching of IC17 and also the switching of the register selection controller IC8.

A single complete viewing cycle requires that each led display must be turned on and off once, each by its own control line; thus four separate actions. Each section of IC17 needs to be opened and closed twice during this time, thus two actions repeated twice. IC8 needs to open and close IC14 once, and also IC15 once, thus two actions needed once.

These separate, but synchronous requirements can be met by using a two-bit binary counter and another multiplexer. IC19 is the counter (it's actually a 7-bit counter, but only the first two bits are used) and it's driven by the oscillator IC9c/d. The first output bit controls the alternate switching of IC17a/b. The second output, which toggles once for every two changes in output one, drives IC8. Both outputs are also fed to the multiplexed selector IC20 which, as with IC8, opens up one of its output lines according to the binary code on its input controls. The control pins cycle through binary 00, 01, 10 and 11 opening up the respective outputs feeding to TR3-TR6.

The four transistors control the respective led display and are turned on in order by the outputs from IC20. Consequently, four oscillator pulses into IC19 achieve the cycle of four changes of the leds, two double switchings of IC17b, and the single switching between IC14 and IC15. The pattern remains the same irrespective of which pair of registers is selected by S1.

DECIMAL POINT

It's nice to see that the clock is counting even when the seconds are not being displayed. One of the four decimal points of the led module is used for this. So that the point flashes once per second, the basic control is from the output of IC3b, which you will recall, has a pulse output with a mark-space ratio of about 50%, ie, it's high for about 500ms each second.

Only one decimal point must be activated, so the output from IC3b must be ANDed with the respective control output from IC20. Had there been a spare AND gate available on the pcb, I would have used that, but since there wasn't, I used the transistor-diode configuration of TR7, D3 and D4.

BLANKING

When displaying day and year data only three of the leds are required, and in order to avoid visual confusion, I have arranged for the unused one to be blanked. The day numeral is shown on the first led, the next is blanked, and the third and fourth show the year (without the '19' prefix).

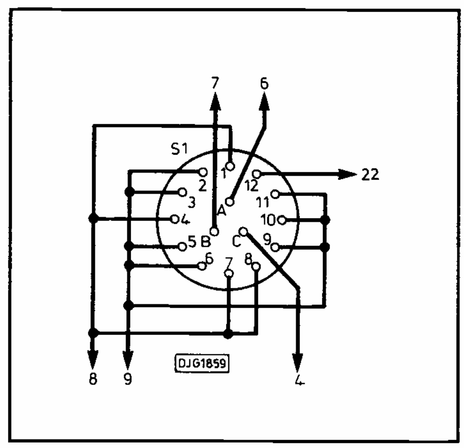


Fig 19. Switch wiring details.

The second output of IC20 is routed to the day/year position of S1c which, when selected, routes it for inversion by IC9e and then to the blanking input of IC18. In the remaining three switch positions, IC9e holds IC18 in the non-blanking mode.

ASSEMBLY

Figs.16 and 17 show the pcb component and track layouts. No special comments are needed, and there is no setting up to be done on this board.

Next month we'll conclude the project by examining the eprom data and its programming options.

PE

SPACE TV

Frank Mendacio updates us on the satellite tv eternal triangle.

PE readers following the saga of the satellite tv companies will have been pleased to learn of the recent successful launch of the rocket Prilistia from Cape Dominique in the Cayenne Isles. Prilistia (named after the Roman goddess of enlightenment) is the first rocket to be launched on behalf of ECOS (Euro-Cosmos Organisation Speciale), the organisation challenging Sky and BSB by offering Britain a third potential satellite tv system.

ECOS-1 was placed into a geo-ecliptic orbit with a tightbeamed altazimuth focus centred on Northumberland and it will ultimately cover an area including the Shetlands in the north, to the Channel Islands in the south.

To maximise the available channel space, co-channel tv signals will be multiplex-chopped and transmitted on the same basic frequency. Colloquially known as the zip-squeal technique, the result is that channel data is transmitted in brief 'packets' with a pause between them. Ground based reception equipment then decodes and allocates the packets to the correct tv channel.

Preliminary tests indicated that all on-board systems survived the rigors of liftoff, but engineers reported anomalies in the reception of test signals. Transmitting on just one test channel, it was expected that the pauses between this channel's signal packets would be totally free of data. This turned out to be far from the case, and for a reason that intrigued radio-astronomers as much as tv engineers.

In between the signal packets, the engineers became aware of periodic interference. Modifying the ground-based decoding/tuning circuits, and computer enhancing the signals, they established the nature of the interference. It was from a station transmitting old tv programs in their entirety, from films and soap-operas to news and current affairs, the latter particularly relating to the Falkland's conflict. The era from which the programs had originated was 1982, and the channel was BBC1. It was confirmed that the BBC had not sanctioned the retransmission of these programs and world-wide monitoring of all tv stations ensued to establish who was breaching international copyright law.

No such illegally-operating station could be located. Further examination of the pirate signals was undertaken, and it was found that the *ECOS-1* retransmission frequency was a harmonic of an American spy satellite frequency modulated by the old BBC 405-line transmission frequency. Enlisting the help of the Americans, *ECOS-1* and the spy satellite *Explorator* were reorientated in an attempt at rdf-triangulation. The results baffled the technicians. The source appeared not to be land-based, but from a direction in space where no known satellite was in orbit.

AD ASTRUM

However, the global positioning of *ECOS-1* and *Explorator* was too tight to establish the precise co-ordinates of the source. Radio astronomers in both hemispheres were requested to assist in the search. The aerials at Takaka in New Zealand, Bardney in Lincolnshire, and Prima Lirpa in Mexico were sufficiently displaced and powerful to pin-point the source. The astronomers immediately recognised the co-ordinates. They represented the precise location of Proxima, our nearest neighbour star. Further calculation established that the period between the original transmission and current reception was equal to twice the light distance of Proxima, approximately eight years. The evidence was too convincing to ignore, the source *was* Proxima.

Inevitably, the natural first question was, could this be First Encounter with other inhabitants of our galaxy? But truth is not always stranger than fiction, and the answer is far more mundane. *ECOS-1* is simply picking up very weak echo signals from Proxima, signals which were transmitted in 1982, taking a journey four years out, reflecting, and taking four years to travel back.

AD NAUSEAM

ECOS have declined to comment, but it seems possible that if they can overcome the periodic signal fading, they can intentionally pickup these eight year-old transmissions and beam them into our homes. Personally, I greet the thought with alarm; it's bad enough having films repeated ad nauseam, let alone having every program repeated eight years later. And if BBC1 programs are being reflected, what about BBC2, ITV, Channel 4, and all other channels world-wide? And worse still: if Proxima is reflecting tv, how about other more distant stars? Could we some day even be treated to a live repeat of Baird's first tv transmission experiment?

Frank Mendacio is the media correspondent for Tyme-Tees Television. Enquiries for further information on ECOS should be addressed to the PE Editorial office. PE

TRACK FEEDBACK

METERS, KNIGHTS AND PUPILS

Dear Mr Becker,

It has been a long six years since I last won anything. This has not escaped the attention of my female descendents : "the old man's losin' 'is touch", "you'll just have to admit it, dad, you're past it", and other such expressions of filial respect have been heard. But the tide now seems to have turned and I am writing to express my most grateful thanks for the receipt of the Cirkit multimeter, won in your 25th Anniversary competition. This will enable me once more to look fate, and my daughters (the same thing?), in the eye. And provide me with a most useful embellishment to my workbench. I look forward to many years of useful service from it. Provided, that is, that I can hide it from the young master, he who makes with the millimetric guides over in Edinburgh.

As a PE reader for more than 15 years, maybe even 20, may I comment on two points arising in the Feb 90 issue?

First: Sir Clive. Too much may be read into the straight award of a knighthood. Ever since the days of Imperial Rome when Augustus incorporated the equestrian order into his scheme of things the award has been more the expression of the needs, and philosophy, of the current administration rather than the qualities of the recipient. (Of course this excludes the genuine Orders of Chivalry such as Garter, Thistle, etc, but probably not Bath.) What distinguishes that man is his sheer *otherness*. I am on record as saying that anyone who purchased a Black Watch kit for a 16 year old on his birthday and went on to buy Sinclair again should be taken into care. I would be willing to repeat that anywhere. And yet here I am typing this letter into my QL. Despite my opinions of its idiosyncrasies (*stated in full, but given the blue pencil treatment! Ed*) there is simply nothing to replace it even now after all the years it has been going.

And that is the point about Sir Clive. If he had not lived, the world would have been that much less of an exciting place. But would there have been a corresponding reduction in reliability or in the quality of life? I think not.

Secondly: schooling of future engineers. I sympathise with your anxiety, and would agree entirely with most of your statements taken separately, but would suggest that there could possibly be an alternative logical framework within which they might be arranged to reach a different conclusion.

To me the first priority is that pupils should be taught by teachers who are committed to and fully conversant with their subjects. What those subjects might be is of secondary importance.

It is in the nature of things that the holder of a qualification in, say, Modern Languages, is likely to receive a lower level of reward in the great world outside than a Science or an Engineering graduate. That person is more likely, perhaps, to think of a career in education. It might be expected, then, that there would be more competition for posts on the arts than on the science sides of schools. Is this not saying that there is a possibility of a bias of quality in favour of the former? And, given freedom of choice, to which side would the better pupils gravitate? (I am, of course, speaking statistically, but funny things can happen when one combines several distributions, each of which may appear to have only a slight deviation from the norm. Especially in the real, non-Gaussian, world.

It has always seemed to me that Science and Engineering Faculties are shooting themselves in the foot, in *both* feet, by insisting on science/technology subjects in their entry qualifications. Mathematics, certainly, and the major national language, probably, should be expected. The particular specifications of the rest are not very important. Perhaps a higher level of attainment might be asked of candidates who offered Middle English Literature rather than Physics, but they should not face a total ban. In some cases the Institutions may feel constrained by a perceived need for their degrees to satisfy the requirements of particular professional bodies. Is such a feeling valid so far as entrance is concerned?

I speak as one who bluffed his way into an Engineering Faculty on the strength of his Latin and Greek (and I spent my last 28 years of full employment before premature retirement on the teaching staff of a University Engineering Department). By opting for the classics stream at school, not very many miles from your office, I was able to sit at the feet of the very best. And the most important thing that I acquired from them was not the knowledge of the particular subjects, although I shall always be grateful for that, but a rationale for learning such as is only to be had from top grade teachers. At University I used to sit there in the lectures lapping up strange new subjects like Physics and Chemistry (ugh!) among struggling friends who had "done it all at school", but who were completely lacking in the intellectual equipment to take any additional information on board, often unable even to recognise that is *was* additional.

Perhaps all that I am suggesting is proper resource management approach. Thank you for listening.

Philip Tanner, Glasgow.

Thank you for your most interesting comments. I feel sure that many readers will recognise several aspects to which they can relate with regard to their own education and subsequent outlook on life. Hopefully, some of them may care to offer their own opinions about current attitudes towards technology and education. ***Ed***

REJUVENATION

Dear Sir,

Please be patient with a pensioner! Although I never cease to be thrilled to the bone by PE, nevertheless a lot of it is, alas, well above my head. The days when, after war service, I made a six inch tv set out of radar disposal stuff (and excellent it was) are long past.

But my aging cells became revitalised when I heard on the radio an old '78' record which had been electronically 'rejuvenated' so that it sounded wonderful.

Does my memory trick me when I think I remember such a circuit being in a back number of PE? I feel that the happy task of building such a project would give me a great deal of rejuvenation as well!

Congratulations and blessings on your work,

Cyril Craske, Cadishead, Manchester.

The record rejuvenation would have involved the use of some extremely sophisticated computerised equipment the likes of which are beyond the scope of PE's constructional projects. PE did, however, publish an article by The Prof (alias Robert Penfold) on click eliminators in PE Oct 87. Robert illustrated this article with some circuits that you might find useful to explore further, and which will go some way to 'cleaning up' old recordings. (Although at the end of the article Robert said he might offer a full constructional project on the subject at some future date, he's been too involved in other areas to follow up the suggestion.) ***Ed***

HORTICULTAERIALS

Dear Ed,

I refer to the "*Bananarama Aerials*" correspondence in PE Jun 89.

My late second cousin, when a radio amateur in the 1900s, experimented with tree aerials and later, when I was boy in pre WWII days, introduced me to using these as receiving aerials as a fascinating subject. I still have his 1922 Radio Experimenter's Handbook which contains a two-page article on the subject, and which, or course pre-dates your correspondent's reference to 1961.

I would stress that such tree aerial experiments call for extreme caution in respect of safety and only battery-operated radios should be used with such arboreal antennae. Even tvs and radios running from mains isolating transformers might present earth potentials with respect to trees which are, in effect, outside the 'earth frame' of the house. Any experiments with such aerials must not be undertaken in bad weather, especially in thunderstorms.

D.E. Stiles, Bellingdon, Bucks.

Many thanks for the caution offered to potential experimenters, and for the photocopy of the 1922 article. The reference to US Army experiments during World War I is particularly interesting. It seems likely that the idea of trees as aerials could well turn out to be as old as radio itself. ***Ed.***

SILVER PLATED PE

Dear Ed,

Since your anniversary year has just been celebrated, I thought it would be relevant to tell you about a recent observation.

While passing through a nearby village, something about the 'personalised' number plate on a parked car caught my attention. On closer inspection I saw it read '25 PE'. Your car, perhaps, or that of a very avid reader?

John Young, High Wycombe, Bucks.

No, not mine, though my plate is partially personalised. I had a choice of numbers from which I could choose, though not of the letters. The choice ranged from 300 to 350, and I chose '324' since this is the number of an opamp for which I find frequent use!

PE is also celebrated vehicularly near where I live, though. I quite often see 'PE 1' driving in the district. Reminds of the observation I made in PE about year ago, regarding how most of the boats in Poole harbour have their numbers prefixed with 'PE'. ***Ed.***

AIR IONISERS

By means of points raised to a very high voltage, ionisers re-structure the air you breathe, turning ordinary air molecules into potent negative ions. The effects of breathing in these ions can be quite startling. Almost everybody reports that it makes them feel good, and there is now strong evidence that it can also improve your concentration, make you more healthy and alert, make you sleep better, and even raise your IQ.

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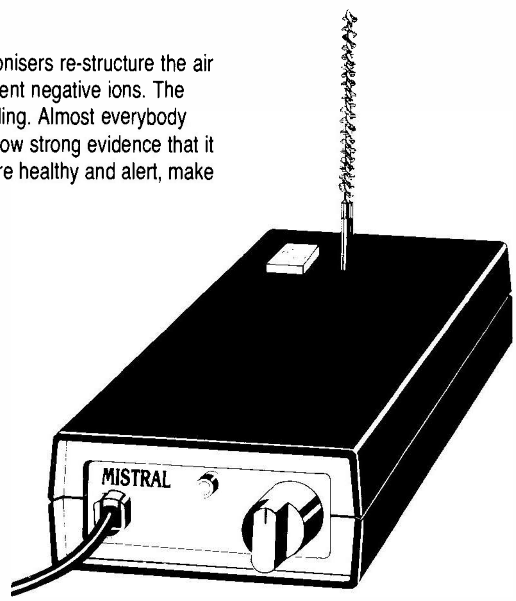

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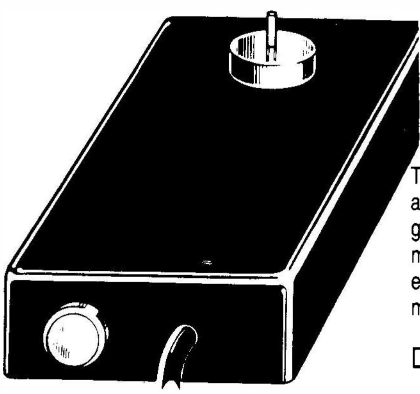

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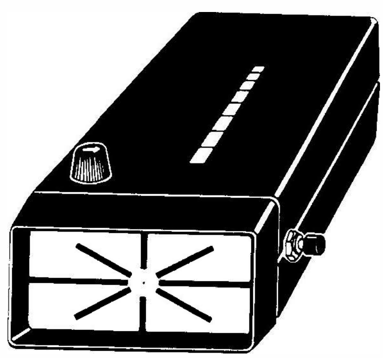


IONISER EXPERIMENTS

* The Vanishing Smoke Trick

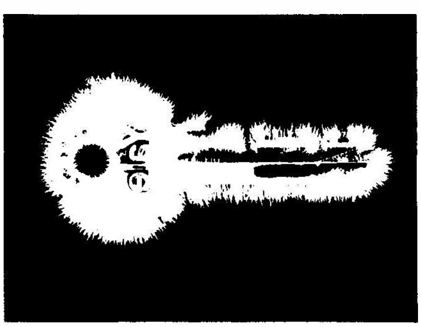
Light up a cigarette and gently puff smoke into a glass jar until the air inside is a thick, grey smog. Carefully invert the jar over the ioniser so that the emitter is inside. Within seconds the smoke will vanish! This is one of the best demonstrations of an ioniser's air cleaning action and with a large jar the effect is quite dramatic.

* Triffids

Connect a length of wire from the ioniser emitter to the soil in the pot of a houseplant. One with sharp, pointy leaves is best. Hold your hand close to the plant and the leaves will reach out to touch you! In the dark you may see a faint blue glow around the leaf tips – this works better with some plants than with others, so try several different types. The plants don't object to this treatment at all, by the way, and often seem to thrive on it.

* The Electric Handshake

Wear rubber soled shoes. Touch the ioniser emitter for a few seconds until your body is thoroughly charged up. When your hair stands on end, that's just about enough. Then give everyone you meet a jolly electric handshake. Just think, you could lose all your friends in a single evening! (A meaner trick still is to charge up a glass of water or a pint of beer. Even your family won't speak to you after that!)



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Our Kirlian photography set contains everything you need to turn the Mistral into a Kirlian camera, your bedroom or spare room into a darkroom, and to expose, develop and print Kirlian photographs (photographs made with high voltage electricity instead of light). The set includes exposure bed, safelight bulb, developing and fixing chemicals, trays, imaging paper and full instructions. A Mistral ioniser parts set is also required.

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Your Ed looks at some of the new books recently received.

Electronic Engineers Reference Book - 6th Edition. F.F.Mazda. Butterworths. £85.00. ISBN 0-408-00590-4. Very definitely a book that should be on the bookshelves of any professional electronic designer. The true value of this book far outweighs the initial cost of purchasing it. With pages measuring 10 x 8 inches, the book is 2.5 inches thick and has several hundred pages (total unknown due to categorical numbering system used), and is liberally illustrated with over 1200 line and tone drawings. It gives comprehensive coverage of all aspects of modern electronics, has been written by more than 60 expert contributors, and is edited by an enthusiastic, reliable and well-respected editor. Now in its sixth edition, this highly regarded book is split into five main parts, techniques, physical phenomena, materials and components, electronic design and applications. The new edition includes new chapters on surface mount technology, hardware and software design techniques, semicustom electronics and data communications. It has also been updated throughout, to take into account recent changes in standards and materials, and advances in techniques.

Practical Transformer Design Handbook - 2nd Edition. Eric Lowdon. Tab Professional. £32.20. ISBN 0-8306-3212-3. The author has taken a broad approach with this book, giving it appeal to most categories of interest, whether that of circuit designer, laboratory technician, experimenter, amateur, hobbyist, electrical science student or teacher. Although the book contains material at professional and academic levels, it is essentially a practical how-to-design-it book, constructed on a substantial but simple how-it-works frame. The book should not be regarded as an itemised projects book, since constructional data is dealt with in broad, general terms. Rather, it deals with the methods used in designing transformers to meet one's own specific needs. There are over 400 pages, with 17 chapters covering the entire subject, including the symbols used, elementary electromagnetics, transformer properties, windings, designing, constructing, selecting, testing and measuring. A final chapter looks at the properties and future expectations for superconductors. I very much welcome this book to my own library and recommend it to anyone seriously interested in transformers.

The Master Handbook of IC Circuits - 2nd Edition. Delton T. Horn. Tab Books. £23.65. ISBN 0-8306-3185-2. Here's a book to delight any true electronics enthusiast, and it's also one which may well find use in school classrooms as a source of fundamental circuit ideas. Over 500 pages are packed with a very wide selection of simple-to-build circuits for an extensive selection of purposes. Virtually meriting the title of Encyclopaedia, the book contains nearly a thousand different circuits, using more than 200 popular ics. The author has updated this edition to make use of some more recent ic designs, dropping some circuits from the original edition where ics have become obsolete. The lack of circuits relating to the newer ics such as those in 74HC series does not detract from this book's usefulness. There are seven parts to this interesting manual, covering opamps, linear ics, regulators, cmos, ttl, radio and tv ics, and special purpose ics. Although an American book, readers should not experience any difficulty in obtaining the majority of the ics listed.

Basic Electronics Theory - 3rd Edition. Delton T.Horn. Tab Books. £20.90. ISBN 0-8306-3195-X. I am becoming very impressed by the prolific and authoritative writing styles of Delton T. Horn. Here is another of his books which should find favour with those looking for instructional information regarding electronics theory. Indeed he covers some aspects which to date I have not seen covered in some equivalent books from other authors. This book is written as a teach-yourself, test-yourself manual, with many experimental projects backing up the informative texts, and each chapter having a section of self-test questions. There is good emphasis on semiconductors and the book is liberally illustrated with a wide variety of interesting circuit examples. In updating this 3rd edition, the author has introduced some additional areas previously uncovered, including electronic fundamentals, circuit analysis, reading diagrams, tips on building and experimenting, microprocessors and related digital ics. Although the price may seem a bit high for someone newly becoming interested in electronics, it is a comparatively small price to pay for the amount of detail offered.

Fundamentals of Pattern Recognition. Monique Pavel. Marcel Dekker Inc. US $107.50. ISBN 0-8247-8025-6. First, I must say that it's difficult to understand how the publishers expect this book to find a market in Britain when it's only available from the USA and the price is only quoted in dollars. However, perhaps those sufficiently interested will not be off-put by the inconvenience (or by the price). It appears to be a highly esoteric book and is greatly concerned with the mathematics of pattern recognition theory. The publishers say that the book contains new approaches and many original results developed by the author, and highlights mathematically the close connection between pattern recognition, robotics and artificial intelligence, providing conceptual understanding of pattern recognition and pointing out areas that need further research. This is not a book that will satisfy casual interest.

101 Optoelectrical Projects. Delton T. Horn. Tab Books. £16.30. ISBN 0-8306-3205-0. Circuits that flash lights in various ways will always find widespread appeal, and I am sure that this book will find a ready market amongst readers of all capabilities, from novice to grandmaster! But there is more to this book than just showing how to be flashy, it also shows ways in which light can be used to control other functions. Optoelectronics has practically become an industry in its own right, and much of modern communications relies heavily on the use of light for transmission purposes. This book will help you to understand some of the technology relating to this important field. It is split into two sections. The first deals with components, and looks at photocells, photoresistors, phototransistors and related devices, light emitting devices, including incandescent lamps, leds, multisegment displays, laser diodes and lcds, optoisolators and fibreoptics. Part two forms the majority of the book and is concerned with practical projects, 102 of them (101 plus a bonus!). The categories cover power supply projects, control circuits, sound and audio circuits, led flashers, test equipment and measurement devices, games, communications, photography and light meters, counters, and a selection of miscellaneous projects. Yes, it's an interesting and useful book.

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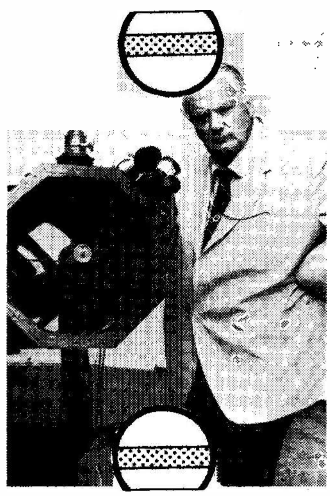
SPACE WATCH



BY DR PATRICK MOORE CBE

The Castle has closed its doors but the HST promises to further open our understanding of the Universe.

Sadly, we have now come to the end of the story of the Royal Greenwich Observatory at its Sussex home, Herstmonceux Castle. Against the advice of every astronomer in the country, the Science and Engineering Council, which controls the finances, has closed it down and transferred the RGO to an office block at Cambridge. The Castle itself has been sold to a developer, and will be turned into a hotel. The astronomers vacated the main Castle in 1989, and they have now made ready to leave the West Building as well.

The decision to abandon Herstmonceux will certainly be regretted; it is a major blow to British astronomy. We can only hope that at Cambridge the Royal Greenwich Observatory will be able to preserve its separate identity, at least for a while.

Things are different in Denmark, where the largest planetarium in Western Europe has just been opened. It is named in honour of Tycho Brahe, the most famous of all Danish astronomers, and it is the most modern in the world, with a dome 75 feet in diameter. The finance was raised by a Copenhagen baker, Mr Helge Pedersen, and his wife Bodil. It is hoped to draw more than 400,000 visitors per year; if you happen to be in Copenhagen, do not forget to go and see it.

A very interesting discovery has been made in China - that of what seems to be the earliest Chinese star map, dating back over 2000 years. It was found near the ancient Imperial capital of Xian during construction work at the local University, and is believed by archaeologists to be on the ceiling of the tomb of Sima Qian, court astrologer to the Emperor Wu Di. Of course, the Chinese constellations were not the same as ours; they had no Great Bear or Orion, but they did have a Cat and a Hippopotamus!

A probe to the planet Pluto has been proposed by Robert Farquhar, of NASA. This would be launched in 2001, and would use 'gravity assist' from Jupiter, reaching Pluto in 2014. At the moment Pluto is at its closest to the Sun - it passed through perihelion last autumn - and it has a detectable atmosphere; but as it moves outward, this atmosphere may condense on to the surface, so that if we want to study it we do not have a great deal of leeway. The critical year is indeed 2001, when Jupiter will be suitably placed to help us. The cost of such a Pluto probe would be of the order of 200,000,000 dollars, which seems a great deal until one compares it with the cost of a nuclear submarine or a Stealth bomber.

HUBBLE SPACE TELESCOPE

This month should, at long last, see the launch of the HST or Hubble Space Telescope. But for the Challenger disaster, it would have been in orbit several years ago: it has had to be kept in readiness, but now, at last, the signals are set for 'go'.

On October 28 last year the telescope was 'powered up' for the first of its tests to make sure that it is ready for flight. Since then it has been at Cape Canaveral, awaiting the moment when the Shuttle will launch it into space.

The HST has a mirror 94 inches in diameter. By today's standards this is no more than medium size, but from its vantage point above the shielding atmosphere the HST should be more effective than any telescope on the surface of the Earth can possibly be. Not only will the 'seeing' be perfect all the time, but there will be no blocking-out of radiations, whereas on the Earth's surface there are only limited 'windows' through which radiation can pass.

The HST will be used for observations of all kinds, including studies of bodies in the Solar System, but of course its main function

THE MARCH SKY

This is the month of the equinox, which falls on March 20. Do not forget that Summer time begins on the 25th, so that we will then be one hour ahead of GMT. At the moment, discussions in Parliament are going on to decide whether we should fall into line with Europe and leave our clocks on Summer Time during the winter, and Double Summer Time in the summer. There are pros and cons; it may be depressing to get up in the dark, but at least one can play tennis at midnight, as I remember doing when I was once on leave from the RAF during the war!

Mercury is to all intents and purposes out of view, but Venus is still a brilliant object in the morning sky, though unfortunately it is well south of the celestial equator and does not rise until about an hour before the Sun. It reaches its greatest angular distance from the Sun (46^{o}) not he 30th, and should then be at half-phase, but as telescopic observers know - half-phase or 'dichotomy' is always slightly late during morning elongations, so that we may expect actual dichotomy in early April.

Mars passes into Capricornus, and is a morning object, but not yet brilliant. Jupiter, in Gemini, continues to dominate the evening sky until well after midnight; owners of binoculars may care to look for its four large satellites, while telescopic observers will be anxious to see whether the Red Spot is regaining its prominence. Saturn is visible just before dawn to southern observers, but we in Britain can forget about it until the late spring.

There are no eclipses this month, and no major meteor showers, but we may well have a bright comet - discovered by the Australian amateur Rodney Austin. It is moving north, and becoming quite prominent. In fact, Austin's Comet may prove to be the best for more than a decade, though comets are always unreliable things, and one never knows!

Orion is rapidly being lost in the evening twilight, while Ursa Major, the Great Bear or Plough, is almost at the overhead point. Follow round the curve of the Bear's 'tail' and you will come to Arcturus in Bootes (the herdsman), which is actually the brightest star in the northern hemisphere of the sky; its only three superiors - Sirius, Canopus and Alpha Centauri - are all in the south.

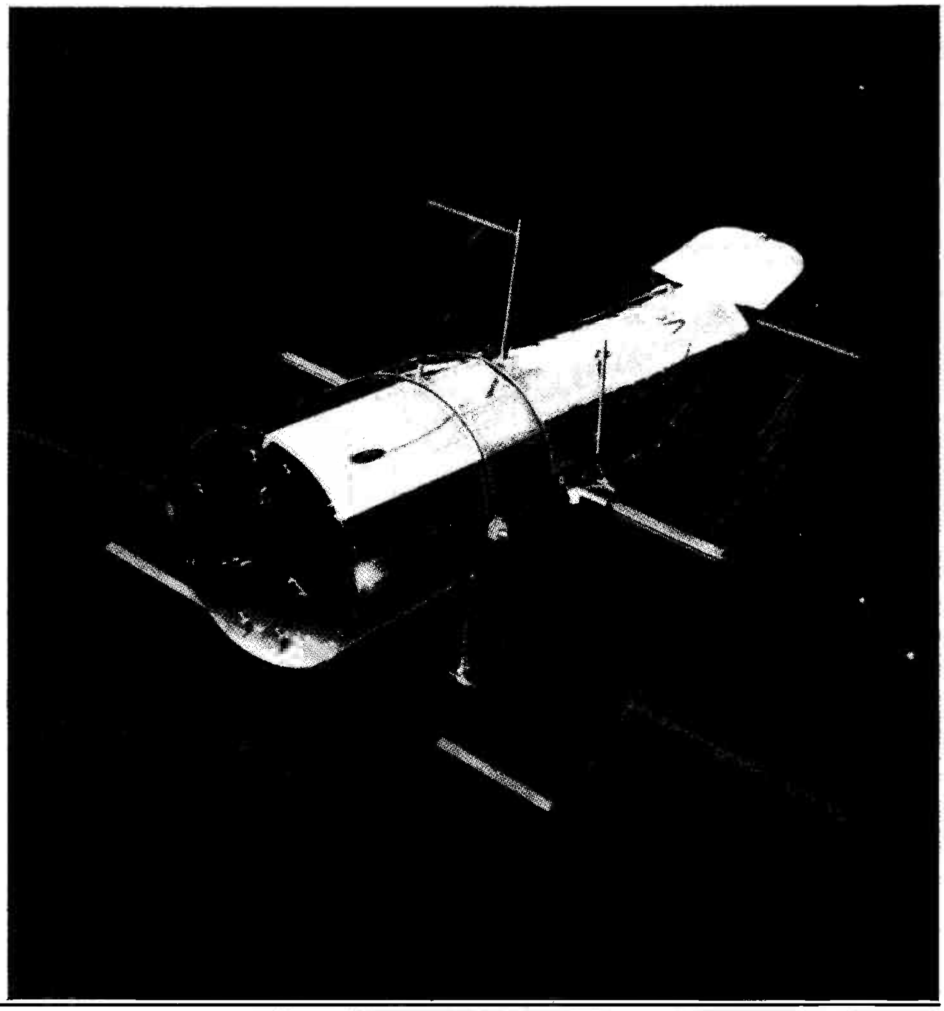
The main spring constellation is Leo (the Lion), now high in the south after dark. There is no problem in identifying the curved line of stars marking the so-called 'Sickle', of which the brightest member is Regulus; simply use the Pointers in the Great Bear 'away' from the Pole Star instead of toward it. Much of the southern aspect is occupied by the large but rather faint constellation of Hydra (the Watersnake) to find its only brightish star, the orange-red Alphard, use the Twins, Castor and Pollux, as direction-indicators.

will be to extend our probing into deep space. At the moment, the holder of the distance record is the quasar PC1158 +4635 in Ursa Major, which has a red shift of 4.73, and whose distance may be as great as 14,000,000,000 light-years - assuming that the red shift really is a pure Doppler effect, which is questioned by some modern leaders of cosmological thought. On the conventional picture, this quasar is receding from us at more than 90% of the velocity of light. If the rule of 'the further, the faster' holds good, we will eventually reach a distance at which an object will be receding at the full speed of light; we will then be able to see it, and we will have come to the boundary of the observable universe.

This is where the HST will help us. Operating from above the atmosphere, it may - it is hoped - be able to penetrate to these extreme distances, and tell us whether or not our current theories are in need of drastic revision.

There is only one Space Telescope, and everything depends upon a successful launch. By this time next month, we ought to know. So let us wish the HST all success.

PE



Artist's impression of the Hubble Space Telescope orbiting in space 370 miles above the Earth. The HST is 43 feet long, 14 feet in diameter and weighs 25,200 lbs. Illustration by courtesy of Lockheed Missiles and Space Company Inc.

BASIC ELECTRONICS

BY OWEN BISHOP

Part 4 - Understanding the elementary principles of why semiconductors function the way they do, and why they need to be doped first.

Before we put your brain cells to work, let's give your hands and soldering iron a bit of action with a couple of Modules and a System to build.

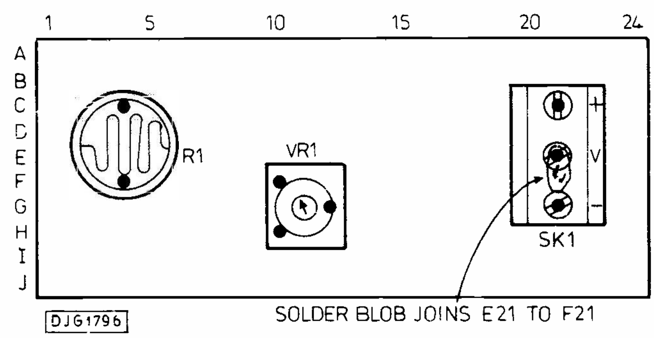
MODULES OF THE MONTH

***Module 4** - Light level sensor*

The module consistes of an ldr (see *Investigation 2*), in series with a s variable resistor. Since these act as a potential divider, and since the resistance of the ldr decreases as light increases, the output of the module (V) increases with increasing light. The variable resistor allows you to set the output voltage equivalent to a given light level (Fig. 1).

Parts required: R1 ORP12 (or similar) light-dependent resistor; VR1 sub-miniature horizontal preset resistor, preferably with small knob as shown; SKT1 3-way PC terminal; stripboard 63mm x 25mm (Vero 15354).

Fig 1. Module 4 - light level sensor layout.



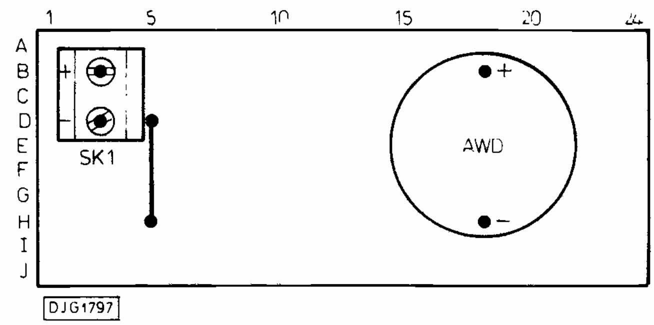
***Module 5** - Audible warning sounder*

The audible warning device, sometimes called an 'electronic buzzer', is a solid state piezo electric device. This module provides a way of connecting it to a system. This could be done more simply by soldering leads to it, but the advantage of mounting the device on the board is that a louder sound is produced. (Fig. 2.)

Note that the device has a positive and a negative terminal and must be connected the right way round. The drawing shows the type that has a cylindrical case, with terminal pins for mounting it on pcbs. Other types may have twin flexible leads and mounting lugs, anbolted to the board.

Parts required: AWDI solid-state audible warning device, for 6V operation: SKT1 2-wayerminal; stripboard 63mm x 25mm (Vero 15354).

Fig 2. Module 5 - audible warning sounder layout. Connect "+" of module 4 to 6V; connect "-" of both modules to 0V.



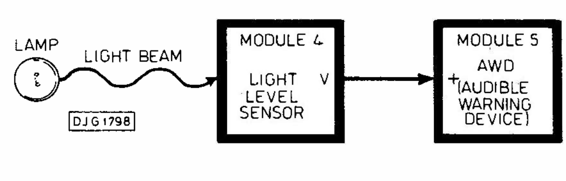
SYSTEM OF THE MONTH

Broken-beam intruder alarm

The system consists of the light level sensor connected to the audible warning sounder (Fig. 3). A beam of light shines from a lamp (or you can use a window) and falls on the ldr placed on the opposite side of the corridor or room. When someone passes between the source of light and the sensor, the resistance of the ldr increases. This increases the output (V) of the sensor. There is now a big enough voltage difference between the sensor output terminal and the 0V line to make the alarm sound. Adjust VR1 to make the system operate correctly.

This system sounds the alarm only when the beam is actually being broken. If the intruder runs through the beam, the sound is so brief that you might not hear it. It would be better if the alarm could be triggered to sound indefinitely when the beam is broken. Readers who followed the earlier series on digital electronics may have built a digital module that can solve this problem

Fig 3. System diagram of the broken-beam intruder alarm.



SEMICONDUCTORS

And now on to the meat of the matter:

The development of techniques for using semiconducting materials brought about the biggest ever surge forward in electronics, and probably has made as big a difference to our everyday lives as the discovery of the wheel or the development of agriculture. So what are semiconductors? This is the question we shall attempt to explain this month. Before we can get down to practical investigations of the properties and uses of semiconductors we much first spend some time in discussing exactly what a semiconductor is. Before that, a brief recap on conduction.

CONDUCTION

For a material to be able to conduct electricity:

* there must be a supply of *charge carriers*
* the charge carriers must be *free to move*
* there must be an *electric field* to make them move

The best conductors are metals (carbon is a good conductor too and what we say about

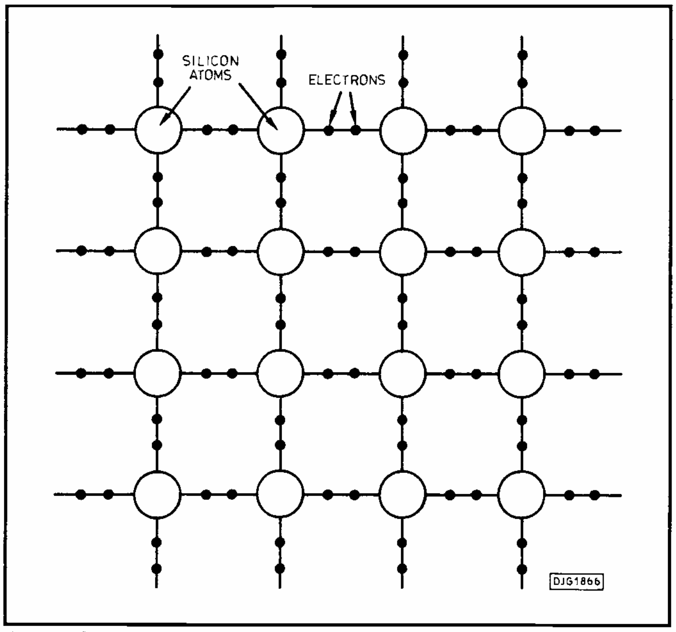


Fig 4. Structure of part of a crystal of pure silicon (diagrammatic).

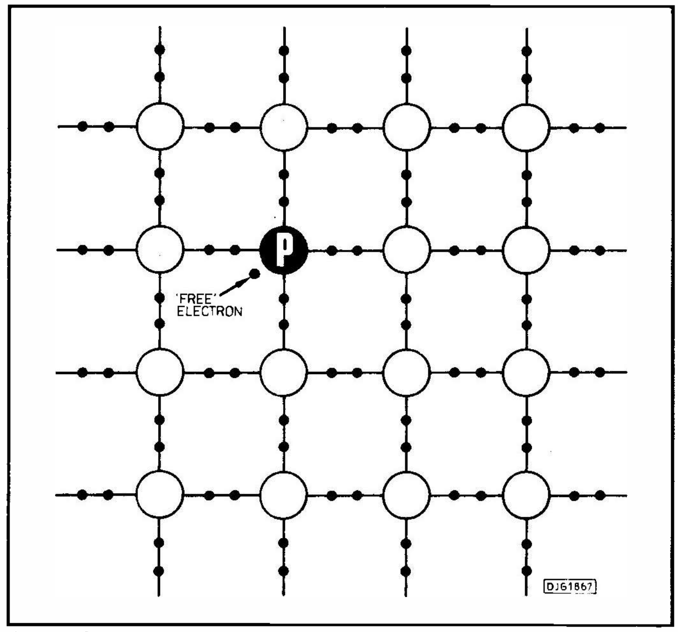


Fig 5. Silicon doped with phosphorus (n-type silicon).

metals below applies to carbon as well). The supply of charge carriers is provided by the atoms of the metal. At any one time a proportion of the electrons leave the atoms and move around in the space between the atoms. They wander in *all directions*. It is as though there is an *electron gas* in the spaces between the atoms. So we have charge carriers and they are free to move. If an electric field move in the *same direction*. There is a flow of electrons from negative to positive - we have an *electric current*.

SEMICONDUCTORS

The atoms of certain elements, such as silicon and genamium, do not release free electrons when the temperature is low. At low temperature they are non-conductors. At room temperature and above they produce a few free electrons and, as temperature increases, they produce more. So they are conductors at higher temperatures. Since they are non-conductors or conductors, depending on temperature, we call them *semiconductors*.

In a bar of pure silicon, the electrons come from the silicon atoms. These electrons are a part of or 'packaged with' the silicon - we say they are *intrinsic* to the silicon. They are therefore known as *intrinsic charge carriers* and the condition is called *intrinsic conduction*. At room temperature the number of intrinsic charge carriers in a bar of silicon is much less than in a bar of metal of the same size. Although silicon does conduct at temperature, it conducts much less readily than a metal. Its resistance is high.

Fig.4 shows the structure of a crystal of pure silicon. The circles represent the atoms of silicon atoms. They are arranged in regular array - a crystal *lattice* - which is actually three-dimential but is shown as two dimensionsal in the figure, for simplicity. The electrons of an atom are in a number of layers, or *shells*. The figure shows the electrons of the outer shell only. The outer shell of an atom of silicon contains four electrons. The ideal number of electrons to fill this shell is eight. In the drawing we see that each silicon atom is sharing its four outer electrons with four adjacent atoms. By sharing electrons it has eight electrons in its outer shell for part of the time at least. This makes for stability in the structure of the crystal. At room temperature and above, some (but few) of these electrons become free and become intrinsic charge carriers.

Fig. 5 shows a way of making silicon a better conductor. We replace a small proportion of the atoms of silicon with atoms of another element, such as phosphorus. We say that the silicon has been *doped* with phosphorus. Phosphorus has five electrons in its outer shell. This gives four electrons to share with neighbouring silicon atoms and one 'spare electron'. This electron is free since it is not needed to make up the eight shared electrons in the outer shells of the atoms. This electron is available to act as a charge carrier. We have made silicon a better conductor than when it was pure. The electrons obtained by doping do not belong to the silicon. We say they are *extrinsic charge carriers*.

Other elements with an 'extra' electron can be used in the same way for doping silicon. These include arsenic and antimony. A semiconductor which is doped to provide *negative* charge carriers is called an *n-type* semiconductor. Note that conduction in an n-type semiconductor is the same as in a metal.

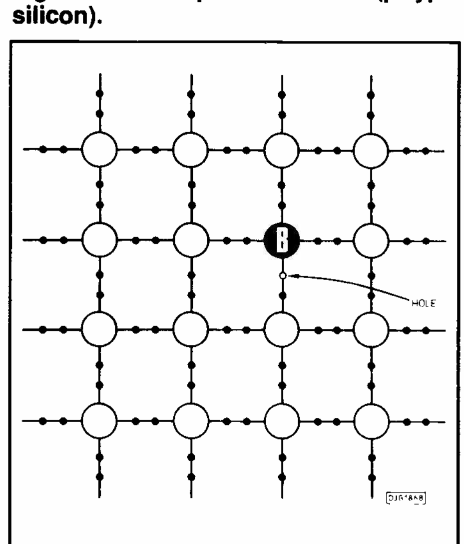
P-TYPE SEMICONDUCTORS

Fig.6 shows part of a crystal of silicon doped with boron. Atoms of boron have only three electrons in their outer shell. Instead of an extra electron there is one missing. We refer to this vacancy in the structure of the lattice as a *hole*. In a bar of silicon doped in this way, the hole may occasionally be filled by an electron that has escaped from another silicon atom. But this only creates a hole elsewhere in the lattice. All the time, holes are being filled and new holes created. Overall there is a shortage of electrons so there are more holes than free electrons.

Now let us see what happens if an electric field is applied to the silicon (Fig.7). The diagram shows only a single row of atoms and does not distinguish between atoms of silicon and atoms of boron. In Fig.7a, the atom on the left (atom A) has a hole (ie, an electron is missing). An electron escapes from an atom further along the row and, *because of the electric field*, moves toward the left. It moves to and fills the hole at atom A. this action has created a hole at atom B (Fig.7b). This is filled by an electron escaping from atom c and moving left in the electric field. Finally, an electron escapes from atom D and fills the hole at atom C.

We started with a hole at atom A and we finish with a hole at atom D. The overall

Fig 6. Silicon doped with boron (p-type silicon).



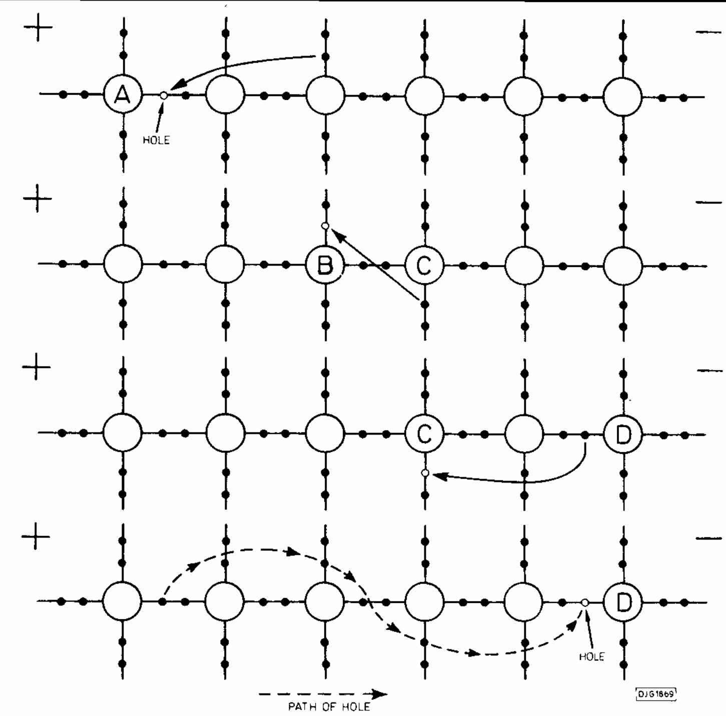
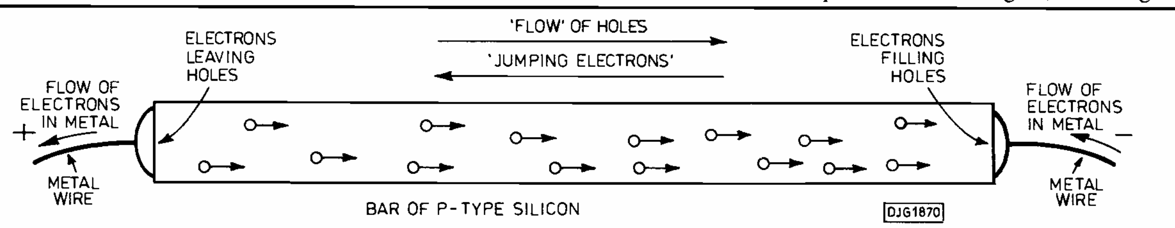


Fig 7. Movement of holes in p-type silicon

Fig 8. Conduction in p-type silicon.



effect, shown in Fig. 7d, is that the *hole has moved* from A to D. Of course a hole does not really move - it cannot move because it is part of the fixed structure of the lattice. But, the vacancy in effect moves, *from positive to negative*. The hole behaves as if it is a positive charge carrier. Semiconductors that are doped in this way to produce such *positive* charge carriers are called *p-type* semiconductors. Indium may be used for doping instead of boron.

Fig.8 shows a bar of p-type semiconductor connected in an circuit. At the positive end, any electrons which escape from the lattice leave the bar and flow out into the metal connecting wire. The holes so created are filled by electrons jumping from atoms further along the bar, as shown in Fig.7. At the other end of the bar the holes are filled with electrons arriving from the connecting wire. In effect, we have a flow of positive charge carriers (holes) from the positive end of the bar to the negative end. We can not think of this as a *flow* of electrons as any individual electron 'jumps' only an infinitesimally small distance along the bar before jumping into a hole and once more becoming part of the lattice structure.

THE PN JUNCTION

Semiconductors as such are not of great practical interest. It is when we put two different types of semiconductor together that the fun begins. Fig.9 shows how this is done. First of all, a bar is made of silicon doped with phosphorous; this give n-type silicon. Now one surface of the bar is exposed to boron vapour in a furnace. Boron diffuses a little way into the n-type silicon. In the surface layer, the boron atoms outnumber the phosphorus atoms so the overall effect is that we have a layer of p-type silicon. The region between the two types is the *pn junction.*

Interesting things happen at the pn junction. In the absence of an electrical field, some of the electrons from the n-type material drift into the p-type material and fill the holes. Similarly, some of the holes from the p-type region drift into the n-type material and are filled by electrons. In the p-type region, the filling of holes means that the atoms have on average more electrons that they should have - the atoms become negative ions. Similarly, in the n-type region, the atoms on average have lost electrons - they become positive ions. But these atoms near the junction are fixed in position. They are part of the lattice. The result is a region of *fixed* ions (Fig.10b). This is called the *depletion region* because it is depleted of charge carriers. There are now no electrons or holes in this region.

There is an additional effect, that the positively charged ions of the n-type region and the negatively charged ions of the p-type region create an electric field. It is the same as having a cell connected across the junction. This *in-built cell* makes the n-type material potential *(a potential hill)* as we cross the junction from p-type to n-type (Fig.10c). This rise is 0.6V in silicon, or 0.2V in germanium.

Now we are ready to investigate the properties of the p-n junction, using a semiconductor device called a *diode* (Fig.11). The two terminals of the diode are named *anode* (p-type) and *cathode* (n-type).

***Investigation 1** - the pn junction*

You need: battery box 6V
D1 1N4148 silicon diode
LP1 6V, 0.06A filament lamp,
in a socket breadboard
Testmeter or voltmeter

Set up the circuit of Fig.12, as in Fig.13. Connect the battery. What happens? Now reverse the diode. What happens? What can you say about conduction through a diode?

Use the voltmeter to measure the voltage across the diode.

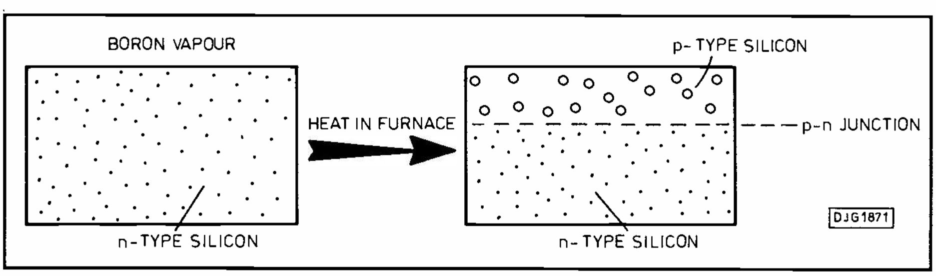
***Investigation 2** - the forward resistance of a diode*

The forward resistance is measured when the diode is forward biased, ie connected, so that current flows easily through it.

You need: battery box 6V
R1 15 ohm
D1 1N4148 silicon diode
VR1 10k variable potentiometer
testmeter or voltmeter up to 10V
testmeter or millimetre up to 50mA

R1 is to protect the diode against excessive current. Connect the circuit of Fig.14 as in Fig.15. Before you connect the battery, turn

Fig 9. Making a pn junction.



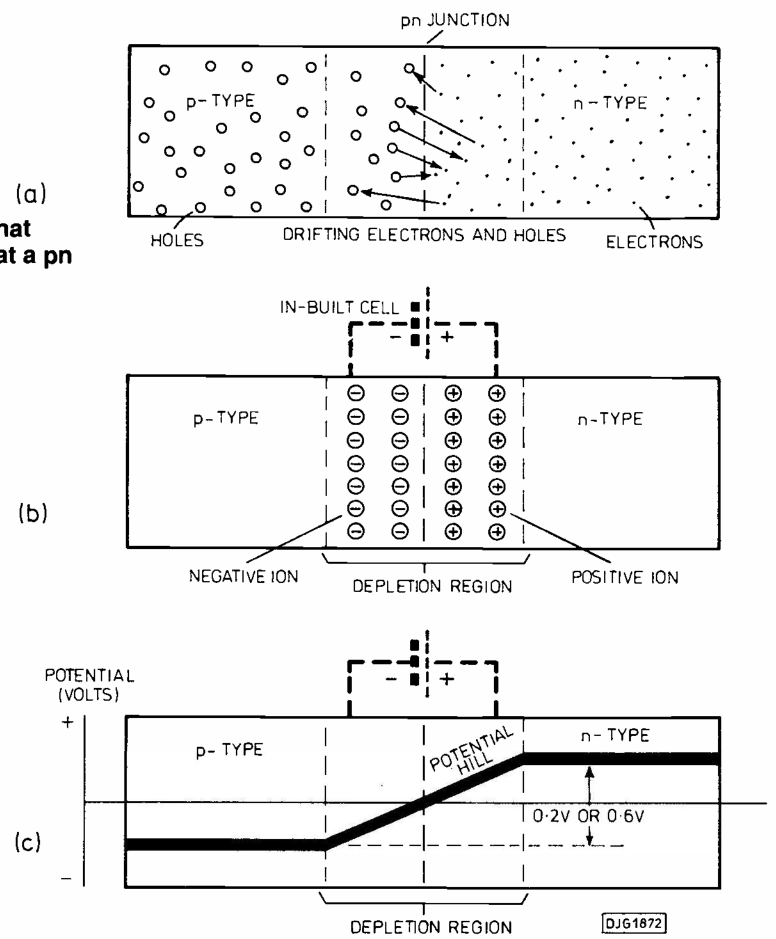


Fig 10. What happens at a pn junction.

VR1 so that its wiper is at the AV. end of the scale. Draw a table for your results:

V	I	Resistance V/I
0.1		
0.2		
0.3		
0.4		
0.5		
0.6		
0.7		
0.8		
0.9		
1.0		

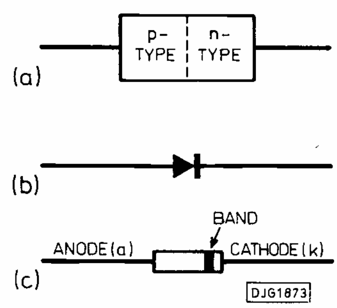
Connect the battery, turn VRI slowly, watching the voltmeter, until the voltage across the diode is 0.1V. Measure the current and record it in amps (1mA=0.001A). Continue, increasing the voltage to 0.2V, 0.3V etc. until the table is completed.

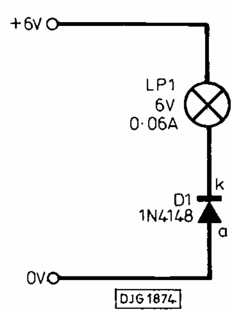
Calculate the resistance of the diode at each stage and write this in the third column of the table. Plot a graph of I against V; explain what is happening?

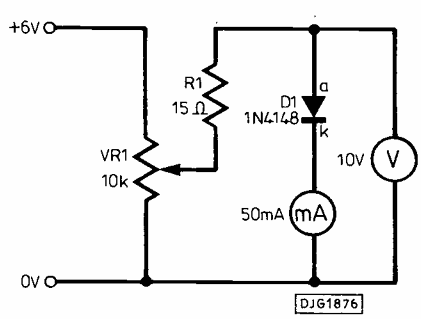
***Investigation 3** - the reverse resistance of a diode*

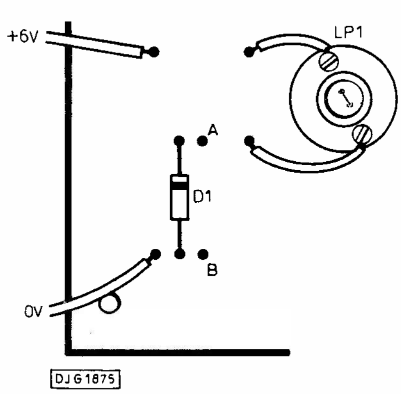
The reverse resistance is measured when the diode is *reverse biased* ie, connected so that current apparently does not flow through it.

You need: battery box 6V
R1 15 ohm
D1 1N4148 silicon diode
VR1 10k variable potentiometer
testmeter or microammeter up to 10 A









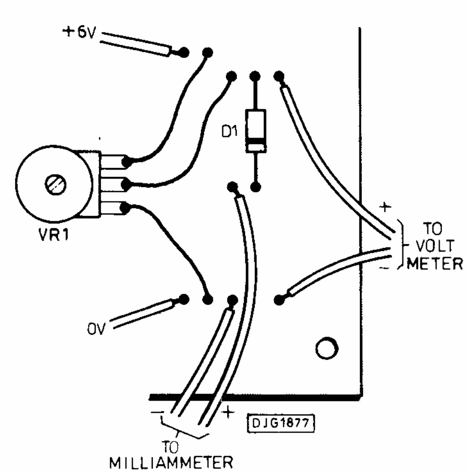


Fig 11. (top left). Semiconductor diode: (a) diagrammatic structure; (b) symbol; (c) typical diode package.

Fig 12. (top centre). Circuit of Investigation 1.

Fig 13. (bottom left). Breadboard layout of Investigation 1. Measure forward voltage drop between A and B.

Fig 14. (top left). Circuit of Investigation 2.

Fig 15. (bottom right). Breadboard layout of Investigation 2.

R1 is to protect the diode against excessive current. connect the circuit of Fig.14 as in Fig.15, but with the diode the other way round. Before you connect the battery, turn VR1 so that its wiper is at the 0V end of the scale. Draw a table for your results:

V	I	Resistance	V/I
1			
2			
3			
4			
5			
6			

Connect the battery, turn VR1 slowly, watching the voltmeter, until the voltage across the diode is 1V. Measure the current and record it in amps (1μA = 0.001A). Continue, increasing the voltage to 2V, 3V etc. until the table is completed.

Calculate the resistance of the diode at each stage and write this in the third column of the table. Plot a graph of I against V; explain what is happening?

Investigations 4 and 5 - Properties of a germanium diode

Repeat investigations 3 or 4, but use a germanium diode (eg, OA47, OA90 or OA91) instead. How does its behaviour differ from that of a silicon diode?

DIODE ACTION

The behaviour of a forward-biased diode is explained by Fig.16a. In forward bias, the external applied voltage is in the opposite direction to that of the built-in cell. If the applied voltage is less than 0.6V (for a silicon diode, or 0.2V for a germanium diode) the in-built cell maintains the depletion region. No charge carriers can cross the region and no current flows. When the applied voltage is greater than 0.6V the potential hill of the in-built cell is much reduced and the depletion region is very narrow (Fig.16b). Charge carriers can flow across it. Electrons leave the p-type material and flow to the battery. Holes are created and flow through the p-type material and flow to the battery. Holes are created and flow through the p-type material to the junction. Conduction in this region of the diode is an in Fig.8. At the junction the holes become filled with electrons flowing across the n-type material from the external circuit.

In the reverse-biase diode, the external voltage reinforces the in-built cell (Fig.16c). Holes are attracted away from the p-type material, leaving more negative ions. Electrons are attracted away from the n-type material, leaving more positive ions. The depletion region becomes wider. The potential hill becomes steeper (Fig.16d). No conduction across the junction can occur.

ONLY ONE METER?

Investigations 2 to 5 are best performed with two meters but it is possible to manage with one testmeter that has voltage and current ranges. Each time you set the voltage, switch to a voltage range and connect the testmeter between 0V and the wiper of VR1. Then, without altering the setting of VR1, switch the meter to a current range and connect it in series with the diode, as in the figures. This technique leads to error in that the output from the potential divider drops slightly when current is draw from it (see Part 1), but the results will illustrate the main points of the investigations.

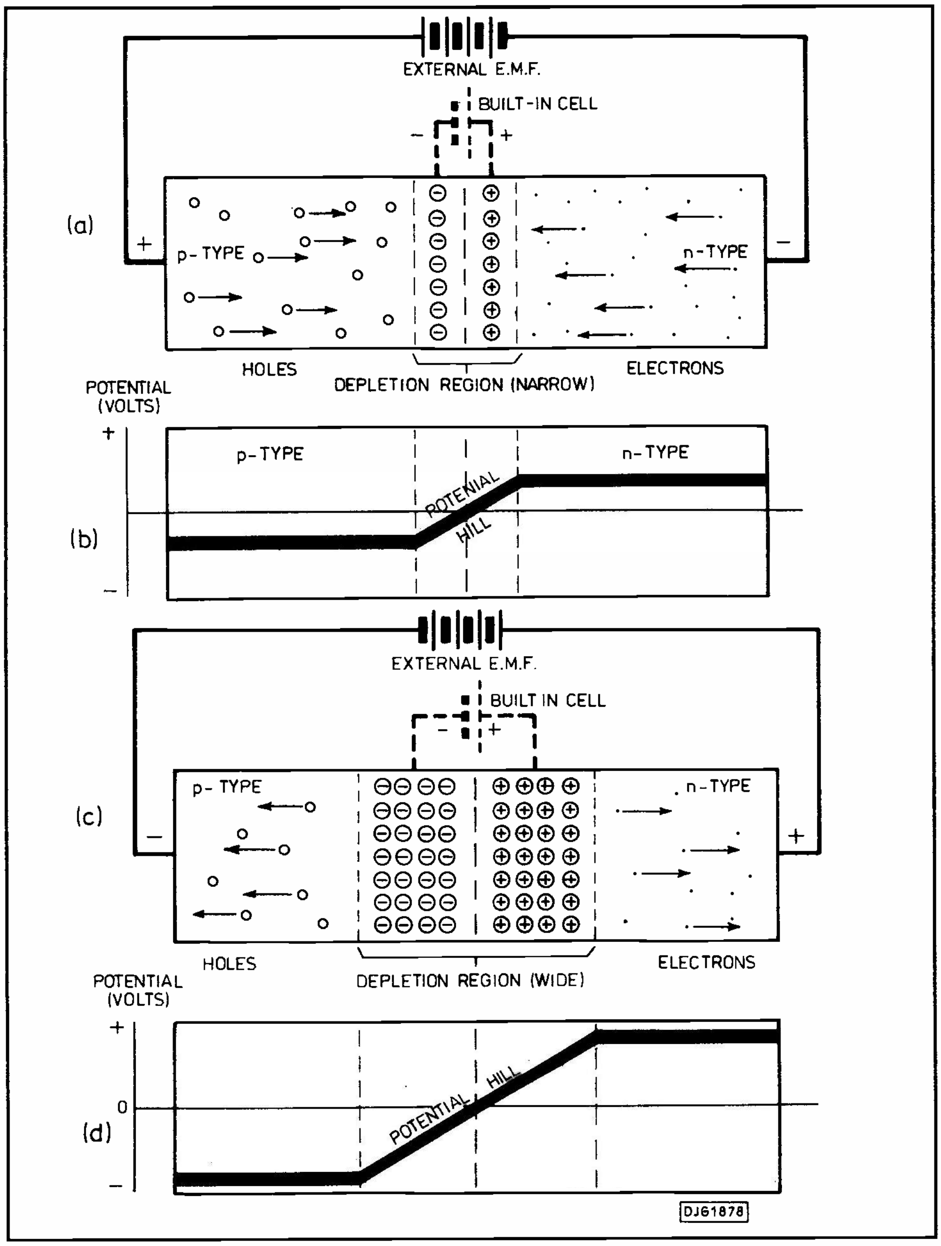


Fig 16. Effects of biassing a pn junction: (a) forward bias; (b) the small potential hill when the junction is forward-biassed; (c) reverse bias; (d) the large potential hill when the junction is reverse biassed.

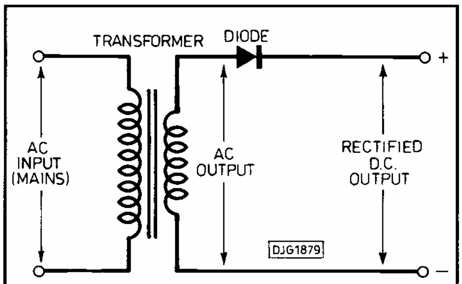
LEAKAGE CURRENT

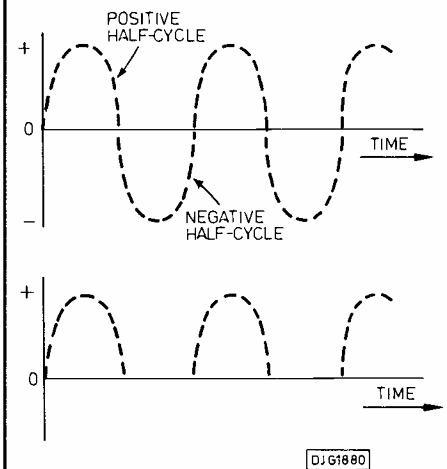
We have stated that no current can flow across a reverse-biased pn junction, yet Investigations 4 and 6 prove that a current *does* flow. The current is a small one, but nevertheless is a current. The explanation is that the discusssion based on Fig.16 referred only to the flow of holes in the p-type material and the flow of electrons in the n-type material. These are referred to as *majority carriers*, because they constitute the majority of the carriers in the two types of semiconductor.

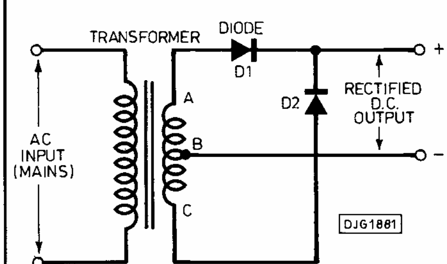
No piece of silicon is entirely pure. Minute quantities of other elements are present in the lattice. These give rise to very small quantities of *minority carriers*, electrons in p-type material and holes in n-type material. If the junction is reverse-biased with respect to the majority carriers, it is forward biased with respect to the minority carriers. The flow of minority carriers produces the leakage through a reverse biased diode.

RECTIFIER DIODES

These are specially made to have a low leakage current and to withstand large reverse







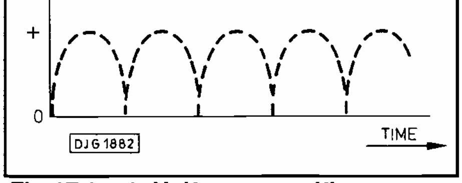


Fig 17 (top). Half wave rectifier.
Fig 18. Action of the half wave rectifier (a) AC output from the transformer; (b) rectified pulsed DC.
Fig 19. Full wave (bi-phase) rectifier.
Fig 20. (bottom). Output of a full wave rectifier.

voltages. As their name indicates, their function is to *rectify*. In other words, they are used to convert an alternating current into a direct current. The simplest type of rectification employs a single diode (Fig.17). The mains is connected to the primary coil of a transformer (see last month) and a lower voltage is obtained from the secondary coil. This is an alternating voltage - the current flows one way and then reverses and flows the other way - which makes it unsuitable for the majority of electronic circuits. The diode in Fig.17 simply makes the current flow one way only. It is known as *pulsed direct current* for, though it always flows one way during the positive half-cycle it does not flow when the current from the transformer reverses (the negative half-cycle). This is called *half-wave rectifier* (see Fig.18).

The next rectifier has two diodes (Fig.19). The secondary coil of the transformer is tapped halfway along its length. During the positive half-cycle, point A is positive of B and diode D1 conducts. Current flows to the (+) terminal and back through the (-) terminal to B. During this phase C is negative of A so D2 does not conduct. During the negative half-cycle point C is positive of A, so D2 conducts. Current flows to the (+) terminal and back through the (-) terminal, as before. D1 is not conducting in this half-cycle. The resulting output is shown in Fig.20. Current is produced on both the positive and negative half-cycles, so this is a *full-wave rectifier*. Its output is much smoother than the half-wave rectifier. The main disadvantages is that only half of the current available from the transformer is being used at any given time, so it is inefficient.

The full-wave rectifier of Fig.21, shown complete with its smoothing capacitor, employs four diodes. The output is the same as in Fig.20 except that this circuit uses the full voltage developed by the transformer. The four diodes connected as shown are called a *bridge*. It is easier to use a *rectifier bridge* which is a ready-made device with four diodes connected inside it.

All of the rectifiers have a pulsed dc output, which may be suitable for, say, powering a lamp, but is not suited for the majority of electronic circuits. The output can be smoothed by using a large-capacity capacitor as a reservoir. Charge from the rectifier charges the capacitor *in pulses*. The capacitor is discharged *steadily* as a current flows to the circuit that is being powered (the load). The resultant output is smoother, though it still may show ripple (Fig.22). The degree of ripple depends on the load current. The larger the load, the greater the ripple. Ripple is reduced for any given load by using a capacitor of greater capacity.

The descriptions above ignore the effects of forward voltage drop. One effect is that conduction does not begin until the transformer voltage exceeds +0.6V in the case of the first two rectifiers, and by two voltage drops (1.2V) in the case of the bridge rectifier.

DISCUSSION

Investigation 1: The lamp does not light until the diode has been reversed. This suggests that current can flow from anode (p-type) to cathode (n-type), but not the other way round. When current is flowing through a silicon diode, the voltage drop across the diode is a little more than 0.7V.

This is mainly due to the forward voltage drop of the pn junction the effect of the built-in cell (Fig.10b).

Investigation 2: Fig.23a shows typical results. No current flows until the voltage of the in-built cell has been overcome. As the voltage increases, the resistance of the diode decreases and a current begins to flow.

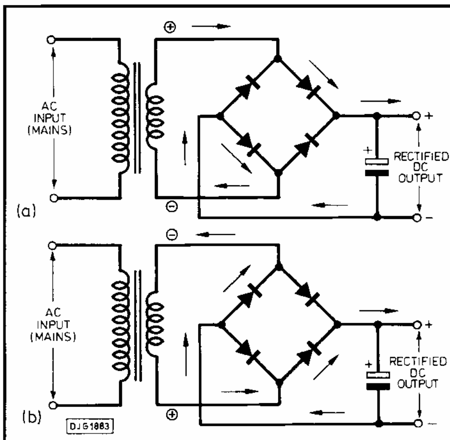
Investigation 3: Fig.23b shows typical results. The resistance is very high at all the voltages tested. Only a very small leakage current flows. Current through the diode remains very low, even if the reverse voltage is considerably increases. the IN4148 withstands a reverse voltage up to -1000V. With greater reverse voltage the diode breaks down and is destroyed.

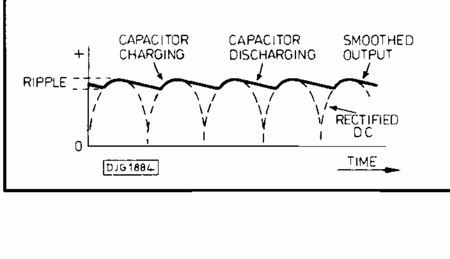
Investigation 4: The results are similar to Fig.23a, except that conduction begins as soon as the voltage exceeds 0.2V, the voltage of the in-built cell of a gemanuium pn junction.

Investigation 5: The results are similar to Fig.23b, except that the leakage current is greater. The OA47 breaks down with a reverse voltage of -25V, the OA90, withstands up to -30V and the OA91 withstands up to -115V.

Next month we'll start off by looking at photodiodes and zeners.

PE





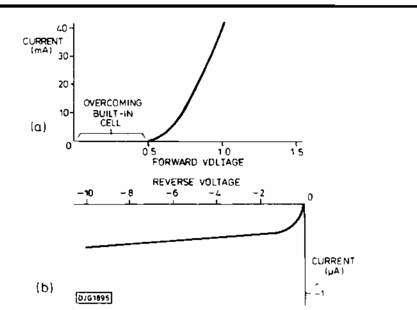


Fig 21 (top left). Full wave bridge rectifier during (a) positive and (b) negative half cycles.
Fig 22 (left). Effect of a smoothing capacitor.
Fig 23 (above) (a) Forward-bias characteristics of a diode; (b) reverse-bias characteristics of a diode. The scales of these figures are different.

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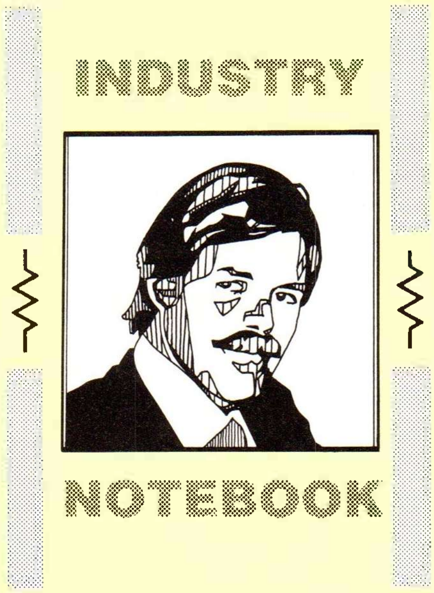

Challenge and choice

By Tom Ivall

If a machine appears to exhibit intelligent behaviour, does it follow that it has a mind and is aware of itself?

Do you think that computers could be conscious? I don't mean the same kind of consciousness that creatures like us have, but something equivalent.

Perhaps you think the question is rather strange, like the casual remark made by world chess champion Garry Kasparov after studying the characteristics of the Deep Thought chess computer program: "Computers have their psychology too."

I was brought back to this notion while attending a recent international conference at the IEE, London, on artificial neutral networks. As you probably know, these electronic networks are considered possible alternatives to the conventional, serial Von Neumann type of computer for processing certain kinds of information. They work in parallel, taking many input signals simultaneously - say picture elements from two-dimensional images - and produce parallel output signals which are coded, meaningful classifications of the input patterns. Real-time speech recognition is one field of application. And these networks are capable of actually learning a required processing behaviour, using the error-feedback principle.

During this conference what struck me as intriguing was the idea, expressed by many speakers, that the artificial neural network learns to form an internal representation of the problem it is dealing with. And that within the network there can be different levels of abstraction in the representation of the problem. Professor T.Kohonen, a notable Finnish researcher in this field, said for example that the layers of interconnected electronic processing elements within a network "often seem to learn responses that are specific to some abstract quality of the input information."

This certainly suggests a kind of awareness, consciousness or similar mind-like behaviour. And the possibility is supported by that old philosophical puzzle called 'the problem of other minds'. Broadly this states that each of us can know for sure by direct experience (introspection) that we have a mind, or mental processes, but cannot know with the same certainty that other persons have minds.

We can't actually get inside other persons' subjective experiences to examine them. We can only infer, from observing their external behaviour etc, that they too probably have minds. On this basis, if we see a machine exhibiting what appears to be 'intelligent' external behaviour it's reasonable to infer that it could have some kind of mind or mental processes.

Perhaps this is just playing with words or, at a deeper level, concepts. But what I'm really concerned about here is the moral aspect - the way this kind of thinking could affect our deeply held convictions of what it is to be a human being.

Because electronics technology has this remarkable ability to simulate natural processes, as well as manmade systems, it is helping to support the reductionist view of living beings. Reductionist, put crudely, is 'nothing but'-ery. We are genetically determined arrangements of atoms and molecules and, like machines, we function according to physical laws (which most of us accept). So we are 'nothing but' machines (which many of us vehemently reject).

It's not easy to throw out this argument. The philosopher John Searle in a BBC Reith Lecture admitted: "I just cannot square my conviction that I am a free agent with my conviction that....the surface features of phenomens are explained by the behaviour of micro-elements."

The first electronic simulators were analogue computers, and electronic analogues are still being used to model living processes such as the electrical activity in tissues. Now digital computers and artificial neural networks are taking over some of this biological simulation. Apart from these specially designed models, built as aids to research, there are the analogies suggested by existing manmade devices. At one time the brain and central nervous system was likened to a telephone exchange. Now it's a computer.

Of course, these popular analogies are simplistic and misleading if pressed too far. But they have still entered the folklore by their emotional effect, especially when more and more human tasks are being performed by clever electronically controlled machines. Perhaps the discussions on whether such machines 'think' are largely philosophical exercises. But the very fact of such discussions by professionals - like those on nuclear war - makes the subject thinkable.

At the lowest level, although brains don't actually work like computers, "the union of nerve fibres by synapses into systems with given overall properties" are realistically comparable with man-made "nets containing cycles" (quoting from Norbert Wiener's famous book Cybernetics.) But now that the fifth generation of computers is almost here, the model becomes more sophisticated. Aided by cognitive psychology, it moves a step nearer to the living processes.

According to Professor Donald Michie, a researcher in machine intelligence, these new machines will function at "a higher level of conceptualisation" than is possible with the existing Von Neumann type computers. For example, research is being done on distributed associative memories modelled on what is known of human memory processes.

Reduction of this kind supports the instrumental view of human life that comes out in behaviourism and the technological fix. It is a challenge we have to meet. It puts us on our mettle to defend and reaffirm our inner experiences, beliefs and values. Faced with a blind determinism of our own biological mechanisms, we can only assert, in a kind of religious 'leap of faith', that it's equally valid to describe human life in subjective terms - consciousness, mind, intention, volition etc. These entail freedom of moral choice and therefore responsibility for our own actions.

What encourages me is that reductionism itself depends on science, which is only valid if it is ruled by a particular ethical decision. The scientist must be honest. He or she accepts the moral discipline that scientific results have to be completely objective. Otherwise they are worthless. The good scientist even tries to disprove his own results, to make sure he is not unconsciously distorting his experimental observations to fit a pet hypothesis. This decision that objectivity must prevail is a moral choice, almost an act of faith, not an outcome of pure knowledge.

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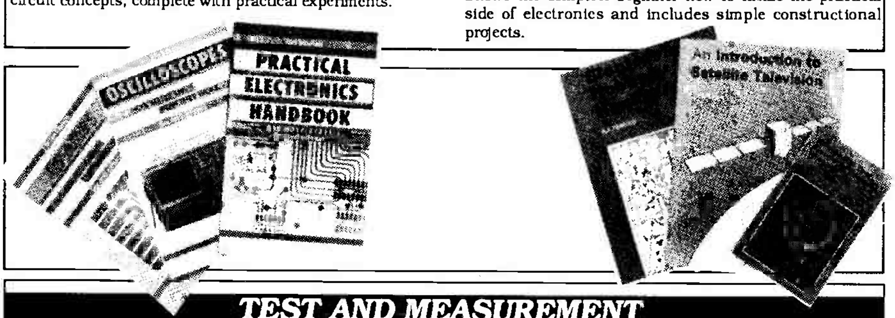

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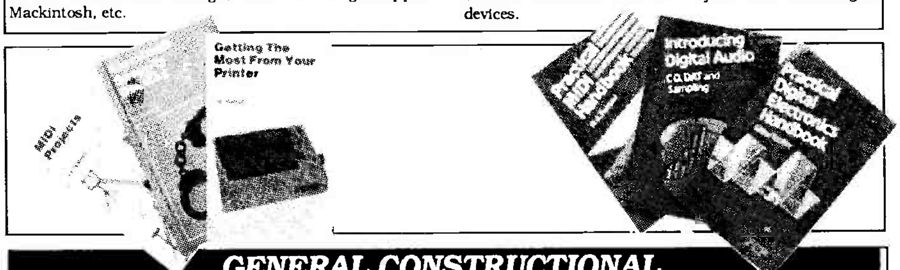

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Newnes Electronics Pocket Book
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Tackles the problems of designing circuits from scratch, introducing the concept of target specifications, the design sequence, device selection, rules of thumb, and useful equivalent circuits.

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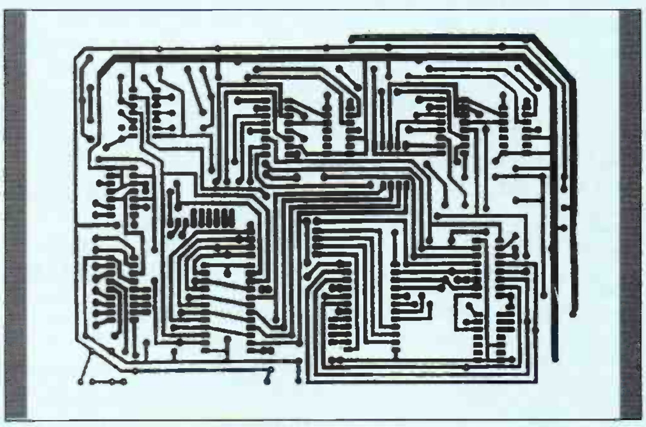

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Gain skills and pleasure by building your own robotics systems.

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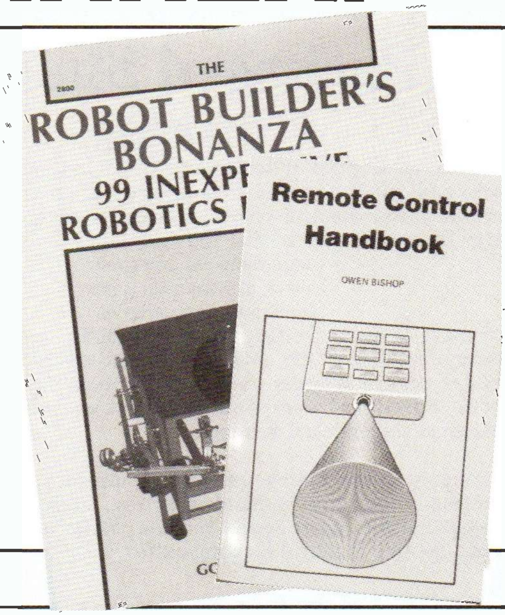
THE "REMOTE CONTROL HANDBOOK"

TEN COPIES OF EACH TO BE GIVEN AWAY AND YOU COULD WIN BOTH OF THEM!

The Robot Builder's Bonanza, by Gordon McComb, takes an educational but fun approach to designing working robots. Its modular projects take you from building basic motorised platforms to giving the machine a brain - and teaching it to walk and talk and obey commands.

The Remote Control Handbook, by Owen Bishop (a regular PE author) is full of information, circuits and project ideas that will delight and instruct you in many aspects of remote control. From remote lamp switching, to controlling model aircraft or operating industrial robots, this book has many suggestions and solutions.

Our grateful thanks to John Wiley and Sons Ltd., and Bernard Babani (Publishing) Ltd., respectively, for kindly making the books available.



HOW TO ENTER

Just answer the simple questions on the entry form and send to: Practical Electronics, Robot Competition, 193 Uxbridge Road, London W12 9RA. All correct answers will be put into the draw to take place on April 30th 1990. The first ten names drawn will each win both books. The Editor's decision is final!

You may send a photocopy of the entry form providing you also attach the original entry coupon clipped from the corner of this page (not a photocopy of it).

ENTERTAINING ED!

Why not amuse your Editor as well? Write him a limerick on robots. It's not necessary to do so in order to qualify for the prize draw, but he'd love to read your offerings. Write them on a separate sheet of paper, and he'll publish the best of them to amuse the rest of you too! Here's Ed's own offering to put you in the right frame of mind (if not on the route to bardship!):

A smart chatty robot called Phipps
Could dialectically program his chips
Till an illogical virus
Bugged up his gyrus;
Now he's randomly un-Boolean with quips.

You've got equal poetic license - have fun!

ROBOT COMPETITION ENTRY FORM

Circle the answer you believe to be most appropriate to the following questions:

1. Who is reputed to have first used the word Robot?

Arthur C. Clarke   Douglas Adams   Karel Capek   Frank Herbert

2. The First Law of Robotics is said to be: "*A robot may not injure a human being, or, through inaction, allow a human being to come to harm*". By whom was it defined?

Plato   Faraday   Napier   Ministry of Defence   Asimov

3. In the context of this competition, which one of the following do you think is most likely to be the odd-one out?

Marvin   Hal   R.Daneel   R2D2   Joe 90   Dalek

4. For which endearing attribute is Marvin likely to be best remembered?

His depression   Hitch-hiking ability   Answer to Life

5. Three of the following are conventionally said to define the axes of robotic arm movement; which are they?

Pitch   Swing   Roll   Gyrate   Turn   Yaw   Twirl
Torque   Circle   Rotate   Revolve   Undulate   Spin

Name (in caps) ....

Address ....

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....

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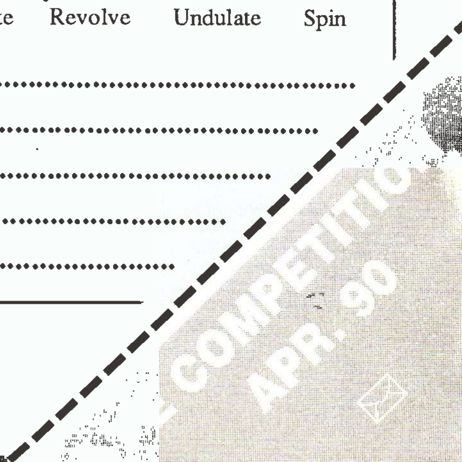

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