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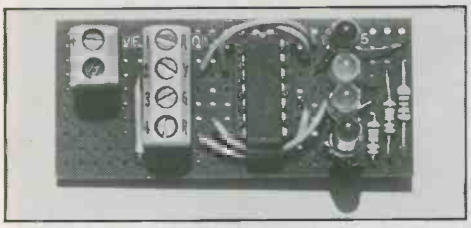
THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS

PRACTICAL ELECTRONICS

PE VOL 24 NO 9 SEPTEMBER 1988



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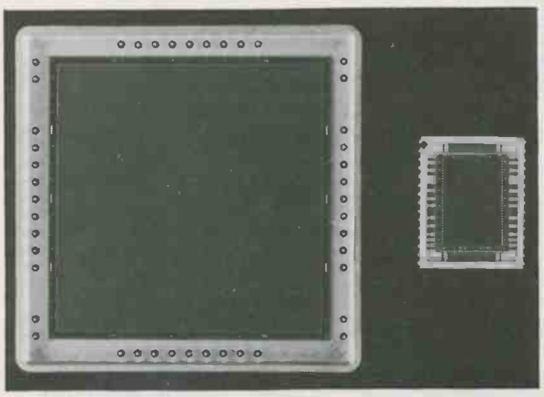
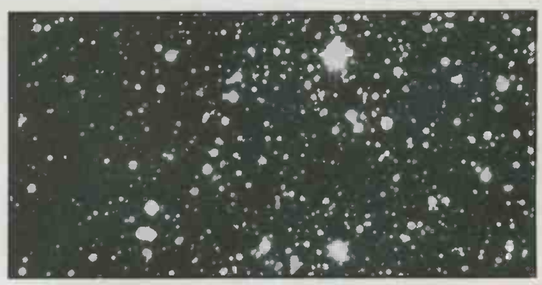


SPECIAL FEATURES

REGULAR FEATURES



PRODUCT FEATURES

NEXT MONTH . . .

WE SPAN THE DEPTHS AND THE HEIGHTS WITH – SUBMARINE CABLES • INFRARED ASTRONOMY • MAKING A METAL DETECTOR • A UNIVERSAL OUTPUT PORT • AND THERE'S MORE OF THE NEW DIGITAL ELECTRONICS TUTORIAL •

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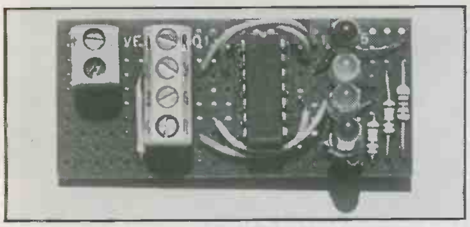

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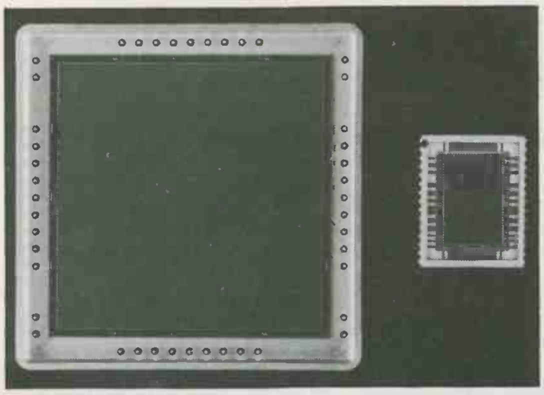

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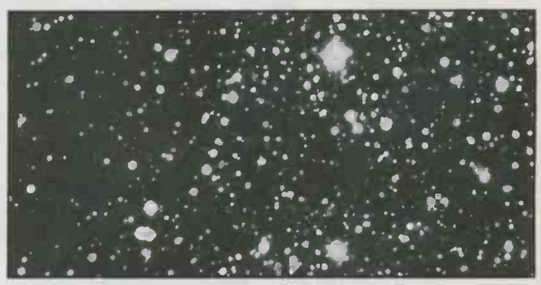

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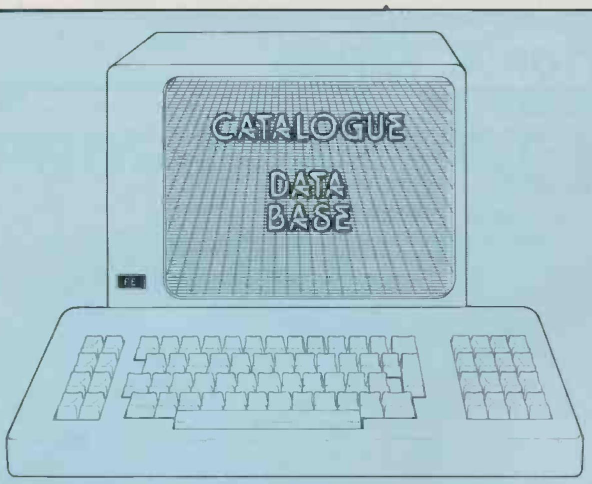


We have recently received the following catalogues and literature:

Allbatteries say on the cover of their catalogue that **this is the year of the customer.** In addition to the large selection of batteries that seem to meet every conceivable use, the company will also construct battery packs to customer's needs. **Allbatteries,** Unit 1, Byfleet Industrial Estate, Old's Approach, Watford, Herts, WD1 8QY. Tel: 0923 770044.

Imagina-tronics have sent their new short form catalogue of interesting technology supplies ranging from matchbox sized **surveillance transmitters to solid state oscilloscopes.** They also have a varied selection of good value component packs to offer. **Imagina-tronics,** Aberdeen House, The Street, Charlwood, Surrey, RH6 0DS.

D&M Components have issued their winter 1988 catalogue of electronic components, hardware, and power supply kit bargains. They also have a **component search facility** under which they offer to obtain parts specially to order at bargain prices. **D&M Component Supply Service,** 2 Glentworth Avenue, Whitmore Park, Coventry, CV6 2HW. Tel: 0203 333195.

TK Electronics autumn catalogue has come in, **full of electronic components,** tools, test gear, security kits, smoke detectors, phone accessories and other items of great interest, **including giant solar cells. TK Electronics,** 13 Boston Road, London, W7 3SJ. Tel: 01-579-9794.

Cirkit tell us that their latest catalogue is now available, featuring many new products in its 184 pages. Among the 3000 lines are a low cost 10MHz scope and the **Easiwire prototyping system,** as well as their usual extensive range of components. They also have a special **free digital travel alarm offer,** and another competition in which a 10MHz scope can be won. **Circuit Distribution Ltd,** Park Lane, Broxbourne, Herts, EN10 7NQ. Tel: 0992 444111.

Magenta Electronics are well known for supplying electronics for education, robotics, music, computing and fun, and their **latest catalogue is worth obtaining** by anyone whose interests cover any of these areas. Their expertise ensures that customers also benefit from a friendly and reliable service. **Magenta Electronics Ltd,** 135 Hunter Street, Burton-On-Trent, Staffs, DE14 2ST. Tel: 0283 65435.

ADVERTISERS – we will be delighted to publicise your catalogues in this section – there is no charge, just send them in and we'll mention them.

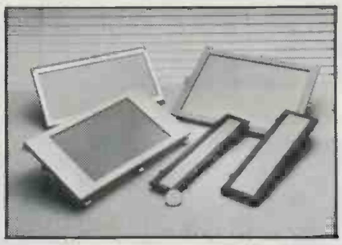
Optimising Analysis

More than just another FFT spectrum analyser, the Schlumberger 1220 provides a totally integrated measurement workstation for dynamic signal analysis, and includes many facilities which would normally require an instrument cluster.

The new spectrum analyser is available as a two-channel instrument which can be enhanced to four channels by the simple insertion of an extra input card. The four-channel version is believed to be the only instrument on the market offering the ability to simultaneously measure frequency response functions between all channel pairs. This level of capability is equivalent to six twin-channel analysers. The 1220 packs many instruments into one for applications in structural analysis, rotating machinery diagnosis, speech and music research, control system analysis, and environmental engineering.

The instrument operates over the frequency range 0 to 50kHz with up to 1000 lines frequency resolution and powerful realtime zoom. It has been designed to give the user the widest possible range of facilities for stimulation of systems, capture and analysis of results, and data output in a compact, easy-to-use package.

Contact: Schlumberger Instruments, Victoria Road, Farnborough, Hants, GU14 7PW. Tel: 0252 54433.



LCD Modules

Epson's range of graphic lcd modules now numbers 16 models with the introduction of six new high contrast, wide viewing angle, silver type Super TN lcd modules.

The new models cover the range 640×64 up to 640×400 dots and one model, 8002, has cold cathode backlighting and is aimed at crt replacement.

Five of the models use Epson's new Chip-on-Flex (CoF) technology. Developed from Seiko quartz watch technology, CoF reduces weight, cost and size by mounting the lcd driver on a flexible pcb strip.

The new models are all compatible with Epson's E1330 graphic lcd controller enabling upgrading throughout the range. Prices range from £71 to £297.

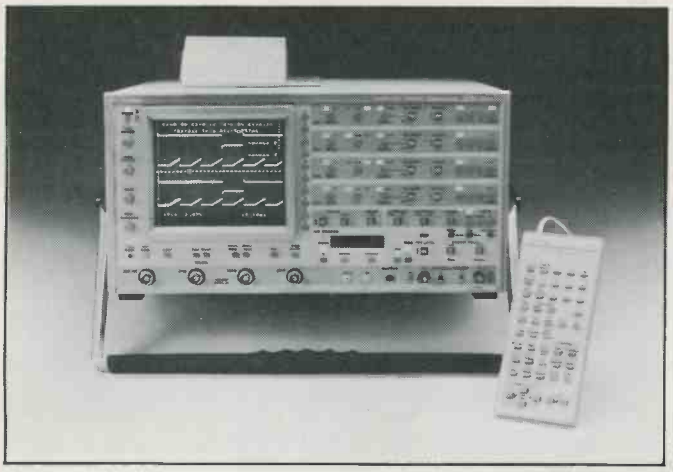
An lcd modules range brochure is available from Epson.

Contact: Tony Westray, Public Relations Manager, Epson (UK) Limited, Dorland House, 388 High Road, Wembley, Middlesex, HA9 6UH. Tel: 01-902 8892 x308.

Flexible Boxing

OK Industries tell us that their new series of enclosures are ideal for housing instrumentation, electronics, modems and similar. The number of parts required are minimised while still affording the maximum degree of flexibility. The cases are moulded from abs in standard colours, black, grey, tan and natural, although specials are optional.

Contact: OK Industries UK Ltd., Chickenhall Lane, Eastleigh, Hants, SO5 5RR.



Waveform Processing

A new range of waveform processors, available as options for Gould's 1600 and 4070 Series of digital storage oscilloscopes, offer powerful analysis features in the frequency domain as well as the ability to program complete sequences of tests. Up to 24 commands can be entered into a sequence, greatly enhancing productivity where similar tests have to be performed on different systems or the same system has to be tested under different conditions.

Documenting the results of sequence testing is simple, since the results of any calculations can be printed out via the oscilloscope's printer interface or a trace can be plotted on the built-in plotter. The new analysis functions — including fast Fourier transforms (ffts) — also allow the instruments to carry out many of the functions of a spectrum analyser for simple 'look/see' tests rather complex measurements. In addition, measurements on many captured signals can now be carried out without the need for peripheral items of test equipment such as voltmeters and frequency counters.

The Gould 260/270 waveform processors are supplied in the form of handheld keypads which simply plug into the oscilloscope.

Contact: Gould Electronics Ltd., Roebuck Road, Hainault, Ilford, Essex, IG63 UE. Tel: 01-500 1000.

Hard Driven

Two high capacity, 40MB and 70MB, 3.5inch hard disk drives and a switchable 1MB/2MB 3.5inch floppy disk drive have been introduced by Epson.

The compact hd drives will communicate with a host computer via ANSI X3T9.2, the enhanced small computer system interface (scsi). Both have a low power consumption of typically 12.9W and a low acoustic noise of 45dBA through use of an efficient rotary voice coil motor and drive circuit.

Supporting 256/512/1024 byte block (sector) sizes, the HMD-946 and HMD-976 have fast average access times of 29ms allied to a dual-ported buffer allowing the host to read a track of data in a single revolution.

Reliability is enhanced by selected parts having 20,000 hours mtbf (mean time between failures) and, upon power down, the heads are parked automatically to prevent damage to the disk data surfaces.

The SMD-440L floppy disk drive is switchable between 1MB/2MB with a fast 500KBit per second data transfer rate in 2MB mode. Measuring only 25.4mm high, 149.5mm wide and 101.6mm deep, the drive has a 3ms track to track access time and a 10,000poh (power on hours) reliability.

It has a 1.8W power consumption, single 5V operation, a unique rack and pinion head positioning system and a control ic designed and manufactured by Epson. There is a guaranteed read/write compatibility with 1MB or 2MB written/read on other machines.

A brochure of Epson hard and floppy disk drives is available from them.

Contact: Tony Westray, Public Relations Manager, Epson (UK) Limited, Dorland House, 388 High Road, Wembley, Middlesex, HA9 6UH. Tel: 01-902 8892 x308.

COUNTDOWN

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.

Sep 6–8. Coil Winding. Wembley Conference Centre. 0799 26699.

Sep 8–12. Sim-HiFi-Ives. International video and consumer electronics show. Milan. 02-4815541.

Sep 27–30. DES. Design Engineering Show. National Exhibition Centre. Birmingham.

Oct 11–13. British Laboratory Week. Grand Hall, Olympia. 0799 26699.

Oct 18–20. Brighton Electronics Show. Metropole Hotel, Brighton (filling the slot vacated by Internepcon). 0822 614671.

Nov 1–3. Custom Electronics & Design Techniques Show. Heathrow Penta. 0799 26699.

Nov 29–Dec 1. DMC-PC. Drives, motors, programmable controllers etc. National Exhibition Centre, Birmingham. 0799 26699.

Dec 11. Satro Annual Computer and Technology Show. Music Hall, Aberdeen. 0224 273161. Satro, the Science and Technology Regional Organisation is a non-profit making organisation dedicated to supporting and enhancing science and technology education. Profits from the show will be devoted to developing computer and electronics clubs. **We hope it will be well supported.**

1989

Apr 5–6. Laboratory Science and Technology Show, Kelsey Kerridge, Cambridge. 0799 26699.

Apr 25–27. British Electronics Week. Olympia. 0799 26699.

Test Cassettes

Ian Harrison has asked us to publicise his new range of test cassettes. They are basically designed for use by non-professionals, though he has supplied them to various professional firms in the UK, companies like Marconi, Clone, Portfolio and Central TV.

He manufacturers nine test cassettes as standard to cater for most alignment factors, but other tapes can be produced to order. The tapes are recorded individually using TDK AD and SA tape, which are top quality formulations, using a Denon DRM30HX which has been very accurately set up.

Unlike most professional test tapes, Ian Harrison's are not recorded full track width and only one side of the tape is used.

Contact: Ian Harrison, 7 Mill Hill, Repton, Derby, DE6 6GQ. Tel: 0283 702875.

Bird Call

A new British Telecom approved interface now allows phone system users to direct voice page over an Eagle pa system from their phone.

This means that in addition to background music and receptionists' announcements, the pa system allows personnel to quickly locate colleagues.

An extension number is allocated and the interface connected, any call received at that extension will be acknowledged by a tone then a chime will sound after which the caller may speak. The interface will give engaged signals to other callers when in use and will automatically reset when the caller has stopped speaking.

Contact: Eagle International, Unit 5, Royal London Estate, 29-35 North Acton Road, London, NW10 6PE. Tel: 01-965 3222.

CHIP COUNT!

2SK973-5 series. A new family of power mosfets that can switch their fully rated currents (from 1.5A to 25A) with gate-to-source voltages as low as 4V, allowing direct drive by microprocessors and other logic sources. **(HT).**

HM511000H and HM514256H. With access times of only 60ns these are the world's fastest 1Mbit drams. Configuration are 1M × 1 and 256K × 4 respectively and key features include single supply operation, 90mA max operating current and 1mA max standby current. **(HT).**

HM628128. The world's first static ram that combines a storage capacity of 1Mbit with a fast access time of 70ns and a low power consumption of 350mW max. Organised as 128K × 8 the sram also offers a typical standby current of only 1μA and data retention down to 2V. **(HT).**

NE5105 series. 12-bit a-d converter incorporating a new comparator and sample-hold amplifier with a conversion time of 5us and a signal input resistance of 1Gohm. **(PL).**

NE5060. Fast precision sample-hold amplifier also featuring low droop rate and high speed acquisition time. **(PL).**

PLSH473. A faster fpla bipolar alternative to the PLC473 with an input to output propagation delay of 22ns max. **(PL).**

PCF2201. Designed specifically for row-column driving of flat panel lcds. It drives the lcd at multiplex rates of up to 1:256 and converts serial or parallel 4-bit display data into parallel lcd drive waveforms capable of driving up to 81 rows or columns of and lcd matrix. **(PL).**

More information can be obtained from —

(HT) Hitachi, 21 Upton Road, Watford, Herts, WD2 7TB, 0923 246488.

(PL) Philips Components, Mullard House, Torrington Place, London WC1 7HD, 01-580 6633.

Handling Antex

Antex has announced the launch of its in-handle temperature control soldering irons, a new power supply unit, and an improved bench stand.

The TCS 24 and TCS 240 soldering irons provide low-cost temperature control in a lightweight compact design. Simple to use, they offer temperature control flexibility without the need for a separate control station. The correct temperature can be easily set at any point in the range 200°/450°, though the handle is maintained at a low temperature even at maximum tip temperature. The advanced ceramic heating element with its high positive temperature coefficient provides rapid warm-up from cold (60 seconds to working temperature of 350°C). Other features include zero voltage switching, sensor open/short–circuit failure protection, and a negligible leakage current of less than 5μA. By exploiting surface mount technology, the TCS 24 and TCS 240 are smaller and lighter, giving operators positive, precise soldering control.

The 24V psu steps down 220–240V mains to a safe operating voltage of 24Vac, and can be used with any 24V soldering iron. The separate holder and sponge tray are designed for convenient iron storage (without entangling the lead), and easy sponge removal. Two anti–static options are offered.

The new bench stand has a heavy metal base for stability, and three spring bezels to accommodate all Antex irons (and many other makes); the spring is designed to prevent contact with the bit, and hence minimise temperature loss.

For Full Information on the whole range of Antex soldering irons and equipment contact: Antex Electronics Ltd., Mayflower House, Armada Way, Plymouth, PL1 1JX. Tel: 0752 667377.

Warmly Welcome

The new Maplin outdoor security sensor, the YP29G, incorporates the latest developments in infra-red detector technology. The system reacts instantly to body heat, within a detection zone range of 33ft. Guests, or intruders, will automatically trigger an internal relay which will power-up to a total of 600W of lights.

A built-in photocell sensor keeps the unit switched off during daylight. When operating automatically, the unit will extinguish the lights after a preset time once the person has left the detection zone.

Application areas include driveways (the heat from a car will trigger the system) entrance porches, patios, stairways, garages, basements, storerooms, warehouses and workshops; in fact anywhere that a welcome or detector light is required. The outdoor sensor, which is completely weatherproof and watertight, has a power consumption of 30W max (excluding load).

All the Maplin shops are offering this warmly welcoming sensor at the warm-hearted price of £29.95 including vat.

Weightless Science

Pioneering experiments aimed at understanding the science of weightlessness and manufacturing unique materials in the environment of space were conducted recently for NASA by Battelle research engineers.

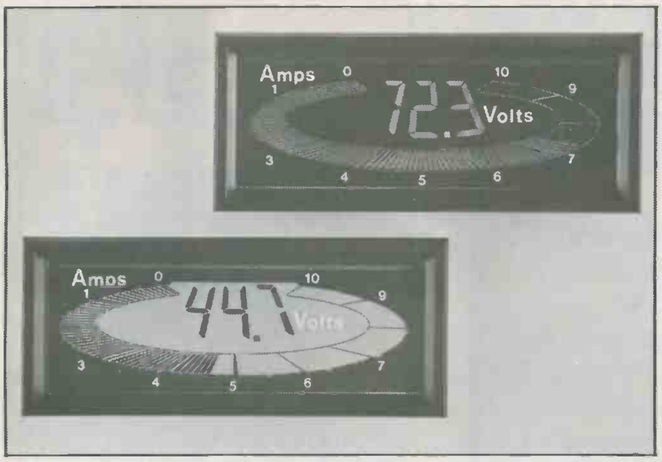
Preceded by extensive ground-based work, the experiments on fabricating polymer composites were conducted in a jet aircraft during brief moments of near weightlessness created when the plane reached the apex of upward swings of a series of parabolic maneuvers.

Battelle engineer Corinne M. Buoni, initiated the experiments as the plane neared the peak of its upward motion, releasing a catalyst into vibrating vials, each containing two liquid monomers. During the 15 to 20 seconds of near weightlessness, or microgravity, while the plane hovered before starting its descent, the monomers mixed together and cured into solid, multiphase polymers.

These proof–of–concept experiments are an important early step to ultimately developing methods for space manufacuring of materials that have unique physical, mechanical, and chemical properties. The composite material properties cannot be duplicated on earth because of gravity–driven settling or uneven distribution or mixing of the different material components. Space production of composites and other materials offers much potential for commercial enterprises in the future. The world market for composites alone by the year 2000 has been estimated to be between $12 and $13 billion.

Battelle's Advanced Materials Center for the Commercial Development of Space of Ohio grant and several industrial member companies represents the aerospace, chemical, manufacturing, and electronic materials industries.

Contact: Ms. Renate Siebrasse, Battelle Institute Ltd., 15 Hanover Square, London, W1R 9AJ. Tel: 01–493 0184.



Elliptical Scales

A miniature electronic elliptical scale bar graph with integral digital readout has been added to the range of lcd devices by Crompton Instruments.

The bar graph is designed as a panel-mounting instrument measuring only 60mm × 22mm, but giving an instantaneous 3-digit readout and separate analogue trend indication on a 100-segment bar graph.

Providing a significant technical advance in an instrument of this size, the digital and analogue displays are provided with separate, isolated inputs. This feature enables the inputs to be fed with two different signals, simultaneously monitoring two independent variables.

The new instrument is available with black digits on a silver background as standard, but alternative back-lit versions can also be supplied. Giving an enhanced viewing quality and improved appearance, displays with a combination of red, black and green bars, digits and backgrounds are available.

Contact: Crompton Modutec, Freebournes Road, Witham, Essex, CM8 3AH. Tel: 0376 512601.

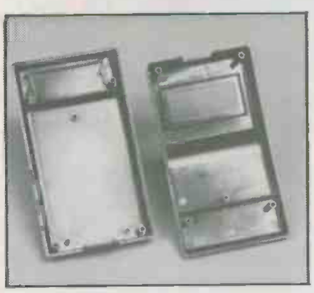
ET Closes In

Electronic Temperature Instruments Ltd are keen for PE readers to know about their mini instrument case whch they say is suitable for designers who want standard off the shelf units.

It is a two-part hand held case moulded in black abs plastic with a textured finish. The overall dimensions are 145 × 80 × 30mm with the upper half including a 50 × 20mm aperture suitable for a meter or led display. The lower half includes a compartment suitable for a PP3 size battery and accessible via an external sliding cover. Both halves have pcb mounting pillars.

ETI can justifiably claim this case to be ideal for constructing hand held meters, circuit testers and other types of display circuit since they use it for some of their own instrumentation products. The cases are only £2.50 each and attractive quantity discounts are available.

Contact: P. Webb, Electronic Temperature Instruments Ltd, PO Box 81, Worthing, W. Sussex, BN13 3PW. Tel: 0903 202151.



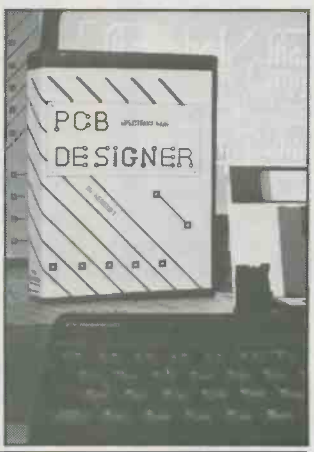
Spectrum PCB CAD

For only £19.95 inclusive, owners of a Spectrum 48K can now design pcb layouts the easy way. The program available from Kemsoft features a large display showing all pads and tracks clearly. Block move, copy, rotate, mirror, preview, fill and unfill, undo, autoscroll are all included.

Designed for use with an Epsom FX-RX80 printer and interface, three printout modes are available, including a quick-check print. There is a large library of pads, including buses, edge connectors, ic and transistor pads, fuse pads and a custom pad design facility. It comes with a 32 page manual and a 'getting started' tutorial. The maximum board size is 4.4in × 6.4in.

Several versions are available catering for different disco sizes, cassette options and Centronics interfaces.

Contact: Kemsoft, The Woodlands, Kempsey, Worcs, WR5 3NB. Tel: 0905 821088.

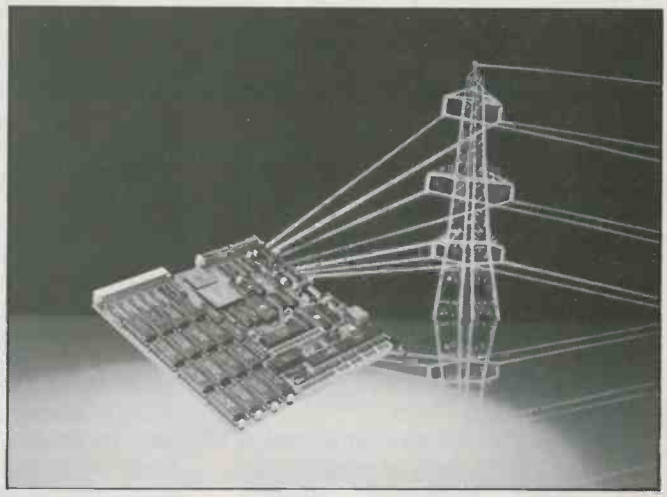


Scoping Currents

The Kenwood PC-80, a high sensitivity ac current probe specifically designed for use with oscilloscopes, is available from Thurlby Electronics.

The maximum measurable current varies with the frequency and the range. 5A rms (14A peak-to-peak) can be measured on the 2mA/mV range above 1kHz; 60A rms (168A peak-to-peak) can be measured on the 10mA/mV range above 1kHz; and using the 100mA/mV range allows 120A rms (560A peak-to-peak) to be measured above 100Hz.

Contact: Thurlby Electronics Ltd., New Road, St. Ives, Huntingdon, Cambs, PE17 4BG. Tel: 0480 63570.



32-Bit Powerhouse

The Alpha/One "Powerhouse" from GMT Electronic Systems is a 68020 single board computer intended for demanding real-time applications. It represents the highest performance design currently available on the ste bus. The Powerhouse achieves maximum performance from the 68020 processor by putting up to two megabytes of fast static memory onboard using a full 32-bit wide local data bus running at speeds up to 25MHz with zero wait states.

The Powerhouse board has provision for up to 2 Mbytes of static ram/eprom, a 68881 math coprocessor, four RS232 serial ports, floppy disks interface, SCSI interface for hard disc, programmable interrupt controller, real-time calendar clock, battery backup for ram and clock, and full ste bus interface.

System performance has been further enhanced by careful design of the ste bus interface. All program, data and file transfer operations are performed onboard with the full speed of the 32-bit cpu available, eliminating bus timing overhead and leaving the ste bus free for i/o operations.

GMT have implemented their own programmable interrupt controller in custom logic. Designed to maximise speed and flexibility in real-time applications, the interrupt controller is configured by an eprom programmed by the user. Any one of seven prioritised interrupt levels from 12 sources can be generated. Any interrupt can be mapped into any level and the priority of interrupts on any level can be selected.

The configuration eprom also selects between interrupt acknowledge type such as vectored or non-vectored, ste or local bus, etc. A software utility written in 'C' is provided to allow the user to generate the eprom code required to configure the interrupt controller.

The exclusive use of static cmos ram onboard has the advantage of high noise immunity and low power consumption. Eprom can be substituted in any combination with ram to simplify the installation of the application software in the target system. Battery back-up is provided for all onboard ram and the real-time calender clock.

Contact: Bob Squirrell Marketing, The Old Mill, Reading Road, Pangbourne, Berks, RG8 7HY. Tel: 07357 5445.

THE HAZARDS OF THE NEW SMOG

By Barry Fox
Winner of the 1987 UK Technology Press Award

CLOUDS OF UNKNOWING

Like soot in the air, electromagnetic debris from the multiplying number of communications and central systems in everyday life threatens to undermine the benefits.

Suddenly everyone is talking about "electronic smog" – an all enveloping blanket of electromagnetic radiation created by all the electronic equipment now in use.

In Japan smog has become a fashionable culprit. It is blamed whenever electronic equipment malfunctions. Radio waves generated by a spark were said to have triggered a lathe-operating robot which killed an assembly line worker; faults on the Osaka Airport radar screen were blamed on a tv aerial amplifier; train doors have supposedly been jammed by stray emission from tv games machines on the station; and a roller coaster crash was reported as triggered by stray radiation.

Although reports like this are hard to substantiate, the smog is undoubtedly real. Some government research centres, eg Malvern, will not allow anyone with a heart pace-maker on the site. Stray radio signals leaking from experimental equipment can upset the timing circuitry which keeps the wearer's heart beating. Airport security checks, which use radiation to identify metal in passenger's pockets, carry a similar warning.

Whenever a heavy load, like a lift motor or welding machine, is switched on, the mains supply suddenly, briefly, collapses because it is feeding a circuit which for a few microseconds has zero resistance. As the power returns it creates a pulse which can radiate a wide band of electromagnetic energy, across the radio spectrum from a few kHz to 100MHz. The same thing happens when a switch is opened or closed and a spark jumps across the contact gap. The spurious energy runs back into the mains and radiates from the mains cables which act as aerials.

When the oil companies checked forecourt petrol pumps to see whether their accuracy was affected by cars fitted with powerful cb radios, they found that the pumps were usually safe – but computerised cash registers would stop working, and suffer blown microchips.

Philips have found odd causes of tv interference. Early colour receivers showed bars in the picture caused by authorised amateur or "ham" radio transmitters, due to interaction with the tuning transistors. The sound on some sets warbled, but only in some parts of the country, because they were picking up radio signals from the Continent. Early remote control tv receivers were liable to switch themselves off if an amateur in the area was using a Morse key.

Industrial, scientific and medical equipment, used for welding metal or plastic, or for diathermy, is permitted to work at unlimited power (in practice up to 100 kilowatts) on a frequency around 27MHz. They can thus induce high voltages into nearby telephone wires.

So far the public has only suffered inconvenience from smog, most often through interference to television and radio reception or lost computer data. There is good reason to fear that smog may in the future jeopardise safety.

Cars rely more and more on electronics to control the engine, brakes, suspension and steering. Mechanics can no longer repair faults. Designers face a stark choice. Either they must make the car electronics immune to all possible interference or the result of interference must be only to cause the system to revert to normal working under driver control, eg the electronic brakes must be 100% resistant to interference, or default to good old-fashioned mechanical braking at the first sign of trouble. The first option is expensive; the second is a somewhat pointless exercise.

Even a carefully designed car, with good interference suppression and immunity – known as emc or electromagnetic compatibility – is still at the mercy of the owner or mechanic who is unskilled in emc and clumsily fits additional equipment, like a mobile transmitter, high-powered hifi or passenger tv.

Cars and taxis which are often now equipped with mobile transmitters, can come within five metres of a first floor office. Interference field strengths of five volts/metre can result because an ordinary glass window provides no reduction of an incoming signal. Larger voltages may be induced in the wiring loom of a nearby car. The problem will get worse as manufacturers make bodies from plastics rather than metal.

Military equipment is designed to cope with strong radio signals. Aircraft rely on a computer to control the engine and aerodynamics, faster than a pilot can hope to respond. They "fly-by-wire". But the computer must work alongside high power communication transmitters and devices which send out powerful jamming signals. Some modern cockpit radios have 100 kilowatt transmitters.

Accidents can still happen. In 1984 a German airforce Tornado crashed, killing both crew members, after it flew close to a group of radio transmitters near Munich which broadcast Voice of America and Radio Free Europe at high power for reception in the Soviet Union.

The folklore is rich with conflicting opinions on the use of pocket calculators, computers and personal stereos in civilian aircraft. Some airlines forbid all electronics, claiming that there is a risk of interference to the radio navigation equipment on board. Others raise no objection whatsoever.

Tape recorders use a high frequency bias signal and control motor speed with a pulse train. Calculators, like computers, rely on high speed switching circuits and some form of video display. Inevitably a rapid stream of sharp edged pulses escape through the plastic casing and can be picked up by any electronic equipment operating close by. (Try putting a portable radio near a calculator or laptop computer; the effect is often quite dramatic).

The automatic direction finding equipment in any modern airliner works over a wide band of radio frequencies, up to 20MHz, and must be able to capture weak signals coming from a long way away. In theory the signals escaping from a passenger's electronics could by misfortune match the frequency of the navigation signal and swamp it. In practice this is highly unlikely because the aircraft reception aerials are outside, and separated from, passenger interference by metal body work. The navigation receivers are on the flight deck, well away from passengers.

Problems are more likely on small aircraft. The body has a lighter skin and the cockpit equipment is only a few metres from the passengers.

Civil Aviation Authority research concludes there is unlikely to be any risk on airlines. PE

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Editor:
John Becker
Sub-Editor:
Helen Armstrong
Technical Illustrator:
Derek Gooding
Advertisement Sales:
Sarah Holtham
Business Manager:
Mary-Ann Hubers
Circulation:
David Hewett
Publisher:
Angelo Zgorelec
Editorial and Advertising Address:
Practical Electronics,
Intra House, 193 Uxbridge Road,
London W12 9RA
Tel: 01-743 8888
Telecom Gold: 87: SQQ567

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ACCEPTING ENCOURAGEMENT

The hardest part of being Ed is that of rejecting articles and projects. I hate disappointing anyone. How nice it would be to accept every offering, so giving budding designers maximum encouragement.

My own entry into professional electronics was undoubtedly speeded by publication of my first article in PE. The last thing I want to do is hinder enthusiasm by rejecting hard thought out work. (Incidentally, I always give a reason for rejection.) It's a fact of life though, governed by space and suitability, that I cannot accept all offerings.

When assessing suitability there are many factors for which I look, the principle ones being workability, originality, simplicity, and cost. Many offerings comply with the first two but are far more complex than is justified – the basic principles are well thought out, but the choice of chips is insufficiently considered.

To give one example, over 20 chips were being used to gate several oscillators and feed out data to a series of displays. Each oscillator was a separate chip; several gates on other chips were unused; and separate decoders and drivers were used for each display. If further thought had been given to the circuit, the unused gates could have been configured as oscillators and the display decoders and drivers replaced by a single multiplexed chip. By simplifying in other areas as well, the total chip count could have been reduced to just seven! This would not only have minimised the component cost, but also have reduced the pcb area and the box size. In this instance the power consumption would have been significantly reduced as well, minimising battery cost.

In another example someone offered me a stable 50Hz generator. It was logically designed using a crystal oscillator and a gated series of counters. It obviously worked, but the author did not know that a single chip is available to perform the same subdivision operation. Another reader had designed an interesting circuit from bits and pieces he must have had for years. Unfortunately several of the chips had become obsolete and there were no modern equivalents.

I don't expect the average amateur to have access to all data relating to all chips available. Even I, despite numerous reference books, don't know every chip produced. Any designer, though, should at least ask the questions: is the sub-function being designed likely to be a commonplace requirement, are components readily available, and are there unused chip sections that could be put to better use? If the former is true a specific chip may already exist and good component suppliers can probably tell you what it is, and also answer the second question. In the third case use imagination to see if unused sections can be configured to replace other separate chips.

Design efficiency is just as important as originality. It has far better commercial appeal and stands more chance of editorial acceptance. In more ways than one, chips count in electronics.

THE EDITOR

74 SERIES

7400	0.30
7401	0.30
7402	0.30
7403	0.30
7404	0.36
7405	0.30
7406	0.40
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7408	0.30
7409	0.30
7410	0.30
7411	0.30
7412	0.30
7413	0.50
7414	0.70
7416	0.36
7417	0.40
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7421	0.60
7422	0.36
7423	0.36
7425	0.40
7426	0.40
7427	0.32
7428	0.43
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7432	0.36
7433	0.30
7437	0.30
7438	0.40
7439	0.40
7440	0.40
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7445	0.70
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7447A	1.00
7448	1.00
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7451	0.35
7453	0.38
7454	0.38
7460	0.55
7470	0.50
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7474	0.50
7475	0.60
7476	0.45
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7484A	1.25
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7492A	0.70
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74175	1.05
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74179	1.50
74180	1.00
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74182	1.40
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74195	0.80
74196	1.30
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74251	1.00
74259	1.50
74265	0.80
74273	2.00
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74279	0.90
74283	1.05
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74293	0.90
74298	1.80
74351	2.00
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74366A	0.80
74367A	0.80
74376	1.60
74390	1.10
74393	1.20
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74LS10	0.24
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74LS21	0.24
74LS22	0.24
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74LS26	0.26
74LS27	0.24
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74LS30	0.24
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74LS33	0.24
74LS37	0.24
74LS38	0.24
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74LS43	1.50
74LS48	0.90
74LS49	1.00
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74LS54	0.24
74LS55	0.24
74LS73A	0.30
74LS74A	0.35
74LS75	0.45
74LS76A	0.36
74LS78	0.42
74LS83A	0.70
74LS85	0.75
74LS86	0.35
74LS90	0.48
74LS92	0.35
74LS93	0.54
74LS95B	0.75
74LS96	0.90
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74LS114	0.45
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74LS123	0.80
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74LS175	0.75
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74LS244	0.70
74LS245	0.90
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74LS253	0.75
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74LS259	1.20
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74LS373	0.70
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74LS467	1.20
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74LS541	1.00
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74LS641	1.50
74LS642	2.50
74LS642-1	3.00
74LS643	2.50
74LS643-1	3.00
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74S05	0.50
74S08	0.50
74S10	0.50
74S11	0.75
74S20	0.50
74S22	0.50
74S30	0.50
74S32	0.60
74S37	0.60
74S38	0.60
74S40	0.50
74S51	0.60
74S64	0.45
74S74	0.70
74S85	5.50
74S86	1.00
74S112	0.90
74S113	1.20
74S114	1.20
74S124	3.00
74S132	1.00
74S133	0.60
74S138	1.80
74S139	1.80
74S140	1.00
74S151	1.50
74S153	1.50
74S157	2.00
74S158	2.00
74S163	3.00
74S169	5.50
74S174	3.00
74S175	3.20
74S188	1.80
74S189	1.80
74S194	3.00
74S195	3.00
74S196	3.50
74S200	4.50
74S201	3.20
74S225	5.20
74S240	4.00
74S241	4.00
74S244	4.00
74S251	2.50
74S257	2.50
74S258	2.50
74S260	1.00
74S261	3.00
74S283	2.70
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4006	0.70
4007	0.25
4008	0.60
4009	0.45
4010	0.60
4011	0.24
4012	0.25
4013	0.36
4014	0.60
4015	0.70
4016	0.36
4017	0.55
4018	0.60
4019	0.60
4020	0.80
4021	0.60
4022	0.70
4023	0.30
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4025	0.24
4026	0.90
4027	0.40
4028	0.60
4029	0.75
4030	0.35
4031	1.25
4032	1.00
4033	1.25
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4035	0.70
4036	2.50
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4038	1.00
4040	0.60
4041	0.55
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4043	0.60
4044	0.60
4045	1.00
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4047	0.60
4048	0.55
4049	0.36
4050	0.35
4051	0.65
4052	0.60
4053	0.60
4054	0.80
4055	0.80
4056	0.85
4060	0.70
4063	0.75
4066	0.40
4067	2.30
4068	0.25
4069	0.24
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4073	0.24
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4076	0.65
4077	0.25
4078	0.25
4081	0.24
4082	0.25
4085	0.60
4086	0.75
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4098	0.75
4099	0.99
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4502	0.55
4503	0.36
4504	0.95
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4506	0.90
4507	0.35
4508	1.20
4510	0.55
4511	0.55
4512	0.55
4513	1.50
4514	1.10
4515	1.10
4516	0.55
4517	2.20
4518	0.48
4519	0.32
4520	0.60
4521	1.15
4522	0.80
4526	0.70
4527	0.80
4528	0.65
4529	1.00
4531	0.75
4532	0.65
4534	3.80
4536	2.50
4538	0.75
4539	0.75
4541	0.90
4543	0.70
4551	1.00
4553	2.40
4555	0.36
4556	0.50
4557	2.40
4560	1.40
4566	1.40
4568	2.40
4569	1.70
4572	0.45
4583	0.90
4584	0.48
4585	0.60
4724	1.50
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22102	7.00
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40085	1.20
40097	0.36
40098	0.40
40100	1.50
40101	1.25
40102	1.30
40103	2.00
40104	1.20
40105	1.50
40106	0.48
40107	0.55
40108	3.20
40109	0.80
40110	2.25
40114	2.25
40107	2.80
40163	1.00
40173	1.20
40174	1.00
40175	1.00
40192	1.00
40193	1.00
40194	1.00
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LM307	0.45
LM308CN	0.75
LM310	2.25
LM311	0.60
LM318	1.50
LM319	1.80
LM324	0.45
LM334Z	1.15
LM335Z	1.30
LM336	1.60
LM339	0.40
LM348	0.60
LM358P	0.50
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LM380N	1.50
LM383	3.25
LM384	2.20
LM386N-1	1.00
LM387	2.70
LM391	1.80
LM392N	1.10
LM393	0.85
LM394CH	4.00
LM709	0.35
LM710	0.48
LM711	1.00
LM723	0.60
LM725CN	3.00
LM733	0.65
LM741	0.22
LM7747	0.70
LM748	0.30
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LM1830	2.50
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NE566	1.50
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TA7204	1.50
TA7205	0.90
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TL062	0.60
TL064	0.90
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DIGITAL ELECTRONICS

BY OWEN BISHOP

PART 1 – ELECTRONIC LOGIC

In the first part of a new series, Owen Bishop reduces the maze of digital logic to crystal clarity with the aid of brain teasers, ttl, build-it-yourself modules and a birthday party.

WHY DIGITAL?

The dial of our kitchen balance looks like that in Fig.1. To weigh out sugar, for example, we pour sugar into the pan, watching the pointer as it moves around the scale. The pointer moves *smoothly* as the amount of sugar in the pan *gradually* increases. We can stop pouring at any time and the position of the pointer on the dial tells us *exactly* how much sugar is there. This balance has an *analogue* display. It is called 'analogue' because the amount that the pointer has turned corresponds to (is *analogous* to) the mass of sugar (or other substance) in the pan. It's *because* the movement of the pointer and the mass of sugar are analogous that we can use the balance for weighing out sugar.

A speedometer is another instrument with an analogue read-out. As a car accelerates, the pointer of its speedometer moves smoothly around the scale. The scale reading is an analogue of the speed of the car. Similarly, a voltmeter of the 'scale and pointer' type (Fig.2) shows a reading that is analogous to the voltage between its terminals. Yes, we know that the physicists among our readers will be groaning and saying that we should say 'potential difference', not 'voltage'. But, to keep the discussion at a practical level, we'll use the term that's short for 'the reading on a voltmeter' – voltage.

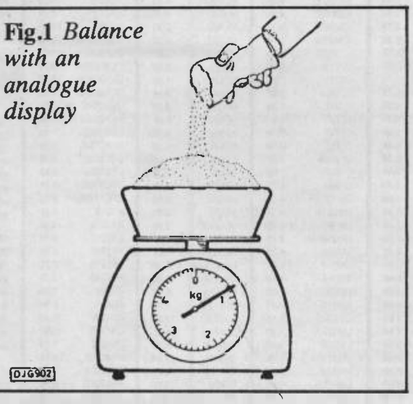

Fig.1 *Balance with an analogue display*

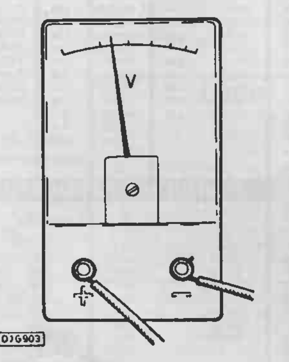

Fig.2 *Voltmeter with an analogue display*

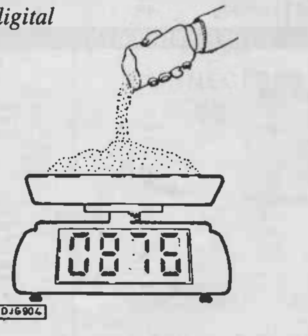

Fig.3 *Balance with a digital display*

SPACE AGE

The dial of our new kitchen balance looks like Fig.3. We have entered the Space Age and treated ourselves to a balance with a *digital* display. It is called 'digital' because the display has digits that directly tell you the mass of sugar. There are four digits in this display. Each digit can have any integer (whole-number) value between '0' and '9'. One difference between our new balance and the analogue balance is that, as the sugar is poured *smoothly* into the pan of our new balance, the mass shown on the display does *not* increase in similar way. It increases *in steps*, a gram at a time. It's rather as if we were pouring lump sugar into the pan, instead of granulated. When we stop pouring, we can *not* tell exactly how much sugar is there. If the scale reads 142g we know only that the mass of sugar is either 124g exactly or between 124g and 125g. We can never obtain a reading such as 124.95g, for example, because there are not enough digits on the scale to express the mass as precisely as this. This does not bother us – weighing to the nearest gram is near enough for making cakes! If we really must know the mass more exactly, we can use a laboratory balance with more digits in its display. But its reading will still be digital and not a true analogue of the mass of sugar in the pan.

Our digital electronic kitchen balance has a sensor connected to the scale pan. The sensor responds to the force acting on it, caused by the mass of sugar in the pan. A voltage is generated between its output terminals. The size of the voltage depends on the mass of the sugar. Thus, the voltage is an analogue of the mass. If we wanted to, we could connect a voltmeter to the sensor, and mark out the scale of the voltmeter to read grams instead of volts. The scale reading would then be an analogue of the mass, as on our analogue balance. There are practical reasons why this does not work very well, mainly the fact that the voltage produced is very small, so it needs to be amplified. This raises the problem that the amplifer (or possibly amplifiers, as a single stage of amplification is probably not enough) does not produce an output that is *exactly* proportional to the input from the sensor. This introduces inaccuracies into our reading. Also, we need an expensive voltmeter to give an accurate and precise reading.

The other approach is to use a digital electronic system (Fig.4). The analogue voltage from the sensor is first converted to its digital equivalent. We shall

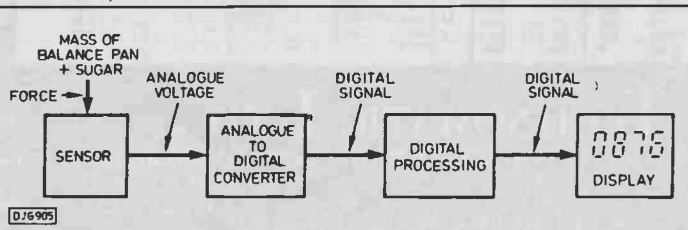

Fig.4 *System diagram of a balance with a digital display*

describe ways of doing this later in the series. Then a digital electronic circuit is used to process this digital equivalent and drive a digital display. The advantages of using a digital techniques are:

* they are reliable
* they are fast in operation
* they are accurate
* they are simple to design and therefore usually cheaper than the equivalent analogue circuit

These features explain why digital electronics is so widely used today in calculators, computers, wrist-watches, and measuring devices. Digital circuits are being increasingly used for the highest quality recording and reproduction of sound. Although digital audio is not cheap yet, prices are falling and will continue to fall further.

ALL DIGITS GREAT AND SMALL

This display shown in Fig.3. uses *decimal digits*. These digits can have any of *ten* values: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. Although the decimal system is one that we find easy to understand and work with, this is mainly because this is the system we learn when young and we are used to it. It probably originated because our ancestors counted on the ten digits of their hands. If their hands had had only four digits each, we should probably be using a number system with only eight digits, 0 to 7, and be just as happy with it. If we are to use an electronic circuit to deal with numbers, we must have some way of representing the values of these numbers electronically, eg by an amount of current, charge or voltage. The decimal system has the big disadvantage that it is not easy to represent decimal digits in a straightforward electronic circuit. If the digit is to be represented by a voltage, for example, we might represent '0' by 0V, '1' by 1V, '2' by 2V, and so on up to '9' represented by 9V. Designing *reliable and inexpensive* circuits to do this is virtually impossible. Slight variations in the values of resistors or capacitors, for example, would introduce serious variations in voltage levels, leading to all kinds of errors and inaccuracies in operation. The simplest plan is to give up the decimal system, with its ten-valued digits, and use a system in which the digits have only two possible values. The two-valued number system is called the *binary system*. Though the binary system is more difficult for *humans* to work with, it is ideal for electronic circuits.

BINARY TABLE

The first few numbers in the binary system are as shown in Table 1.

Binary number	*Decimal equivalent*
0	0
1	1
10	2
11	3
100	4
101	5
110	6
111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	14
1111	15

Table 1. *The binary system*

Before we look at the binary numbers in detail we will study the familiar decimal ones. Take '13', for example. This is written as '1' followed by '3'. The '3' means '3', ie 3 objects such as these three 'stars':

* * *

But the '1' does not mean '1'. It means '10'. A '1' as the second digit from the right is taken to mean '1 *times 10*':

* * * * * * * * * *

So the total value of '13' is thirteen, 1 times 10, *plus* 3. We are so used to this system of writing out numbers that we rarely think about it. It is helpful to think about it now, so that we can understand the binary system.

Take another example, say, '437'. The '4' does not mean '4'. It means '400'. A '4' as the third digit from the right is taken to mean '4' *times 100*'. The total value of '437' is made up like this:

'4' meaning '4 *times* 100' = 400
'3' meaning '3 *times* 10' = 30
'7' meaning '7 *times* 1' = 7
So, '437' has a total value = 437

In the decimal system, as we go from right to left, the digits mean 'ones', 'tens', 'hundreds', 'thousands', 'ten-thousands' and so on multiplying by 10 at each stage (increasing power of ten). In the binary system, as we go from right to left, the digits mean 'ones' 'twos', 'fours', 'eights', 'sixteens' and so on, multiplying by two at each stage (increasing powers of two).

For example, the binary number 10 has:

'1', meaning '1 *times* 2'
= 2 (in decimal)
and '0', meaning '0' *times* '1'
= 0 (in decimal)
So '10' has a total value
= 2 (in decimal)

Fig.5a shows a digital electronic circuit (without any details of how the circuit is built) which has two output lines. A low voltage is taken to mean '0', while a high voltage is taken to mean '1'. The voltages in Fig.5a represent the binary number '10', equivalent to 2 in decimal. This shows how simple it is to represent numbers in binary form, using digital circuits.

The binary number 1101 has:
'1', meaning '1 *times* 8'
= 8 (in decimal)
'1', meaning '1 *times* 4'
= 4 (in decimal)
'0', meaning '0 *times* 0'
= 0 (in decimal)
and '1', meaning '1 *times* 1'
= 1 (in decimal)
So '1101', has a total value
= 13 (in decimal)

'13' decimal and '1101' binary are simply two different ways of expressing the same quantity, the number of stars below:

* * * * * * * * * * * * *

Fig.5b shows a digital circuit with outputs representing binary '1101', or 13 in decimal.

The phrase 'binary digit' is so often used in digital electronics that we shorten it to *bit*.

In the binary system the digits (or bits) have only two possible values, 0 or 1. As illustrated in Fig.5, these two values of the bits can be represented in a digital circuit by two distinct voltages. A suitable choice of voltage to represent '0' is 0V (or a low voltage very close to 0V). Binary '1' may then be represented by *any* convenient higher voltage, for example 5V or 10V.

BINARY LOGIC

Using the binary system to represent numbers fits in well with another important aspect of electronic circuits – logic. The best way to understand what we mean by logic is to look at an example. Cars often have a blue indicator lamp on the dashboard. This tells the driver the state of the headlamps. If the headlamps are on main beam, the blue lamp is lit. If the headlamps are not on main beam, the

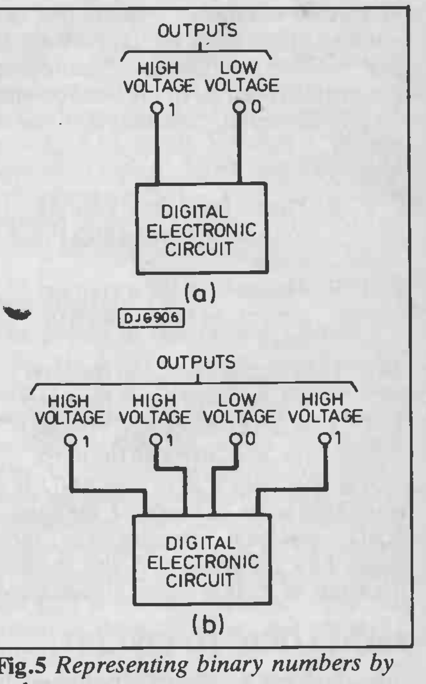

Fig.5 *Representing binary numbers by voltages*

blue lamp is not lit. The blue lamp conveys *information* to the driver about the state of the headlamps. This is *binary* information because there are only *two* possible states for the blue lamp – *on* or *off*. This reminds us of the binary number system, with only two values for the digits, '0' or '1'. In binary logic, everything goes in 'twos'. The twos are opposites, and never occur at the same time. The blue lamp is either *on* or *off*. It is never *on* and *off* at the same time. Neither is it ever half-way between *on* or *off*. If the lamp is ever seen to be *half-on*, something is wrong. The car needs servicing!

In logic, a statement is either *true* or *false* ('twos' again!). A statement such as "The headlamps are on full-beam" must either be *true* or *false*. It can never be both *true* and *false* at the same time. Neither is it allowable for it to be *half-true*.

We can extend this *true-false* idea to two or more statements, for example:

A "It is six o'clock" (we assume we 6 pm)
B "The tv set is on"
Z "I can watch the Six o'clock News"

Statements A and B can be *true* or *false*. They are *independent* of each other – the truth or falseness of A has no effect at all on the truth or falseness of B, neither does B affect A. In the example, the tv set can be on or off at any time of the day, and whether the tv set is on or not has no effect on the time. But the truth or falseness of Z may depend on the truth or falseness of A and B. We can join these statements together to show one way in which this can happen:

"**IF** it is six o'clock **AND** the tv set is on, **THEN** I can watch the Six o'clock News."

This statement has the logical form '**IF A AND B THEN C**'. In the first two columns of the table we have set out all four possible *true/false* combinations of statements A and B. In the third column we give the result – whether Z is *true* or *false*:

A	B	Z	Meaning
F	F	F	The set is off and it's not six o'clock, so I can't watch the news
F	T	F	The set is on but it's not six o'clock, so I can't watch the news
T	F	F	It is six o'clock, but the set is off, so I can't watch the news
T	T	T	It is six o'clock AND the set is on, so I can watch the news

Z is true only if A is true AND B is true. This is an example of the logical AND operation. Because the table shows how the truth of A and B affect the truth of Z, it is called a *truth table*.

FROM LOGIC TO CIRCUIT

Fig.6 shows a logic circuit that could be built to decide if I am able to watch

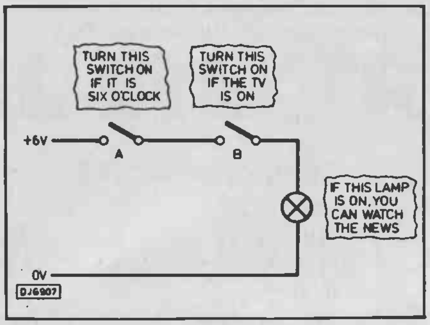

Fig.6 *A simple circuit for the AND operation*

the news or not. I operate the two stitches according to the instructions, and the lamp tells me if I can watch the Six o'clock News. This circuit works because the logical rules that decide how it works are the same as those that decide if I can watch the News. The two switches are so arranged that current passes to the lamp only when switch A is closed AND switch B is closed. In short, the circuit performs the logical AND operation. It works equally well for any other logical AND situation, such as '**IF** you pay the window-cleaner £5 **AND** give him a cup of tea, **THEN** he will clean the windows well'.

Another logical operation is OR, in the form '**IF A OR B THEN Z**'. An example is:

A "It is my birthday"
B "I have passed my exams"
Z "We will have a party"

There need be only one excuse for the party! This is the true table:

A	B	Z	
F	F	F	How disappointing!
F	T	T	Congratualtions!
T	F	T	Happy Birthday!
T	T	T	A double celebration.

The circuit of Fig.7 tells you whether to hold the party or not. If either switch A OR switch B are closed, current flows to the lamp.

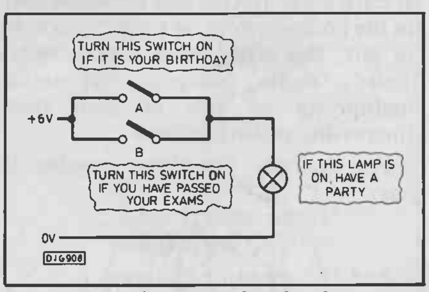

Fig.7 *A simple circuit for the OR operation*

TRANSISTOR LOGIC

Circuits based on the wiring of switches illustrate the principles of electronic logic, but they are not practicable if we want to perform the logic very quickly (ie in a few microseconds). Also, if we want the result of one logical operation to be passed on to another logical operation, it is essential not to use switches that have to be operated by hand. Instead, we use transistors, as these can be switched on or off electronically. Fig.8 shows a transistor circuit for logical AND. A transistor is switched on by connecting its input to the 6V line. The transistor is off if the input is connected to the 0V line.

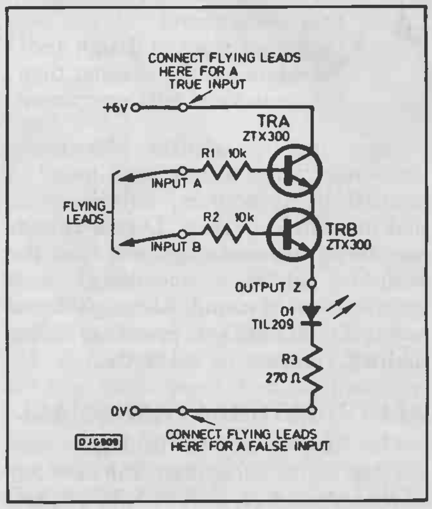

Fig.8 *A transistor circuit for AND*

You could try building this circuit on a breadboard (Fig.9). Then run though the four possible combinations of the inputs:

Input A	Input B	Output Z
F	F	
F	T	
T	F	
T	T	

F = transistor off; its input connected to 0V.

T = transistor on; its input connected to 6V.

The output (Z) is shown by the state of the light emitting diode D1. In the third column write 'F' if the led is off; write 'T' if the led is on. Compare your results with the truth table for AND given earlier. The reason that this circuit performs the AND operation is that the two transistors are wired in series. Current flows through the led only when transistor A AND transistor B are both switched on.

Earlier we said that we use transistor switches because these do not have to be turned on by hand. Yet you are having to make the connections by hand in this demonstration. This is just for convenience. If we wanted to, we could wire up to circuits so that the transistors could be controlled electronically, perhaps by the outputs from other circuits.

Fig.10 shows a transistor circuit for the OR operation. Build this on a breadboard and try it out. Compare its operation with the truth table for OR given above.

These logical circuits are often called *gates*. Fig.8 is an AND gate. for example, and Fig.10 is an OR gate. You

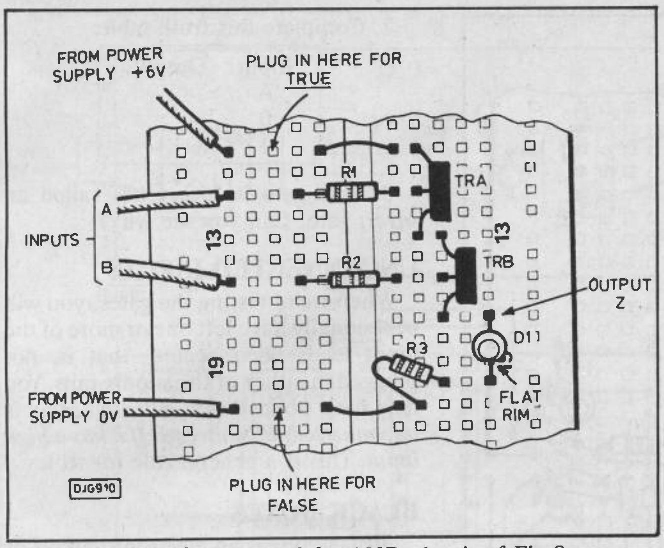

Fig.9 *Breadboard version of the AND circuit of Fig.8*

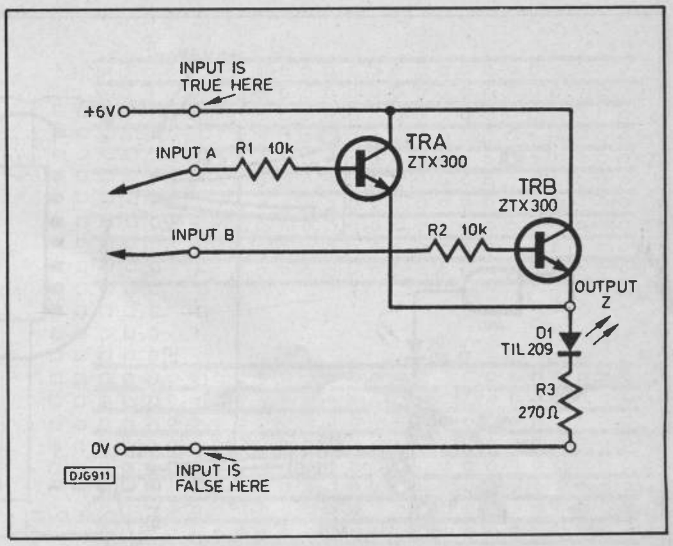

Fig.10 *A transistor OR gate*

can think of a gate as something you have to pass through, and that you are allowed through only under certain conditions. You pass through the gate to a football match only if you have a ticket. You pass through an AND gate only if both inputs (A AND B) are true. You pass through an OR if either one of the inputs (A OR B) are true (or both are true).

TRANSISTOR TRANSISTOR LOGIC

Transistor gates similar to those just described were used for logical operations in the earliest computers, but we have much better circuits available nowadays. One of the best known types of logic circuit is based on a design called *transistor transistor logic*, or ttl for short. In ttl, each gate is built from several transistors, diodes and resistors. As a result, it is faster and operates more reliably than the simple gates we have just described. You can buy ttl ics that contain AND gates and ics that have OR gates as well as ics with several other sorts of gate that we shall be working with next month. You can also buy ttl ics on which many such gates are connected together so as to do much more complicated things than just working out AND and OR. Some can store data (memories and registers), others can count, others can add two numbers together. All these functions, and more, are available on ttl ics. Furthermore, the components used for making the gates are formed and interconnected on a single chip of silicon. In other words, they are *integrated circuits*. This is another reason why ttl is faster, more reliable, and cheaper than circuits built from individual components. Integrated circuits are much smaller in size too, taking up less room on the circuit board and so allowing really complicated logical circuits to be built in a small volume. Good examples of small size are the circuits of digital wrist-watches and pocket calculators.

The standard series of ttl ics is known as the '7400 series' or sometimes as the '74 series'. The type numbers of all ics in this series begin with '74'. An example is the 7408 ic, which contains four AND gates. The integrated circuit is enclosed in a plastic package which has 14 pins, arranged in two rows on either side. This is called a 14-pin double-in-line (dil) package. (Sometimes called 'dual-in-line'. Ed.) The pins are numbered as in Fig.11, which also shows the way the gates inside are connected to the pins.

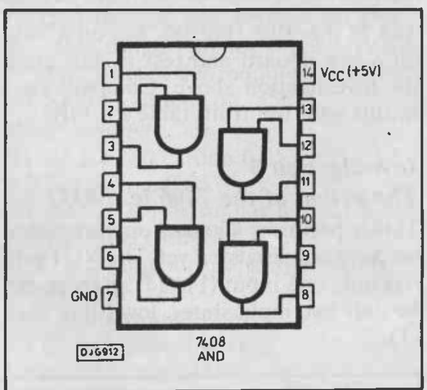

Fig.11 *The pin-out of the 7408*

The numbers of the pins do not appear on the ic itself, but there is either a small dot to indicate pin 1, or a semicircular cut-out at that end of the package. From Fig.11 it can be seen that each AND gate has its own two input pins and an output pin. For example, pins 1 and 2 are the inputs (A and B) to one of the gates, and pin 3 is the output (Z) from that gate.

The power supply for all four gates is connected to pin 7 (0V or 'ground') and pin 14 (+5V, or V_{cc}). The 'CC' in the symbol V_{rcc} refers to the fact that this is the terminal to which the collectors of the transistors are connected. The mention of V_{cc} raises the important point of ttl requires a regulated power supply close to+5BV (between 4.75V and 5.25V). However, it is found that a 6V battery can be used instead and normally gives satisfactory results.

We have already said that logic is a matter of 'twos'. For instance, inputs to gates may be 'high' or 'low'. Outputs from gates may be 'high' or 'low' too. Normally, 'high' represents *true*, and 'low' represents *false*. In the truth tables we have written 'T' for *true* and 'F' for *false*, but it is more usual when dealing with logic circuits to write '1' for *true* and '0' for *false*. Let's sum up these 'twos' in a table:

True	False
T	F
1	0
high	low

These are just four different ways of representing the same things. In ttl, 'high' is usually thought of as +5V. But, if you use a voltmeter to measure the output from a gate, you may find that it is not as high as +5V. In practice, a ttl circuit treats any voltage in the range of +2V to +5V as 'high'. Similarly, 'low' is usually thought of as 0V, but any voltage in the range 0V to +0.8V is treated as 'low' by a ttl circuit. Voltages in the 'in-between' range of +0.8V to +2V are life *half-true* statements – they must not be allowed to occur. If they do, there is no telling how the logic will behave.

Investigation 1
The action of the 7408 ic (AND)

Fig.12a shows a circuit for testing one gate of this ic. The gate is represented by the special symbol (see Fig.13). The numbers beside the inputs and output refer to the pins of the ic. We do not show the power connections to the gate. The state of the output of the gate is monitored by an led (D1), the resistor R1 being to limit the amount of current to a safe level. The led is off when the output of the gate is low, and when the output of the gate is high.

1. Set up the circuit on a breadboard, as in Fig.12b. Note that the breadboard

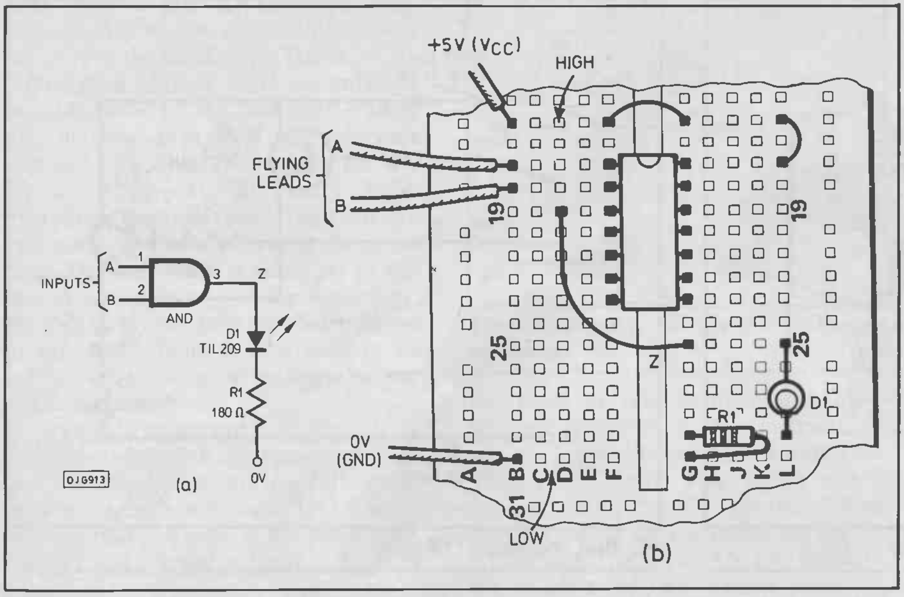

Fig.12 *Investigating the action of the 7408*

shown has a 'gap' between the left and right halves of it. This is so that there are no connections between the pins on the left side of the ic and the pins on the right side. The breadboard you use must have such a 'gap'.

2. Connect the power supply (+5V from a mains power supply unit, or 6V from a battery).

3. This is a table of the four possible combinations of inputs to the gate:

Inputs A	B	Output Z
0	0	
0	1	
1	0	
1	1	

Push both flying leads A and B into sockets in the bottom rail (both inputs *false* or low), as in the first row of the table. Is the led on or off? If it is on, it means that the output of the gate is high. In that case, write '1' in column Z. If it is off, it means that the output of the gate is low. In that case, write '0'.

4. Leave lead A plugged into the bottom rail (=0), but plug lead B into the top rail (+5V). This gives the combination of inputs (01) shown in the second row of the table. Note the state of the led to find out if the output is high or low. Write the result ('1' or '0') in column Z.

5. Repeat step 4, but with input A high and input B low (10), as in the third row of the table.

6. Repeat with both inputs high (11), as in the fourth row of the table.

7. Compare your completed table with the truth table for AND given earlier. Does this confirm that the 7408 operates as an AND gate?

Investigation 2
The action of the 7432 ic (OR)

The 7432 contains four OR gates, connected to the pins in exactly the same way as the 7408 (Fig.11). Set up a 7432 on a breadboard and test it, just as in the investigation above. Compare your results with the truth table for OR.

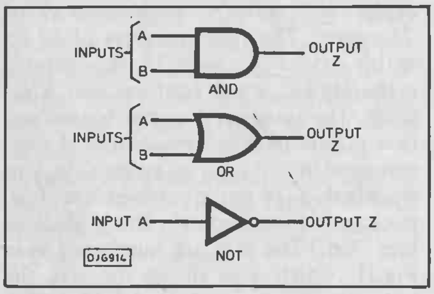

Fig.13 *Logic gate symbols*

Investigation 3
The action of the 7406 ic (NOT)

This ic performs a logical operation that we have not discussed yet. The NOTgate has only one input (Fig.14) so there can be only two input states, low (0) or high (1).

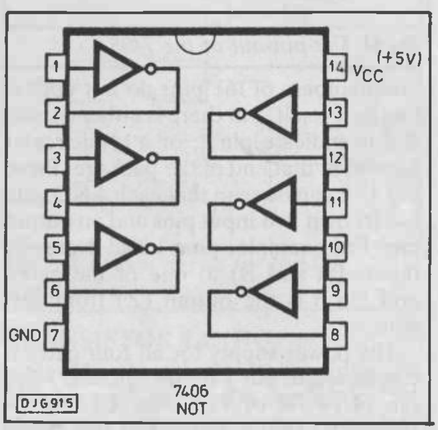

Fig.14 *The pin-out of the 7406*

1. Connect a 7406 ic on a breadboard. It requires the power supplies to pins 7 and 14 as in Fig.12. There is only one input lead, to pin 1. The output to the led is connected to pin 2.

2. Complete this truth table:

Input A	Output Z
0	
1	

3. This gate is sometimes called an *invert* gate. Can you see why?

UNCONNECTED INPUTS

When we're testing the gates, you will occasionally have left one or more of the input leads unconnected, that is, not plugged in either of the supply rails. You may have noticed that *when an input is unconnected, it behaves as if it has a high input.* This is a general rule for ttl ics.

BLACK BOXES

A black box is an electronic circuit or device that we can use without knowing how it is made or what goes on inside it. TTL ics are good examples of black boxes. When using ttl, we do not need to know *what components* a gate is built from, or *how* the gate works. All we need to know are the practical details for using it (ie supply voltage, what inputs it takes and what output it gives). Essentially, we need to know only *what it does*. 'What it does' can be summarised by writing out the truth table for the gate. Because ttl is used as a series of black boxes, it makes it easy to design and use circuits in which several ttl ics are connected together, as we shall explain next month.

TEST YOURSELF

(Answers at end of text.)

1. What type of display (digital or analogue) do you find on the following?
   (a) the petrol indicator of a car
   (b) a cash register
   (c) Big Ben

2. What are the binary equivalents of these decimal numbers?
   (a) 4; (b) 14; (c) 6; (d) 20; (e) 67.

3. What are the decimal equivalents of these binary numbers?
   (a) 11; (b) 101; (c) 1101; (d) 10001; (e) 11101.

4. What logical operation probably connects these 3 statements?
   A It is midnight
   B The sky is cloudless
   Z You can see the stars

5. What logical operation is performed by the gate in Fig.15?

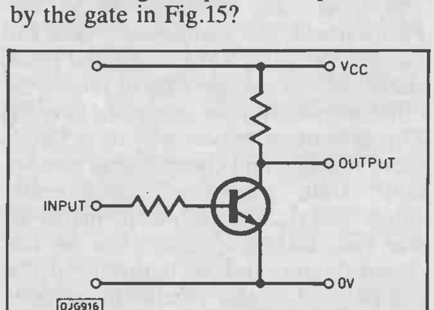

Fig.15 *See question 5*

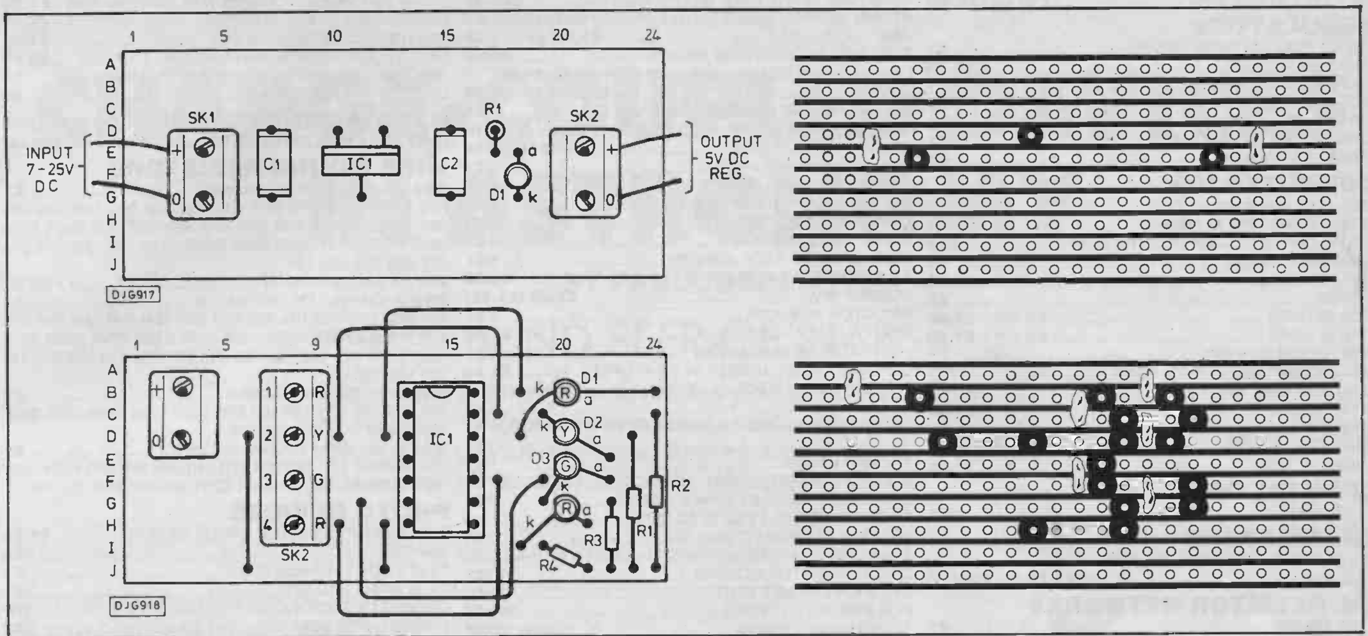

Fig.16 *(Top left) 5V regulated supply layout and track side view (top right). (Bottom left) Indicators layout and track side view (bottom right)*

MODULES OF THE MONTH

Each month in this series we will present details of simple logic circuit modules that you can construct yourself. They are intended to simplify the task of project design. Being compatible with each other, you can join them together, to build up working logic circuits from these simple, easily understood units.

1. 5V-regulated supply

This takes power from a low-voltage dc supply, such as a bench psu or a 'battery eliminator' and delivers a +5V regulated supply, suitable for operating ttl. The voltage of the psu must be between 7V and 25V. Power output is 1A maximum, or the maximum output given by the psu, whichever is the lesser. Bolt a heat sink to the regulator if the input voltage is high, or you intend to draw large currents.

Parts required

R1 150, carbon, 0.25W
C1 470nf, polyester layer
C2 100nf, polyester layer
IC1 uA7805UC, 5V regulator
D1 TIL209 or similar led
SKT1-SKT2 pc terminals 2-way (2-off)
Heat sink, twisted vane, 17°/W.
Stripboard Vero 14345

2. Indicators

Four leds ready-wired for use as indicators of logic outputs. The leds are driven by AND gates; they respond correctly to logic levels and do not overload the driving circuit. Connect unused inputs to 0V to hold the leds off. LEDs 1 to 3 are red, yellow and green, as in traffic lights. The power requirements of this module are: all leds off 3.4mA; all leds on, 35mA.

Parts required

R1,R3,R4 180 carbon 0.25W (3 off)
R2 120 carbon 0.25W
D1-D4 TIL209 or similar led (2 off red, 1 off yellow, 1 off green)
IC1 74LS08 quadruple 2-input AND
14-pin dil socket
SKT1 pc terminal 2-way
SKT2 pc terminal 4-way
Stripboard Vero 14345

Next month in part two we look at using logic gates.

ANSWERS TO QUESTIONS

Don't look until you need to!

1. (a) analogue; (b) digital; (c) analogue
2. (a) 100; (b) 1110; (c) 110; (d) 10100 (=16+0+4+0+0); (e) 1000011 (=64+0+0+0+0+2+1).
3. (a) 3; (b) 5; (c) 13; (d) 17 (=16+0+0+0+1); (e) 29 (=16+8+4+0+1).
4. AND. If it is midnight AND the sky is cloudless then you can see the stars.
5. NOT(or INVERT). When the input is low (0) the transistor is off and the output is high (1). When the input is high (1) the transistor is on, pulling the output voltage low (0).

A simple NOT gate like this can be useful in a circuit – especially if you need just one NOT gate, instead of the six provided by the 7406 ic.

PE

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CHARGE-COUPLED DEVICES IN ASTRONOMY

BY PAUL JORDEN

BLIND SEER OF STARS

Today's most sensitive telescopes and tv cameras "see" by converting light directly into electrical charge and storing the charge to build up an image. It may become feasible to detect distant stars literally photon by photon.

The charge-coupled device (ccd) has only been used for astronomy within the last decade and yet there can be few astronomers who are not aware of its extreme efficiency as a light detector. In recent years, it has become particularly important to make full use of our modern and expensive telescopes. An efficient faint-light detector allows us to make the best use of our telescopes to see fainter objects than ever before. The ccd is almost unique in having a high detection efficiency, over a wide wavelength range, and a large dynamic range.

Historically, astronomers have used photographic plates as a means of recording an image of the sky; with the ccd we now have a detector with a wider wavelength range and more than an order of magnitude increase in sensitivity. Image intensifiers are also used in photon-counting cameras, which are used at low-light levels – sometimes with a ccd as a detector. Here I shall concentrate on describing ccds as direct detectors of light, as opposed to the intensified detector.

This new form of tv camera consists of a two-dimensional array of silicon elements which directly convert light to electrical charge. The ccd finds a wide variety of applications in astronomy, ranging from a rugged eyepiece-viewing tv, to a sophisticated, high-efficiency spectrograph. The small size of this device (about 1cm square) gives some limitations to its use but also opens up new, unique applications in specialised instruments.

WHAT IS A CCD?

The ccd was first conceived about 20 years ago as a new form of memory element, and indeed has some similarities to the familiar random access memory. The ccd consists of a two-dimensional array of picture elements (or 'pixels') fabricated from silicon. In fact, this device has been used for delay-lines, signal-processing and most importantly as a light detector. The name, charge-coupled device, describes the way in which electrical charge is manipulated within the array and this accounts for some characteristic properties of the device.

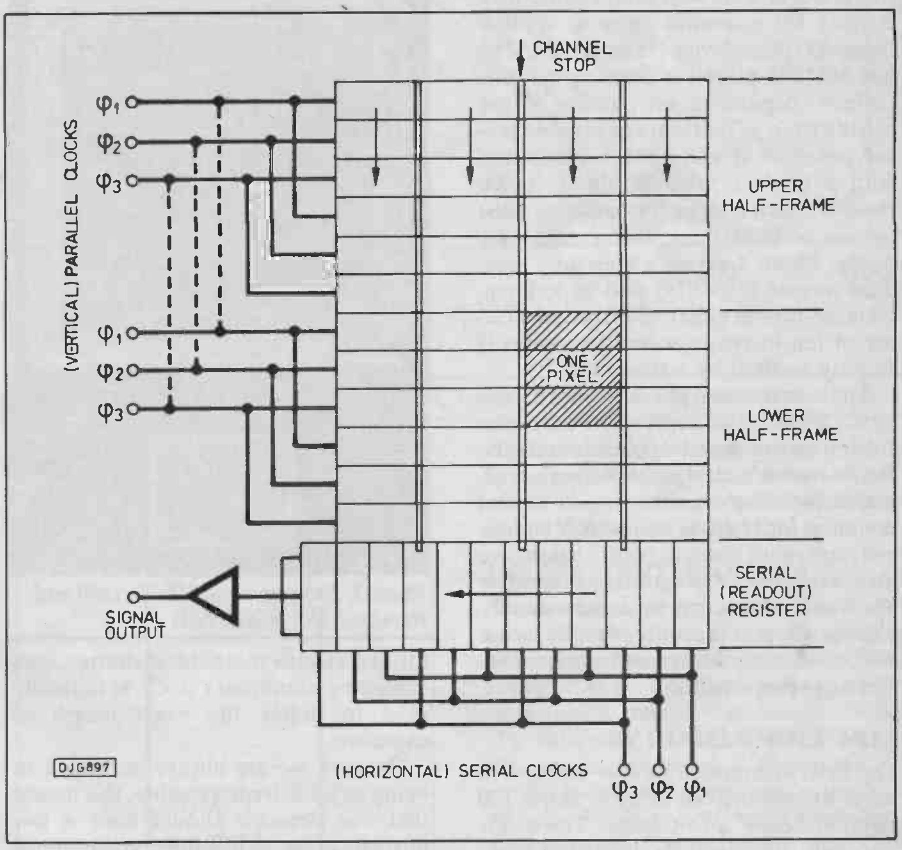

Fig.1 *A three-phase frame-transfer ccd (4 × 4 array)*

Fig.1. gives a schematic view of the ccd array which indicates the general structure, and the coupling between elements. The array is not a random-access device since it does not have row and column addressing of every pixel. Each pixel is sensitive to light and a charge-image builds up within the array, in direct proportion to the light falling on the detector.

The device is fabricated with many columns with a physical delineation (the 'channel-stop') between them. Each row of the device is defined by a set of electrodes (a three-phase ccd is shown). Applying appropriately phased clock voltages to these electrodes causes charge to transfer from one to the next. When a row of charge reaches the edge of the device it passes to a readout register with an orthogonal set of phased electrodes. Thus a combination of parallel and serial clocking is used to transfer charge to the readout corner. Fig.2 shows a typical clock waveform sequence which would be used to read out a complete frame of image from the ccd.

Finally, the charge from each pixel is converted to a voltage across an internal capacitance which then feeds a simple output transistor circuit.

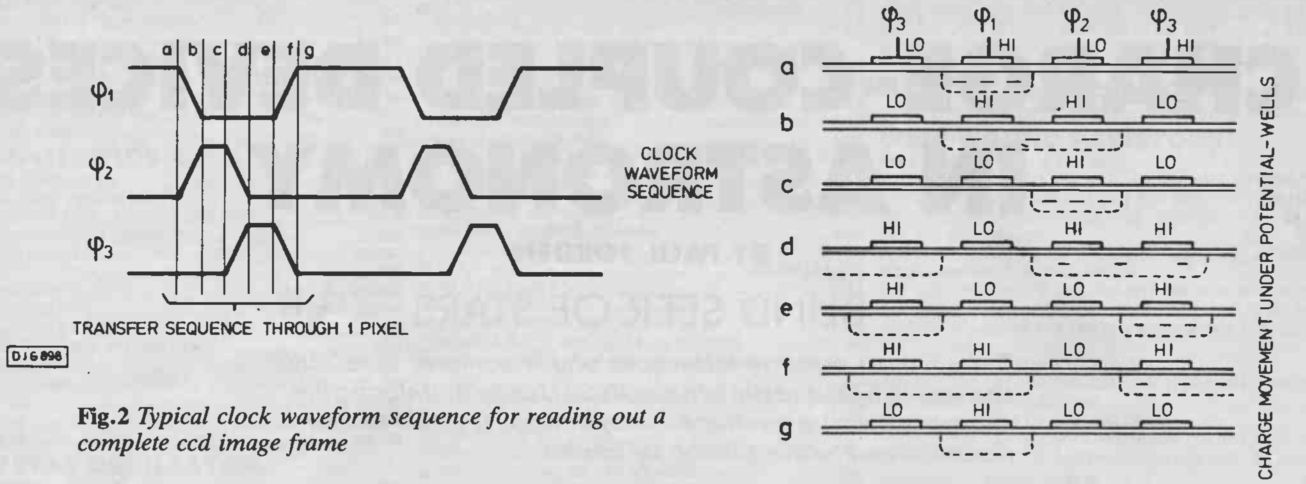

Fig.2 *Typical clock waveform sequence for reading out a complete ccd image frame*

There are approximately six manufacturers world-wide who offer competitive devices for scientific imaging applications. A typical device (from GEC/EEV) has 385*578 pixels; it costs up to 2000 pounds, depending on quality. At the other extreme, Tektronix have made prototypes of a ccd with a 2048*2048 format with a grade-1 price of about 50,000 pounds. Such a large-format array must be one of the largest silicon chips ever made. Photo 1 shows a view of a standard-format (385*578) and experimental large-format (1500*1500) ccd; the factor of ten increase in sensitive areas is eagerly awaited by astronomers.

There are several possible ways to construct a solid state sensor. The most useful for astronomical applications is the frame-transfer design; however a so-called interline transfer device is also common for tv applications. X-Y addressed, and other non-ccd constructions are also available. Astronomers illuminate the whole of an array for maximum efficiency, whereas it is only possible to use half of an array for frame-transfer readout at tv-frequencies.

LOW LIGHT IMAGING

The first, essential thing that we have to do is to cool the ccd array to about 120 degrees below zero Celsius. The ccd is normally designed for use as a traditional tv imager at room temperature, and indeed works well in this way. However, the intrinsic leakage of charge, or dark-current, means that only a short exposure time (eg 30ms) may elapse before a significant charge accumulates. By using liquid nitrogen to drastically cool the detector we reduce this effect by many orders of magnitude. A dark current of less than 1 electron/hour/pixel hardly matters when the peak signal-handling capacity is usually greater than 100,000 electrons/pixel.

For astronomy, our observation can be made over many minutes or hours in order to collect as many photons as possible. Modern telescopes can "track" any celestial object very precisely and keep the image stationary on the detector. An electro-mechanical shutter, controlled by a computer clock, is normally used to define the exact length of exposure.

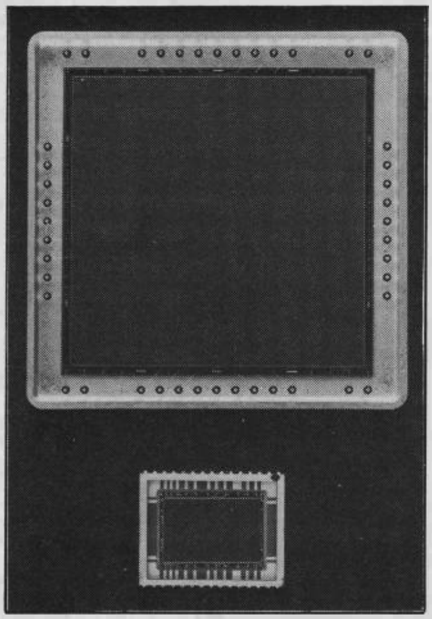

Photo 1. *Experimental 1500 × 1500 and standard 385 × 578 ccds*

Because we are always interested in being as sensitive as possible, this means that our detector should have a low intrinsic noise. A low-noise ccd requires external circuitry with a corresponding low-noise performance. In order to be dominated by the noise of the on-chip transistor (which gives us our output signal), it is necessary to design very low-noise preamplifiers and sampling circuits.

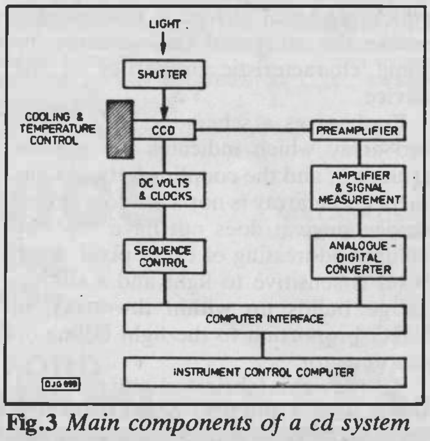

Fig.3 *Main components of a cd system*

Fig.3. gives an indication of the important components that constitute a complete ccd system. There are, of course, a variety of ways to use the ccd but it is ironic that such a compact and efficient light detector usually requires quite a large mass of ancillary electronics in order to be used.

A complete camera system consists of the following main elements: a cryogenic container to maintain the detector at a stable low temperature; low-noise preamplifier and signal-sampling circuitry; a precision analogue-to-digital converter followed by a data interface to a computer system, as well as appropriate electronics to generate dc bias voltages and clock waveforms to control the ccd operation.

ELECTRO-OPTICAL CHARACTERISTICS

The ccd is useful as an optical detector because light is converted directly to electrical charge as it penetrates the silicon. This conversion of photons to hole-electron pairs is very efficient and Fig.4 shows some typical plots of quantum efficiency versus wavelength. The peak efficiency can exceed 80% in some devices. The silicon bandgap of 1 eV means that photons of wavelength less than 1.1 microns can be detected. At the short wavelength end of the spectrum the wavelength limit is determined by device structure and surface absorption effects.

The ccd has a total signal handling capability that is defined by the 'full-well' capacity of each pixel; this is typically 200,000 electrons. Since we are mostly concerned with detecting rather faint astronomical objects this is rarely a limitation to performance. In fact, the incorporation of "anti-blooming" control on some tv-sensor chips is a disadvantage for our application since it only controls high light-level overloads

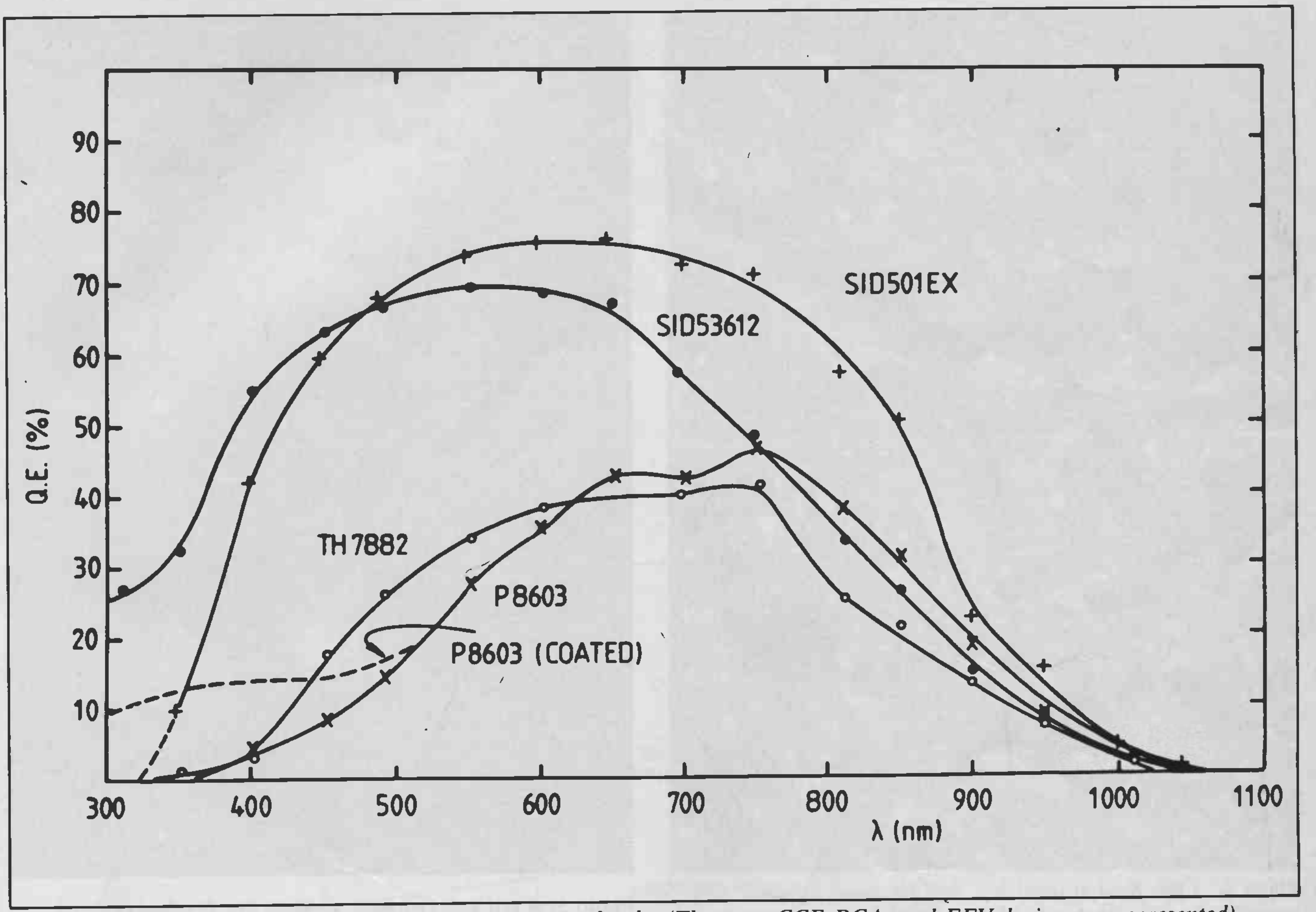

Fig.4 *Quantum efficiency versus wavelength for a variety of ccds. (Thomson-CCF, RCA, and EEV devices are represented)*

at the expense of introducing some non-linearity of response.

An important parameter for ccds is the readout noise; this is the statistical fluctuation of signal charge that is measured when the signal from each pixel is sampled. It is possible to build low-noise preamplifiers with an input noise equivalent to 1-2 electrons, and this allows system noise to be dominated by the ccd characteristics. Thus, high-grade ccds have an output transistor noise of the order of five electrons — this determines the smallest signal that can be measured. A dynamic range of 10,000–100,000 can be achieved; careful design of electronics allows the measurement of a linear signal over most of this range.

The direct electrical output signal from the ccd means that an image can be recorded optically and transferred immediately to an astronomical data computer. It is then possible to analyse the results with few intermediate steps.

The configuration of most ccds varies from a typical 385*576 (tv) format to a 512*512 (scientific) format. Pixel sizes vary from 15–30 microns, depending on the manufacturer. These allow us to resolve detail in a variety of astronomical instrument configurations. Where possible we design optics to match the pixel size to the resolution, provided by a telescope or other instrument. A particular advantage of ccds is their stability with time; this means that they provide a reliable instrument that does not require calibration too frequently.

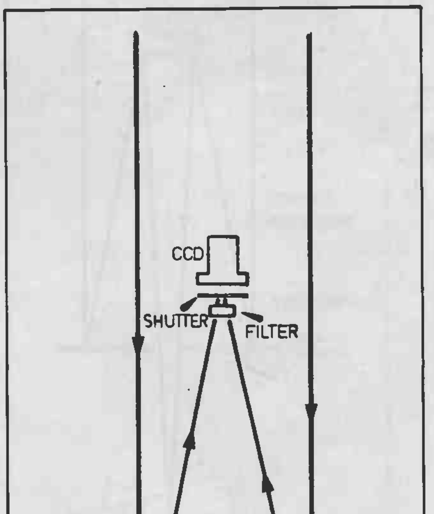

Fig.5 *Prime focus direct imaging*

Again, since telescope time is at a premium, it amounts to a loss of efficiency if one has to spend time calibrating an instrument at night.

INSTRUMENTATION CCDS

The simplest, and probably most common, use of a ccd is as a direct-imaging camera. In this case the detector head is placed at the appropriate focus of the telescope to record the images of the sky. The prime focus is most efficient for this purpose although a Cassegrain or similar position is sometimes more convenient. Fig.5. indicates this traditional direct-imaging application. The ccd much exceeds the photographic plate in sensitivity (and linearity), but suffers from a rather small sensitive area. However, in many cases astronomers wish to concentrate on a single object or small area of sky and this need not be a serious disadvantage. For photometric purposes optical filters would be used to select the wavelength of interest.

The limited size of the device precludes its use for large-field viewing; however, it clearly can be useful for a variety of purposes: measuring total brightness (photometry) of compact objects, measuring distribution of luminosity across extended objects (eg surface photometry of galaxies), and detection of very faint objects. Many distant objects are found to be red in colour

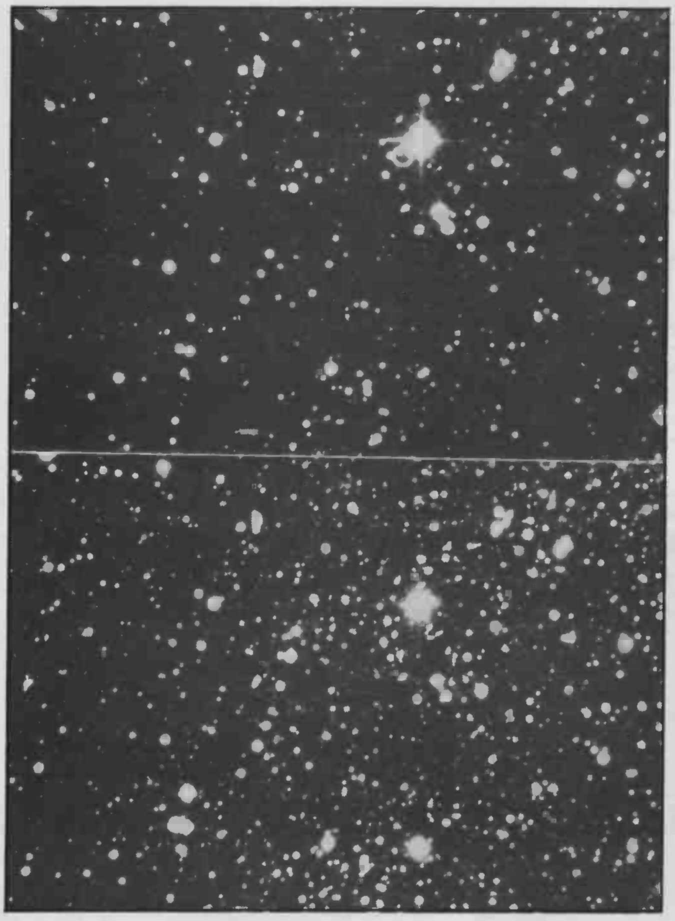

Photo 2. *A star field at (top) red, and (bottom) infrared wavelengths. The images in photos 2 and 3 were recorded at the European Southern Observatory 1.5m telescope*

Photo 3. *A ccd galaxy image — (top) low brightness detail, (below) higher intensity core*

and the silicon long-wavelength sensitivity allows us to detect and measure them very efficiently. Photo 2 shows two ccd images of a star field, with a known x-ray source (GX354+0), the images were recorded at the R-band (mid-colour 650nm) and the Gunn-z band (centred near 1 micron). The stars in this field are heavily reddened and the sensitivity of the ccd at the longer wavelength allows a startling increase in the number of stars which can be seen (and measured).

The large dynamic range of the ccd is particularly beneficial when we wish to record the distribution of brightness of a galaxy. Many galaxies are characterised by bright central cores and extended outer regions; the measurement of these components simultaneously poses a problem for most detectors. Photo 3 illustrates one ccd image of a galaxy (0224-304) which is reproduced in two frames to display all available detail. The outer morphology of the galaxy, as it fades into the sky background, is seen (Photo 3a) and the central core is represented as it would be recorded in a photographic emulsion. The second frame (Photo 3b) shows that, in fact, full information about the core structure has been recorded – although the low intensity background levels are not reproduced in the picture shown.

Another significant application of the ccd is as a spectroscopic detector (it is used in laboratory instruments, as well as the ones described here). The two-dimensional format allows measurement of brightness along the dispersed spectrum as well as recording spatial information. Fig.6. shows one example of this type of instrument; a grating spectrograph is used to generate a spectrum which is recorded by the ccd. The particular advantage of this detector is that red wavelengths can be measured with high efficiency at wavelengths in excess of one micron. The lower intensities (of dispersed light) dictate that only low-noise ccds can be competitive in this application.

In addition, the ccd allows us to record the brightness of an adjacent patch of night-sky spectrum in order to subtract it correctly and hence determine the true

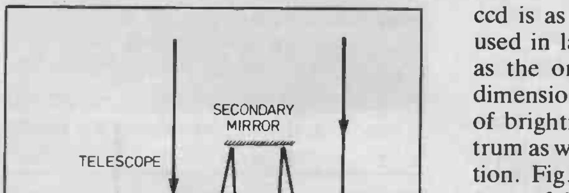

Fig.6 *A ccd on an astronomical spectrograph*

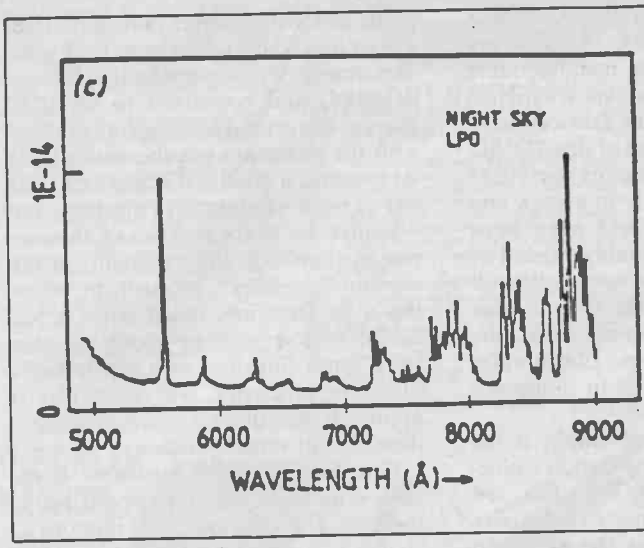

Fig.7 *The night sky spectrum*

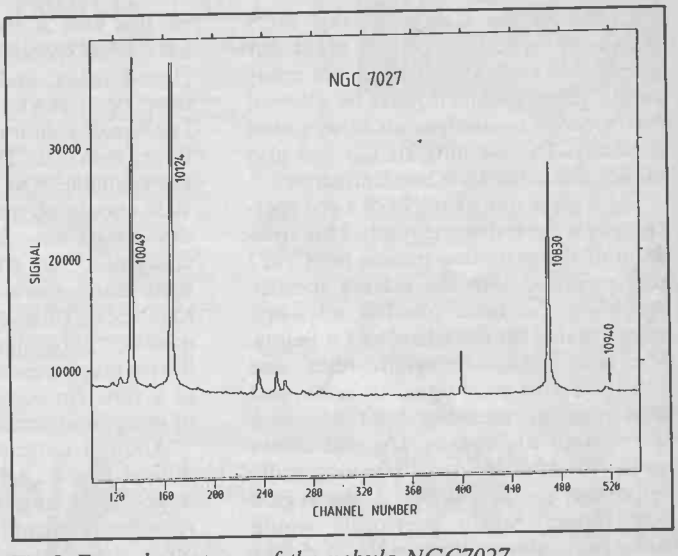

Fig.8 *Far-red spectrum of the nebula NGC7027*

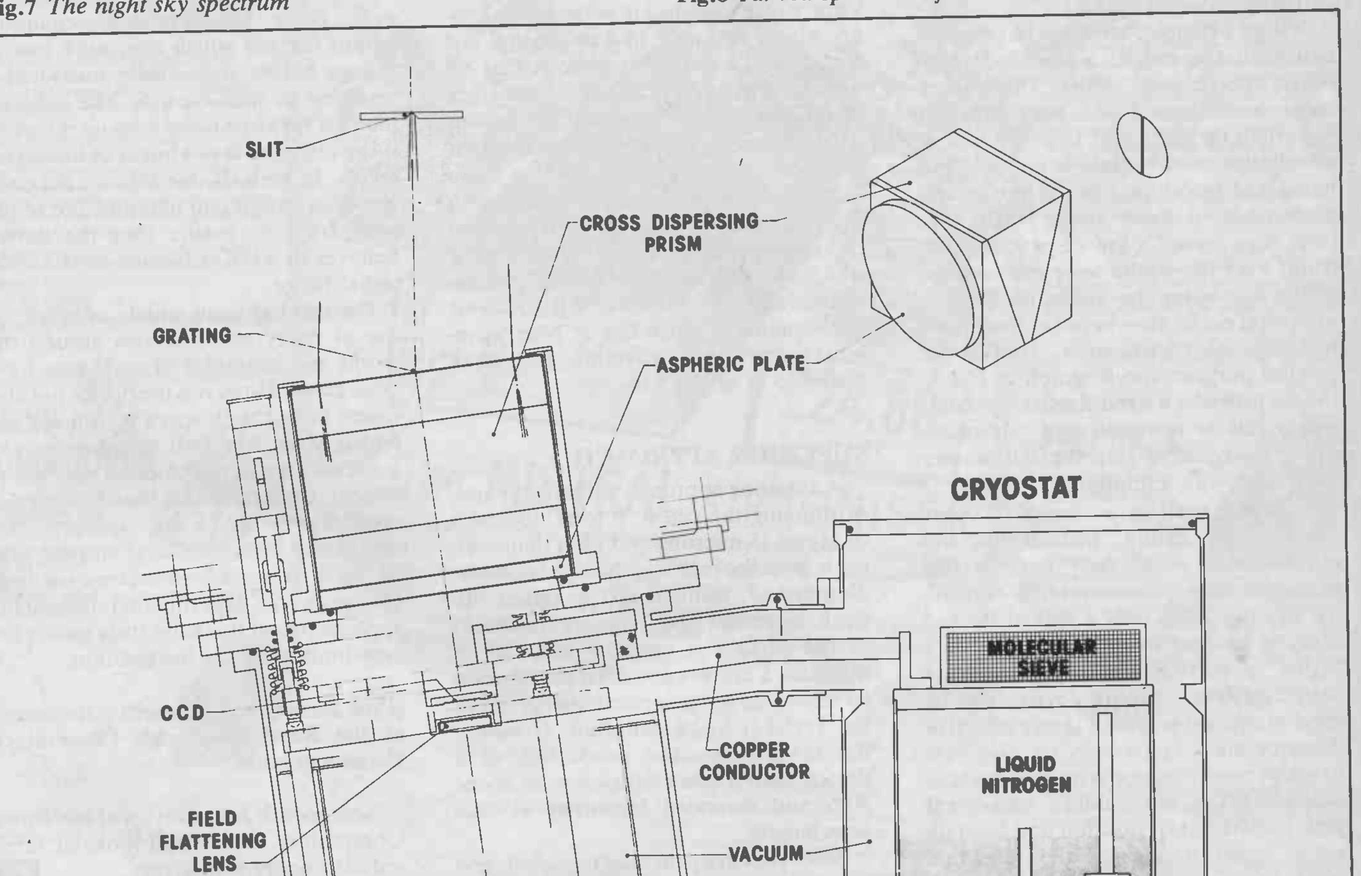

Fig.9 *R.G.O. Durham University L.P.O. 2.5m faint object spectrograph*

spectrum of the star or galaxy. Fig.7 shows the spectrum of the night sky alone; it is evident that there are many strong features which must be allowed for in order to analyse an observation correctly. The stability of the ccd also makes this operation more effective.

Fig.8 gives one example of a ccd spectrum at a far-red wavelength. This spectrum of the planetary nebula NGC7027 was recorded with the grating spectrograph on the Isaac Newton telescope now situated on the island of La Palma. Various bright emission lines are recorded with good signal-to-noise, and it is possible to see a faint line at a wavelength of 1094nm. The ccd allows us to record a variety of astronomically important spectral lines (in the region 900-1100nm) which previously would have been almost impossible to detect with alternative detectors.

A third example, utilising the compact nature of the ccd, is a so-called faint-object-spectrograph (fos). This instrument is optimised for very efficient recording of spectra of faint objects. It is only designed to do this one job and has a ccd embedded inside the instrument body, as shown in Fig.9. The purpose is to record a low-dispersion spectrum, over the whole wavelength range of the ccd, using the minimum number of optical elements – in order to achieve high optical transmission. Unlike the general purpose spectrograph of Fig.6., the fos provides a fixed-format spectrum which can be recorded and "automatically" analysed to give the astronomer his results with a minimum of delay.

Ccds are used in a variety of other simple, and exotic, instruments too numerous to detail fully here; a few examples may demonstrate its versatility. In some cases only a part of the ccd array is utilised in order to achieve a higher speed readout. In other cases a matrix of four or more devices can be used in consort to give a larger effective detector area. Some ccds are also now in use as position sensors on modern telescopes – these "autoguiders" measure if a star drifts out of position and send an error signal to correct the telescope tracking.

LIMITATIONS AND FUTURE DIRECTIONS

The ccd is not perfect. A variety of the attractions of this device have been presented and indeed in certain respects it is superior to other imaging detectors. However, we are aware of limitations in performance that in some cases should be removed in the forseeable future.

The restricted size of the silicon array is the first feature that we are looking to expand. One solution is to use a matrix of ccds to deliver a larger area with which to collect the precious sky photons – one must suffer the losses due to the gaps between devices. An improvement on this idea is the use of devices that have been specially made to allow very close butting, and some manufacturers have been working on this technique. The 'final' solution is the fabrication of larger area ccds. Devices of size 512*512 are available now, devices of size 1024*1024 should be available in a year, and devices of size 2048*2048 have been announced but are arguably "ahead of their time". Certainly it is very difficult to fabricate such very large arrays in high quality, particularly since only one device may be made on one silicon wafer at a time (in comparison to thousands of integrated circuits).

Another current disadvantage is the difficulty of achieving good blue-wavelength response. The far red response is already an improvement over other detectors whereas the blue and ultra-violet response is poor. Astronomers would certainly like to use the ccd for ground-based measurements at all wavelengths beyond 350nm. The surface electrodes, that allow the device to work, normally absorb short-wave light very strongly. A "simple" solution is the technique of coating the chip with fluorescent dyes; these allow uv light to be converted to longer wavelengths which the ccd can record. This process can achieve an enhancement to about 20% quantum efficiency at blue wavelengths, without affecting the peak response of about 50%.

SUPERIOR APPROACH

A superior approach is the technique of thinning the ccd to a total thickness of about 15 microns and then illuminating it from the rear side. Such a backside-illuminated, thinned ccd is rather difficult to make; also, correct treatment of the surface is essential in order to maintain a correct potential distribution to allow the uv-generated charge (near the surface) to be collected. However, the rewards are the production of a device with a peak efficiency of about 80% and extended sensitivity at blue wavelengths.

Since ccds are generally regarded, and used, as low light level detectors, their lowest detectable signal level is of some importance. Once a faint image has been detected, and converted to electrical charge, it is crucial to measure the signal with the minimum possible noise level. At present, a good ccd achieves a read-out of noise of about five electrons rms – limited by characteristics of the mos output transistor. Improvements of this on-chip "amplifier", probably by adopting a fet structure, could allow a predicted performance of about 1-2 electrons noise. Together with nearly 100% quantum efficiency, we could clearly approach the ultimate performance – detection of single photons.

One last important necessity is the achievement of linear response within the ccd. The conversion of photons to charge is a direct linear process. However, there are various mechanisms within the ccd which can cause loss of charge before it is finally measured – resulting in non-linearity. The achievement of very low-noise readout is wasted if the response is not linear at low signal levels. In general, we rely on improvements in design and manufacture of the ccd arrays to ensure that the device behaves in a linear fashion over a wide signal range.

The ccd has been widely adopted for use at many observatories around the world and examples of such uses have been given. However, the device has also found favour with space astronomy scientists since it is well suited as an element of a space telescope or satellite tv system. Ccds have also found important applications as x-ray sensors (for astronomy from satellites) and can also be used as particle detectors (in high energy physics experiments). Indeed the applications of this solid state sensor are only limited by the imagination.

(Paul Jorden is a Research Astronomer at the Royal Greenwich Observatory, Herstmonceaux).

Next month John Davies of the Royal Observatory, Edinburgh looks at infra-red astronomy with arrays. PE

Trade Off

"You've got a new motor John," observes self-employed car mechanic friend I'd not seen for a while.

"The other was getting delusions of becoming vintage, but without the pedigree," quips I.

"You had a yen for the Rising Sun, though," he rebukes.

"Ah, but it's British *built*," I rejoinder, "and it's hi-tech."

"Putting me out of business, these hi-tech motors - all the electronics that's in them," grimaces friend. "This five years has really seen some changes."

"Thought you'd welcome it - harder to service, more to charge ...," beams I, monetarily.

"No way - I don't understand the changes," growls friend, stonily. "I'm a blooming car mechanic, not an electronic wizz-kid."

"You can retrain," I try to encourage.

"Can't find time - I'd miss trade if I went on courses. And can't find money for new test gear," he admits, reluctantly. "No mate, the days of blokes like me are numbered. Soon there'll be so many electronic cars around there won't be enough real motors to keep me going. I'm one of a dying breed who can't afford to change, and can't afford not to."

It's a tough fact, history is littered with ghosts of craftsmen whose trade has passed its need. Survival is only for those who train for the new technologies. **Ed.**

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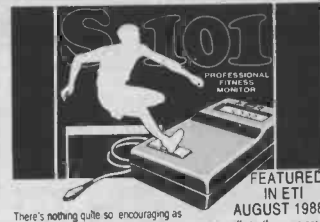
Mono power meter	£3.90 + VAT
Stereo power meter	£7.20 + VAT

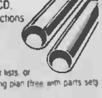


FEATURED IN ETI AUGUST 1988

There's nothing quite so encouraging as having a quantifiable result to show for your training efforts. If you are not particularly fit, your resting heart rate will be around 80 beats per minute. As your jogging, aerobics or sport strengthens your heart, the rate will drop dramatically – possibly to 60bpm or less. With the S101, you can watch your progress day by day.

Breathing is important too. How efficiently do you take up oxygen? How quickly do you recover from 'oxygen debt' after strenuous activity? The S101 will let you know.

The approved parts set consists of: case, 3 printed circuit boards, all components (including 17 ICs, quartz crystal 75 transistors, resistors, diodes and capacitors), LCD, switches, plugs, sockets, electrodes, and full instructions for construction and use.



PARTS SET **£33.80** + VAT

Some parts are available separately. Please send SAE for lists, or SAE + £2 for lists, circuits, construction details and training plan (free with parts set)

THE DREAM MACHINE

FEATURED IN ETI
DECEMBER 1987

Adjust the controls to suit your mood and let the gentle, relaxing sound drift over you. At first you might hear soft rain, sea surf, or the wind through distant trees. Almost hypnotic, the sound draws you irresistably into a peaceful, refreshing sleep.

For many, the thought of waking refreshed and alert from perhaps the first truly restful sleep in years is exciting enough in itself. For more adventurous souls there are strange and mysterious dream experiences waiting. Take lucid dreams, for instance. Imagine being in control of your dreams and able to change them at will to act out your wishes and fantasies. With the Dream Machine it's easy!

The approved parts set consists of PCB, all components, controls, loudspeaker, knobs, lamp, fuseholders, fuse, mains power supply, prestige case and full instructions.

PARTS SET **£16.50** + VAT

AVAILABLE WITHOUT CASE FOR ONLY **£11.90** + VAT

FEATURED IN ETI
SEPTEMBER 1988

£24.80
+ VAT

The MISTRAL AIR IONISER

Air ions are as essential to life as food and drink. In sterile city environments the natural ions are wiped out by dirt, dust, pollution and traffic fumes. The resulting feelings of pale, tired listlessness are so easy to change.

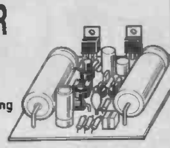
The Mistral is designed to restore the natural ion balance, and with it your sense of energy, health and vitality. A highly developed circuit combined with an efficient phosphor-bronze emitter fills the most spacious room with life giving ions. You'll feel the difference within hours!

- Variable ionisation potential for maximum ion rush
- Hundreds of phosphor bronze ion thrust points
- Built-in ion counter – see the output level at a glance
- Over 100 top grade components
- Speedy relief for hay fever and asthma sufferers
- Feel the difference within hours

Some parts are available separately, Please send SAE for lists, or SAE + £1 for lists, circuit, construction details and further information (free with parts set).

ARMSTRONG 75W AMPLIFIER

FEATURED IN PE
JULY 1988



A.J. Armstrong's exciting new audio amplifier module is here at last!

Delivering a cool 75W (conservatively rated – you'll get nearer 100W), this MOSFET design embodies the finest minimalist design techniques, resulting in a clean, uncluttered circuit in which every component makes a precisely defined contribution to the overall sound.

You can read all about it in the July issue of PE, but why bother with words when your ears will tell you so much more?

Parts set includes top grade PCB and all components.

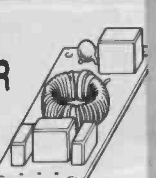
SPECIAL INTRODUCTORY PRICE FOR FULLY UPGRADED MODULES.

SINGLE PARTS SET **£14.90** + VAT
STEREO PAIR **£25.90** + VAT

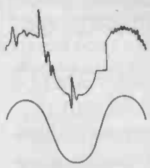
Please send SAE + £1 for data and circuits (free with parts set), including diagrams for matching pre-amp and power supply. This amplifier will not be available from your usual audio supplier – we produce the only designer approved parts set.

MAINS CONDITIONER

FEATURED IN ETI
SEPTEMBER 1986



Cleans up mains pollution easily and effectively. You'll hardly believe the difference in your Hi-Fi, TV, Video, and all other sensitive equipment.

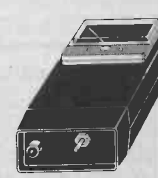


PARTS SET **£4.90** + VAT

RUGGED PLASTIC CASE **£1.65** + VAT

BIO-FEEDBACK

FEATURED IN ETI
DECEMBER 1986



Bio-feedback comes of age with this highly responsive, self-balancing skin response monitor! The powerful circuit has found application in clinical situations as well as on the bio-feedback scene. It will open your eyes to what GSR techniques are really all about.

The complete parts set includes case, PCB, all components, leads, electrodes, conductive gel, and full instructions.

PARTS SET **£13.95** + VAT

BIO-FEEDBACK BOOK **£3.95** (no VAT)

Please note: the book, by Stern and Ray, is an authorised guide to the potential of bio-feedback techniques. It is not a hobby book, and will only be of interest to intelligent adults.

POWERFUL AIR IONISER

FEATURED IN ETI
JULY 1986

Ions have been described as 'vitamins of the air' by the health magazines, and have been credited with everything from curing hay fever and asthma to improving concentration and putting an end to insomnia. Although some of the claims may be exaggerated, there is no doubt that ionised air is much cleaner and purer, and seems much more invigorating than 'dead' air.

The DIRECT ION ioniser caused a great deal of excitement when it appeared as a constructional project in ETI. At last, an ioniser that was comparable with (better than?) commercial products, was reliable, good to build . . . and fun! Apart from the serious applications, some of the suggested experiments were outrageous!

We can supply a matched set of parts, fully approved by the designer, to build this unique project. The set includes a roller tinned printed circuit board, 66 components, case, mains lead, and even the parts for the tester. According to one customer, the set costs 'about a third of the price of the individual components'. What more can we say?

Instructions are included

PARTS SET WITH BLACK CASE **£11.50** + VAT

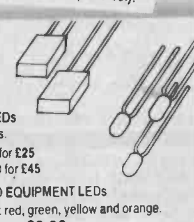
PARTS SET WITH WHITE CASE **£11.80** + VAT

LM2917 EXPERIMENTER SET

Consists of LM2917 IC, special printed circuit board and detailed instructions with data and circuits for eight different projects to build. Can be used to experiment with the circuits in the 'Next Great Little IC' feature (ETI, December 1986).

LM2917 EXPERIMENTER SET **£5.80** + VAT

LEDs



Green rectangular LEDs for bar-graph displays.

50 for £3.50	500 for **£25**
100 for £6	1000 for **£45**

DIGITAL AND AUDIO EQUIPMENT LEDs

Assorted 3mm LEDs: red, green, yellow and orange.

25 of each (100 LEDs) for **£6.80**

BRAINWAVE MONITOR

FEATURED IN ETI
AUGUST 1987

The most antonishing project ever to have appeared in an electronics magazine. Similar in principle to a medical EEG machine, this project allows you to hear the characteristic rhythms of your own mind! The alpha, beta and theta forms can be selected for study and the three articles give masses of information on their interpretation and powers.

In conjunction with Dr. Lewis's Alpha Plan, the monitor can be used to overcome shyness, to help you feel confident in stressful situations, and to train yourself to excel at things you're 'no good at'.

Our approved parts set contains case, two PCBs, screening can for bio-amplifier, all components (including three PMI precision amplifiers), leads, brass electrodes and full instructions.

PARTS SET **£36.90** + VAT ALPHA PLAN BOOK **£2.50**

SILVER SOLUTION (for plating electrodes) **£3.60** + VAT

Parts set available separately. We also have a range of accessories, professional electrodes, books, etc. Please send SAE for lists, or SAE + £2 for lists, construction details and further information (free with parts set).

Prices shown are exclusive of VAT, so please add 15% to the order total. UK postage is 70p on any order. Carriage and insurance for overseas orders £4.50. Please allow up to 14 days for delivery.

Specialist
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DAT SAGA CONTINUES

BY WAYNE GREEN

MAINFRAME CASSETTES?

While the American recording industry appears to be shooting itself in the foot over digital audio tape, the real losers, argues Wayne Green, are the computer industries.

The Recording Industry Association of America (RIAA) has whipped up so much media attention in their fight against dat that they've cost the record industry an estimated $1 billion in sales in the US so far.

The media in the US, like in UK, just can't get enough of anything controversial. So no matter how ridiculous the claims for losses due to cassette taping, the media has unhesitatingly endorsed them. To make matters worse, there's always a political todey eager to get a headline with something like this. In the US it was Senator Gore who was fanning his presidential aspirations with the RIAA hype. I see you've got your counterpart in one Simon Coombs. We all have our crosses to bear.

Despite the headlines and pressure from Gore, congress refused to take any action against dat until National Bureau of Standards (NBS) reported back on the efficacy of the CBS notch system which was supposed to prevent dat recorders from copying cds.

CODE BUSTING

It turned out that the CBS copy code was a disaster. The NBS reported to congress that it sometimes failed to let dat copies be made of non–encoded cds, it allowed the copying of encoded cds, the difference in sound was noticeable when a cd was encoded and the whole system was easily bypassed. A bust on all four counts.

The only recourse left to RIAA was to use the threat of expensive, if frivolous lawsuits to stop the importation of dat recorders. If you can't stop 'em with logic, use lawyers.

Of course what happened was that millions of Americans read about how great RIAA was claiming dat to be, so they concluded that cds were dead. The sale of cd players plummeted in the last quarter of 1987 and the first quarter of 1988 – down 1.1 million units from the projections for 1987 alone. That's a loss to the manufacturers of around $275 million. Worse, this in turn resulted in a slowing down of cd buying, with an esti-

mated loss of over $1 billion in cd sales so far directly attributable to the RIAA campaign. No one can say the RIAA isn't effective!

DATA LOSS

The real loser, unfortunately, is the computer industry. When you realise that a dat tape can hold as much data as 13 reels of 9–track computer tape and read it at six times the speed – and with fewer errors, perhaps you can get an idea of the potential.

One little dat tape can hold as much as three cds. Even the problem of wearing out the little tape with endless fast searching isn't difficult to solve. If we dump the data from the dt onto either a hard disc or ram for the faster searching of a data base we'll be able to handle the data in up to 20 or 30 megabyte lumps.

With 8 and 16–megabyte ram chips being promised soon, we may be able to dump data from dt into 160 MB of ram, even in a laptop computer. Not many data bases are larger than that.

DT will be a godsend for hard disk backup. It'll also be great for storing archival data such as sales information, banking transactions and other ongoing data streams.

I see the opportunities for thousands of new entrepreneurial businesses to spring up providing frequently updated data bases for use on dt. These could be sent over a satellite link or via fibre optics. Almost any profession has a need for a large, updated data base.

THE HAM CONNECTION

DAT also offers some interesting potentials for amateur radio communications. It's not only practical, but also legal to send music over any ham band right now – if you use digitally coded audio. All you're sending is digital information, Whether it is decoded as music, a weather satellite photo, computer data, a computer program, graphics or even a three–D full colour photograph depends on how you decypher the data.

So how would I sendThe Blue Danube over 20m to Australia? I'd load the first 30 megabytes of data from a cd into a hard disc. Then I'd program my computer to slow down the sampling rate from 44,100 per second to 2,205 (one–twentieth speed) and pop it over 20m. On the receiving end I'd load this data onto another 30 MB hard disk and then load that to a dat tape at 20x speed. Then I'd load the next 30MB and so on.

Sure, it's going to take twenty times as long to send the data, but the bandwidth will be in line with our ham restrictions. A six minute selection will take two hours to send. Yes, if we had several thousand hams sending their record collections over 20m we'd have a mess. But, heck, we already have a mess, so what's new? At least we'd be communicating something which would be of lasting value for a change.

Once we start using dt for computers I'll be surprised if we don't start seeing some systems with a choice of recording and playing speeds. We'll need about ten times the speed for a high quality digital video recording (500 MHz). And we'll want much slower speeds for storing fm–quality sound – and even slower for am–quality sound. For ham quality I think we can just stop the tape.

Continued on page 49

MUXING THE BEEB

BY ROGER MORGAN AND KARL STRINGER

A-D-C TO THE A/DC

You can increase the number of analogue input lines on the BBC micro, without attaching expensive add-on adcs, by building a multiplex unit. Here we give two circuits, giving from four to sixty inputs via the multiplexer.

Nearly all modern computers are digital in operation operating as vast arrays of on-off switches, while most of the rest of the world is analogue, in other words, capable of varying continuously. Thus if we want computers to make sense of the real world we need to convert from an analogue representation to a digital one. Transducers are readily available which will produce an analogue voltage representation of nearly anything you might wish to measure eg temperature, sound, pressure, radioactivity etc. All that is needed is a way of turning this voltage into a binary number inside the computer.

By turning a voltage into a series of binary digits we also limit the number of possible values to the number of bit patterns available instead of the infinite number of voltage levels in the real world. Thus if we turn a voltage between 0 and 1.8V into a 12 bit number it can adopt only one of 4096 values. This is a measure of the resolution of the converter.

The adc chip used in the BBC Computer is quite an accurate one as these chips go, although noise and drift due to temperature instability reduce the theoretical 12-bit accuracy somewhat. There are ways of dealing with both these problems using averaging and by improving the reference voltage (with a special link in the Master).

Quite often when you want to monitor some process using the adc the four lines are just not enough and a way of increasing these has to be found. It would be possible to build another adc and hang it on the 1MHz bus or user port. This would however be quite expensive and a simpler option exists in the technique of multiplexing.

The built in adc uses this technique to provide its four lines and this explains the change in the speed of sampling from 40ms to 10ms when you select only one channel. All we need to do for more lines is multiplex the multiplexer!

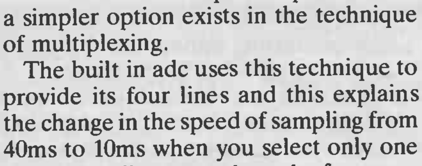


Fig.1

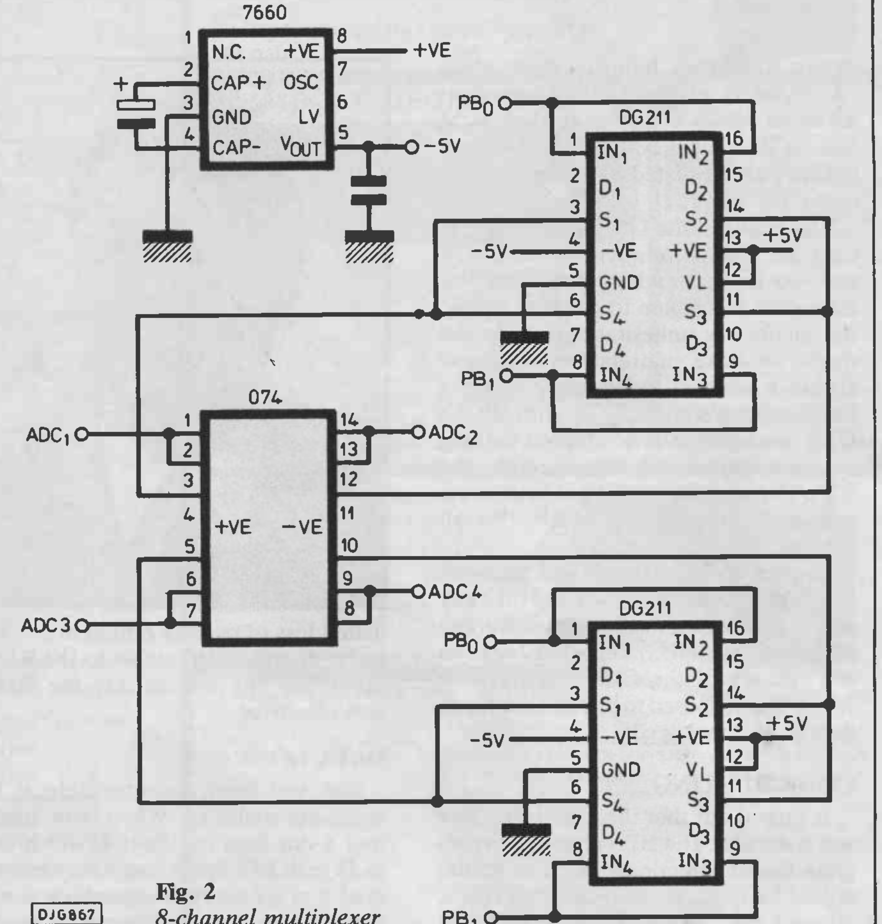


Fig. 2
8-channel multiplexer

Multiplexing is a technique you make use of every time you use the phone. It would be impractical to have a wire connecting each telephone to every other one in the world. Instead the system depends on the fact that not everyone will make use of their phone at the same time by routing calls along a limited number of lines. This limitation is exposed when you find you cannot get through to a number at a particularly busy time.

In basic terms a simple mpx would involve a switch to toggle between two lines and a mechanism to control the switch. (Fig.1.)

It should be noted that we are interested in the voltage level on the supply lines A and B, so we are looking for a switch that can pass on a voltage level not just a digital on/off signal. This rules out all those nice digital signal multiplexer/demultiplexers.

We are left with two reasonable choices – relays or analogue switch ics. We will use the latter in this project for reasons of speed and cheapness although for perfect channel isolation the mechanical relay would be the choice.

So what do we need in hardware terms? Well that depends on how many extra channels you require. Two circuits will be described that supply from as few as four extra channels up to a maximum of 60 extra channels.

The first circuit makes use of a chip with four spst switches, the DG211 (Fig.2.). Note that each side of the chip

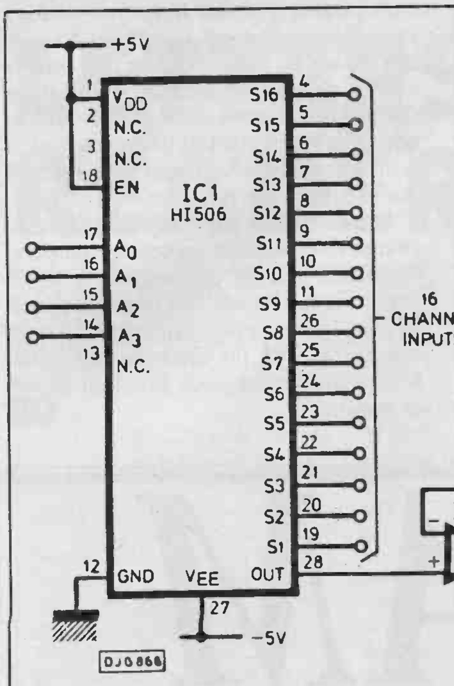


Fig.3
16-channel multiplexer

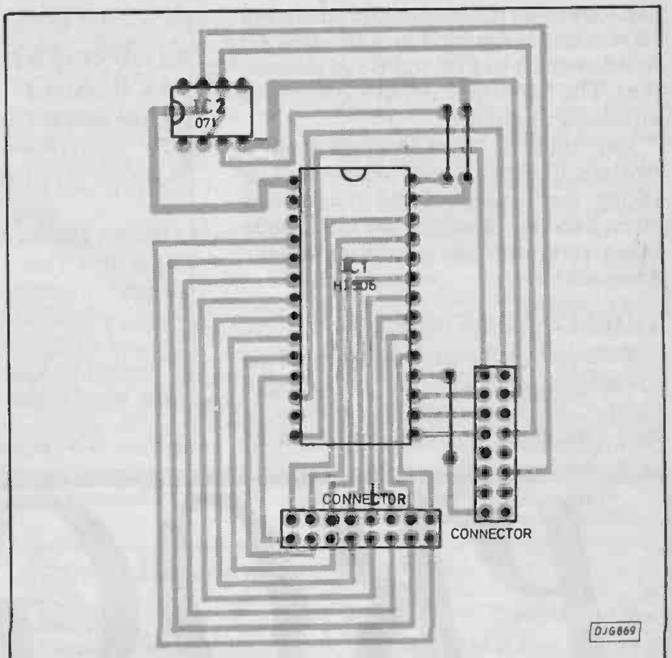


Fig.4 *PCB layout for the 16-channel multiplexer*

has two switches which service one adc input. A switch is closed, ie input and output connected if its control line is brought low, and is disconnected otherwise. Notice that we are using two pins from the adc connector marked PB0 PB1 for these control lines. These are normally used for the fire buttons on the joysticks and are in fact PB4 and PB5 of the system VIA. These are configured as inputs by the operating system so we need to alter this by writing to &FE42, the data direction register for port B. Take care when tampering with this port as it is used by the system in connection with sound, speech, and screen display!

As connected the two control lines should complement each other at all times to route one of the switches onto the adc line. (Note that by inverting one of the control lines using a transistor we could make do with just one line – you may like to make this modification).

The power supply is provided by the 5V line from the analogue port with the negative voltage produced by the 7660 voltage converter chip. You could use a negative voltage from the power connector but this would spoil the 'one-connector' design.

The op amp is set up as a buffer (ie a voltage follower) to improve the driving potential of the output. This is important as the voltage produced by the multiplexer is very sensitive to load, even being affected by the high impedence adc input on the BBC.

Two DG211s connected in this way give a possible eight adc inputs. The short function in Program 1 shows how the software could handle this setup.

This function operates by making PB4 and PB5 outputs (line 120) and then switching one line on and the other line off depending on which bank of four lines is to be selected (line 140). An average over r% readings from channel c% is then obtained and returned (lines 160-200).

16 CHANNEL MULTIPLEXER

The second design uses a sixteen channel multiplexer chip. The circuit diagram is shown in Fig.3. If anything this is a simpler chip to handle as it has been designed for just this purpose. Note that this time we need four address lines to select which of the sixteen inputs is to be connected to our one adc line. We will need to use the user port to provide these address lines (PB0 to PB3). The power supply can be taken from the ±5V line available at the auxiliary power outlet or a separate power supply. The chip enable pin has to be held high (5V).

The sequence of operation for this setup is similar to that for the previous circuit. The correct channel is selected by outputting its binary value on the lower four pins of VIA port B. The program must then wait for or force a conversion on the adc channel used (see line 150 below), then read the value using ADVAL as normal. The multiplexer operates very rapidly and draws a small current so we need not worry about the adc picking up an intermediate value as it switches between channels as long as we force a conversion after changing the address lines.

A function to control this chip connected to ADC 1 is shown in Program 2.

CONSTRUCTIONS

For both designs you will need a 15-way D-type analogue port connector and for the 16-way design a user port cable with an insulation displacement connection at the machine end.

A pcb layout for the x16 board is shown in Fig.4. (No pcb is offered for the x8 unit, which can be built on Veroboard). It is advisable to socket the two ics, especially the multiplexer. The con-

```
100 DEF FNadc(c%.r%)
110 LOCAL t%.1%
120 ?&FE42=?&FE42 OR &30: t%=0
130 IF c%<1 OR c%>8 THEN =0
140 IF c%>4 THEN ?&FE40=(?&FE40 AND &CF OR &20):c%=c%-4:ELSE
    ?&FE40=(?&FE40 AND &CF OR &10)
150 OSCLI"*FX17,"+STR$c%
160 FOR 1%=1 TO r%
170 REPEAT UNTIL ADVAL(0) DIV 256=c%
180 t%=t%+ADVAL(c%)
190 NEXT
200 =t% DIV (r%*16)
```

Program Listings
Left: *Program 1*
Right: *Program 2*

```
100 DEF FNadc(c%.r%)
110 LOCAL t%.1%
120 IF c%<1 OR c%>16 THEN =0
130 ?&FE62=&0F : ?&FE60=c%
140 t%=0
150 *FX17,1
160 FOR 1%=1 TO r%
170 REPEAT UNTIL ADVAL(0) DIV 256=1
180 t%=t%+ADVAL(1)
190 NEXT
200 =t% DIV (r%*16)
```

nections to be made at the terminals are shown in the figure. Lines labelled A0 to A3 connect to PB0 to PB3 of the user port. The line labelled 'out' connects to an analogue input.

Care must be taken to avoid damage by static to the analogue switch chips by taking the usual earthing precautions when handling. Touching the metal body of an earthed soldering iron is usually adequate.

TRIPLED MULTIPLEXING

With one of the x16 chips connected to each adc input we obtain 64 analogue input channels. If you require even more then you could go to a third level of multiplexing by switching one of four x16 chips onto each adc input to give 256 channels, the maximum that port B with its eight lines will drive. At this stage the speed of conversion of the built-in adc (10ms) will start to become a limitation as it will not be possible to read all the inputs at a given time.

The author is currently using the 16 channel version for recording temperatures and energy consumptions in an experimental house. This involves a total of over 160 sensors multiplexed into two computers with the software side handled by a machine code program stored in eprom. PE

COMPONENTS
16-CHANNEL MULTIPLEXER
SEMICONDUCTORS

IC1	HI506 multiplexer
IC2	TL071 opamp

MISCELLANEOUS
8-pin dil socket
28-pin dil socket
16-pin pcb mounting connectors (2 off)
Printed circuit board

The printed circuit board is available from the PE pcb service (see page 60).

LETTERS READERS'

SAT DELIGHT

Eric Cook, the winner of our satellite tv receiver competition, tells us he is delighted with his prize.

In his letter of thanks to us and to Connexions he says that in addition to the newly opened possibilities of satellite television reception, the dish antenna will be invaluable to him for his radio astronomy projects and hopes to eventually link it up to a computer system, as and when time and funds permit. I am pleased to learn that he already takes PE's sister magazine *Astronomy Now*.

For over a decade, Eric has been involved with electronics as a hobby and as a career. Though presently unemployed, he was mainly in telecommunications with BPO Telecoms as well as with Seimens and Pye TMC. As he said in his entry form, he is interested in many aspects of electronics, computing and astronomy, especially radio astronomy. He is now planning to continue building a radio telescope — a project which he started to build at college. Now that he has been saved the task of aerial construction he looks forward to carrying out some solar radio observations in due course.

However, he says that part of the remaining equipment he intends to build needs to use some opamps that have now become obsolete and wonders if any reader knows of a source for the SL612 and SL613. All that my data books tell me is that the SL612 comes under video, if and rf category, the SL613 is a limiting-amplifier/detector, and both were manufactured by Plessey.

I have also had a long and interesting chat with Eric on the phone. We are pleased that our prize should go to such a kindly and deserving winner.

Eric sends his condolences to the other entrants.

Ed.

REASHAWRANCE

Dear John,

I was interested by your comment about dynamic range on the letters page of May 88. In the 1950s there was protracted correspondence in the "wireless" journals about this problem, particularly in *Wireless World*.

Correspondents' complaints were answered by the BBC who claimed that speech and music signal levels were determined by experiments with audience listening groups. I have always found it a problem and do not understand why equating the rms signal levels is not the answer. I can certainly recommend a remote control for sedentary tv listening.

John C. Shaw Ph. D., Chidham, W. Sussex

Perhaps part of the problem again lies with the listener as I mentioned in my answer to your previous letter in PE Feb 88. Perhaps also the furnishings of one's surroundings, or even the quality of the tv set may be contributory factors to observed imbalance between voice and music.

What do other readers' feel?

Ed.

A HARD DAY'S NOTCH

Dear Ed,

I've been following the saga of dat, notches and copy piracy with some interest and think you might be ironically amused by a recent domestic scenario.

Some time ago I borrowed the biography of George Martin, the Beatles' producer and a great hero of mine. The biography is called 'All You Need Is Ears' and from it I gather Martin's premise is that to be a great producer-engineer what you need to do mostly is listen discriminatingly. He has also been a major defender of the anti-home-taping lobby, including copycode. While reading the book, a friend comes in and spots photo of GM — "Oh yes," sez he, "he's the bloke who can't hear the notch in copycode, isn't he?! ..."

Marvin Troy, Bedford.

Irony comes to the fore again concerning other problems created by advancing technology.

Sound sampling techniques are now so refined that complete music productions can be created by recording just one sound and electronically manipulating its pitch, timbre and duration.

Apparently, some producers are taking their original sound sources from sections of other producer's recordings. It seems the practice is so widespread that producers have been known to copy someone else's sound only to find that it was their own sound that had been pinched in the first place!

As yet no-one knows if and how the law should be changed to protect the sampling originator's copyright. I can't help but feel, though, that proof of piracy of a single composite sound would be too complex to stand up to the rigors of law enforcement. Surely, applying the same law that protects the copyright of musical themes is the only reasonable approach?

Ed.

ASTRO ELECTRONICS

Dear John,

Further to my previous letter (*see Aug 88*) and your kind reply, it is good to see that amateur astronomers have an ally on the electronics side.

I am a retired carpenter and have been interested in astronomy since a child. After the war I could not afford to buy a telescope so learned how to make mirrors by reading books. I knew Patrick Moore many moons ago when a member of the lunar section of the BAA.

My equipment includes several refractors, camera and equatorial mount but I still wish to update my equipment electronically where possible. My electronics knowledge is good enough to build equipment from drawings but not enough to design anything. One device I would like is a good variable-speed mount-driving unit, possibly using a joystick in place of control buttons. Interfaces for computer controlling stepper motors would be welcomed, with software in Basic rather than machine code allowing programs to be constantly improved with minimal computing knowledge.

A sidereal clock and timer would be useful for astro photography, perhaps giving audible signals every minute or so to eliminate the need for spectacle removing to read digital displays. I am sure such a clock would also be of use in photographic darkrooms if a bit of extra circuitry were included — you can't beat using a bit of equipment for more than one purpose. How about a light sensor project for the variable star gazers, to measure light variations?

Here's to the future ...

W.C. Trice, Peacehaven, Sussex

I showed your letter to Dr John Mason of our sister magazine Astronomy Now *and have had (another) good chat with him. We both agree that the ideas are worth investigating but fear that the sensitivity and accuracy required for the gadgets might make them too expensive to appeal to most amateur astronomers — John says they're nearly all impoverished! (Surely that's only because they spend all their money on an interesting activity? Like I do with electronics ...).*

One project that appears to be inexpensively practical is the sidereal clock and I'm actively pursuing the idea. The other ideas I throw open to the inventiveness of PE readers — come on folks, don't disappoint me and other space watchers.

Ed.

HOT POT LINE

Dear Editor,

There are circuits for getting an output that is linear with temperature and there are other circuits for electronic thermostats. But nowhere have I seen a discussion of a truly linear thermostat, one in which a degree is represented by an equal space on an analogue meter dial – why not, are linear meters really so expensive?

Still on linearity, it seems to me that the variable potential divider is invariably used to feed a transistor or opamp and is also basically non–linear. Surely the current at the wiper will vary with its setting so affecting the linearity of the voltage delivered? I have additionally found that the track ends of pots are virtually dead for several degrees of turn which doesn't help linearity either.

S. Berger, Israel.

The simple answer is yes to all points. If you really need a linear readout a digital scale is probably the best solution. With an analogue meter one is normally forced to accept an amount of non-linearity imposed by the mechanics of the meter movement, a physical problem rather than an electronic one.

When selecting a resistance value for a potential divider, the art is to select for a low source impedance when compared with the sink impedance, so minimising the non-linear effect (if in fact it actually matters). In circumstances where matching is of great importance interposing a buffer between source and final sink may be required.

Low cost pots will usually have the dead ends you've experienced. Where the extremes of pot rotation have to be used as an integral part of the design either choose more expensive pots, or design for an alternative solution.

Ed.

bookmark

Your Ed looks at some of the new books published.

Troubleshooting and Repairing VCRs. Gordon McComb. Tab Books. £13.20. ISBN 0-8306-2960-2. Gordon McComb operates a successful vcr and electronics repair business and from his experience believes that many vcr faults can readily be corrected by a competent diy-er. With that in mind he has written this book specifically for the consumer, offering schematics and step-by-step details on the general upkeep and repair of home vcrs, from the simple cleaning and lubricating of parts, to troubleshooting psu and circuit problems. The book is well presented, has many illustrations and photographs, and the author explains, in a non-technical manner, the care and repair of over 100 machines. It certainly appears to be a manual that could save you a note or two.

How to Read Electronic Circuit Diagrams - 2nd Edition. Robert M. Brown, Paul Lawrence and James A. Whitson. Tab Books. £10.00 ISBN 0–8306–2880–0. Tab claim that with this updated and revised edition *anyone* can learn the 'language' of modern circuitry, becoming proficient at reading electronic circuit diagrams - even if they've never seen one before. While appreciating that even electronics experts have had to learn from scratch at some stage if their life, I have also learned to be wary of grandiose all–embracing claims. There is more to understanding circuit diagrams than just being able to read them. However, reading and understanding circuit *symbols* is easily achieved, and in describing the symbols actually shown this book does a reasonable job. But there are an awful lot missing, and though some of those shown may be recognisable to American readers, some are new to this UK Ed. It's such a shame that imported books don't always live up to the standard implied by their titles and visual presentation. I hope the 3rd edition of this book, if it's published, will be more all–inclusive.

Electronic Conversions, Symbols and Formulas - 2nd Edition. Rufus P. Turner and Stan Gibilisco. Tab Books. £11.60. ISBN 0–8306–2865–7. ('Formulas' is their plural - not mine!) The technology of electronics may change rapidly, but subjects such as most of those covered by this hand reference source are largely timeless. This second edition of a book first published in 1975 has, nonetheless, been expanded, particularly regarding the mathematics, to provide more formulae and concepts in the general areas of electronics. More detail has also been included concerning the nature of complex impedances, and the semiconductor information has been updated. The formulae, tables, symbols and conversion factors commonly used in electronics (though I've spotted a few omissions) organised for easy access and this book should be a valuable addition to the library of any serious electronics enthusiast.

Meters and Scopes – How to use Test Equipment. Robert J. Traister. Tab Books. £11.60. ISBN 0-8306-2826-6. Over 300 pages of very informative detail well related to the title. In separate chapters it covers matter and measurement, electronic values and components, circuit testing considerations, measuring instruments, multimeters, other test instruments, oscilloscopes, building your own test gear, transmitter and distortion measurements, and how to buy test instruments. (Readers should note that this last chapter is basically written for the American market, but much of the advice is relevant to other countries.) Two very useful appendices give semiconductor letter symbols and a selection of essential formulae.

The Benchmark Book Company, 59 Waylands, Swanley, Kent, BR5 8TN. Tel: 0322 64042.

Heinemann Professional Publishing, 22 Bedford Square, London, WC1B 3HH. Tel: 01–631 5446.

Tab Books are imported by **John Wiley and Sons Ltd.,** Baffins Lane, Chichester, West Sussex, PO19 1UD. Tel: 0243 779777.

HOW TO USE PCB TRACK PATTERNS

FIRST MAKE TRANSPARENT COPY

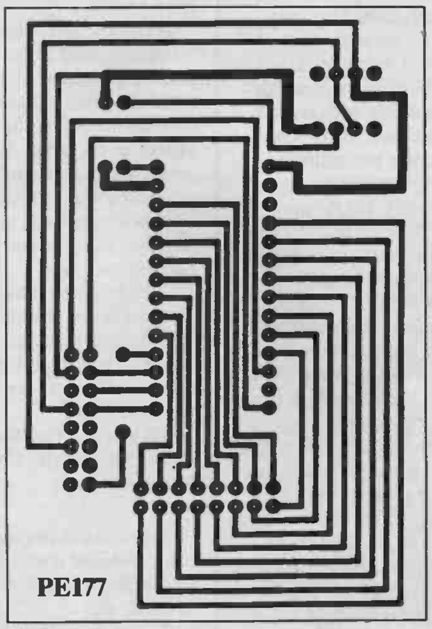
(We regret that we cannot supply transparent copies of PCB tracks.)

HOME PHOTOGRAPHY METHOD

Using even, bright illumination, photograph track onto fine grain black and white negative film. Develop film for high contrast. Photographically enlarge image up to lifesize and print onto high contrast lithographic cut film, such as Agfa Copyline HDU 3P Type 2. Develop in Agfa Litex G90T litho developer, or similar.

ISODRAFT METHOD

Have a normal photocopy made, ensuring good dense black image. Spray ISOdraft Transparentiser onto copy in accordance with supplied instructions.



MULTIPLEXER PCB

ISOdraft is available from **Cannon & Wrin,** 68 High Street, Chislehurst, Kent. Tel: 01-467 0935.

NEXT PRINT ONTO PCB

Place positive transparency onto photosensitised copper clad fibre glass, cover with glass to ensure full contact. Expose to Ultraviolet light for several minutes (experiment to find correct time – depends on UV intensity).

Develop PCB in Sodium Hydroxide (available from chemists) until clean track image is seen, wash in warm running water. Etch in hot Ferric Chloride, frequently withdrawing PCB to allow exposure to air. Wash PCB in running water, dry, and drill holes, normally using a 1mm drill bit.

(PCB materials and chemicals are available from several sources – study advertisements.)

*** CAUTION – ENSURE THAT UV LIGHT DOES NOT SHINE INTO YOUR EYES. PROTECT HANDS WITH RUBBER GLOVES WHEN USING CHEMICALS.**

ALTERNATIVE METHOD

Buy your PCB ready made through the PE PCB SERVICE, most are usually available. PE

MORE LETTERS

BETTER BATTERIES

Dear Ed,

Regarding Rod Cooper's articles on *Better use of Batteries* in PE June and July 86, and the update in May 87.

I do not understand why he talks about using true rms for measuring current through the pcr circuit. Surely with charging cells we are concerned with (coulombs), not power dissipation or (not directly) energy (Joules).

We know that rms is used to calculate the equivalent dc voltage or current (of any waveform) which delivers the same power. If the current is measured using an rms scale, even true rms, through the pcr circuit, the discharge part of the cycle is regarded as also charging because squaring a negative inverts the sign to positive. What we want is the *average current.* For example, the average current of a sine wave is zero, and if this was applied to a cell it would not charge it up, just heat it.

The average can be measured using a dc current meter, the slow response of the meter movement being used to average the waveform. Another, and better, way to measure average current is to use a scope measuring the voltage waveform across a low value resistor, switching between ac and dc to ascertain the voltage shift on the screen.

Could you please also answer three other questions?

Why does the charging efficiency change for different charge rates? Why is the minimum charge rate C/40? Do charge rates greater than C/10 reduce the life expectancy (number of cycles) even if there is no overcharging?

John Goatcher, Worthing

Dear Mr. Goatcher,

Thanks for your interesting letter. Regarding current measurement on the charging circuit I think most readers who attempted to measure forward charge current got the position of the meter right in the circuit. That is, as in Fig. 1 to measure the discharge current, and as in Fig. 2 to get the forward charge current, and a simple subtraction to reach the effective forward charge current.

Battery capacity is measured in amp–hours, so it is more convenient to measure the charge current in amps rather coulombs, for the purposes of checking probable recharge times for instance. But, you could check the pcr ratio in coulombs.

Unfortunately, there is a rooted idea that all moving coil meters can be used as averaging meters. However, I could provide you with two meters from different manufacturers, each having 1mA movements. Starting with a sine wave input, both meters could easily give about the same reading. Apply a pulsed waveform, and you might then see one meter give 10% fsd, and the other give 50% fsd. Why the difference? The answer is in movement ballistics. The movement of the first meter is a relatively undamped type, the movement of the second is underdamped, and their responses become more and more different as the pulses become more 'spiky'.

Where does this leave the average moving coil multimeter? In no–mans–land when it comes to measuring pulsed waveforms!

Also, you might question what use is an average value for the forward current, because it is not much use in making calculations. All in all, the rms value is the most snag–free measurement.

Since it seems that many readers were in utter confusion about making rms measurements on non–sine waveforms. I am publishing an article in PE in the near future which describes a thermal–conversion ammeter and voltmeter, which are simple and cheap to make. I feel sure you will be interested in this!

Regarding your other questions, 1) is too complex to answer in a letter and I suggest you look in a standard textbook on Ni–cads, 2) to avoid dendrite formation and oxidation of separator if kept on trickle charge permanently, 3) No.

Rod Cooper

SPICED HAM

Dear Ed,

We thank you for the valuable publicity which you gave to our rally at Longleat on page five of your June issue. I am sure that many of your readers enjoyed themselves at one of the largest events of its type in the country.

There are a couple of points which we would like to make to you though. Although we work closely with our national society, we are the Bristol Group of the RSGB. We are financially and constitutionally quite separate from the RSGB HA and they do not organise or help us with this rally.

Secondly, although we recognise your need to provide some journalistic spice to your articles, we do rather regret your concentration on the negative aspect of cb radio. Radio amateurs have to work very hard to convey the real differences between ourselves and cb, hopefully in a positive and constructive way.

CB equipment has never been allowed at any RSGB event, but the reminder quoted in our promotional leaflet was aimed chiefly at our traders, not the visitors.

Shaun P. O'Sullivan G8VPG,
Hon Sec, RSGB City of Bristol Group

Your thanks are appreciated, but I thought it was YOU, the organiser, who were negative towards cb!

To me cb radio has a valuable place in the community. (I owe my speedy rescue from a scuba-diving mishap to a cb radio on board.) I acknowledge, though, that devotees to cb and amateur radio do not nescessarily share the same outlooks. However, I did not appreciate from your promotional leaflet that your comments were aimed at traders and not the public (or editors). Indeed, I recall that my reaction to your ban on cb at the rally was that you were quite rightly placing the emphasis on the serious side of amateur radio involvement. I also believed you might be concerned about the possible problems created by numerous cb transmissions all taking place in a confined locality! It appeared you wanted to publicise the ban.

I hope next year's rally is an equal success. Let me know the dates and I'll publicise it for you – if you'll risk me hamming-up my lines again...

Ed.

CADSOFT AND AMSTRAD

Dear Ed,

Some time ago you kindly mentioned our pcb design utility for the Amstrad CPC range of computers in your new pages. We can now supply a similar utility for the Amstrad PCW8256/8512 computers.

The utility allows single or double sided pcbs to be designed using the computer's screen and keyboard, and will produce a high quality, twice full size printout on the dot–matrix printer. The utility costs only £29.99 fully inclusive and is available direct from us. For further information, including sample printouts, please ask you readers to send us a stamped addressed envelope.

Mrs. P. Dean,
Cadsoft Systems, 18 Ley Crescent, Tyldesley, Manchester, M29 7BD.
Tel: 0942 870376.

FILMLESS CAMERA

The Patents Office at the British Library have sent me an interesting bit of information. Under patent number GB 2 109 615A, Canon KK has introduced a still video camera in the UK. This enables a newspaper photographer, for example, to record up to fifty images on a magnetic disc, inspect them on a video monitor and transmit them back to the newspaper's picture desk. At the desk they can be electronically stored on a disc before the editor selects the best for a printed story. *Today* newspaper is already using this system.

Incidentally, 1988 is the centenary year of the Kodak box camera, introduced by George Eastman under British patent number 6950.

More information on patents can be obtained fromThe British Library, 25 Southampton Buildings, London, WC2A 1AW.

Ed.

POOLING RESOURCES

Regular readers will remember that until 1986 PE was published from Poole in Dorset. I've recently spent an enjoyable scuba diving weekend down there (didn't actually dive as the seas were too rough, but that's another story - as is the pleasure of the scenery, and the taverns!). I must say, though, that I admire the initiative of the original PE staff at Poole – every boat in the harbour seemed to have its identity number prefixed by the letters 'PE'! Well done folks. I wonder if the Port of London Authority, or even the Admiralty, might be open to negotiation over a bit of similar PE promotional publicity? **Ed.**

POINTS ARISING

Vocal Eliminator (July 88)
R7-R10 should all be 100k. IC1 should have notch at bottom of Fig.8.

ELECTRONIC BAROMETER

PART ONE BY JOHN BECKER

TAP INTO A PRESSING MATTER

There are 5000 billion tons of air above us. With this barometer, which uses a low-cost serial analogue to digital converter, and can be placed, if so desired, under computer control, you can take a weighty interest in what it is up (or down) to.

At the end of the Weather Centre project that I described in the March to May 1988 issues of PE, I promised to bring you an electronic barometric pressure sensor. This is the unit, and it can be used as either a simple meter monitored device, or it can be used under computer control allowing for record keeping and, to a certain extent, the prediction of weather conditions. It additionally keeps track of ambient temperature levels.

During the course of the article I shall also show how a low cost serial analogue to digital converter (adc) can be used in situations where more expensive high speed parallel a-d converters are unnecessary.

ATMOSPHERIC PRESSURE

We live on a planet that is completely surrounded by an ocean of air, generally known as the atmosphere. There is no true surface to this ocean, but its first tenuous beginnings occur at around 500 miles above the surface of the planet. Earth's gravitational field holds the atmosphere largely in place, though there is a slight leakage away into space. The closer we get to the surface of the planet, so the gravitational effect becomes stronger, and the atmosphere increases in its density. About three quarters of the world's air is held within seven miles of the earth, and this region is known as the troposphere. Figs. 1 and 2.

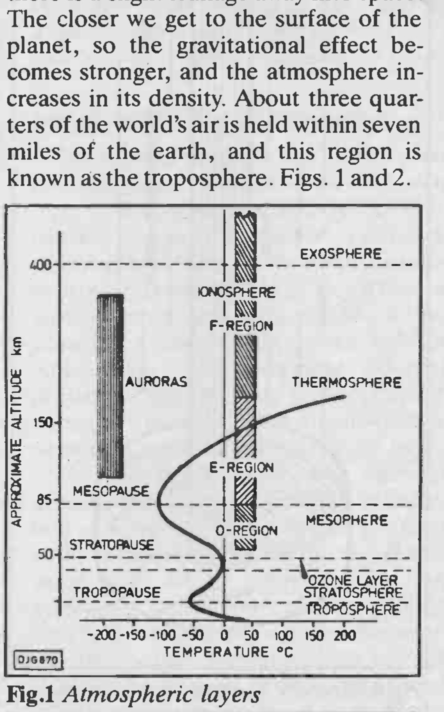


Fig.1 *Atmospheric layers*

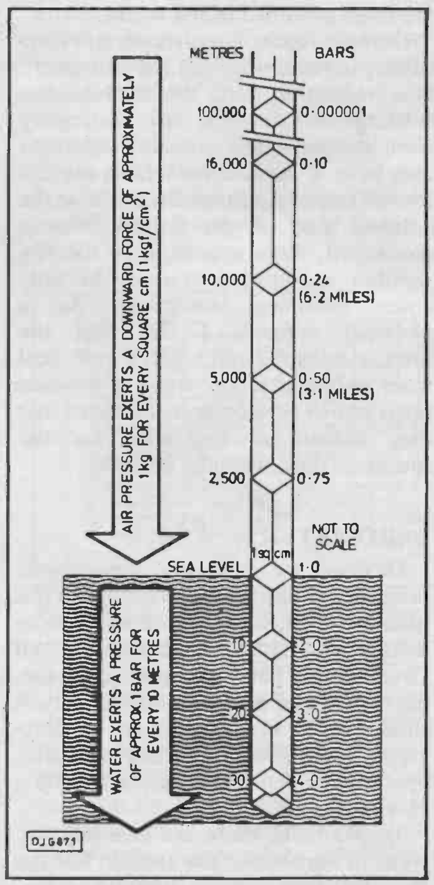


Fig.2 *Atmospheric and hydrostatic pressure*

Air is surprisingly heavy, and at surface level, a cubic yard of it weighs about two pounds. Estimates of the total weight of the atmosphere put it in the region of 5000 billion tons. Even the breathing tanks that scuba divers use actually increase their weight when being charged up. My 60 cubic foot bottles are usually charged up to around 3000 pounds per square inch, and the increase in weight can have a noticeable effect upon buoyancy.

The surface of the earth covers some 197 million square miles, so there is about a ton of air on every square foot of the surface, about 14.72 pounds per square inch (1kg per square cm). Fortunately, we are not usually aware of this immense pressure since the gases and fluids of our bodies exert a similar pressure against the weight of air.

We can become aware of air pressure, though, when changing our relative altitude. We must all have noticed our ears 'popping' when ascending or descending in a lift. Air travellers will be even more aware of this effect during takeoffs and landings. Although aircraft cabins are 'pressurised', the cabin pressure is permitted to drop to around half of normal sea level pressure when flying at some 35000 feet. The 'popping' of our ears is simply the air pressure within the tubes connecting to them equalising to the external pressure. On occasions, the failure to 'pop', caused by catarrh blockage, can bring pain, though blowing one's nose, or swallowing will usually relieve it.

Popularly, the 'normal' atmospheric pressure is taken as 1 bar, usually referred to as 1000 millibars (mb). More precisely, meterologists regard 1013.25mb as being the norm. One atmosphere of pressure is also defined as the pressure which will support a column of mercury 29.92 inches (760mm) at 0°C, sea level and at latitude 45°.

The great envelope of atmosphere is in constant turmoil, from the heating and cooling effects of day and night, from the rotation of the earth, and to a lesser extent, from the heat created by centres of civilisation, all causing great swirlings of movement. As these sweep around the planet, so localised pressure changes occur, varying between about five per cent of the normal. This may seem insignificant but remember that a drop in pressure from 1013mb to 950mb removes a load of some two million tons from a square mile of the earth's surface.

The peaks and troughs are constantly trying to equalise themselves, and great masses of higher pressure air rush in to fill the depressions. The steeper the pressure changes, so the stronger the force of the air moving in to fill them, causing wide variations in wind speed.

If you look at an ordinary barometer you will probably see that it is marked from about 940mb to 1060mb. These two extremes are seldom reached at surface level, though might be seen respectively high up a mountain, or deep in a mine. The lowest sea-level pressure I can find recorded was 877mb during hurricane Ida in the Pacific, on September 24th 1958.

THE STORM OF 87

The infamous storm that created havoc in south east England on the night of 15th–16th October 1987 resulted from a depression far less deep. At midnight on the 15th of October, the centre of the storm entering the English Channel was 960mb. It passed over the south east at about the same pressure, but had reached 954mb off the Shetlands by 6pm on the 16th (Fig.3).

The London Weather Centre report for the 16th states that there were 'gusts from 0200 hours well in excess of 70 knots, and reaching a peak in the period of 0300 hours to 0700 hours, with gusts to 90 knots reported from Herstmonceux and St Catherine's Point in the early hours'. One knot equals approximately 1.15 mph.

Obviously, weather conditions are directly related to the various changes of pressure and temperature. Consequently, if we can monitor the changes, we can begin to make predictions about forthcoming conditions. Professional

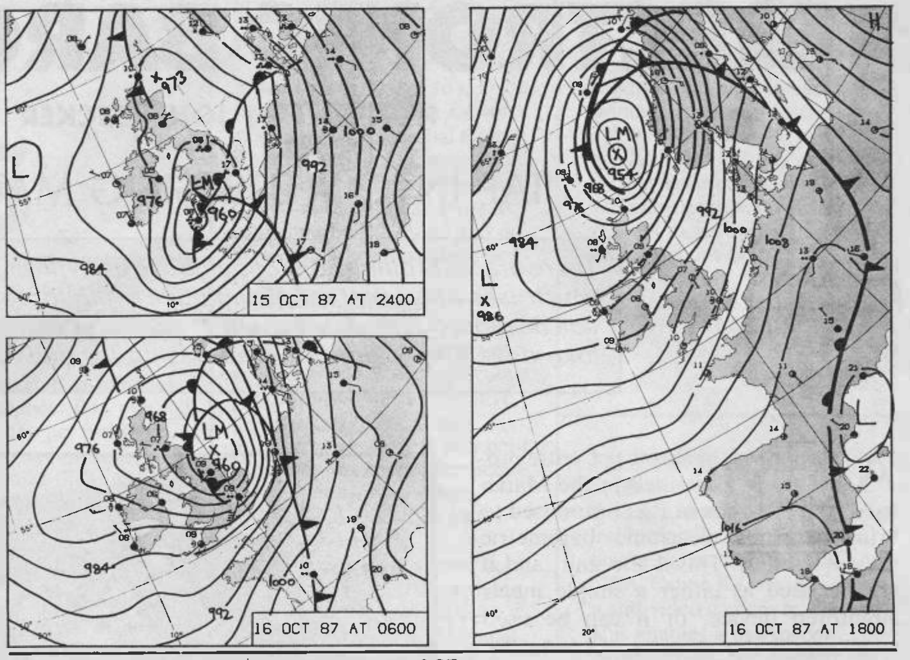


Fig.3 *The trail of the infamous storm of 87*

weather forecasters take measurements of prevailing situations at selected places all across the globe, ranging from weather monitors out at sea, across the land masses, up into the higher atmosphere, as well as observations via satellites. Powerful computers then assess the data, relate it to known factors, and determine the likely trends. Indeed, I understand that the computer at the Met Office in Bracknell is one of the most powerful in the world.

Despite such sophistication, forecasting in some ways still remains an art. One reason is that, the mathematics relating to air flow are extremely complex, and minor unrecorded changes can have a cumulative effect on the overall scene. Additionally, so far as the Atlantic side of the British Isles is concerned, there appear to be too few weather monitoring stations to fully cover incoming conditions. As a personal opinion, I feel that the forecasters sometimes get a raw deal from public reaction when a forecast turns out to be incorrect. I believe that they should be applauded for the successes they normally achieve.

BAROMETERS

Devices to measure atmospheric pressure, or barometric pressure, as it is usually called, are referred to as barometers. The name comes from the two Greek words baros and metron, meaning weight and measure, respectively. A similar word in common use is barograph, but this only refers to a barometer operating a pen that traces a line on a moving length of paper.

Traditionally, there are basically two types of barometer, the aneroid and the mercury. The mercury barometer consists of a glass tube a little under three feet long (80cms), which is filled with mercury. One end is sealed, and the open end is placed in a reservoir of mercury (Fig.4). The weight of the mercury in the tube causes a vacuum gap to appear between its upper surface and the end of the closed tube. The level to which the mercury will fall is determined by the counteracting atmospheric pressure acting on the reservoir, trying to force the mercury back up the tube. The difference in height between the surface of the reservoir and the top of the column indicates the pressure level.

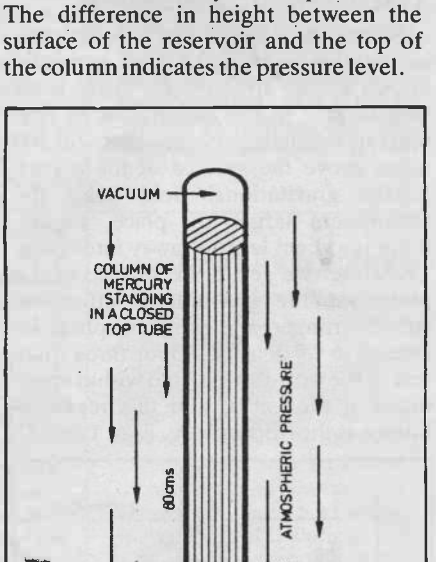


Fig.4 *Mercury column supported by atmospheric pressure*

Aneroid barometers consist of an evacuated metal cylinder, flattened and corrugated at either end, with a spring inside preventing inward collapse. Changes in external pressure react against the spring pressure causing the distance between the ends to vary. An attached pointer indicates the relative pressure. Calibration of an aneroid barometer is usually made against a mercury instrument.

Aneroid barometers can be used as altimeters, as depth gauges for underwater use (though air-filled capillary gauges are more common), and they are the type widely sold for consumer use. For the latter application, they can be bought very cheaply. My own, bought at the end of 1987, cost just £14.50, complete with alcohol thermometer and quite a nice wood surround. Though probably not totally accurate, it's quite satisfactory for domestic inquisitiveness.

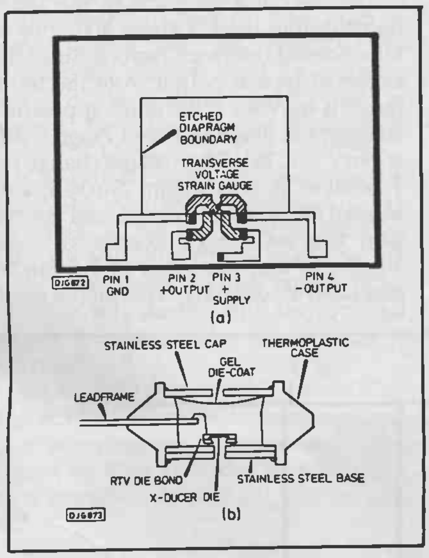


Fig.5 *Schematic outlines of Motorola transducer pressure sensor package*

PIEZO ELECTRIC SENSORS

The aneroid principle can also be used in electronic pressure sensors. One such type is the Motorola MPX100A. This consists of an evacuated reference chamber to which is connected a piezo-resistive transducer (Fig.5). When a voltage potential is applied across it, the transducer produces an output voltage which rises with increasing external pressure relative to the reference vacuum. Conversely, the output voltage decreases as the relative pressure falls.

The construction of the element actually produces two output voltages, one positive, the other negative, and it is the difference between the two that is monitored. In its simplest form, an electronic barometer can be created simply by connecting a meter between the two output terminals. The voltage differential, though, is very small, and ideally should be buffered to avoid the loading effects of the meter. One possible circuit is shown in Fig.6.

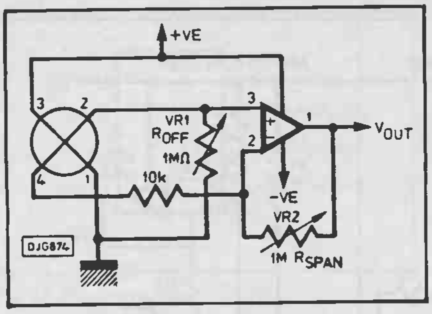


Fig.6 *Simple pressure sensor amplifier*

Here, the twin outputs are fed to an opamp connected in a differential mode. The gain is provided by VR2, and a balancing offset level is controlled by VR1.

Typically, the output from the MPX100A transducer will vary across a range of 60mV for a change in pressure of one atmosphere, that is, a change of about 1000mb. Judging by the markings on an ordinary aneroid barometer, atmospheric pressure is likely at most to vary between 940 and 1040 millibars, a range of only one tenth of 60mV, in other words, a change of only 6mV. Though 60mV is a typical figure, manufacturing tolerances allow the full scale range to vary from 45mV to 90mV.

Unfortunately, the transducer construction makes it subject to temperature changes, and these take several forms. One is the rate at which the primary output voltage will change with temperature, and is typically negative-going at about 0.19 percent of each degree Celsius. The reference offset voltage also changes with temperature, positively at about 0.24% °C. The graph for the overall output voltage produced at different temperatures is shown in Fig.7.

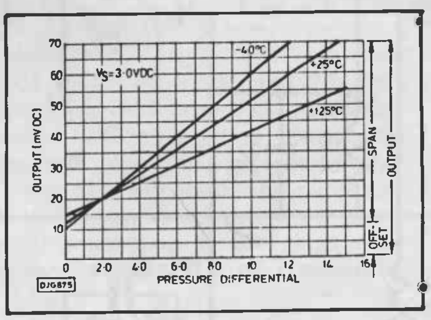


Fig.7 *Output versus pressure differential*

Thirdly, there is a hysterisis factor that affects the response of the transducer. In other words, although a specific pressure will give a certain voltage output if the temperature has risen to a particular level, a different output will result if the temperature has fallen to that same level. Similar hysteresis affects the output when the pressure is changing but the temperature is static. Of course, if both temperature and pressure are constantly changing, the effects can be complex to calculate. A simple hysterisis graph is shown in Fig.8.

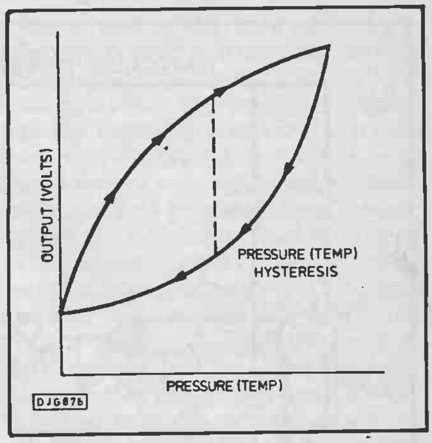


Fig.8 *Pressure versus temperature hysterisis*

The quoted figures for the MPX100A are typically ± 0.05% of full scale (2000 millibars) for pressure, and ± 0.5% of full scale (−40°C to +125°C) for temperature.

For domestic purposes these hysterisis factors can be regarded as unimportant. I cannot believe that most people will want to know the precise weight of air around them at any particular moment, especially as the extreme range is only around 100 millibars. Even scuba divers, for whom knowledge of pressure under water is critical in determining diving duration without decompression problems, do not need such accurate pressure figures. Those sitting at home pondering weather prediction need only be concerned about the trends in barometric changes.

TEMPERATURE COMPENSATION

It is practical though, to take basic compensatory action for normal temperature changes. It can also be taken quite simply by a variety of methods.

One such method is shown in Fig.9. Here R1 is inserted in series with the positive psu input lead of the transducer. The theory is that as the temperature changes, so the current drawn by the transducer through the resistor will change accordingly. As it does, so the voltage seen at the junction between R1 and the transducer will vary in the opposite direction to the inherent voltage change at the positive output feeding to IC1b.

The temperature change in the offset output voltage is compensated for by the combination of IC1a and IC1b. The required bias level is set by R2 and R3. The gain of IC1a is then set by the ratio of R4 to R5, and the output of IC1a fed to the inverting stage of IC1b. Here the gain is set by the ratio of R6 to R7. To the second input of this stage is fed the

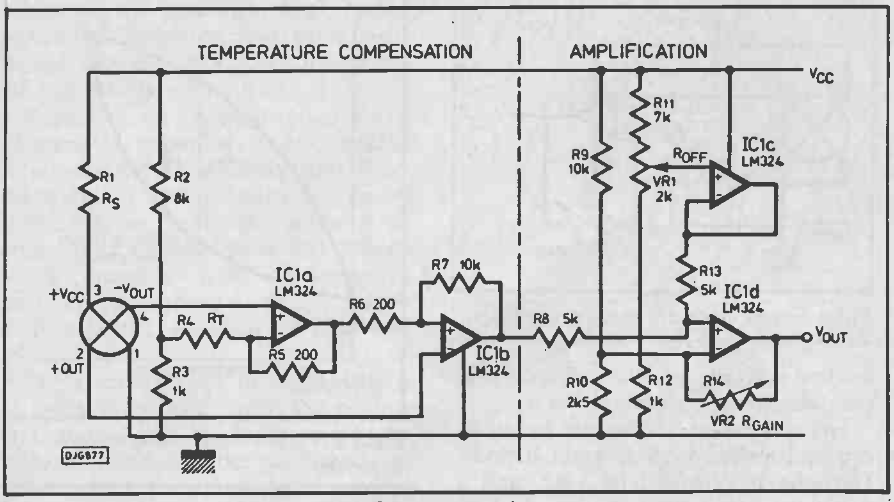


Fig.9 *One method of pressure to voltage conversion*

other output from the transducer. The value of R4 is then selected so that the drift in the transducer's offset voltage will inversely be balanced against the main output voltage. With the correct values of R1 and R4, temperature change effects can be minimised.

The formulae for calculating R1 and R4 are complex, but as a rough guide, if the positive power line is 10V, then R1 will be about 1k8, and R4 about 4k2. Note that the basic resistance of the transducer will also come into play, and this can vary between individual devices from 400 to 550 ohms. (Also note that the maximum voltage allowed across the transducer itself must be kept below 6V.)

If the temperature compensation circuit of Fig.9 were to be used, amplification and final offset control could be carried by the stages around IC1c and IC1d.

I played around with this circuit for a while, but decided that it was inappropriate for offering as a constructional project. The calculation of the formulae, and the practicalities of describing how to finely set the circuit were too complex for some readers to stand a reasonable chance of success. Instead, I decided to use a separate temperature sensing circuit, and to balance its output against the drift from the pressure sensing circuit.

PRACTICAL SENSING CIRCUIT

In Fig.10, the twin outputs from the transducer are taken to the differential amplifier IC1a. The basic gain here is taken as the ratio of R1 to R2, nominally around x22. Via R4, VR1 provides for adjustment of the bias level controlling the centre of the span range at the output of IC1a, round about 2.5V.

From IC1a the differential voltage goes to the inverting amplifier IC1b. Further gain is given here, set by the ratio of R6 to R7, at roughly x21. C3 is not essential, but just offers a bit of damping to sudden surges of pressure change — even the opening and closing of a door in an otherwise closed room can be picked up by the sensor.

The overall gain given to the transducer output level is about 460, give or take normal tolerance factors. Since the expected typical output from the transducer is 6mV for a 100 millibar pressure change, the amplified span range is 460 × 6mV = 2.76V. The voltage change for 1 millibar is thus about 27mV. If one wanted to be more precise and set the gain for, say, 25mV exactly, or even 10mV per mb, the value of R6 can be amended accordingly. A preset pot could

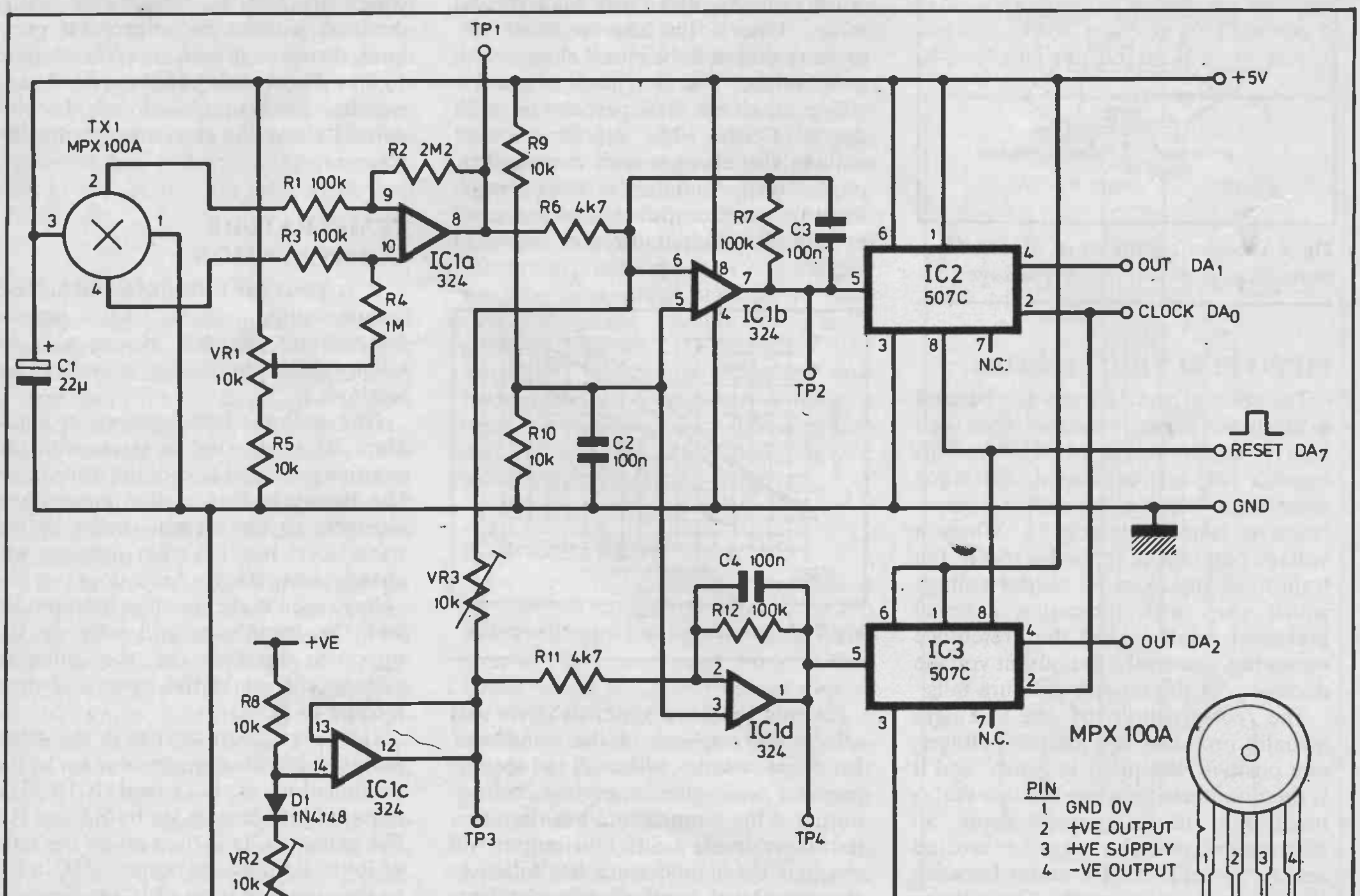


Fig.10 *Circuit diagram for the full electronic barometer*

be substituted for R6 and adjusted for greater precision, though I have not allowed space directly on the pcb for such a pot.

The output at pin 7 of IC1b can be monitored by a voltmeter, adjusting VR1 so that the meter needle would be at the 2.5V mark when atmospheric pressure is at 1013mb. In this unit, the output is also fed to the adc, IC2. But more of that later.

The level arriving at the input to IC1b will also contain any temperature error level as well. It is at this point that a corrective level is introduced.

DIODE THERMOMETER

In part one of the Weather Centre in PE March 87, I showed that a transistor can be used as a temperature sensor. It is equally possible, and in point of fact easier, to use a diode as the sensor. Any diode will exhibit a forward voltage drop across it when reverse biased, and this is temperature sensitive. The drop is pretty linear in its response to temperature changes, and for a silicon signal diode such as the 1N4148, is around 1mV per degree Fahrenheit (1.8mV °C).

In Fig.10, D1 is forward biased via R8, into VR2. As the temperature of D1 increases, so the voltage at its junction with R8 will fall. This is taken to the unity gain non-inverting buffer IC1c. VR2 can be adjusted until the required output for a particular temperature is obtained.

VR3 is then connected between IC1c and IC1b to adjust the temperature bias gain according to observed drift. The output of IC1c may also be monitored on a meter, or through the second adc, IC3.

SERIAL ADC

Many circuits have been published in PE for converting analogue data to digital equivalents. These usually have taken the form of 8-bit parallel converters such as the ZN448. Both Robert Penfold and I have recently described their principles in the Real World Interfacing and Polywhatsit articles. These were published in Jan–Feb 88, and May–Jun 87 respectively.

Parallel converters are preferable when high speed analogue to digital conversion is required. There are many situations, though, when digital sampling need only be carried out at widely spaced intervals. In this case a slower speed, and less expensive converter can be used. One such device is the serial a-d converter type 507C. Fig.11.

Whereas in a parallel converter the analogue data is translated into an equivalent multibit binary code, the 507C produces a ratiometric logic output. Putting that last phrase into English, the length of time that the

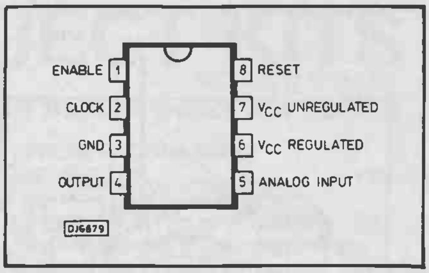


Fig.11 *Pin outs for the 507C*

output is high is compared with the length of time that it is low. The ratio of the two is determined by the analogue voltage level on the input. Note that the output is an open collector, and so a positively connected load is required for correct operation.

The block diagram for the 507C is shown in Fig.12. A clock signal is sent to a negative-edge triggered synchronous counter within the adc. Binary weighted resistors from the counter are connected to an opamp which is used as an adder. The opamp generates a ramp output which is compared to the analogue input voltage by a comparator. The lower the input voltage, so the longer the comparator output is held high.

In the case of the 507C, 128 clock pulses are needed to trigger the conversion through its complete cycle, which is the equivalent of 7-bit binary resolution. The maximum speed at which this conversion can take place is about 1ms, though there is no practical limit to how slowly the clock pulses are sent, providing that the sampled dc level is stable.

The analogue input voltage level is limited to a range of 1.28V to 3.82V. The maximum span is therefore 2.56V, so, dividing by 128, the sample step level is 20mV. You will recall that I allowed for a similar swing range of around 2.5V for the output from the pressure sensor.

Referring back to Fig.10, IC2 is the adc used to convert the pressure level to a digital form that can be accessed by a computer. The controlling software has been written so that the conversion cycle is stepped through by instructions from the computer.

COMPUTER CONTROL

The unit is intended for use with a computer that has an 8-bit parallel output port. Such ports include Centronics, User and IEEE488 as found on many computers. I have written the

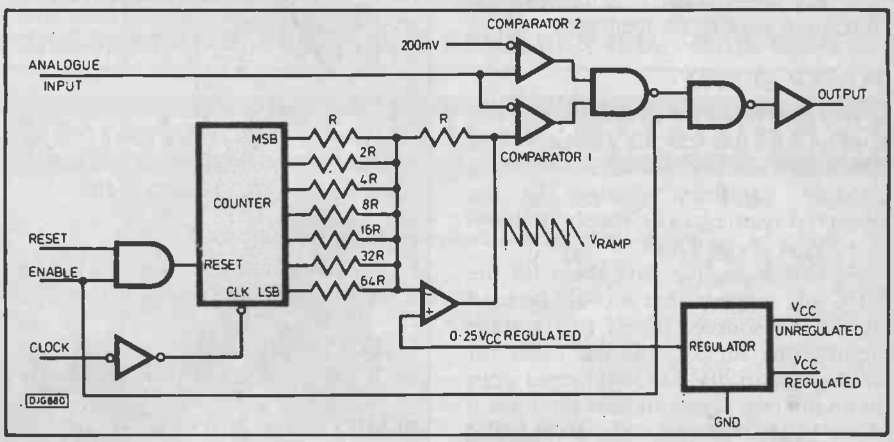


Fig.12 *Block diagram for the 507C serial a-d converter*

Initially, the ramp is triggered to a high level and the adc output also goes high. The ramp then begins its downwards decline. When its level crosses the threshold point, the comparator output reverts to a low level. The ramp continues its downward path to a preset level, whereupon it goes high once more, and the next cycle commences. Fig.13.

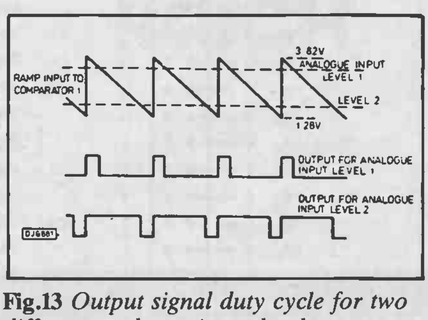


Fig.13 *Output signal duty cycle for two different analogue input levels*

program in Commodore Pet Basic, but apart from minor dialect differences between other basics, it is only necessary to change the output port address data to make the program suitable for use with other machines. The listing shows the equivalent addresses for the Commodore C64, and for the BBC-2. For use with other machines it will be necessary to refer to their handbooks.

Although parallel output ports usually have a variety of access lines, for this project it is only necessary to use four of the input/output data lines.

Initially, there is a reset pulse sent out along line DA7 to both IC2 and the other adc, IC3. This keeps the two adcs synchronised, though in actual fact, the way in which the program is written makes synchronisation unnecessary. Still, it makes things neater to do so.

The clock pulses are sent out in batches of 128 along line DA0. The digital output of IC2 is returned to the computer along DA1, and the computer simply counts up the number of pulses during which this line is held high. The answer will obviously fall in the decimal range of 0 to 127. This number can be displayed directly on the screen, or converted to a millibar equivalent.

The second adc, IC3, is included so that temperature can also be monitored. The output of the buffer IC1c is inverted and amplified by IC1d. The inversion causes the output level to rise as temperature increases. The gain is approximately set by the ratio of R11 to R12 so that a temperature change of 1°F will produce an output change of 20mV as seen at IC1d. IC3 converts the analogue level into a digital representation in the same way as IC2. The necessary clock pulses also come from DA0, but the digital output goes back along DA2. The processing of this output is performed by the program in a similar fashion to pressure data processing. The screen displays it either directly in Fahrenheit, or in Celsius using a simple conversion formula line. VR2 should be adjusted so that the screen shows the correct figures when checked against an ordinary thermometer. Additionally, the program keeps track of minimum and maximum data levels recorded.

POWER SUPPLY

It is vital to use a well stabilised power supply for this circuit. Even minor variations in psu voltage level can produce significant changes to the observed readings. The supply required is +5V, at about 22mA of current.

At first sight, the data sheet for the 507C adc suggests that it could be used as the 5V source. It has two voltage inputs, one for 5V, and the other for voltages up to 20V. The latter input feeds to an internal regulator that stabilises it down to 5V. Unfortunately, it was found that the regulation was insufficiently stabilised to provide power to the rest of the circuit. The level could quite easily be seen on a scope to jiggle up and down in sync with the clock pulses.

Obviously that was quite unsatisfactory, and a separate psu has to be used. It is quite probable that the required 5V can be supplied direct from the computer. Many have such an output, allowing for at least 100mA to be drawn. Alternatively, another well stabilised 5V source may be used. It is recommended that you do not use a zener diode to achieve regulation since the precise voltage available from it may very well vary with temperature changes. The usual 7805 voltage regulated psu used in so many published circuits is a far more satisfactory answer. Fig.14.

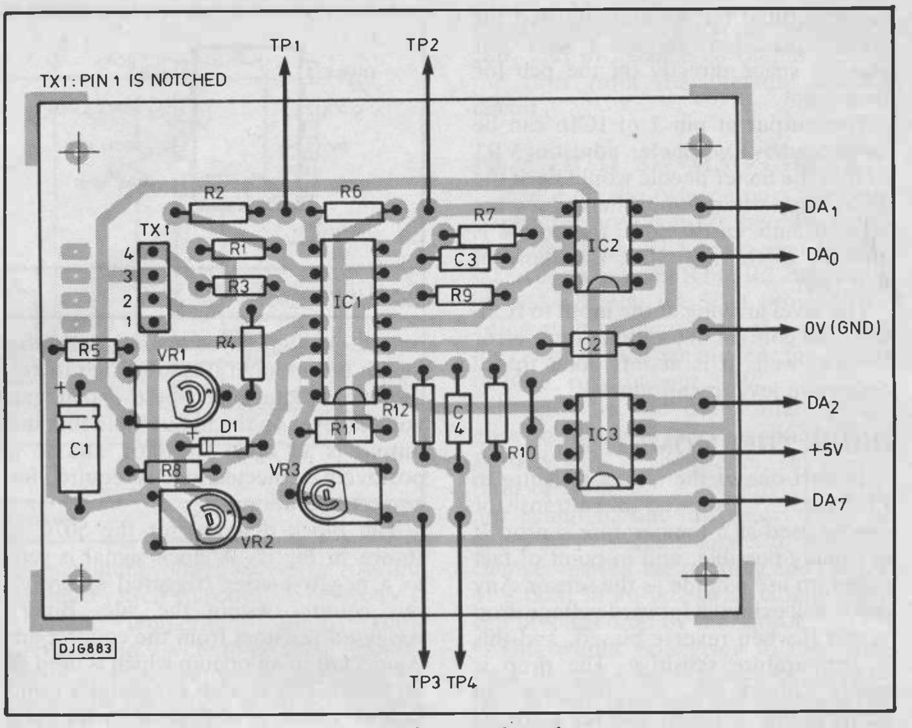


Fig.15 *Component layout on the printed circuit board*

BAROMETER COMPONENTS

RESISTORS

R1,R2,R7,R12	100k (4 off)
R2	2M2
R4	1M
R5,R8–10	10k (4 off)
R6,R11	4k7 (2 off)

All resistors ¼W 5% carbon film.

CAPACITORS

C1	22µ 16V electrolytic
C2–C4	100n polyester (3 off)

POTENTIOMETERS

VR1–VR3	10k skeleton (3 off)

SEMICONDUCTORS

D1	1N4148
IC1	324
IC2,IC3	507C (2 off)

MISCELLANEOUS

MPX100A pressure transducer, pcb285A, 8-pin ic socket (2 off), 14-pin ic socket, box to suit.

ASSEMBLY

The printed circuit board layout is shown in Fig.15. Its assembly is quite straightforward and needs no special comment. Fig.16 shows the suggested port connections for the BBC, C64 and Pet computers. The box used to house the unit is a nice little plastic one, measuring 120 × 65 × 40 cms. The pcb size is suitable for using the supports normally supplied with such boxes to hold it in place.

Next month I'll describe the setting up and present the program listing. PE

CONSTRUCTOR'S NOTE

The transducer, pcb and a kit of parts is available from Phonosonics (address in advert).

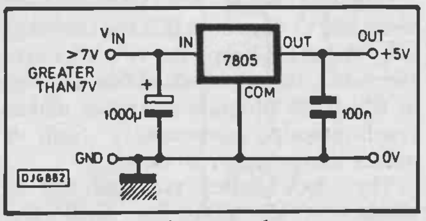


Fig.14 *Suggested 5V regulator*

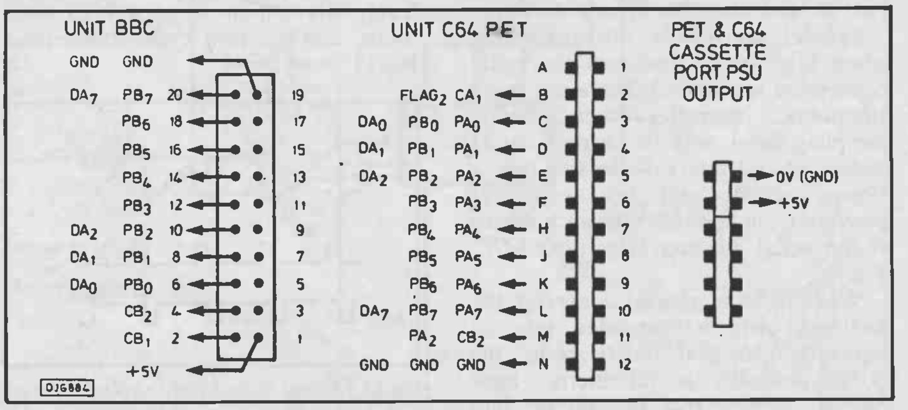


Fig.16 *Port sockets of the BBC, C64 and PET computers*

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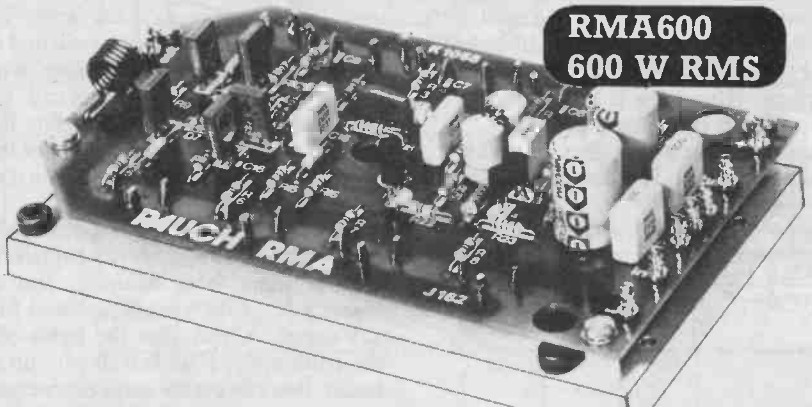

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Central Heating Controller

MANY people with gas C.H. must, like me, have only part-controlled systems, ie, boiler, radiators and probably a time switch, but no tank or room thermostats. Even if a room stat is fitted it probably only switches the pump on and off. This means that when the system is enabled by the clock, the boiler is always on, maintaining its water jacket at the required temperature, even when no heating is demanded.

This "short cycling" is very wasteful of gas (15% is claimed), and does not occur in modern, complete systems. Such systems are usually fully pumped; that is, the hot water to the tank is pumped rather than being gravity-fed. However, that is plumbing, not electronics...

This C.H. controller was designed to take inputs from room and tank stats and switch pump and boiler according to demand, turning the system completely off if no heating is demanded. In addition, various status indicators were desired. The idea was to make the system as good as possible without resorting to plumbing mods. The controller has worked very well throughout the winter.

Because of the plumbing shortcomings, the controller cannot be ideal: for example, the tank stat should shut down further heating of the tank when it has achieved the set temperature. It does when only hot water is called for, but if the C.H. is on too, the tank is further heated until the room stat operates. A motorised valve is required in the tank feed to overcome this. A relay is included in the circuit to operate it.

Fig. 1 shows the main wiring dia-gram, and a simple 12v power supply. The truth table for the controller is given below.

The controller uses simple relay logic and divides neatly into low and high voltage parts. All the thermostat wiring carries only 12V, making things safer than normal.

Relays 1 and 2 control boiler solenoid and pump respectively; relay 3 is optional, for a motorised valve. They are 2pco types, and mine were rated at 250V, 5A. The power being switched is not high, but both pump and solenoid are inductive loads.

S1 is the main system switch, S2 enables the C.H. and S3 is the hot water priority switch. The function of S3 is to prevent the pump from running until the tank has been heated, thus enabling hot water to be more quickly obtained. Once the pump is running it will be further interrupted if the tank is depleted.

There are four pilot lights in the unit; note that LP1 and LP2 are neons, while LP3 and LP4 are 12V indicators. If the latter are leds, D1 and D2 should be included to suppress back emf. LP1 indicates that the system is switched on, so hot water should be available, while LP2 shows that the C.H. is on call. LP3 warns that the tank is demanding heat and LP4 that the room is below set temperature. (LP4 is operational even if the C.H. is disabled via S2).

For testing it is strongly recommended that a pair of 12V lights are substituted for the pump and solenoid, and the mains side of the circuit powered for a 12V supply. Check that the lights obey the truth table. If all is well wire up the boiler. **Don't forget the earth connections.**

D. Blandford, Poole

TRUTH TABLE

S3(h.w.p.)	Room	Tank	Boiler	Pump
Don't Care	0	0	0	0
"	0	1	1	0
"	1	0	1	1
"	1	1	1	1
Open	1	1	1	0

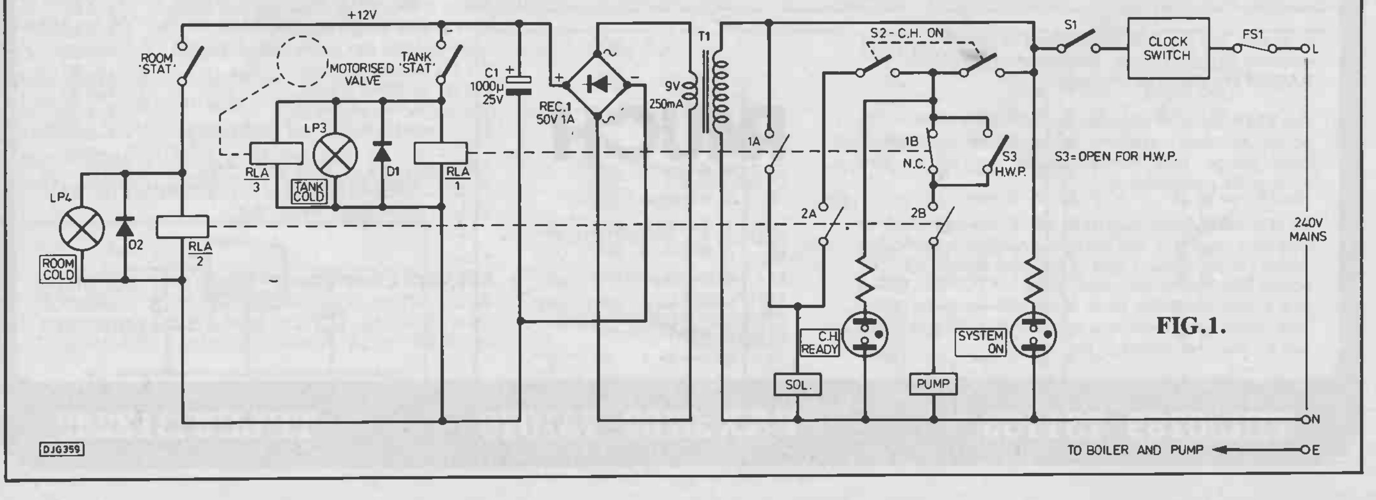
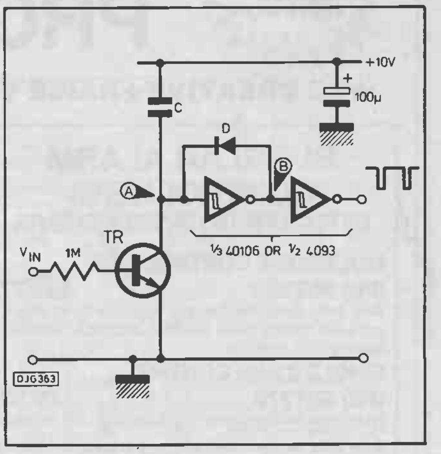


FIG.1.



SIMPLE LOW-COST VCO

USING a supply voltage of about 10V the response is quite linear. Almost any desired frequency may be attained using different values for 'C', the upper limit being determined by excessive leakage. It can also be controlled from the upper limit down to 0Hz by taking Vin below 0.6V.

The output waveform can be turned into a regular squareware by adding an edge triggered flip-flop such as the 4027. Any general purpose silicon diode, and any low leakage npn transistor will be suitable.

T. Thompson, Newcastle on Tyne.

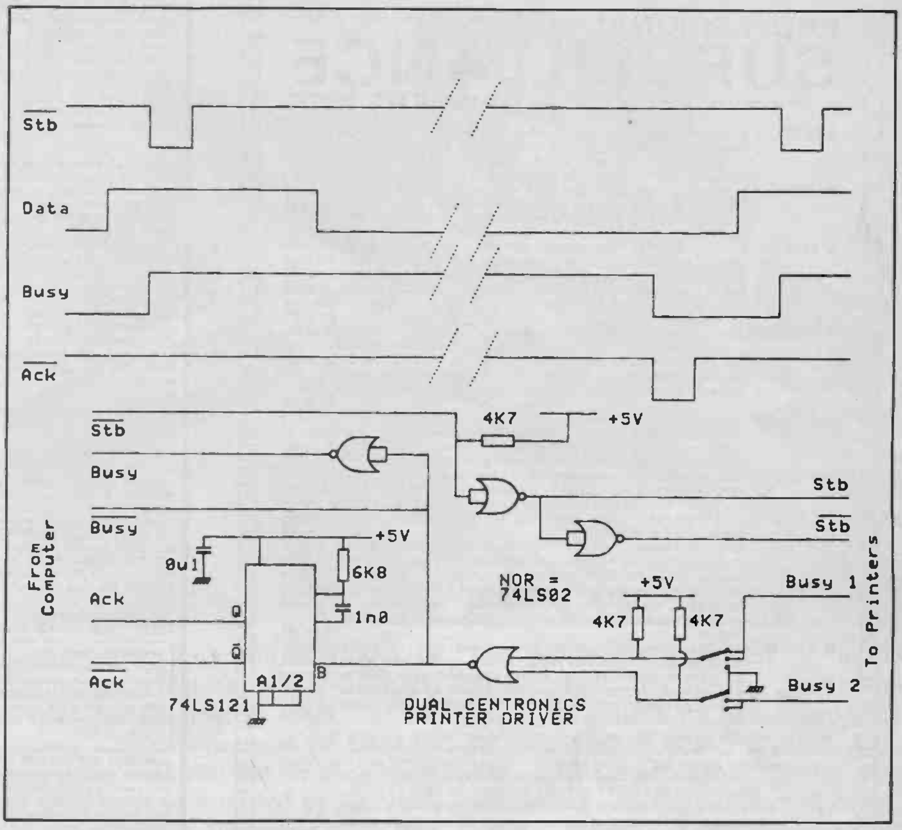
Dual Centronics Printer Driver

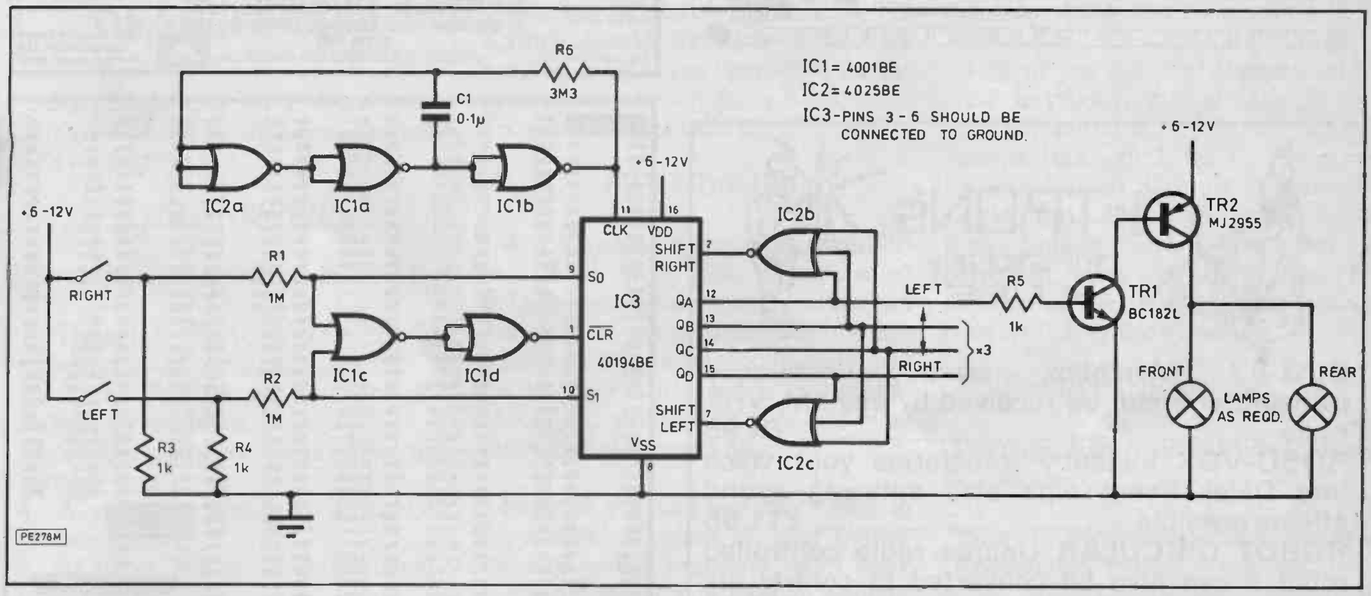
THE circuit enables a Centronics interface port to drive two printers simultaneously.

The timing diagram shows the normal Centronics data transfer sequence. Data at ttl levels is presented in parallel to the printer, then the STROBE line is pulsed. The BUSY line from the printer is taken high and stays high until the character is accepted. When BUSY returns low, an ACKNOWLEDGE pulse is sent back to the computer to request the next character.

The dual interface ORs the printer busy lines, providing a composite control line for the computer. A 5μS monostable provides the necessary acknowledge pulse. The 3-way switch can direct output to either printer, whilst halting the other. A further two poles, (not shown), break the strobe line to the de-selected printer. Two 74LS125 buffers, not shown on the diagram, prevent excessive loading on the host computer port data lines. To make the interface more universal, and to use up spare gates, inverted strobe, busy, and acknowledge lines are available.

F. Wright, Sunderland.





Bike Safety Indicators

SINCE direction indicators on bicycles and motorcycles are so close together, it can be difficult in the heat of the moment to see which side is being operated. Ths circuit shows a moving sequence in either direction through a row of four lamps. The basis of the unit is the bidirectional cmos shift register ic, which is clocked at around 4Hz by IC1a, IC1b and IC2.

When neither swith is closed, IC1c and IC1d cause IC3 to be cleared, so that no output will result and no lamp will light.

Suppose that the 'left' switch is pressed. The CLR line on the IC3 will go high (pin 1), as will the S1 line (pin 10). This sets the shift register in the 'shift left' mode. IC2c detects that none of the three right hand lamps is lit, and forces a logic 1 at the right of the shift register. As this is clocked along the register, the output of IC2c goes low, so that no further ones are set until the regiser empties at the left end. Thus only a single lamp is lit at any one time.

Signalling right is exactly the same, except that S0 (pin 9) is set high instead of S1 and IC2b sets the 'shift right' pin when the left hand three bits of the shift register are low.

If both switches should be pressed simultaneously, IC3 will be put into the 'parallel load' mode. Since the input pins 3-6 are gounded, the output will be low and no lamp will light. Since this is the same situation as when neither button is pressed, the switches may be wired active-low, ie switching to ground, if this is more convenient. If this is to be done, the only modification required is to connect R3 and R4 to pull-up instead of pull-down.

The output stage will handle the output current of any motorcycle indicator bulb, and the specification may obviously be relaxed for less demanding applications. If the device is to be used on a motorcycle, some form of power supply filtering will be advisable.

Keving Jones, Lancs.

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4036	180p
4037	75p
4038	48p
4039	190p
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4041	38p
4042	30p
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4044	38p
4045	72p
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4051	38p
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4054	53p
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4056	52p
4060	40p
4063	52p
4066	20p
4067	130p
4068	13p
4069	13p
4070	13p
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4072	13p
4073	13p
4075	13p
4076	45p
4077	13p
4078	13p
4081	13p
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4085	40p
4086	32p
4089	80p
4093	18p
4094	40p
4095	58p
4098	50p
4099	45p
4501	30p
4502	38p
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4506	80p
4507	33p
4508	70p
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4512	42p
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4514	75p
4515	75p
4516	40p
4517	120p
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74LS160	48p
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74LS164	43p
74LS165	85p
74LS166	74p
74LS168	92p
74LS169	85p
74LS170	80p
74LS174	39p
74LS175	42p
74LS190	55p
74LS191	52p
74LS192	50p
74LS193	51p
74LS194	53p
74LS195	52p
74LS196	62p
74LS197	52p
74LS221	58p
74LS240	55p
74LS241	55p
74LS242	55p
74LS243	80p
74LS244	50p
74LS245	50p
74LS247	50p
74LS248	50p
74LS249	92p
74LS251	30p
74LS253	350
74LS256	80p
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74LS259	58p
74LS260	40p
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74LS273	52p
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75154	110p
75158	140p
75159	200p
75160	400p
75161	400p
75162	700p
75172	720p
75182	100p
75183	100p
75188	60p
75189	60p
75195	185p
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78L18	28p
78L24	28p
79L06	40p
79L12	45p
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THE Z88 WINNER!

AND WHO'S THE LUCKY WINNER OF THIS SUPERB COMPUTER?

Well, that was not easy to decide. There was an enormous response to our latest competition and 80% of the answers to those helpful questions were absolutely correct! Then there were so many good reasons given for why you would recommend PE to a friend. There was no way we could select a best answer to that question. So out comes Ed's oversized hat, the best were all crammed in and a winner selected by a random lucky dip. And the winner is ....

MR J. WOOLHOUSE OF SHEFFIELD!

Congratulations Mr J. Woolhouse. You've won one of Sir Clive Sinclair's Z88 computers.

THE ANSWERS

The answers that we were looking for:

1. Heinrich Hertz is famous for discovering electromagnetic waves.
2. Barry Fox is an awarded PE technology journalist.
3. A superconductor carries electrical current.
4. A printed circuit is a tracked assembly board.
5. Sir Clive Sinclair is enterprisingly marketing the Z88.

ENIGMA VARIATIONS

The first four questions caused no one any problems - indeed they shouldn't have for the alternative answers were all humorous improbables. Question five though gave 20% of you something to get wrong. Sir Clive is certainly *knighted* but in no way is he *benighted* - he's made his fame through modern technology, not that from the dark ages!

Some of you think he is a Cambridge professor. I dare say he deserves to be, but his principle connection with Cambridge is that his company is called Cambridge Computers. This, I know, caused a bit of indecision for some of you since you know that the trade name of Sinclair is now owned by Amstrad, Therefore, you thought, Sir Clive would not be marketing the Z88, but Amstrad would. Recognising the trick spelling in Q5a, you then opted for the professorial answer. Sorry folks, these deceptive choices were intentional!

FRIENDSHIP

And why would you recommend PE to a friend? Well, some of you wanted to keep the good news to yourself - and didn't give me any answer to this question. Why ever not? Surely you could have confessed a few words about your excitement over this most interesting electronics mag?

Some of you said you didn't need to recommend PE since all your friends already took it regularly. Well done friends! Lots of you thought another reason was obvious - that PE is far superior to any of the competitive electronics mags.

Many of you agree with me that PE is ideal for early beginners and experienced constructors alike, and that we have a good balance of easy to medium complexity constructional projects. You like the way in which technology is presented from theoretical and practical points of view, and that we keep you abreast with the latest developments. Barry Fox, Tom Ivall and Patrick Moore are well appreciated, as are the brief reports of new products and happenings on the news pages. You enjoy the letters pages, are grateful for Bazaar and think the new-style covers are great. And, yes, advertisers are offering you interesting products to buy. Thanks, too, for saying you like the flashes of humour.

Lots of you put your imagination to work in producing final answers that used the initial letters from Practical Electronics, such as - Practical Research And Circuit Theory Is Certainly A Logical Electronics Lead Every College Teacher, Researcher Or Novice Included, Can Study. Which, by the luck of the draw, happens to have been written by the winner.

RUNNERS-UP

The three runners-up, also drawn from Ed's hat, are -

Miss L. Baxter, Montrose, Angus - "Reasonably priced magazine with useful projects, interesting features and handy adverts".

N.Cheesman, Bordon, Hants - "It's so up to date its on sale a month before the news has even happened".

Ivanovic Milovan, Titograd, Yugoslavia - "PE is a source of information from various fields, of realistic topics, of self-made circuits, of knowledge".

A years subscription to PE goes to all three.

Commiserations to the rest of you but thanks for entertaining me with your entries. Ed.

SPACEWATCH

BY DR PATRICK MOORE CBE

OUR REGULAR LOOK AT ASTRONOMY

August is the month for meteors – an area of astronomy in which more research by informed amateurs would be very valuable.

Voyager 2 is still working well as it crosses that region of the Solar System between the orbits of Uranus and Neptune. Neptune is scheduled to be by–passed in August next year. But interesting though Neptune itself is, a great deal of attention will be concentrated upon its large satellite Triton, which is larger than our Moon and is thought to have a very considerable atmosphere – composed probably of methane, and perhaps opaque enough to conceal the surface from Voyager's cameras. The only other planetary satellite with an appreciable atmosphere is Titan, in Saturn's system, where the chief constituent is nitrogen, with a good deal of methane mixed in. The clouds of Titan are permanent and all–concealing, Whether Triton will behave in the same way remains to be decided. It could be that Triton's surface is covered with an ocean of liquid nitrogen, in which case it will be unique; alternatively, there may be a solid surface with a layer of methane ice. The other known satellite of Neptune, Nereid, is very small. Whether there are rings is not certain, but on the whole a full–scale ring system does not seem very likely.

If all goes well, the Hubble Space Telescope will be launched on the Shuttle *Atlantis* in June 1989. The crew has now been selected for this mission; Loren J. Shriver (commander), Charles F. Bolden (pilot), Steven A. Hawley (astronomer) and Bruce McCandless and Kathryn D. Sullivan (mission specialists). If the launch is successful, the telescope should begin operating almost at once. Astronomers everywhere await further news with impatience!

THE AUGUST PERSEIDS

August is the favoured month for meteor observers. We pass through the

The Sky This Month

Apart from Mercury, all the naked-eye planets are on view this month. Venus dominates the eastern sky during the early hours of the morning; it reaches its greatest elongation (46 degrees) on August 22, at magnitude –4.3 by far the brightest object in the sky apart from the Sun and the Moon. Any small telescope will show its changes in phase from a crescent at the start of the month to a half-phase at the end.

Jupiter is 'only' of magnitude –2.3 two whole magnitudes fainter than Venus but it cannot be mistaken as it moves eastward between the star-clusters of the Pleiades and Hyades. Look for its belts and bright zones, and also for the four large satellites which have proved to be such fascinating objects – from the icy, inert Callisto to the violently red and volcanic Io. The other giant, Saturn, is an evening object, though it is very low down in Sagittarius and is hardly likely to be seen during the last part of the month.

This leaves Mars, which is moving in Cetus – one of those constellations which intrudes into the Zodiac even though it is not one of the 'official twelve' so beloved of astrologers! Mars is now of magnitude –2, but is brightening all the time as it nears opposition next month. Observers of the planet will be watching for signs of the dust-storms which so often cover much or all of the surface when Mars is near perihelion. The southern hemisphere of the planet is turned towards us, though the ice-cap there is shrinking.

The Moon is new on August 12, and full on the 27th. On the 27th there a partial lunar eclipse; 0.3 of the disk will be covered by the Earth's shadow, but unfortunately the eclipse will not be visible from anywhere in Britain. It begins at 10.08 GMT and ends at 12.00.

The starry sky during evenings is still dominated by the 'Summer Triangle' of Vega, Deneb and Altair. Ursa Major, the Great Bear or plough, is low in the north-west, which means that the W of Cassiopeia is high up; the Bear and Cassiopeia are on opposite sides of the Pole Star and about the same distance from it. Neither actually sets over Britain (neither, for that matter, do Vega or Deneb, though Altair spends part of its circuit below our horizon). In the east the Square of Pegasus has come into view, while the low south is occupied largely by the vast, dull Zodiacal constellations of Capricornus and Aquarius. Sagittarius, the Archer, is setting toward the south-west. It has no first-magnitude star and no really distinctive shape (some people have likened it to a teapot) but at the moment it is graced by the presence of Saturn.

This is an excellent time for studying the Milky Way. Starting from the Auriga–Perseus region in the north–east, it runs through Cassiopeia, Cygnus (past Deneb), Aquila (near Altair) and down to Sagittarius. The Sagittarius star–clouds mask our view of the mysterious centre of the Galaxy, but look too for the dark rifts in Cygnus, due to obscuring matter blocking out the light of stars beyond. It was Galileo, the first great telescopic astronomer, who found in 1610 that the Milky Way is made up of stars; it is tempting to think that the stars there are in imminent danger of collision, but in fact the Milky Way is a mere line of sight effect, produced when we look along the main plane of our flattened Galaxy. Altogether the Galaxy contains around 100,000 million stars, of which our Sun is only one; it is in slow rotation, and the Sun takes about 225,000,000 years to complete one circuit – a period sometimes called the 'cosmic year'. One cosmic year ago, the most advanced life–forms on Earth were amphibians; even the dinosaurs had yet to make their entry. It is interesting to speculate as to what the Earth will be like one cosmic year hence!

main part of the Perseid stream; the shower begins in late July and goes on until about August 17, with its maximum on the 12th. As this is also the day of new moon, 1988 should be a really good 'Perseid year'.

There is still some popular confusion between a meteor and a meteorite. Acutally the two are very different. A meteorite, which may reach the ground as a solid mass and cause a crater (such as the famous crater in Arizona) is either a stone, an iron or a mixture of both; it probably comes from the asteroid belt, and is not connected with any meteor shower. In fact, there seems to be no difference between a small asteroid and a large meteorite. A meteor, on the other hand, is cometary debris, and is very small indeed - usually smaller than a grain of sand. Dashing into the Earth's air at anything up to 45 miles per second, it burns away in a very short period, ending its journey to the ground in the form of fine dust. Obviously, what we see is not the tiny meteor itself, but the effects produced as it plunges downward through the upper atmosphere, burning away by the time it has dropped to about 40 miles.

The Perseids represent the most reliable of all showers. They are associated with a periodical comet, Swift-Tuttle, which was last seen in the year 1862; in that year it reached the second magnitude, so that it was a conspicuous naked-eye object with a tail almost 30 degrees long. Calculations gave it a period of 120 years, so that it should have reappeared in 1984, but it has not been seen. It is not likely to have disintegrated, as some periodical comets have been known to do, so that either we have missed it or else the calculated period is wrong. At any rate, searches for it will continue.

The usual ZHR of the Perseids is of the order of 70. The ZHR indicates the number of naked-eye meteors which would be expected to be seen by an observer under ideal conditions, with the radiant at the zenith (in practice, of course, these conditions are never fulfilled, so that the actual observed rate is always rather less than the theoretical ZHR). If you stare upward against a dark, clear sky for several minutes any time around mid-August, you will be virtually certain to see a meteor or two. After midnight is the best time, as the meteors then meet the Earth 'head-on' and enter the air at greater speeds.

Meteor radiants were first determined by visual observers well over a hundred years ago, and visual work is still valuable. Photography is also of great use - and meteor spectra are fascinating when they can be obtained; amateurs have a fine record in this field of research, though it is painfully clear that trying for meteor spectra is time-consuming and often frustrating. Today, however, there is also radar detection, and in many ways this has supplanted visual work. A meteor trail acts in the same way that a solid body would do so far as radar is concerned, and of course clouds and daylight are no bar.

There are some amateurs who have taken up this work (which was pioneered by Sir Bernard Lovell and his team at Jodrell Bank soon after the war), but not enough amateurs are involved in it, and radar detection of meteors can be strongly recommended to any competent amateur who is anxious to undertake some really valuable research. Of course, the Perseid shower is not the only one - there are many showers every year - and there are also sporadic meteors, which may appear from any direction at any moment and which do not seem to be associated with any definite shower.

Meteors may be the junior members of the Solar System, but they can tell us a great deal, and they will repay careful study. Visual, photographic and radar methods complement each other - and if you are interested in becoming a meteor observer, now is a good time to start. PE

COMPACT DISC ROM

BY VIVIAN CAPEL

THE LIBRARY NOW ON THE TURNTABLE ...

CD rom gives the concept of the compact dictionary, portable service manual or pocket classic a new meaning. Next, the cd rom "Walkman"?

The new Philips CM121 Stand Alone CD-ROM Drive

The fact that a compact disc can store a full hour of high quality stereo digital sound along with other incidental information is possible only because of its tremendous storage capacity. As we have seen in previous articles (July-August 1988), the individual digits take up only 0.3μm of track length which is about a third of the wavelength of the laser light used to scan them. It means that nearly 85,000 bits are stored in every linear inch of track. Such a packing density offers an attractive possibility for computer memory storage; in fact cd roms were introduced since 1985, and a number of discs have been made.

When a cd is used as a rom (read only memory), it has a density of one million bits per mm^2, which gives it a capacity of 600 megabytes. This can be compared to the 5½-inch floppy disc having a capacity of one megabyte which when the disc is formatted is reduced to 800 kilobytes. Hard discs range from 10 to 40 megabytes. Converting that 600-megabyte capacity to more familiar terms, it is equivalent to 250,000 typed pages of A4 paper.

Access time for such a prodigious quantity of stored data may be expected to be long, but the longest, that is from the first 'page' to the last, is just 1.5 seconds. A single disc is claimed to not only have a greater capacity than most data banks anywhere in the world, but also the fastest access time.

DATA FORMAT

The format of the data on the disc is similar to that of the audio cd, in that it consists of a number of frames, each containing data, error correction and control and identification bits. The diffference is that there are 75 frames per second compared to the 7,350 frames of the audio disc which needs to be split up into much smaller units. The identification information is thus updated 75 times per second and so can take the form of elapsed time in minutes, seconds and 75ths of a second, sequence numbers, dates or any other desired reference. Data location is extremely precise as the player can locate the exact frame if so instructed. Usually this would be the starting frame for a particular sequence of data.

An error correction system using parity bits similar to that of the audio disc is used for the cd rom, but the likelihood of data corruption due to surface blemishes is considered to be even less. The chances are that only one 10^{15} bits will be faulty, which is less than that of the source if it is a main frame computer. The magnetic disc memories usually used with these are likely to have a much greater incidence of data faults.

The disadvantage is that at present cds can only be made economically in quantity and cannot be written to by the computer, as can a magnetic disc. It could not then take the place of the floppy disc for the small user, but there are many situations where a fairly large number of copies may be required for distribution within a large organisation, or to subscribers.

ENCYCLOPAEDIA

An example of such a use is the publication of a large encyclopedia, which can be frequently updated by simply issuing a new disc. One that has appeared is the *"Academic American Encyclopedia"* published by Grolier Electronic Publishing Inc. This consists of more than 10,000 printed pages made up of 30,000 articles contributed by 2,500 experts. All this represents just 16 megabytes, so there was room for a 15-megabyte index and still a lot of space to spare on a single disc.

A software program is necessary to process the disc, for optimum use of the index and to locate information. This is the Activenture Knowledge Retrieval System which is supplied on an accompanying floppy disc. A microcomputer with a memory of 256K and a cd rom player such as the Philips CM100 is required to run it. The publishers plan to bring out a wholly revised edition of the encyclopedia each year at a cost of only 25 dollars.

Another example is the American Library Corporations Bibliofile which consists of references by author, title, ISBN and LCCN numbers and ISSN numbers for periodicals, of the whole Library of Congress, some three million entries. Included are all of the 1½ million books published in the last 15 years. This huge databank is recorded on just four cd roms.

ROMING HOMER

Of interest to students of ancient languages is the compilation of the works of Homer, Sophocles, Plato, Aristotle and Plutarch along with the Greek New

Testament and Hebrew and Greek versions of the Old Testament plus works by various Coptic and Latin writers including Virgil. These are contained on a single cd rom produced by Ibycus Systems.

The cd rom can be of great value in the medical field. The Microdex Computerised Clinical Information System uses four data-banks to cover all the information needed by hospitals and first aid posts on such subjects as the symptoms, diagnosis and treatment for the vast number of poisons that are known to man. Originally this was accommodated in a mainframe computer databank, but has been transferred to cd rom so that the information can be immediately and locally available, instead of having to consult the mainframe by telephone with all the delays that could entail. Four other companies are reported to be working on similar projects.

COMPACT MEDICINE

It seems that there are some 4,500 medical periodicals which regularly report on new developments so producing several gigabytes of new information each month. If all this can be recorded, classified, narrowed down and indexed so that a medical specialist could find the information he wants without having to wade through vast quantities of irrelevant material, the benefits to doctor and patient alike would be considerable.

In situations involving long periods of isolation with difficult or impossible telecommunications, the cd rom could be invaluable. In a submarine for example, all repair and maintenance manuals could be carried on board. There is a report that NASA intends doing something of the sort for their planned space station.

As the cd rom discs are the same physically as music cds, the same pressing plant can be used to make them, so helping to reduce production costs of limited runs. The situation is the same as for privately made lp records. Private studios will cut a master disc from your tape, which is sent to one of the large pressing companies that make records for the major labels, who will then press off a dozen or so discs. You may have to wait a short while until spare pressing time becomes available, but you have the advantage of making use of expensive pressing equipment at moderate cost.

THE CD-I

A new step is currently being developed which is the cd-i, the interactive cd. The main feature of this is that text and data can be mixed with pictures, drawings or animations plus sound as well. It is therefore a total information concept as all these can be recalled simultaneously, so that the illustrations normally to be found in most encyclopedias but which are absent from the cd rom versions can be included. In fact they can go one better than the conventional ones in that they can be animated if desired.

In the case of dictionaries, the sound facility enables pronunciation to be included, while the large storage space available allows a thesaurus or collection of synonyms and autonyms to be added.

A still colour picture of studio quality requires about 600 kilobytes of information space, but with the cd-i technology this can be compressed into some 100KB. The 600-megabyte disc capacity thereby allows 6,000 pictures to be stored. Many more can be recorded if in black and white, or simple line illustrations and cartoons.

Sound storage can be of several quality levels, the choice depending on the use. This also determines the playing time. Stereo music of the quality obtainable from the standard cd permits a shorter playing time than speech quality sound in mono. In the latter case, the capacity produces some 16 hours, which is available as 16 parallel channels each having a playing time of one hour. If a further quality reduction can be tolerated playing times of up to a thousand hours are possible. Even the longest talking book can thus be easily accommodated on a single disc.

Many if not most home computers are used for computer games *(A truth that saddens me. Ed)*, some of which have fairly predictable patterns. With cd-i the storage capacity permits games to be devised that would never follow the same pattern twice.

This really is where the interactive feature comes in, because like the cd rom, the user can select any sequence of information, repeating as necessary in the case of educational subjects, to check what has been learned.

By using suitable access program software, the user will have a variety of means to access the material; a conventional keyboard or a mouse is the immediate prospect, but the makers envisage a time when speech recognition will enable the user to ask questions and even hold a conversation with the cd rom.

So, there is much more to those shining silver discs than meets the eye; it looks as though they will be playing an increasing part in our lives. PE

Interactive seedy music blossoms forth.

DAT SAGA
continued from page 27

THE TANDY THOR

Tandy threw a monkey wrench into the industry by announcing their Thor–CD. This is a write/erase/rewrite cd–compatible disc system. They claim the recorders will be available in about two years, are expected to cost around $500 and the discs around $20.

Such a technology, if it were available this year, could well upstage dt and could do serious harm to the cd–rom business. In two years we may have enough of an installed base of dt and associated data services so the writable disc is no longer needed.

There has been a serious need for some sort of rewritable cd. The cd–rom is great in that it holds a humongous amount of data – 600 megabytes. but the down side is that it is not updatable, so any data base which changes requires the frequent pressing of cd–roms, shipped via expensive overnight delivery.

These also require special cd–rom players, which are expensive. It's a technology which isn't really right for most applications. Digital tape provides the lowest cost answer to this need so far. We'll see if Tandy is able to field their Thor–CD before dt takes the steam out of the product.

There are some application for a combination of permanent data and updatable disc. Tandy may mix a regular cd–rom and their Thor–CD on one disc, providing the best of both technologies. That would give them an edge over dt for some users.

DT PLAYER ANNOUNCED

The first computer oriented digital tape recorders were shown at Comdex in Atlanta in May. At under $1,000 and using $10 dat tape cassettes which will store about 1,000 megabytes of data, these should be in short supply for some time to come. It's started. PE

MICROPROCESSOR BASED SYSTEMS DEVELOPMENT

PART ONE BY TIM WATSON BSc (HONS) AMIEE

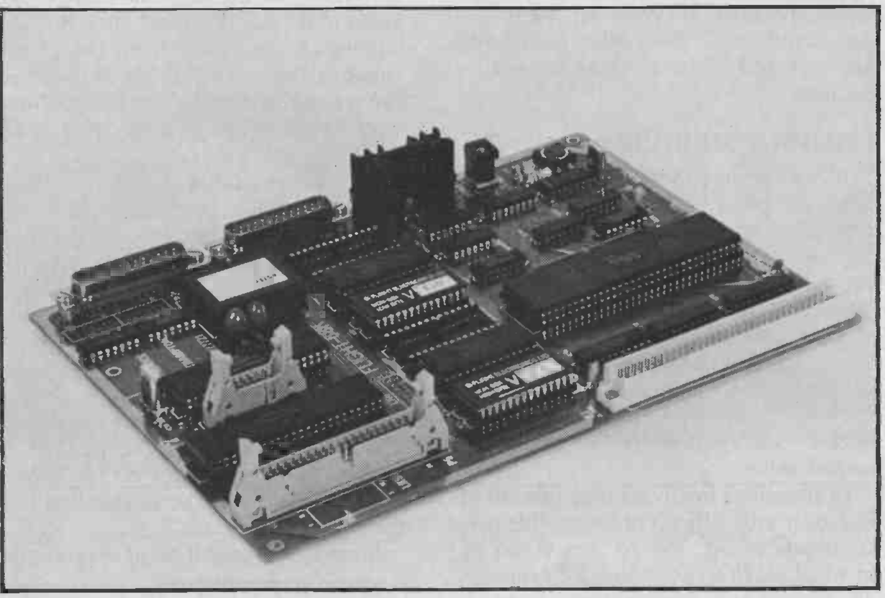
WHY EMULATE?

You'll never stand alone – until you have grasped the essentials of microprocessor system development. A microprocesor and its supporting systems form a miniature computer inside an appliance or piece of test equipment. Development means designing new hardware and software around the central processor. Simple systems are within the home constructor's reach.

The purpose of this article is to describe the techniques used and tools required to develop stand-alone microprocessor based systems. Without these tools and techniques, development (that is, getting the hardware and software to work) of microprocessor systems would be a great deal more difficult. The article is relevant to the hardware and machine level software designer. In fact the hardware designer needs to be aware of the software designer's problems/limitations, and vice versa. It is for this reason that hardware and software information is mixed together in this article.

The article begins by giving an introduction to the hardware design of a microprocessor system, giving typical reasons for the choice of hardware. However, the subject is only briefly covered. If any readers are not sure of their ability to design the hardware, they should read one of the numerous books or articles written on the subject. Later in this article it will be assumed that the reader has an understanding of such hardware. It is also assumed that the reader has a basic grasp of programming, particularly assembler. Next the article considers what type of equipment could be used to ease development problems. In particular the use of processor emulators and eprom emulators are discussed. In the case of eprom emulators the actual emulation hardware is also discusssed. As will become clear the hardware and software tools needed to allow easy development are quite considerable, but within the scope of the hobbyist. Towards the end advice is offered on how to get a stand-alone system going in easy stages. Finally, there is a brief word on assemblers and compilers. As an analogue the development tools to be described here are the equivalent of the analogue person's oscil-loscope, signal generator, etc.

The term stand-alone system has been used above. It is worth considering what this means. Usually it refers to a microprocessor based system which has hardware and software designed for a specific application. The system always runs the same program, which is typically stored in eprom. Examples are the controllers inside some washing machines, the intelligence inside video recorders etc. However, a clear cut definition is not possible. Consider taking a stand-alone system and adding a vdu, keyboard and disk drive; what have you got? An advanced stand-alone system or a general purpose microcomputer? The tools to develop both are the same, but it is useful to retain the concept of a stand-alone system.



A typical microprocessor development system – the Flight Electronics 68000

PROCESSOR HARDWARE DESIGN

Most microprocessor circuits, using current processors, are basically the same. At the heart of the circuit there is a microprocessor, which is a single chip capable of decoding and executing instructions. Memory is provided by means of ram and rom. Ram is volatile, that is the contents are lost when the power is turned off. Rom is not volatile, but its contents can not be altered (they are set at the manufacture/programming stage). Ram is used to store values that change during the program operation and rom is used to store the instructions which tell the microprocessor what to do; this is the program (or software). Ram could be used to store instruc-tions, but this is not common for stand-alone systems since the program would be lost when the power is removed. Connecting the microprocessor, ram and rom together gives us the ability to run a program; make decisions, do calculations etc. We now need the ability for the system to tell us humans what it is doing. This is done by the input/output circuitry (i/o). The i/o varies according to the application of the system. For driving a disco light show the output circuitry would need to take the logic level high/low signals and convert them to high voltage, high power levels, capable of turning mains lamps on and off.

Another example is a greenhouse controller. The input circuitry would need to take analogue information from low voltage probes and convert it into digital data. Dependent on this information the processor would need output circuitry capable of driving motors to open and close windows. It is interesting

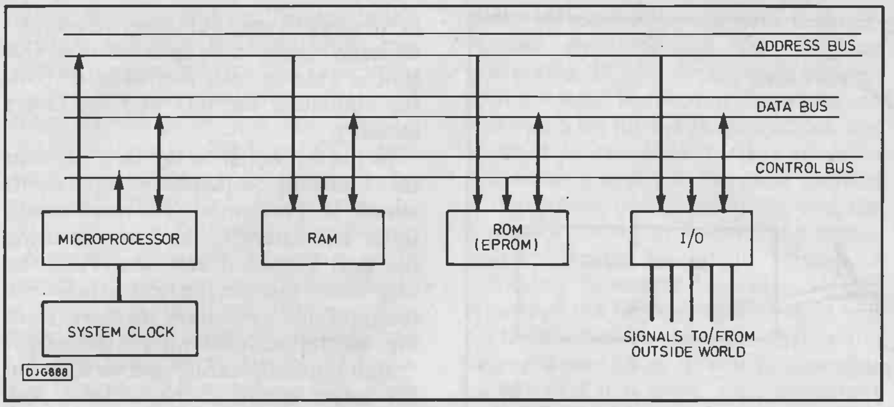


Fig.1. *Bussing arrangement*

to note that *all* signals start or end as analogue. For example turning a lamp on. Though the signal to the lamp is digital in nature, the lamp converts to light, and this is analogue! It is an analogue world.

The processor, memory and i/o are all bussed together, see Fig.1. A bus is a group of signals that are related in some way to each other. For example, the data bus is made up of eight signal lines (8 bits) and together the signals form a binary value. Operations are performed synchronously, timed by the system clock, under control of the processor. The processor will set up the address bus to give access to the required memory of i/o location; it will set the control bus so the memory and i/o sections know what is going on; finally the processor will send data to or fetch data from the data bus, that is, perform a write or read. Though this is basically what happens it is a simplification and there are many variations on the theme, some very complex. More complex circuits may have multiprocessors and busses, advanced memory management units, ability to allow devices to access memory directly without the help of the processor (known as direct memory access, dma). The possibilities are endless ....

How do we set about designing the hardware for a stand-alone system? The first step is to identify what the system has got to do. Next a judgement needs to be made of what should be done in software and what should be done in hardware. The hardware requirements are considered here.

Has the system got to do a lot of real time processing? If so a high speed processor is required, which in turn will require high speed memory and interface devices. If high speed numeric processing is required a processor with the ability to easily interface with a numeric co-processing unit is desirable. Use of a 16 bit data bus would allow faster processing, because compared with an 8 bit bus twice as much information is fetched and processed at a time.

Does a lot of data need to be stored? If so a wide address bus is required. If this still does not allow addressing of enough memory then memory banking techniques are needed. A processor with a built in memory management unit would make life easier.

If the stand-alone system is being used to perform a simple task then a 4-bit processor might be powerful enough. However many chips are organised around 8-bit data, so it is probably cheaper and easier to use an 8-bit processor.

How many chips are required to implement the system? The fewer the better, cheaper, easier to wire up, more reliable. There are many good processors around which have on-board goodies, such as memory, i/o etc. If one of these can be used it is usually cost and design effective in small stand-alone systems. Typical on chip features are serial asynchronous port(s), small amounts of parallel i/o (this is limited by the number of package pins required for parallel data); counter/timers (can be very useful); analog to digital and digital to analog converters. Small amounts of ram (of the order of 512 bytes) may be enough for the whole system, avoiding the need for external ram chips.

The processor chip may also be selected because the hardware/software designer has previous experience of the chip, a change being rejected because of the time needed to learn a new chip. Finally, the processor may be dictated by the availability of a processor emulator with which to do the development — see later.

HOST AND TARGET CONCEPT

Consider that we have designed and built the hardware for a stand-alone system. At this stage we are probably not sure if the hardware is working; we need some software to be able to easily fully test the system. The software may not run if there is a hardware bug. Catch 22. Whether the software will run or not in the presence of a hardware fault, depends on the particular fault. For example a lack of a system clock will definitely stop the system working, or the ram might be permanently deselected.

As an aside, let us consider the ram deselected case a little further. The software will run providing that it does not use the ram for important program operation parameters, that is, values which have a direct effect on program operation. In practice this means no subroutines can be called, because return addresses are usually put on a stack which is held in ram. When the subroutine tries to return to the main program it will not have a valid return address, and the program will crash. In real life this is an extremely heavy restriction on the program, only specially written simple test programs would avoid this restriction.

Returning to our original problem, we have the system hardware which we feel is working (we have had a look around with a meter, voltages look reasonable, the system clock has been checked with a scope etc). Now the software must be developed. We cannot write the software directly on the stand-alone system, as we would when using a general purpose microcomputer. To do this requires software, a keyboard and a display, to allow us, the programmer, to input and edit data. Most stand-alone systems will probably not even have the keyboard and display hardware.

A possible method to produce the software for our stand-alone system is to write the program out on a sheet of paper, in assembler, then get a data sheet for the processor and decode all the instructions into hexadecimal. Using an eprom programmer, on which the instructions can be entered using a hexadecimal keypad, we could program an eprom. Once this eprom is programmed we plug it into the eprom socket on our stand-alone system, turn on and watch it work, end of story!

The last sentence is of course a bad joke, as nothing works perfectly first time. At the very least we could have typed a wrong character into the eprom pro-grammer. Every bug, hardware or soft-ware, could well mean going through the above procedure many times, and it would get tedious very quickly. We can make life easier by using a normal general purpose microcomputer. The program would be entered as text and an assembler used to produce the executable hexadecimal code. Rather than type the hex code into an eprom programmer, it could be directly down loaded to the programmer via an RS232 link (or other). The programmed eprom would then be plugged into the stand-alone system, as before. We have made things a little easier, using a computer and assembler makes it simpler to do program changes. Program assembly will be more accurate and direct down load-ing to an eprom programmer will avoid some typing errors.

Using this new procedure still requires eproms to be programmed and plugged into the system every time a change is made. This is still time taking and tedious. Also, when the program goes

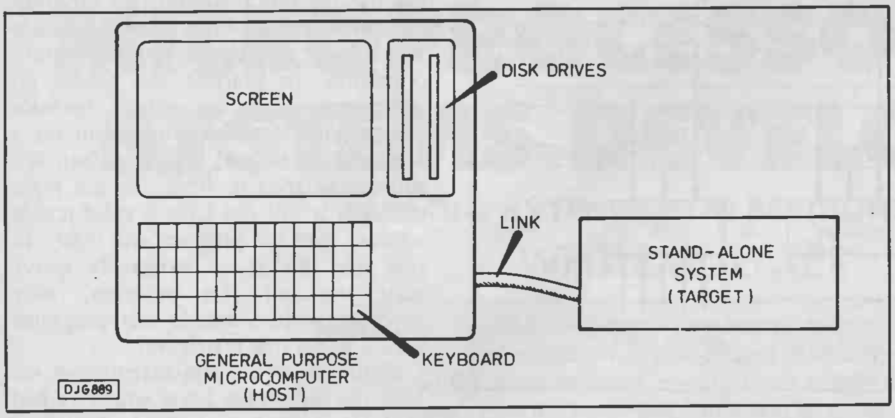


Fig.2. *Host and target*

wrong we have no ability to interrogate the stand-alone system and find out why.

The next step is to give the general purpose microcomputer some special hardware which links it to the stand-alone system. This link would provide a means to see what is going on, and allow the stand-alone system to run programs which are not held in the normal eprom. See Fig.2. The general purpose microcomputer is referred to as the *host*, and the stand-alone system is called the *target*. These terms will now be used. In order to make the link universal it must not be particular to the target. If the link was unique to the target system then we would have to develop a new link for every new target system. This takes time, costs money and means we have another bit of hardware to get working. The target may be functioning perfectly, and we would not know because the link was failing.

To summarise, the host is the system on which we input the program, assemble it, edit it and store it on disk when we have finished for the day. The host allows us to run the program on the target without programming eproms, and then interrogate the target when things go wrong.

There are two common methods for linking the host and target, processor emulation and eprom emulation. Each will now be considered in turn.

PROCESSOR EMULATION

The method of processor emulation is a technique by which the target system processor is removed from its socket and replaced by a dil header with connecting wires to the host. This forms the link to the host. The host then performs all the functions of the processor: it generates the control signals, decodes and executes instructions etc, It is totally transparent to the target that the processor functions are being performed by the host, and not a true processor. The host emulates the processor. The exact facilities provided to the user depend on the particular host emulator system; typical facilities will be considered here. Processor emulators are available as a complete system, with no other hardware required, or as a unit which interfaces to a normal microcomputer via an RS232 link. In the latter case the microcomputer forms the user interface and the emulator unit forms the target system interface. An important point about processor emulation is that the emulator is particular to a processor. If you buy a Z80 emulator, and then want to emulate into a 6502 based target, you can't. At the very least a new interface module will be needed and in the worst case a complete new emulator. This makes clear an earlier point that the processor for a new target system design may be dictated by the available emulator(s).

A simplified block diagram of an emulator is shown in Fig.3. The vdu and keyboard form the user interface, the means by which programs can be entered, and the host system is controlled. The emulation interface logic, emulation memory, emulation registers and cpu emulation blocks form the section that emulates the processor. The emulation registers replace the registers normally contained in the processor being emulated, for example the accumulator, stack pointer, program counter, flag register etc. The registers required will obviously depend on the processor being emulated. The emulation memory occupies address space in the target system, in the same space as the target ram and rom. Memory contention between the target memory and the emulation memory is avoided by the emulation interface logic mapping one of the banks of memory out. The bank of memory to map out is user selectable, either in blocks or for each location. The host is able to read and write to both the emulation memory and the target memory.

To run a program in the target system the following sequence of operations would be performed. The user would input and assemble the program using the host keyboard and vdu. Then the user would instruct the host to place the program into emulation memory, starting at the address where the target eprom normally exists, and to map out the target eprom at this address. Any accesses then made to this block of memory will fetch data from the emulation memory. Finally the program is run by instructing the host to go into emulation mode, fetching the first instruction from the block of memory where the target program has just been placed. Program execution will take place as if the program was held in eprom and a true processor was plugged into the processor socket. The target system ram can also be mapped out, and emulation ram used instead. By using emulation ram a target program can be run without having any memory in the target, thus avoiding another source of errors.

The above sequence of operations has allowed us to run a program in the target without having to program an eprom. The next step is to provide facilities to help debugging of the target hardware and software. The following is a list of typical facilities:-

1) Start target program execution
2) Stop target program execution
3) Break on address (breakpoint)
4) Break on Nth loop
5) Examine emulation registers
6) Modify emulation registers
7) Examine memory (target or emulation)
8) Modify memory (target or emulation)
9) Single step program
10) Step N times

Each of the above will now be discussed, in turn.

Starting program execution has already been mentioned and is an obvious requirement! Execution can be

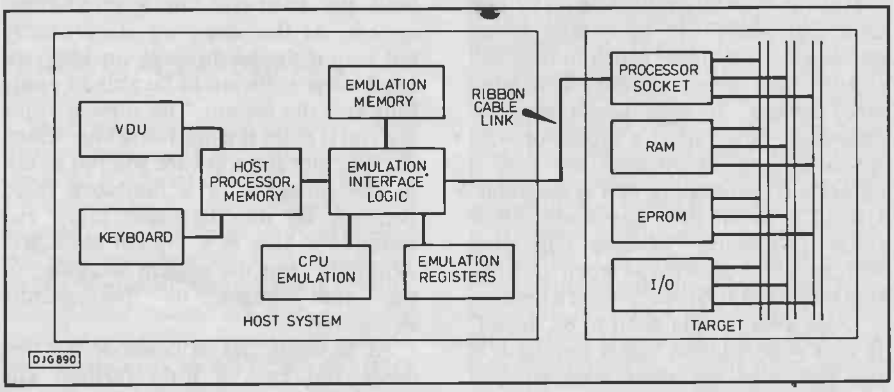


Fig.3. *Processor emulation*

started from any address. The emulation registers will not be setup with any special values when the execution begins, they will contain the values held when the program was last stopped (unless modified by the user, as I discuss later). This allows a program to be continued rather than always having to restart from the first program address.

Stopping program execution may happen by various means, the most basic of which is a 'hot key'. This is a key/command which when hit by the user will stop program execution. The purpose of stopping the program is to allow examination of the emulation registers and/or target memory. It would be fairly pointless to attempt such examinations while the program was running since the values would probably be changing far too quickly for the user to take in and comprehend. What is more, to be able to do real time examination would make the emulation hardware more complex (and expensive!).

BREAK POINTS

Another way of stopping program execution is a breakpoint. The user selects the breakpoint address, and then starts program execution. When the program reaches this address (if at all) program execution is automatically stopped. This allows the user to stop the program at trouble spots and inspect registers etc.

Alternatively a breakpoint could be placed at an address in the program which should not be reached, if this address is then wrongly reached execution will stop and the user thus informed of the error. Depending on the emulator it may be possible to set more than one breakpoint; typically around five will be allowed. There are two ways that the emulator may implement a breakpoint, a hardware breakpoint and a software breakpoint. A hardware breakpoint is implemented by using a binary value comparator. The value of the address bus is compared with the breakpoint value. If the values are the same program execution will be stopped. This method requires a value comparator per breakpoint. A software breakpoint is implemented by replacing the program instruction at the breakpoint address with a 'break' instruction. The emulator will watch for the break instruction, and when it is executed, further program execution is stopped. The exact method is dependent on the emulator and the processor being emulated, the break instruction may be a halt, a jump, a software interrupt, a restart etc. Whatever the implementation is, it will be transparent to the user, that is the user will not know how it is done but merely that it is done. One important difference between software and hardware breakpoints is that hardware breakpoints can be placed anywhere (even in memory data areas) and software breakpoints can only be placed in program memory areas, on instruction boundaries. That is, a software breakpoint cannot be put on the second byte of a two byte instruction. This limitation is not as bad in practice as it sounds.

Break on Nth loop is a simple extension of breakpoints. Rather than cause program execution to stop on the first occurance of the breakpoint address it causes execution to stop on the Nth occurence. N is a number set by the user.

Examination of the emulation registers allows the user to read the register's values. When program execution stops the register values are left intact, and it is these values that will be read. The registers are not the true microprocessor registers but the emulated registers, see Fig. 3.

REGISTER EXAMINATION

Examination of the registers is useful to check that the program is operating as expected. For example, consider a routine in the target program that adds the values 2 and 5 together, and leaves the result in the accumulator. To check this routine a breakpoint should be placed immediately after it. If the program is then executed, when it stops at the breakpoint the user can examine the accumulator and check it contains the value 7.

Modification of the registers allows the user to set any register to a specific value. One possible use is to be able to test sections of the program without having to rely on other sections to setup the registers with suitable values. For example, a routine when entered may expect the accumulator to have a value between 20 and 42, this value normally being setup by another routine. To avoid having to execute this other routine first (after all it may not even be written yet!) the accumulator would be set up manually by the user, to a value between 20 and 42. Program execution may then begin at the start of the routine and, if a breakpoint is placed at the end, any results produced can be checked.

Examine and modify memory provides the same facilities as for the registers but applies to memory. Note that both the emulation memory and the target memory can be examined/modified.

Single step program allows the target program to be executed one instruction step at a time. After each instruction is executed the emulation registers values are displayed. At the next step command the next program instruction is executed and the registers again displayed. Single stepping is like having a breakpoint on every address. Single stepping through trouble spots in the program at a slow speed allows the user to comprehend what is happening and thus more easily spot errors, normally it all happens too quickly.

Step N times is an extension of single step. The next N instructions are executed, with the registers displayed at each step. N is selected by the user.

The basics of processor emulation have now been covered. It is not intended that this article should cover greater detail because it is felt that the technique is not widely applicable to hobby electronics, mainly due to the high cost of the technique. A cheaper technique is that of eprom emulation, as we shall see in part two next month. PE

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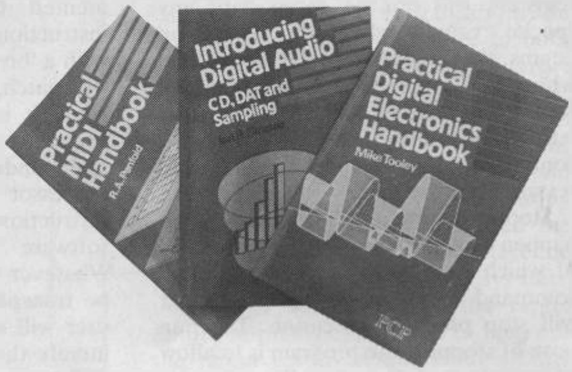

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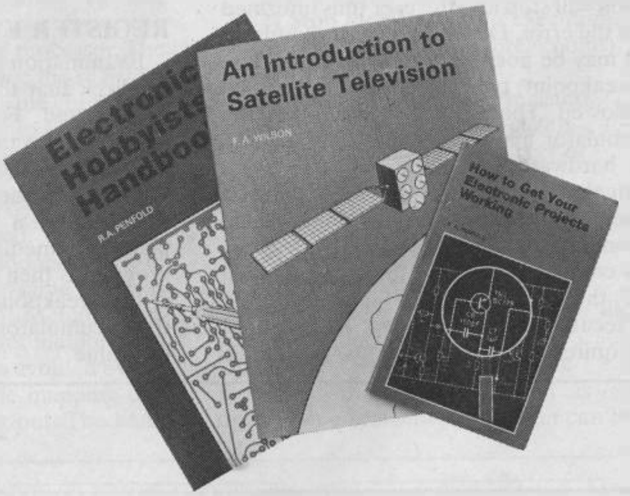

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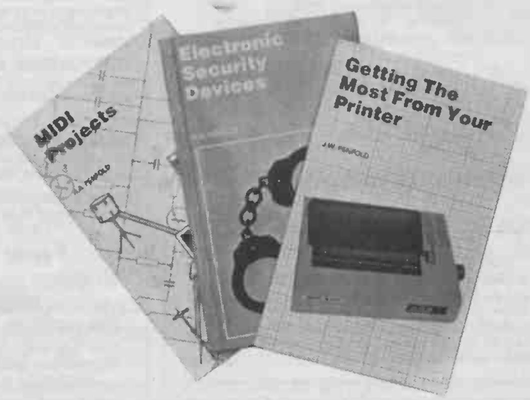

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PIEZO ELECTRIC FAN an unusual fan, more like the one used by Madame Butterfly, than the conventional type, it does not rotate. The air movement is caused by two vibrating arms. It is American made, mains operated, very economical and cause's no interference. So it is ideal for computer and instrument cooling. Price is only £1 each. Ref BD598

SPRING LOADED TEST PRODS – heavy duty, made by the famous Bulgin company. Very good quality. Price four for £1. Ref. BD597.

CASE WITH 13A PRONGS – to go into 13A socket, nice size and suitable for plenty of projects such as car battery trickle charger, speed controller, time switch, night light, noise suppressor, dimmers etc. Price – 2 for £1. Ref. BD565

ALPHA-NUMERIC KEYBOARD – this keyboard has 73 keys arranged in two groups, the main area is a QWERTY array and on the right is a 15 key number pad, board size is approx. 13" × 4" – brand new but offered at only a fraction of its cost namely £3 plus £1 post. Ref: 3P27.

WIRE BARGAIN – 500 metres 0.7mm solid copper tinned and p.v.c. covered. Only £3 + £1 post. Ref. 3P31 – that's well under 1p per metre, and this wire is ideal for push on connections.

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3-30V VARIABLE VOLTAGE POWER SUPPLY UNIT – with 1 amp DC output. Intended for use on the bench for experimenters, students, inventors, service engineers etc. This is probably the most important piece of equipment you can own. (After a multi range test meter). It gives a variable output from 3-30 volts and has an automatic short circuit and overload protection, which operates at 1.1 amp approximately. Other features are very low ripple output, a typical ripple is 3mV pk-pk, 1mV rms. Mounted in a metal fronted plastic case, this has a voltmeter on the front panel in addition to the output control knob and the output terminals. Price for complete kit with full instructions is £15. Ref. 15P7.

TRANSMITTER SURVEILLANCE (BUG) – tiny, easily hidden, but which will enable conversation to be picked up with FM radio. Can be housed in a matchbox, all electronic parts and circuit. Price £2. Ref. 2P52.

MODEM TIMES

BY TOM IVALL

CATTLE TRUCK – OR AUTOMATIC MILKING?

Tom Ivall argues that the main factor standing between information technology and the home-based worker is the vested interest of the commuter service industries.

If you have ever commuted to work in a big city you may well have given an occasional horrified thought to the colossal waste of it all. The sullen-faced travellers packed into trains, buses and crawling cars are obviously not enjoying it. Commuting takes time out of life, costs money which has to be earned, and saps energy through fatigue and discomfort.

Most of these people work in offices, as cities are mainly centres of commerce and administration. In general their function is to process information. This goes on at all intellectual levels, from making crucial decisions on the basis of information down to manipulating detailed information like records and messages (orders, invoices, advice notes etc). Computers have certainly mechanised a lot of paper-work – indeed they sometimes seem to be better at producing paper than human beings are. But still can't match the versatility, flexibility and resourcefulness of the human brain in dealing with the multitude of quite simple problems and decisions that have to be handled throughout a working day.

So hundreds of thousands of human brains have to be transported into a city every morning and taken out again eight hours later. As the bodies can't be left behind, an enormous quantity of flesh and bone is being trundled back and forth every working day. Assuming a typical body weight of 65 kilograms, the million or more London commuters represent a total mass of about 65,000 tonnes, to be moved against the inertial and frictional forces say 20 miles on average – and the whole thing twice a day. Without even working it out, and ignoring the weight of the vehicles, you can see that it adds up to a colossal expenditure of mechanical energy, most of which comes ultimately from non-renewable fossil fuels.

Considering how long this wasteful consumption of energy and the resulting atmospheric pollution has been going on, and considering we have had telecommunications for over a century, it seems strange that teleworking is still very much in its infancy. Teleworking means doing your information processing work at home rather than travelling to an office to do it. The basic tools are a telephone line to your home, a telephone set, a modem (modulator-demodulator) and a workstation, word processor or personal computer. On top of this you can have other terminal services such as a printer, fax machine, teletext and electronic mail.

Certainly about 8% of the UK's total workforce has been working from home for several decades – sales representatives for example – but they seem to have managed with just the domestic telephone. In the UK I know of only two large companies which have set up teleworking schemes – Rank-Xerox and ICL. Both, significantly, earn a living from information technology.

Rank–Xerox has about 60 people in its scheme, with a turnover of one or two each month. The original idea was to transfer some of their employed managers into self-employment in order to reduce office overheads and avoid forced redundancies. These 'networkers' are guaranteed certain hours of work per week at agreed rates. Typically they provide consultancy sevices – market research, financial analysis, legal, recruitment and tax advice, and public relations work.

ICL, the computer and data networks firm owned by STC, has about 150 people in its teleworking scheme but still as employees. They tend to be mainly skilled technicians working flexible hours and have all the necessary hardware and software on tap at home. Other ICL networkers write software and technical manuals.

Apart from these teleworkers linked with particular big companies there are, of course, many independent self-employed people who provide knowledge-based services for a variety of industrial clients. They may well use the kind of telecommunications equipment listed above but essentially they function like the cottage industries that preceded the Industrial Revolution. They are not the result of large companies de-centralizing and diffusing their existing workforces.

Why, then, has there been so little development in teleworking at least in the UK? I think the answer probably lies in that aspect of our society which is controlled by economic factors. Here, any changes which occur are usually made in order to meet economic criteria like profits, costs, operational efficiency and so on.

In ancient and traditional societies the needs of people were largely met by direct exchange of goods between individuals or small groups. There was no formal organization of supply and distribution. In communal and more recently communist – societies, some official or committee makes decisions on how these needs shall be met and determines the rules and system of allocation.

In the kind of market economy we live under in the West there is no comprehensive control. Decisions are dispersed throughout the market, not centralized. In most things the market price is the determining factor. The pattern of distribution of goods and services depends mainly on the ability of individuals to pay the market price.

Thus in the UK's market economy there is nobody to decide in a general way that teleworking would be a good thing for our society and nobody with the power to put such a decision into practice. Even though the shameful waste of energy and human resources on unproductive travelling is plain for all to see, the system doesn't provide any motivation or machinery for correcting it. On the contrary, there will be people benefiting from the regular sale of fuels for commuting.

So nothing is done about the waste because it is not a problem for the market as such. The market only sits up and takes notice when it begins to get hurt.

Typically, for every £1 of salary paid to a worker in such accomodation the employer has to fork out another £3 or so on overheads. Avoiding this cost is the main attraction of teleworking to companies, not any consideration of the benefits to people or the environment, though these may be incidental. PE

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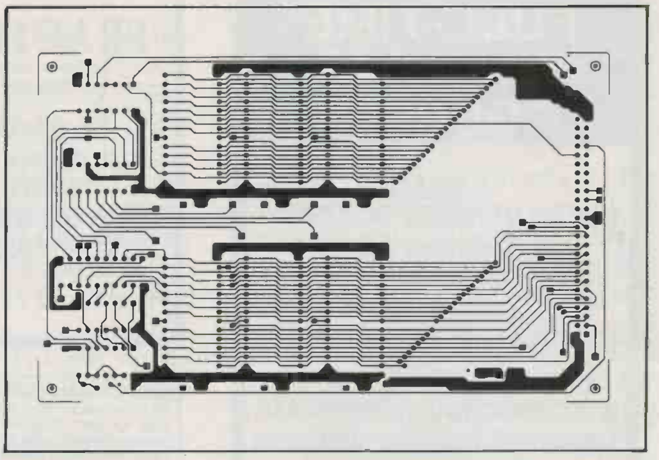

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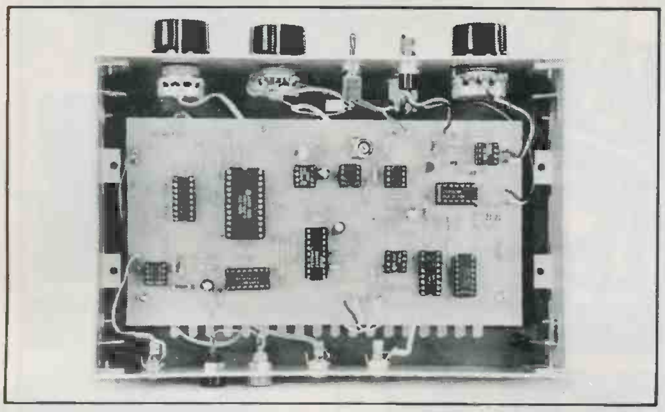

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IDENTITIES

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TOOLS

For many projects you only need a few simple tools – Soldering iron between 15W and 25W, with a bevelled tip. Damp sponge for keeping the tip clean. Good multicore solder of 18swg or 22swg grade. Fine nose pliers for wire shaping. Adjustable spanner or heavy pliers for tightening nuts. Miniature screwdriver for adjusting preset controls. Small wire cutters for trimming component leads. Drill and selection of bits for drilling holes in boxes. Strong magnifying glass for checking joins in close up. It's also preferable to have a multimeter for setting and checking voltages. There are some very good low cost ones available through many of our advertisers, but get one that is rated at a minimum of 20,000 ohms per volt. Many projects do not require you to have a meter, but if you are serious about electronics, you really should have one.

ASSEMBLING THE PCB

Authors will sometimes offer their own advice on the order of assembly, but as a general guide, it is usually easier to assemble parts in order of size. Start though with the integrated circuit sockets. Please use them where possible, they make life much easier than if you solder the ICs themselves – with sockets you can just lift out an IC if you want.

Then insert and solder in order of resistors, diodes, presets, small capacitors, other capacitors, and finally transistors. Clip off the excess component leads after you have soldered them. Now use a magnifying glass, ideally one that you can hold to your eye, and take a good look at the joins, checking that they are satisfactorily soldered, and that no solder has spread between the PCB tracks and other joins. Be really thorough with visual checking since errors like this are the most likely reason for a circuit not working first time.

SOLDERING

Bring the tip of the iron into contact with the component lead and the PCB solder pad, then bring the end of the solder into contact with all three, feeding it in as it melts. Once sufficient solder has melted to fully surround the pad and the lead, remove the solder, and then the iron. Now allow the join to cool before touching it, otherwise the solder may set unsatisfactorily. If it does move, just reheat the join once more.

WIRING

Connecting the PCB to the various panel controls is the final assembly stage. Do this just as methodically, following the published wiring diagram. You can connect the wires to the PCB in one of three ways. The best is to insert terminal pins into the connecting holes on the PCB, and then solder wires direct to them. Or, pass the end of the wire through the PCB hole, soldering it on the other side. Alternatively, the wire can be carefully soldered direct to the PCB tracking. In all cases first strip the plastic covering off the wire, twist the strands together, and apply solder to them to keep them secure.

TESTING

Now you are ready to test and use the project as described by the author. Components can occasionally fail, but these days it is extremely uncommon, and if you have followed the instructions, been careful with your joins, and bought the parts from a good supplier, you will have the enormous satisfaction of having built an interesting and working unit. It really can be easy if you do it with care.

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We can usually supply copies of back issues of PE up to three years old. These are £1.50 each including postage (£2.00 for overseas readers). If we no longer have the issue needed, we will be pleased to send a photocopy of the article for the project that you want to build. These are £1.00 each per issue, including postage (£1.50 to overseas readers).

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Some projects are available from advertising suppliers as complete kits. Where this is so, the source often will have been stated in the project text. If no supplier is quoted, contact the normal kit suppliers anyway – they might well have introduced a kit after publication. Otherwise, all the components listed in the text will be available from suppliers who specialise in individual components.

Occasionally a specific part may only be available from a particular supplier, if so the source will be given in the parts list. Otherwise there should be no difficulty in buying the parts. We have many good suppliers advertising in PE so have a look through their adverts – that's why they're there! Even though a part may not be listed in the adverts, a phone call or two should find a supplier who will be pleased to help. Like us, they too are in the business of encouraging you to enjoy electronics! PE

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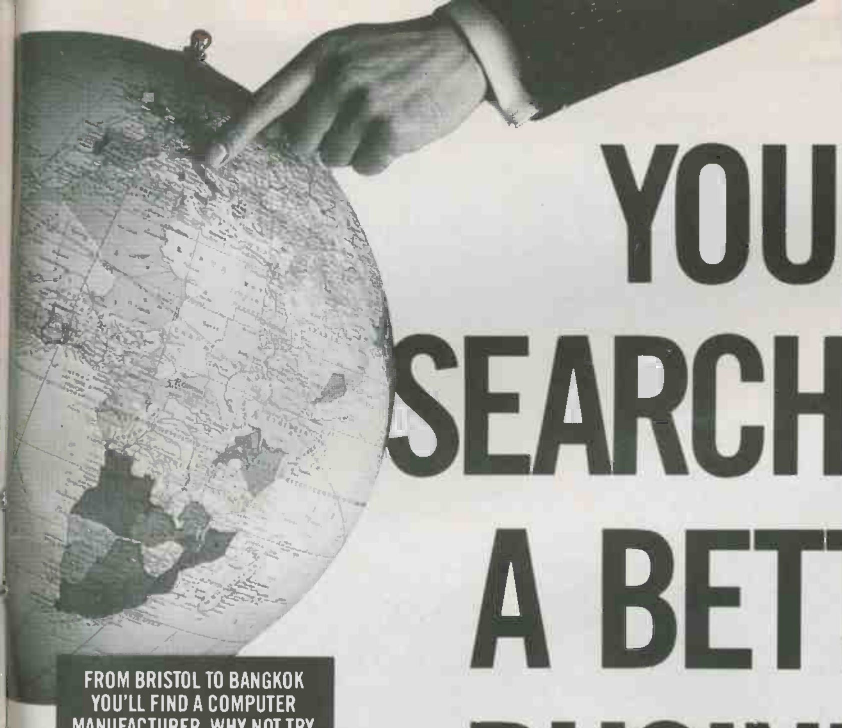

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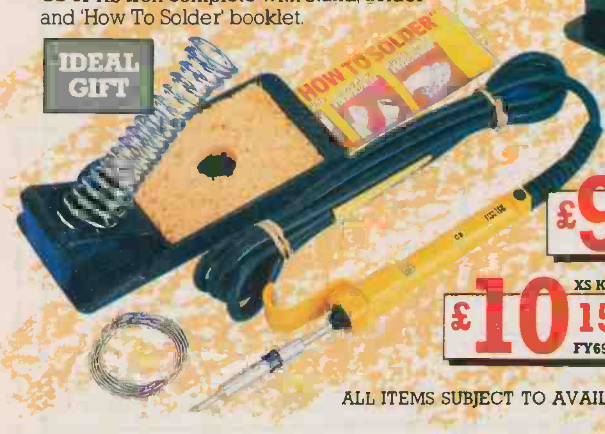

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