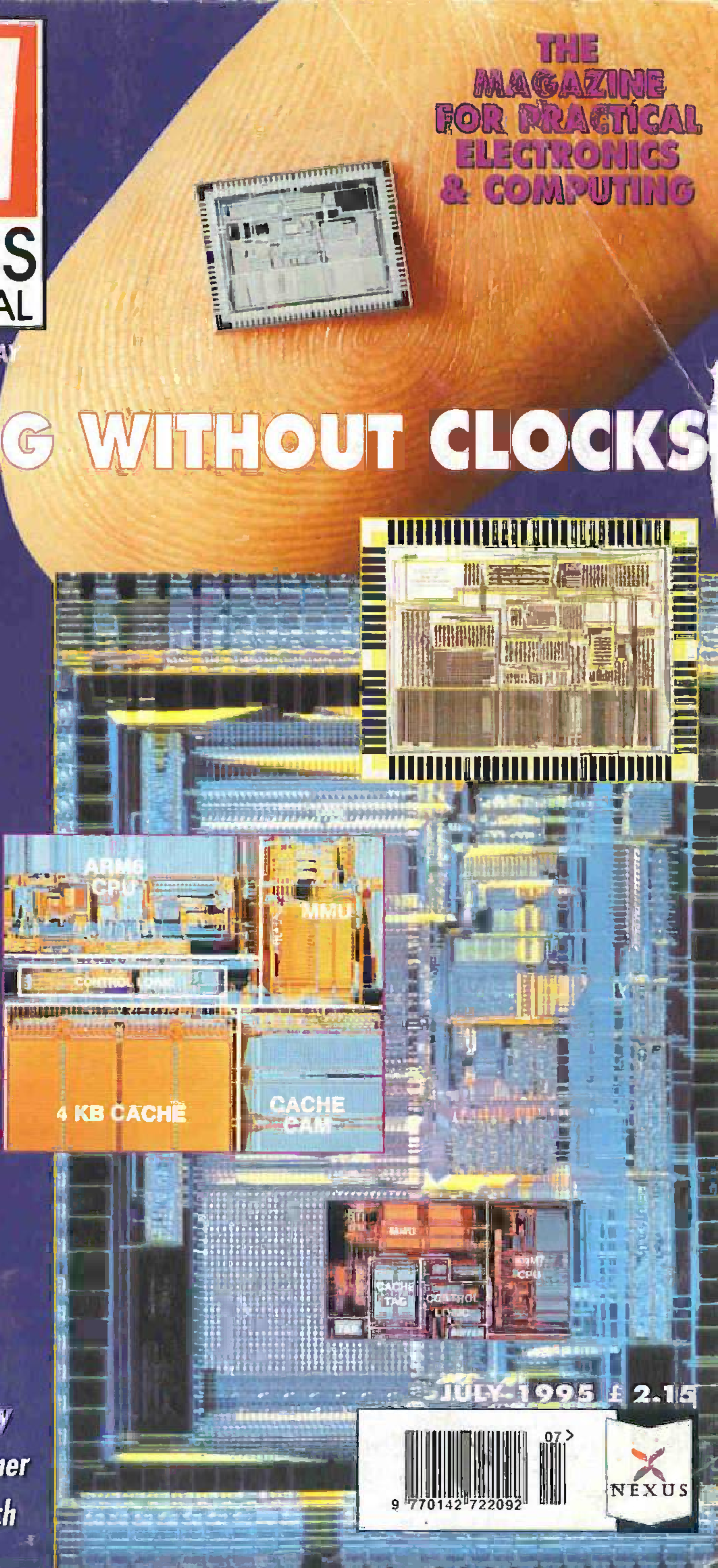
ETI

ELECTRONICS TODAY INTERNATIONAL

TOMORROW'S TECHNOLOGY TODAY

THE MAGAZINE FOR PRACTICAL ELECTRONICS & COMPUTING



COMPUTING WITHOUT CLOCKS

British designed asynchronous computer could change the world

Build a fibre optic communications link for PCs

Versatile large character display

Analog virtual instrument interface for the ETI 80188 single board computer

PLUS

- *Designing and building switch regulators*
- *Making PCBs the transfer way*
- *Build a low cost PIC programmer*
- *Using PICs – a practical approach*

JULY 1995 £ 2.15

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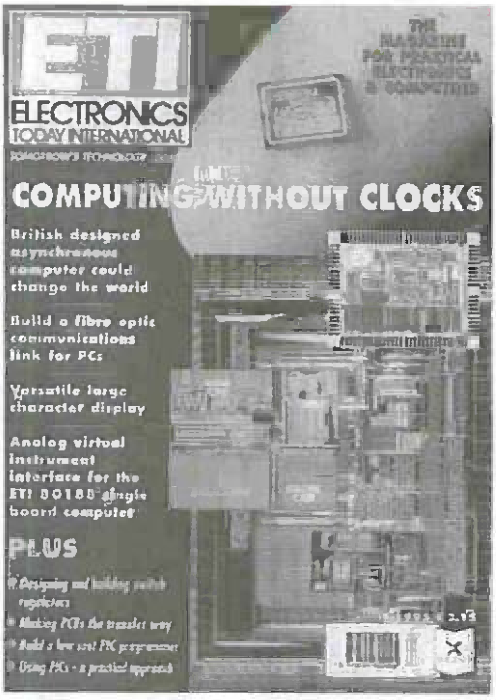
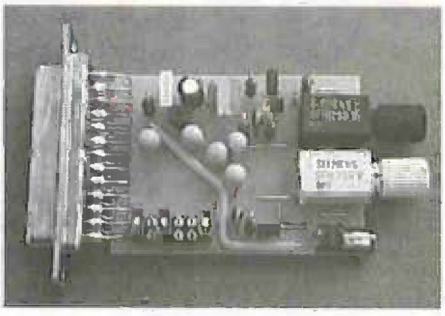
Contents



Volume 24 No.7

& Features Projects



Regulars

ENERGY BANK KIT 100 6"x6" 6v 100mA panels, 100 diodes, connection details etc. £69.95 ref EF112.

CCTV CAMERA MODULES 46X70X29mm, 30 grams, 12v 100mA, auto electronic shutter, 3.6mm F2 lens, CCIR, 512x492 pixels, video output is 1v p-p (75 ohm). Works directly into a scart or video input on a tv or video. IR sensitive. £79.95 ref EF137.

IR LAMP KIT Suitable for the above camera enables the camera to be used in total darkness! £5.99 ref EF138.

PASTEL ACCOUNTS SOFTWARE, does everything for all sizes of businesses, includes wordprocessor, report writer, windowing, networkable up to 10 stations, multiple cash books etc. 200 page comprehensive manual. 90 days free technical support (0345-326009 try before you buy!) **Current retail price is £129, ours? just £29** ref EF134. SAVE £100!!!

MINI MICRO FANS 12V 1.5" sq just £3.99 each. Ref EF199.

C ITOH PRINTERS 80 col, 9 pin matrix, serial/parallel, NLQ/draft, 3 mth warranty, good condition. £49 ref EF133.

MICROSOFT TRACKBALL AND MOUSE Combined unit with 4 buttons and trackball, PS2 type connector. Complete with storage bracket. Our price just £11.99 ref EF201.

REUSEABLE HEAT PACKS. Ideal for fishermen, outdoor enthusiasts elderly or infirm, warming food, drinks etc, defrosting pipes etc reuseable up to 10 times, lasts for up to 8 hours per go. 2,000wh energy, gets up to 90degC. Price is £12 ref EF129. rrp £37!

1.44MB 3.5" DISC DRIVES Returns from a top PC manufactuer so they may need attention, bargain price £8.50 ea ref EF203.

1.2MB 5.25" DISC DRIVES Again returns so may need attention, bargain price is £8.50 ref EF204 (1 of each 1.2+1.44 £14.99 ref ef205

A4 DTP MONITORS Brand new, 300 DPI. Complete with diagram but no interface details.(so you will have to work it out!) Bargain at just £7.99 each!!!! Ref EF186

OPD MONITORS 9" mono monitor, fully cased complete with raster board, switched mode psu etc. CGA/TTL input (15 way D), IEC mains. £15.99 ref DEC23. Price including kit to convert to composite monitor for CCTV use etc is £21.99 ref DEC24.

12V 2AMP LAPTOP psu's 110x55x40mm (includes standard IEC socket) and 2m lead with plug. 100-240v IP. £8.99 ref EF200.

PC CONTROLLED 4 CHANNEL TIMER Control (on/off times etc) up to 4 items (8A 240v each) with this kit. Complete with Software, relays, PCB etc. £25.99 Ref 95/26

COMPLETE PC 300 WATT UPS SYSTEM Top of the range UPS system providing protection for your computer system and valuable software against mains power fluctuations and cuts. New and boxed, UK made Provides up to 5 mins running time in the event of complete power failure to allow you to run your system down correctly. SALE **PRICE just £119.00.**

RACAL MODEM BONANZA! 1 Racal MPS1223 1200/75 modem, telephone lead, mains lead, manual and comms software, the cheapest way onto the net! all this for just £13 ref DEC13.

HOW LOW ARE YOUR FLOPPIES? 3.5" (1.44) unbranded. We have sold 100,000+ so old Pack of 50 £24.99 ref DEC16

5mw LASER POINTER. Supplied in kit form, complete with power adjuster, 1-5mw, and beam divergence adjuster. Runs on 2 AAA batteries. Produces thin red beam ideal for levels, gun sights, experiments etc. Cheapest in the UK! just £39.95 ref DEC49

SHOP WOBBLERS! Small assemblies designed to take D size batteries and 'wobble' signs about in shops! £3.99 Ref SEP4P2.

RADIO PAGERS Brand new, UK made pocket pagers clearance price is just £4.99 each 100x40x15mm packed with bits! Ref SEP5.

BULL TENS UNIT Fully built and tested TENS (Transcutaneous Electrical Nerve Stimulation) unit, complete with electrodes and full instructions. TENS is used for the relief of pain etc in up to 70% of sufferers. Drug free pain relief, safe and easy to use, can be used in conjunction with analgesics etc. £49 Ref TEN/1

COMPUTER RS232 TERMINALS. (LIBERTY) Excellent quality modern units,(like wyse 50,s) 2xRS232, 20 function keys, 50 thro to 38,400 baud, menu driven port, screen, cursor, and keyboard setup menus (18 menu's). £29 REF NOV4.

OMRON TEMPERATURE CONTROLLERS (E5C2). Brand new controllers, adjustable from 0 deg C to +100 deg C using graduated dial, 2% accuracy, thermocouple input, long life relay output .3A 240v o/p contacts. Perfect for exactly controlling a temperature. Normal trade £50+, ours £15. Ref E5C2.

ELECTRIC MOTOR BONANZA! 110x60mm. Brand new precision, cap start (or spin to start), virtually silent and features a moving outer case that acts as a fly wheel. Because of their unusual design we think that 2 of these in a tube with some homemade fan blades could form the basis for a wind tunnel etc. Clearance price is just £4.99 FOR A PAIR! (note-these will have to be wired in series for 240v operation Ref NOV1.

MOTOR NO 2 BARGAIN 110x90mm. Similar to the above motor but more suitable for mounting vertically (ie turntable etc). Again you will have to wire 2 in series for 240v use. Bargain price is just £4.99 FOR A PAIR!! Ref NOV3.

OMRON ELECTRONIC INTERVAL TIMERS.

*****NEW LOW PRICES TO CLEAR!!!******

Minature adjustable timers, 4 pole c/o output 3A 240v,

HY1230S, 12vDC adjustable from 0-30 secs. £4.99
HY1210M, 12vDC adjustable from 0-10 mins. £4.99
HY1260M, 12vDC adjustable from 0-60 mins. £4.99
HY2460M, 24vAC adjustable from 0-60 mins. £2.99
HY241S, 24vAC adjustable from 0-1 secs. £2.99
HY2460S, 24vAC adjustable from 0-60 secs. £2.99
HY243H, 24vAC adjustable from 0-3 hours. £2.99
HY2401S, 240v adjustable from 0-1 secs. £4.99
HY2405S, 240v adjustable from 0-5 secs. £4.99
HY24060m, 240v adjustable from 0-60 mins. £6.99

PC PAL VGA TO TV CONVERTER Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware £49.95. Ideal for laptops or a cheap upgrade. We also can supply this in kit form for home assembly at £34.95 ref EF54.

DRINKING BIRD Remember these? hook onto wine glass (supplied) and they drink, standup,drink,standup ETC! £4 each Ref EF1

EMERGENCY LIGHTING UNIT Complete unit with 2 double bulb floodlights, built in charger and auto switch. Fully cased. 6v 8AH lead acid req'd. (secondhand) £4 ref MAG4P11.

GUIDED MISSILE WIRE. 4,200 metre reel of ultra thin 4 core insulated cable, 28lbs breaking strain, less than 1mm thick! Ideal alarms, intercoms, fishing, dolls house's etc. £14.99 ref MAG15P5

ASTEC SWITCHED MODE PSU BM41012 Gives +5 @ 3.75A, +12@1.5A, -12@.4A 230/110, cased, BM41012 £5.99 ref AUG6P3.

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt. £9.99 ea ref AUG10P3.

FLOPPY DISCS DSDD Top quality 5.25" discs, these have been written to once and are unused. Pack of 20 is £4 ref AUG4P1.

ECLATRON FLASH TUBE As used in police car flashing lights etc, full spec supplied, 60-100 flashes a min. £9.99 ref APR10P5.

24v AC 96WATT Cased power supply. New. £13.99 ref APR14.

MILITARY SPEC GEIGER COUNTERS Unused anstraightfrom Her majesty's forces. £50 ref MAG 50P3

OUTDOOR SOLAR PATH LIGHT Captures sunlight during the day and automatically switches on a built in lamp at dusk. Complete with sealed lead acid battery etc £19.99 ref MAR20P1.

ALARM VERSION Of above unit comes with built in alarm and pir to deter intruders. Good value at just £24.99 ref MAR25P4.

CARETAKER VOLUMETRIC Alarm, will cover the whole of the ground floor against forced entry. Includes mains power supply and integral battery backup. Powerful internal sounder, will take external bell if req'd. Retail £150+, ours? £49.99 ref MAR50P1.

TELEPHONE CABLE White 6 core 100m reel complete with a pack of 100 clips. Ideal 'phone extns etc. £7.99 ref MAR8P3.

MICRODRIVE STRIPPERS Small cased tape drives ideal for stripping, lots of useful goodies including a smart case, and lots of components. £2 each ref JUN2P3. Box of 10 just £9.99 ref EF207.

SOLAR POWER LAB SPECIAL You get TWO 6"x6" 6v 130mA solar cells, 4 LED's, wire, buzzer, switch plus 1 relay or motor. Superb value kit just £5.99 REF: MAG6P8

BUGGING TAPE RECORDER Small voice activated recorder, uses micro cassette complete with headphones. £28.99 ref MAR29P1.

ULTRAMINIBUG MIC 6mmx3.5mm made by AKG, .5-12v electret condenser. Cost £12 ea. Ours? just four for £9.99 REF MAG10P2.

RGB/CGA/EGA/TTL COLOUR MONITORS 12" in good condition. Back anodised metal case. £79 each REF JUN79

ANSWER PHONES Returns with 2 faults, we give you the bits for 1 fault, you have to find the other yourself. BT Response 200's £18 ea REF MAG18P1. PSU £5 ref MAG5P12.

SWITCHED MODE PSU ex equip, 60w +5v @5A, -5v@.5A, +12v@2A,-12v@.5A 120/220v cased 245x88x55mm IEC input socket £6.99 REF MAG7P1

PLUG IN PSU 9V 200mA DC £2.99 each REF MAG3P9

PLUG IN ACORN PSU 19v AC 14w , £2.99 REF MAG3P10

POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

ACORN ARCHIMEDES PSU +5v @ 4.4A. on/off sw uncased, selectable mains input, 145x100x45mm £7 REF MAG7P2

9v DC POWER SUPPLY Standard plug in type 150ma 9v DC with lead and DC power plug. price for two is £2.99 ref AUG3P4.

AA NICAD PACK encapsulated pack of 8 AA nicad batteries (tagged) ex equip, 55x32x32mm. £3 a pack. REF MAG3P11

13.8V 1.9A psu cased with leads. Just £9.99 REF MAG10P3

PPC MODEM CARDS. These are high spec plug in cards made for the Amstrad laptop computers. 2400 baud dial up unit complete with leads. Clearance price is £5 REF: MAG5P1

INFRA RED REMOTE CONTROLLERS Originally made for hi spec satellite equipment but perfect for all sorts of remote control projects. Our clearance price is just £2 REF: MAG2

200 WATT INVERTER Converts 10-15v DC into either 110v or 240v AC. Fully cased 115x36x156mm, complete with heavy duty power lead, cigar plug, AC outlet socket Auto overload shutdown, auto short circuit shut down, auto input over voltage shutdown, auto input under voltage shut down (with audible alarm), auto temp control, unit shuts down if overheated and sounds audible alarm. Fused reversed polarity protected, output frequency within 2%, voltage within 10%. A well built unit at an keen price. Just £64.99 ref AUG65.

UNIVERSAL SPEED CONTROLLER KIT Designed by us for the C5 motor but ok for any 12v motor up to 30A. Complete with PCB etc. A heat sink may be required. £17.00 REF: MAG17

MAINSCABLE Precut black 2 core 2 metre lengths ideal for repairs, projects etc. 50 metres for £1.99 ref AUG2P7.

COMPUTER COMMUNICATIONS PACK Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PC's over a long distance. Complete kit £8.99.

ELECTRIC MOTOR KIT Comprehensive educational kit includes all you need to build an electric motor. £9.99 ref MAR10P4.

VIEWDATA SYSTEMS made by Phillips, complete with internal 1200/75 modem, keyboard, psu etc RGB and composite outputs, menu driven, autodialler etc. £18 each Ref EF88.

BOOMERANG High tech, patented poly propylene, 34cm wing span. Get out and get some exercise for £4.99 ref EF83

AIR RIFLES .22 As used by the Chinese army for training puposes, so there is a lot about! £39.95 Ref EF78. 500 pellets £4.50 ref EF80.

PLUG IN POWER SUPPLYS Plugs in to 13A socket with output lead, three types available, 9vdc 150mA £2 ref EF58, 9vdc 200mA £2.50 ref EF59, 6.5vdc 500mA £3 ref EF61.

VIDEO SENDER UNIT. Transmits both audio and video signals from either a video camera, video recorder, TV or Computer etc to any standard TV set in a 100' range! (tune TV to a spare channel) 12v DC op. Price is £15 REF: MAG15 12v psu is £5 extra REF: MAG5P2

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

***FM CORDLESS MICROPHONE** Small hand held unit with a 500' range! 2 transmit power levels. Reqs PP3 9v battery. Tuneable to any FM receiver. Price is £15 REF: MAG15P1

LOW COST WALKIE TALKIES Pair of battery operated units with a range of about 200'. Ideal for garden use or as an educational toy. Price is £8 a pair REF: MAG 8P1 2 x PP3 req'd.

***MINATURE RADIO TRANSCEIVERS** A pair of walkie talkies with a range up to 2km in open country. Units measure 22x52x155mm. Including cases and earp'ces. 2xPP3 req'd. £30.00 pr REF: MAG30

COMPOSITE VIDEO KIT. Converts composite video into separate H sync, V sync, and video. 12v DC. £8.00 REF: MAG8P2.

LQ3600 PRINTER ASSEMBLIES Made by Amstrad they are entire mechanical printer assemblies including printhead, stepper motors etc etc in fact everything bar the case and electronics, a good stripper! £5 REF: MAG5P3 or 2 for £8 REF: MAG8P3

LED PACK of 100 standard red 5m leds £5 REF MAG5P4

UNIVERSAL PC POWER SUPPLY complete with flyleads, switch, fan etc. 200w at £20 REF: MAG20P3 (265x155x125mm).

GYROSCOPE About 3" high and an excellent educational toy for all ages! Price with instruction booklet £6 Ref EF15.

FUTURE PC POWER SUPPLIES These are 295x135x60mm, 4 drive connectors 1 mother board connector, 150watt, 12v fan, iec inlet and on/off switch. £12 Ref EF6.

VENUS FLYTRAP KIT Grow your own carnivorous plant with this simple kit £3 ref EF34.

PC POWER SUPPLIES (returns) These are 140x150x90mm. o/ps are +12,-12,+5 and -5v. Built in 12v fan. These are returns so they may well need repairing! £3.50 each ref EF42.

***FM TRANSMITTER KIT** housed in a standard working 13A adapter!! the bug runs directly off the mains so lasts forever! why pay £700? or price is £15 REF: EF62 Transmits to any FM radio. (this is in kit form with full instructions.)

***FM BUG KIT** New design with PCB embedded coil for extra stability. Works to any FM radio. 9v battery req'd. £5 REF: MAG5P5

***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

TALKING COINBOX STRIPPER originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? Price is just £3 REF: MAG3P1

TOP QUALITY SPEAKERS Made for HI FI televisions these are 10 watt 4R Jap made 4" round with large shielded magnets. Good quality. £2 each REF: MAG2P4 or 4 for £6 REF: MAG6P2

TWEETERS 2" diameter good quality tweeter 140R (ok with the above speaker) 2 for £2 REF: MAG2P5 or 4 for £3 REF: MAG3P4

AT KEYBOARDS Made by Apricot these quality keyboards need just a small mod to run on any AT, they work perfectly but you will have to put up with 1 or 2 foreign keycaps! Price £6 REF: MAG6P3

DOS PACKS Microsoft version 3.3 or higher complete with all manuals or price just £5 REF: MAG5P8 Worth it just for the very comprehensive manual! 5.25" only.

GAS HOBS Brand new made by Optimus, basic three burner suitable for small flat etc bargain price just £29.95 ref EF73.

GAT AIR PISTOL PACK Complete with pistol, darts and pellets £12.95 Ref EF82 extra pellets (500) £4.50 ref EF80.

DOS PACK Microsoft version 6 with manual £9.99 3.5" ref EF209

WINDOWS 3.1 3.5" with manual £24.99 ref EF210.

NOVELL NTEWARE LITE (network s/ware) £24.99 ref EF211.

PIR DETECTOR Made by famous UK alarm manufacturer these are hi spec, long range internal units. 12v operation. Slight marks on case and unboxed (although brand new) £8 REF: MAG8P5

MOBILE CARPHONE £5.99 Well almost! complete in car phone excluding the box of electronics normally hidden under seat. Can be made to illuminate with 12v also has built in light sensor so display only illuminates when dark. Totally convincing! REF: MAG6P6

6"X12" AMORPHOUS SOLAR PANEL 12v 155x310mm 130mA. Bargain price just £5.99 ea REF MAG6P12.

FIBRE OPTIC CABLE BUMPER PACK 10 metres for £4.99 ref MAG5P13 ideal for experimenters! 30 m for £12.99 ref MAG13P1

HEATSINKS (finned) TO220, designed to mount vertically on a pcb 50x40x25mm you can have a pack of 4 for £1 ref JUN1P11.

STROBE LIGHT KIT Adjustable from 1 hz right up to 60hz! (electronic asssembly kit with full instructions) £16 ref EF28.

ROCK LIGHTS Unusual things these, two pieces of rock that glow when rubbed together! belived to cause rain! £3 a pair Ref EF29.

AMSTRAD GX4000 games machines, returns, untested, sold as seen. Just £2.99 ref EF186.

NEW HIGH POWER LASERS

15mW, Helium neon, 3 switchable wave lengths .63um,1.15um,3.39um
(2 of them are infrared) 500:1 polarizer built in so good for holography. Supplied complete with mains power supply.790x65mm. Use with EXTREME CAUTION AND QUALIFIED GUIDANCE.
NEW SALE PRICE TO CLEAR JUST £249+VAT

WE BUY SURPLUS STOCK FOR CASH

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1995 100 PAGE CATALOGUE NOW AVAILABLE, 45P STAMP OR FREE WITH ORDER.

BULL ELECTRICAL

250 PORTLAND ROAD, HOVE, SUSSEX . BN3 5QT. (ESTABLISHED 50 YEARS).

MAIL ORDER TERMS: CASH, PO OR CHEQUE WITH ORDER PLUS £3 POST PLUS VAT.

PLEASE ALLOW 7-10 DAYS FOR DELIVERY PHONE ORDERS WELCOME (ACCESS,VISA, SWITCH, AMERICAN EXPRESS)

TEL: 01273 203500

FAX 01273 323077

PORTABLE RADIATION DETECTOR

WITH NEW COMPUTER INTERFACE £59

A Hand held personal Gamma and X Ray detector. This unit contains two Geiger Tubes, has a 4 digit LCD display with a Piezo speaker, giving an audio visual indication. The unit detects high energy electromagnetic quanta with an energy from 30K eV to over 1.2M eV and a measuring range of 5-9999 UR/h or 10-99990 Nr/h. ref NOV18

ETI News...

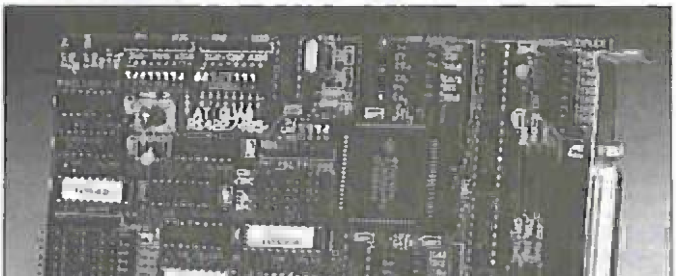
ELECTRONICS TODAY INTERNATIONAL

Cut the Cost of PCBs

For further information, contact Tracks on 01344 55046.

Tracks Cad Systems has announced the new Protomat series of PCB prototype milling machines for the production of one-off-and prototype PCBs.
These new systems extend the existing, proven range of machines and, with prices starting at £7,950, exclusive of VAT, make it possible for a whole range of new users to derive the benefits of making their own PCBs. The price of the new entry level Protomat 91s, is £7,950, and includes PCB design software - a package price which equals about half the cost of previous entry level systems. All you need is a suitable PC to run the software and connect the machine to. the new Protomat series are ideal for independent operators, laboratories, small or occasional users, new businesses and educational establishments. The Protomat series offers a standard bed size of 420mm x 375mm (Protomat 91s 340mm x 200mm) and all models perform to the same high standards of precision and accuracy as other professional systems in the LPKF range. Repetition accuracy and precision are measured at +/- 0.02mm. The machines can cut the full, standard range of PCB materials and are suitable for both single-sided and double-sided PCBs.

4 Port RS422 from Brain Boxes



Especially useful where limited motherboard slots are available is the new Quad RS422, providing 4 industry standard 422/485 ports. Each port is independently configurable, either as RS422 with or without handshaking, or RS485 with full and half duplex.

The RS422 standard provides higher speed and longer distance data transmission. The card provides reliable communication up to 1.2 kilometre (4,000ft).

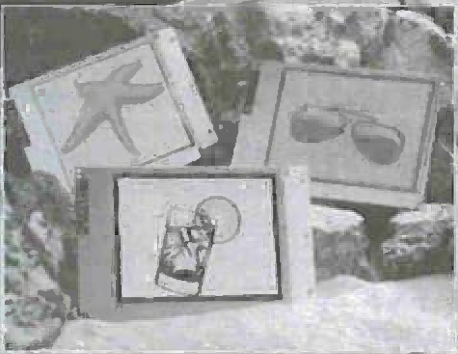
On-board, fail-safe, open circuit detection prevents false start bits and bad data being detected, whilst fail-safe closed circuit detection protects receivers and drivers. The on-board terminating resistors prevent echoes. IRQ's 2-7, 10-12 and 15 are provided, together with the addition of IRQ 14 for greater freedom.

A shared interrupt mechanism provides fast and flexible interrupt handling. Baud rates up to 115,200 and FIFO enhanced chip for Windows users completes this tidy package.

Designed and manufactured in the UK by an ISO9001 Registered Company, this new product is offered inclusive of full documentation, three-year warranty, and telephone technical support.

For further information, contact Brain Boxes on 0151 220 2500.

Extended Range of Flat Panel Displays

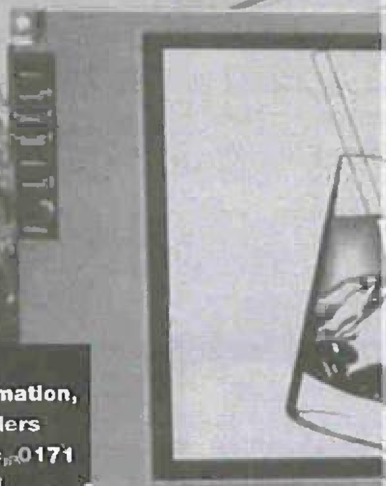


Anders Displays has extended its range of flat panel displays with a number of colour and monochrome modules from Citizen.

Available in three versions - transmissive, reflective and transflective. The G6485H-FF series of 5.3" monochrome graphic LCDs feature 640 x 480 VGA resolution, and are ideal for applications such as hand-held data capture and notepad computers, as well as equipment which has traditionally required bulky 5" CRTs. Relying on ambient light, the reflective version has a minimum power requirement, while the transmissive module features a CCFT backlight. The transflective version can be used in transmissive or reflective modes according to ambient light conditions. This range is complemented by the G648H-FF series, featuring 640 x 480 VGA resolution and which are suitable for applications such as compact portable PCs.

An 800 x 600 SVGA resolution modules - the 10.4" K8600L-FF - is specially designed for the workstation and industrial control markets, and will also be in demand for applications such as SVGA notebooks. Also available is the K648LFF, and 8.4" dual-scan SVGA passive colour display with a resolution of 640 x 480 dots.

The LCM512C is a highly advanced colour LCD monitor using dual-scan passive Super Twisted Nematic (STN) LCDs. Displaying up to 512 colours with a resolution of 640 x 3(RGB) x 480 VGA, the device offers excellent picture definition and colour saturation, and meets or surpasses the performance of CRTs. Very compact, and able to be desk or wall mounted, the monitor has very low power consumption, and the non-glare, flicker-free display meets the latest EMC regulations. Potential applications range from computer terminals for financial institutions to customer reservation systems and touchscreen-based Information systems.



For more information, contact Anders Electronics plc, 0171 388 7171.

New DX4 Single Slot PC

Designed and manufactured in the UK, Blue Chip Technology continues to expand their extremely successful range of single slot PC processors with the release of the DX4/100MHz CPU version.

The latest high speed CPU takes advantage of the on-board local bus GUI accelerated video with resolutions of up to 1280*1024. Together with the on-board 256KBytes of level 2 cache, (up to 64MBytes of DRAM), 2MBytes of Flash, 512KBytes of SRAM, IDE and floppy controllers, 2 serial ports, (both RS232 or RS485 software selectable), parallel, keyboard and PS/2 mouse ports, it is intended for use in mission critical applications where the power monitoring and watchdog features assure integrity of operation. The processor card is already used extensively in a wide range of applications from network nodes/servers through to EPOS terminals.

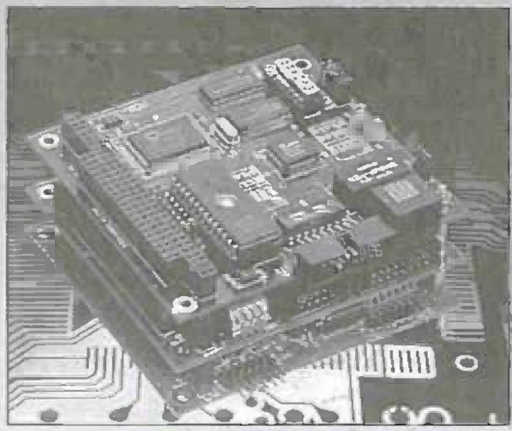
Further information, contact Blue Chip Technology on 01244 520222.

New Modules for Embedded PC Applications

The PC-104 modules from IMS offer the benefit of the standard PC-Bus architecture but on a miniature form size, measuring only 3.6"x3.8" and with exceptionally low power consumption. PC-104 is therefore ideal for embedded applications where PC architecture is desired, but current PC motherboard/plug-in cards technology is too bulky and power-hungry.

The current range offered by IMS includes a diverse mix of products, including such modules as CPUs, peripheral interfaces (hard/floppy disk), serial & parallel I/O, SVGA& flat panel display controllers, PCMCIA, ethemet network, RS422/485 communications, solid state disks, digital I/O and analogue A/D & D/A.

The PC-104 modules can be used as 'Lego' style building blocks, by interconnecting them in a stack, enabling a wide variety of configurations to be implemented, thereby offering the versatility and flexibility required in many diverse embedded applications. Because of the miniature size, developers can now embed PC-based control in a variety of machines and equipment, retaining the development investment based on PC technology as well as benefiting from the enormous development support products available on the PC.



For further information, contact Integrated Measurement Systems Ltd on 01703 771143.

Compact Loudspeaker
from Maplin

The new Compact Stage Monitor is a high quality, low cost loudspeaker which has been specially designed to allow musicians to hear themselves clearly in situations where bass and amplified instruments are being used. The unit contains a high quality 12in. woofer, and a 1 3/8" titanium high frequency driver, which are driven through a specially designed crossover/equaliser network to give the best possible sound quality.
The substantial cabinet is covered in a hardwearing material to cope with the rigours of professional use.
contact Maplin on 01702 554161.

Specification:

Frequency Response:	65Hz to 20kHz	
Crossover Frequency:	2kHz	
Nominal Impedance:	8ohm	
Sensitivity:	97dB	
Power handling		
	longterm/continuous:	100W
	short-term peak:	200W
Dimensions:	410 x 560 x 410mm	

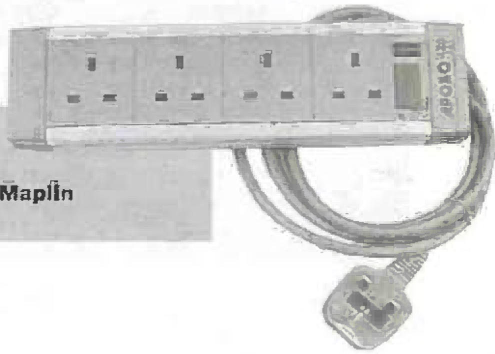
The stage monitor costs £189.99 (inc VAT). For further details contact Maplin 01702 554161.

Maplin Spikes Mains Supply

The new Spike Protector from Maplin Electronics is a 4-way mains socket strip that redirects transients and surges on the mains supply safely to earth. The unit has a response time of less than ten nanoseconds.

A built-in neon glows brightly when three conditions are met: the protection unit is intact, the supply fuse is not ruptured and the correct earth is present. Any problems will cause the neon to glow, or if the earth is not present, the neon will glow with a reduced light output.

To help comply with BS 6396, the socket strip is provided with an external earth terminal to ground other desk-mounted electronic equipment. The socket strip can be mounted on a wall or desk and comes with two metres of mains cable and a BS plug fitted with a 13A fuse. The socket strip is fitted with an integral 7A fuse.



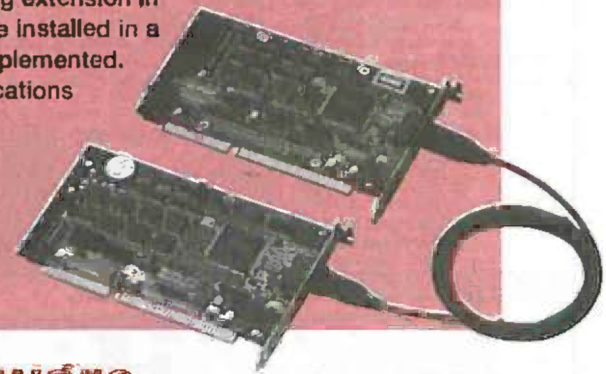
The Spike Protector costs £29.99 (inc. VAT) For further details, contact Maplin on 01702 554161.

Optical PC-Bus Extender

IMS has announced a new Optical PC-Bus extension kit enabling a standard PC-Bus (ISA) to be extended up to distances of 100m. Code-named the PCX-797, this kit comprises two, half-size standard PC-bus plug in cards. A master card, which plugs into the main PC and a slave card which plugs into the extended bus, joined by fibre optic cable up to 100m away. A number of multi slot extender backplanes (from 3 to 20 slots) as well as remote housing chassis are also available.

The fibre optic link operates at very high transmission rates (96Mbps) thereby eliminating bus timing problems usually associated with limited bandwidth cable based bus extension. The optical link also provides the benefit of interference-free communications allowing extension in electrically noisy environments. Multiple Master/Slave kits can be installed in a single PC allowing a star network of remote outstations to be implemented.

The PCX-797 is ideal for remote monitoring and control applications from a central controller, where the distances are too great for conventional cable-based extends, as well as for applications in hazardous areas.



For further Information, contact Integrated Measurement Systems Ltd on 01703 771143.

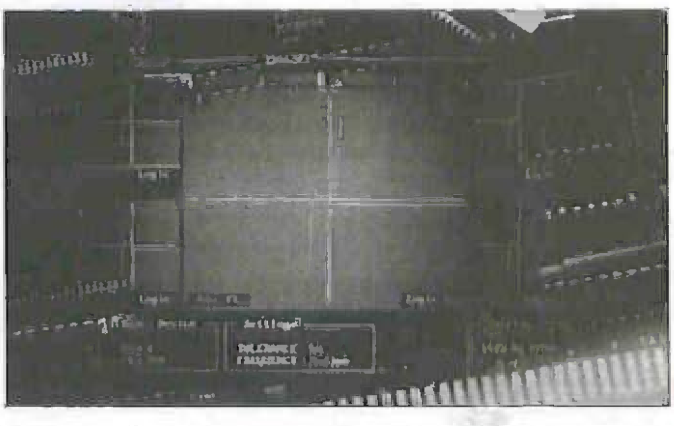
Electronics Service Test Software

Polar Instruments has introduced a powerful new software capability for its analog signature analysis (ASA) test systems which eliminates a major cause of lost productivity in electronics service test and repair - invalid fault diagnosis. ASA is one of the most common electronics service techniques in use today, but logic ICs from different vendors - although functionally compatible - can exhibit marginal signature variances which appear as faults. Polar's software, called AVR (Advanced Vendor Recognition), takes advantage of the digitised signature facilities in its PC-based T4000, T6000 and TD8000 field service testers to detect these variances automatically, eliminating confusion for the user - and potentially unnecessary repairs. When the time to accomplish such repairs - and the necessary retest - is taken into account, AVR can double the throughput of test and repair operations.

For example, AVR can significantly improve for in-house maintainers of process control and automation equipment who may have difficulties building up a repair knowledge base due to low volumes of a particular board type. For these groups, ASA is a key maintenance technique and Polar's AVR can clarify the fault location process, resulting in fewer unnecessary repairs, reduced maintenance costs and increased overall efficiency. Similarily, in test and repair depots, AVR can cut the time necessary for a new service engineer to become effective in fault diagnosis.

Working without powering up a suspect PCB and without the need to circuit documentation, ASA provides a fast, diagnostics-oriented, type of testing which can quickly detect failures in digital and analog circuitry, and typically allows equipment to be returned into service for the price of a simple component. PCBs are tested on a component-by-component basis by applying an AC signal - which is both voltage and current limited - to produce an impedance 'signature' that is characteristic of a node's in-circuit behaviour. Wrong, or failing, components present different characteristic signatures, making it very easy to identify faults.

The introduction of PC-based virtual instrument panel front-ends for this type of equipment automated the ASA application by providing powerful signature digitisation, storage and comparison facilities. Digitally-stored signatures are ideal for long-term system maintenance tasks and for service organisations adopting distributed repair strategies, because they eliminate the need for expert electronics knowledge of the circuit under test, and speed component-level fault diagnosis. However, logically equivalent ICs from different manufacturers - for example 74HC373s from Harris Semiconductor and Texas Instruments - produce marginally different signatures, creating confusion for the user which can result in invalid fault diagnosis. For example, one frequent cause of such signature deviations arises from the various methods used by different manufacturers to construct pin protection diodes. AVR's powerful correlation techniques identify where three or more pins of an IC fail in an identical manner and produces the message "probable vendor difference", eliminating both the confusion and the need for repair. Interestingly, AVR also highlights the common case in bus-based boards where different build standards may or may not contain pull-up resistors, making it extremely useful for experienced users servicing computer and peripheral boards.



For further Information, contact Polar Instruments Ltd on 01481 63081.

Computing without

A revolutionary British-designed clockless asynchronous processor chip could fundamentally change the way in which computers are constructed and used, Nick Hampshire looks at this world beating technology, and why it is considered to be the Holy Grail of computer science.

When buying a new computer one of the first questions most of us will want to know is the system's clock speed. This is because the clock speed gives us some idea of the processing power of the system; it is a guide to how many instructions the system can perform in a given period. It thus allows us to distinguish between systems which are otherwise identical. But a processor's clock is not there to simply give the user some idea about how powerful the system is. Indeed it has a far more important function. The main function of the processor clock is to synchronise the different operations of the processor. It ensures that all logic levels are steady at the same time, and that all logic levels which are about to change will change at the same time.

The function of the clock is, therefore, to synchronise all the diverse different operations of the processor and the system of which it is part. In other words, not only the CPU operations are synchronised by the clock but also memory, I/O, even disk drives and video displays. Such systems are therefore described as synchronous processor systems.

Every digital computer which has been produced so far, except for some of the very earliest designs has been a synchronous clocked system. But although it has served computer designers - in particular microprocessor designers - well in the past, it is a technique which is starting to come up against severe limitations as processors become both larger and faster. These limitations are already stretching designers' ingenuity and capabilities to the limit.

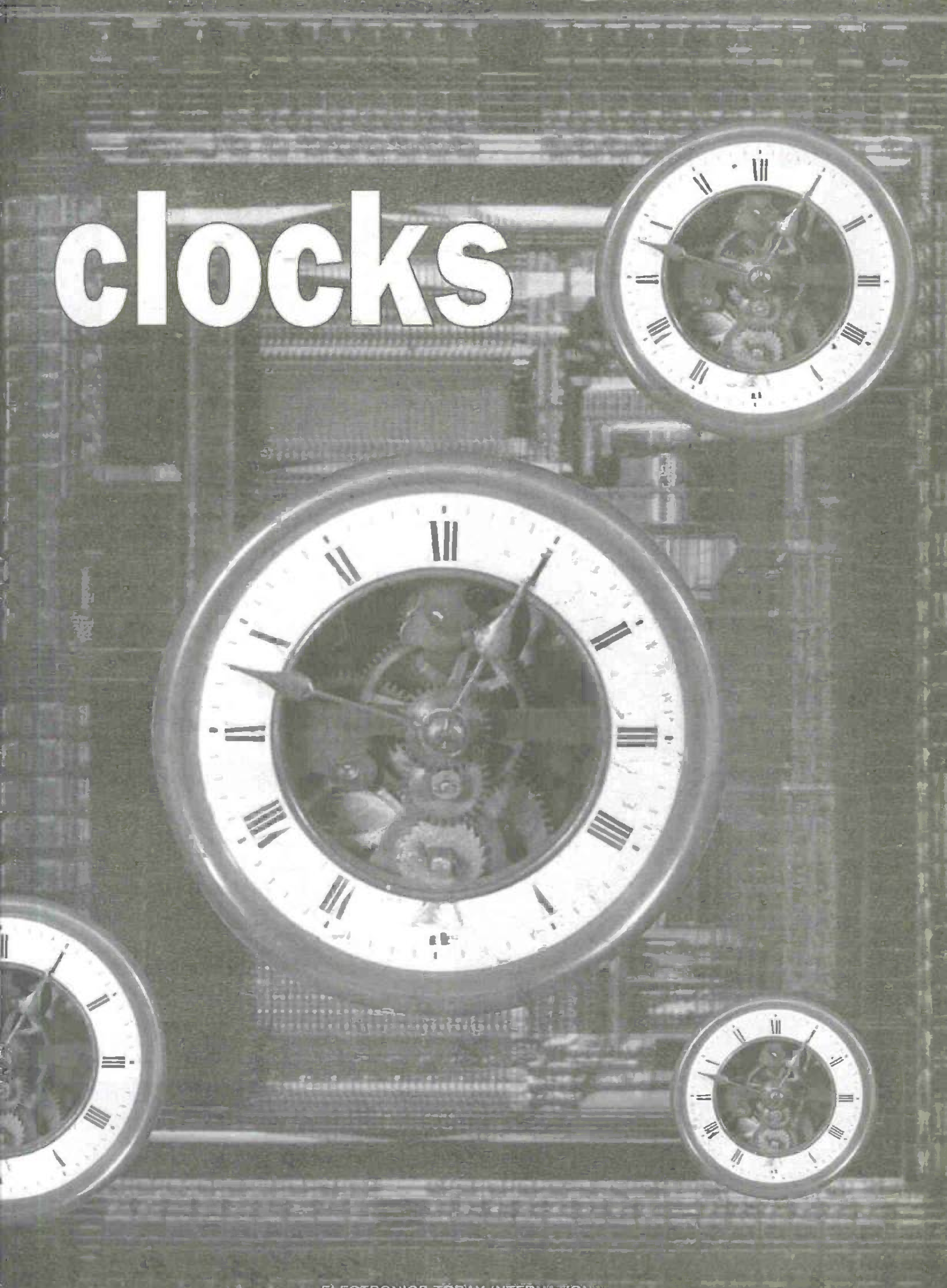
The limitations which are becoming a serious problem in designing larger and larger, and faster and faster microprocessors - and we are now looking at devices with ten million transistors running at clock rates of well over 100MHz - can be broadly grouped into four categories.

First of all there is the question of power usage. With all those transistors being switched at very high speed, such a processor needs a lot of power, and it dissipates that power in the form of lots of heat. Already, microprocessors which consume 20 or 30 watts are not unusual; indeed if current design trends continue we could be looking at a 0.1um 5V CMOS processor dissipating 2kW by the year 2000. (This could of course be a design feature! every system has a built-in central heating unit equivalent to a two bar electric fire.)

Power consumption is already a serious problem; even today's fairly moderate power usage requires special techniques to channel away the unwanted heat, as well as posing problems in the design of battery-powered portable systems. The DEC Alpha uses heat pipes to channel the heat away, whilst the SPARC uses Peltier Effect devices to actively cool the chip, others use fans mounted directly on the processor chip or special heatsinks.

Power consumption is being kept down by several techniques, such as the use of lower supply voltages (reduction to 3V operation will reduce power consumption by a factor of 3 over 5V operation). More significantly, the use of power management techniques to switch off the clocks to some areas which are not currently being used but are still consuming power. Typical of this technique is the 'sleep mode' found on many low power microprocessors, but such techniques are fairly crude and their granularity very course.

Secondly, designers are faced with physical limitations, the speed of light, on how far a pulse can be sent down a wire in a given period; as the period gets shorter so the distance gets shorter. In a nanosecond, light travels just 30cms in a vacuum; an electron moving along a thin gold wire would probably only go a couple of centimetres. This essentially means that a very fast processor has to be built on a single piece of silicon using as small a device geometry as possible. The supercomputers of today are


clocks

Transition Signalling and Micropipelines

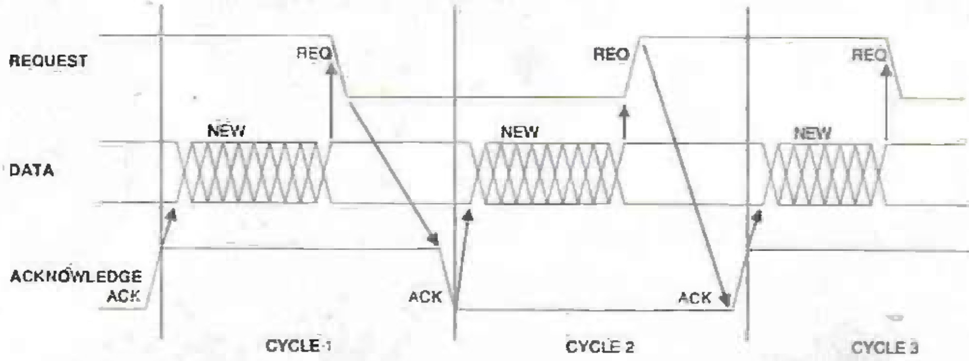


Fig.1. The timing diagram showing how the two event signalling lines are used

Much of the original theoretical work on designing an asynchronous computer was done by Ivan Sutherland in the States. Sutherland, who is well known as the founding father of modern computer graphics, started looking at the problems involved in designing an asynchronous system during the late 1970s when he was at Caltech. This work formed the subject of his famous Turing Award lecture in 1989.

The publication of that lecture in the Communications of the ACM inspired researchers around the world to look again at the design of an asynchronous computer. Sutherland had proposed that the best design was what is known as a pipelined processor, a computer architecture which can provide very high speed processing because the separate stages of the pipeline are able to work concurrently.

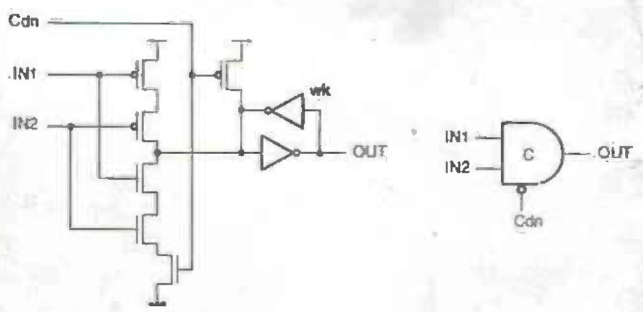


Fig.2a The transistor level implementation of a Muller C gate for use on an IC

Pipelines are widely used in modern high-speed processors, such as graphics processors and DSPs, and are best understood by using an analogy with a manufacturing assembly line. In an assembly line, a succession of objects, such as motor cars, passes down the line along which different people working concurrently perform small specialist operations. Productivity is increased because each individual has optimised the task that he or she does. The same goes for a computer pipeline since it uses concurrency to maximise processing speed.

A pipeline processor therefore operates on data as it moves along the pipeline - in other words, down the assembly line. This implies of course that the pipeline both stores and processes data, and not just one byte of data but a sequence of bytes of data, with storage elements alternating with processing elements. If we remove the processing elements of a pipeline then it becomes a sequence of storage elements through which data can pass, much like either a shift register, or a FIFO buffer.

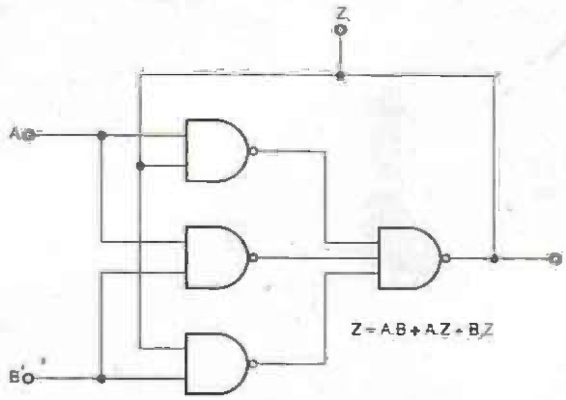


Fig 2b Muller C gate implementation using AND gates

The virtue of a pipeline is that it can be either clock driven or event driven, on all current processors the pipelines are of course clock driven, but for an asynchronous processor it will be event driven. The problem with many types of clocked pipeline is that they tend to be inelastic and, when stripped of the processing element, rather like a shift register. In such inelastic pipelines, the amount of data in them is fixed and the output from the pipeline exactly matches the input.

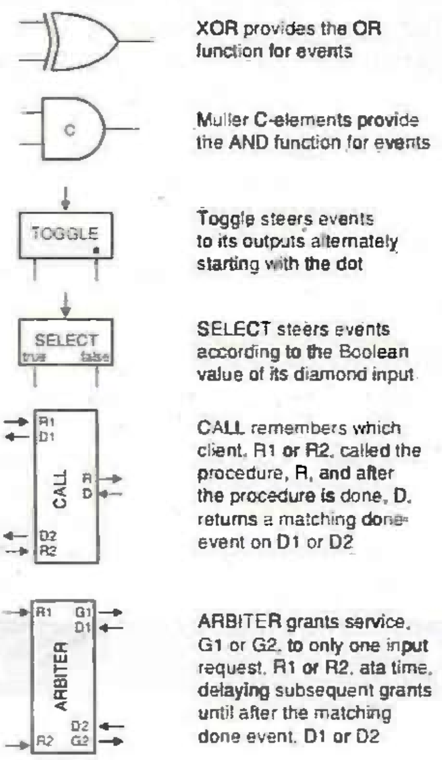


Fig.3. Other event driven logic modules required for constructing an asynchronous processor

Input and output rates, as well as storage capacity can only be made to vary when the pipeline is elastic. An elastic pipeline stripped of its processing component is essentially a flow through first in first out memory, or FIFO. Sutherland realised that event driven elastic pipelines, with or without processing capability, were one of the keys to the design of an asynchronous computer system, and he referred to them as 'micropipelines'.

The other main key was to move from using the 'high/low' voltage levels of a clocked system for defining logic true and false to a system where the absolute voltage level is ignored and it is the transition between the two levels which specifies the 'event'. This he referred to as transition signalling, and has the potential of being twice as fast, and a lot more energy efficient than clock based systems since information is transferred in both the rising and falling edges of a pulse, as opposed to the pulse itself.

Transition signalling can be used to provide the event signalling which is essential for the proper operation of a micropipeline. The actual data is still stored as high and low voltages representing true and false. Event signalling is the key component of an asynchronous system, and just as asynchronous communications ports use 'request' and 'acknowledge' handshaking lines, so a micropipeline also uses 'request' and 'acknowledge' event signalling lines.

The timing diagram (Fig.1.) shows how these two event signalling lines are used. In phase 1, the sender places a value on the data lines and then sends an event on the request line. In phase 2, the receiver accepts the data and responds with an event on the acknowledge line. Because the events use transition signalling, they can be either a rising or a falling edge.

Superficially, this resembles a common two phased clocked system, but it is actually rather simpler since such systems have five events per cycle as opposed to two. But what makes it really different is the fact that, in the micropipelined system, the two phases can be of different and variable duration - this identifies it as being a true asynchronous system.

On a practical level, the problem is that transition signalling of events is something which cannot easily be done using standard logic gates; these are all designed for level sensitive operation rather than transition based operation. To solve this problem Sutherland used a special circuit which contains a 1-bit memory cell and is known as a Muller C gate after its inventor David Muller.

The Muller C gate is represented by an AND gate symbol with a C inside it. It has two inputs, one of which is often inverted, and one output, and a reset line, Cdn (see Fig.2a which also shows the transistor level implementation for use on an IC; an implementation using AND gates is shown in Fig.2b.). In operation, the C gate will only output an event when both its inputs enter the same logic state after both have received an event. A range of other event driven logic modules required for constructing an asynchronous processor are shown in Fig.3; most of these are constructed using C gates.

One module which is not in that list is the event driven transparent latch shown in Fig.4a. The Muller C gate handles the event signalling on a micropipeline but to construct such a pipeline one also needs to give it storage capability, hence the need for the transparent latch, a sort of event driven version of the D-type flip-flop.

Each latch has two event driven inputs called PASS and CAPTURE. The PASS input is used to render the latch transparent - in other words, the state of the data input is directly transferred to the data output; the latch essentially disappears. The CAPTURE event input latches, and thus stores, a 1-bit data value, so that the logic values on the data input and the data output lines may well be different, depending on the value stored in the

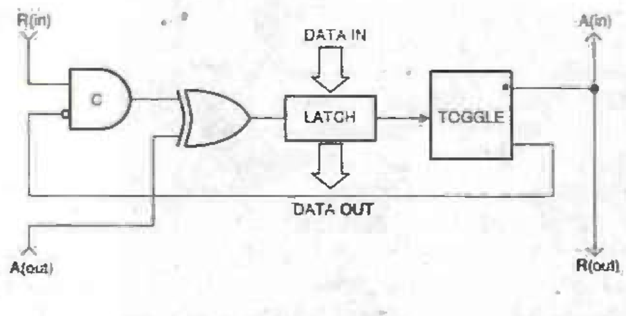


Fig.4a An event driven transparent latch

microprocessors, the DEC Alpha - probably the most powerful micro currently in production - has a power equivalent to that of a Cray super-computer produced just three or four years ago.

Thirdly, there is the problem of accurately synchronising all the operations within a large chip operating at very high speed. Once again, the length of data paths is a critical factor. If an operation is to be performed in several different areas of the chip concurrently, then the designer will have to build delays into some of the data paths to ensure this concurrency. This effectively means that the processor can only operate as fast as its slowest component, and a lot of silicon and design effort is usually devoted to making such rare worst case operations fast.

Fourthly, and finally, there is the problem of clock slew at high data rates. This is the tendency of the clock pulse to lose its sharp rising and falling edges and therefore become an inaccurate means of ensuring synchronisation. The only real way around this is to use brute force to drive the clock pulse and prevent it being slewed. Thus, on the DEC Alpha the clocking system is a major engineering achievement with the drivers; essentially in the form of a 40 watt power transistor, occupying over 20% of the silicon area. The designers of the Alpha have pushed the solution of this problem to the limits; there is little further scope for improvement.

All these limitations add up to the inescapable fact that the designers of conventional sequential microprocessors, both CISC and RISC versions, are starting to encounter technical limitations in their quest to build ever faster and more powerful processors. These limitations may be uneconomical to solve in traditional processor designs, but might be easily soluble if we simply change the way in which we think about designing a computer system or, for that matter, any highly complex high speed logic circuit.

Changing the design paradigm

The development of computer science has been one of a continuous search for ways of constructing machines which are more powerful. Because of some of the constraints which have just been outlined, in particular the maximum distance that an electrical pulse can travel in a very short period, it is now widely accepted that very fast computers will have to be

latch. One can construct such a transparent event driven latch using three conventional latches and three standard inverters. The transparent event driven latch elements can then be assembled to build byte wide storage registers.

A simple micropipeline would consist of one register per pipeline stage, plus Muller C gates for the event driven control; a block diagram for such an event driven elastic FIFO micropipeline is shown in Fig.5. The data passes through the latches from left to right, and elasticity is ensured because empty latches are completely transparent; with the four stages shown it could have just one data element or four elements stored.

Stability is ensured by the fact that each stage is a control event loop which checks to see if the predecessor and successor stages are different. If they are, then it copies the predecessor's state. If not, it holds the present state and goes back round the control loop. It is this type of event control loop which eliminates the need for clock synchronisation.

So far we have only looked at micropipelines with storage capability but no processing, and in fact micropipelines could be used to construct very fast and efficient memory systems. Adding processing to the micropipeline increases the circuit complexity but it does not destroy the fact that it no longer needs any clock synchronisation to function.

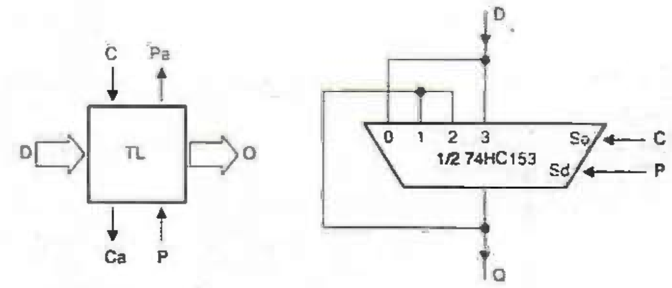


Fig.4b. Gate implementation of event driven latch

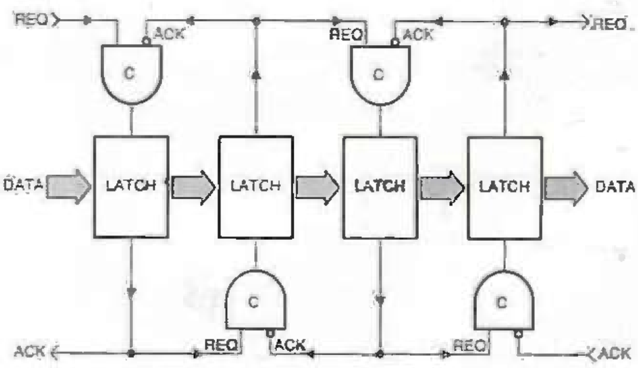


Fig.5a. An event driven elastic FIFO micropipeline

built on a single piece of semiconductor using very small component geometries.

This is fine so long as the processor design is very simple since, as we have seen, increasing device complexity brings with it other serious limitations, clock slew, synchronisation, and excessive power requirements. Device simplicity is the clue to one attempt at minimising some of these problems, hence the enormous interest in Reduced Instruction Set Computers, or RISC processors.

With a RISC processor the complexity of the device is reduced by reducing the instruction set to the absolute minimum, and transferring the task of performing complex operations from the processor hardware to either the software or other specialist hardware such as a maths coprocessor. This is a technique which has proved very popular in applications, such as graphics processing, where a lot of simple repetitive instructions are used. In such applications, RISC processors can be made to perform at significantly higher processing rates than comparable conventional processors.

Another approach is to create a parallel processor which is capable of breaking a complex task into a lot of simple tasks and then performing these concurrently in order to achieve higher processing power. This is a very successful technique, and some of the world's most powerful computers such as the Connection Machine, are parallel architecture systems.

The problem is that these and other similar approaches do not actually solve the problem, they simply delay the time at which they become serious, and indeed they may actually add further problems. For example, RISC processors are excellent in certain applications but indifferent in others. This is because processor complexity is reduced at the expense of an increase in software complexity. Similarly parallel processors may be very fast but they are not particularly amenable to being scaled down so that a whole parallel system can fit on a single chip, once again designers are faced with the problem of wire length and signal speed.

These are all problems which have been exercising the minds of computer designers for many years, and there is one solution which has been proposed on several occasions during this period and which should, if the theorists are right, eliminate, or substantially reduce, most of these limitations. Indeed, it should enable designers to go on producing ever faster and more complex processors on a single chip of semiconductor for many years. That is until new limitations caused by attempting to fabricate components from just a few atoms start to make their appearance.

This solution is the asynchronous computer, the clockless processor - a solution which has become the Holy Grail of many computer designers.

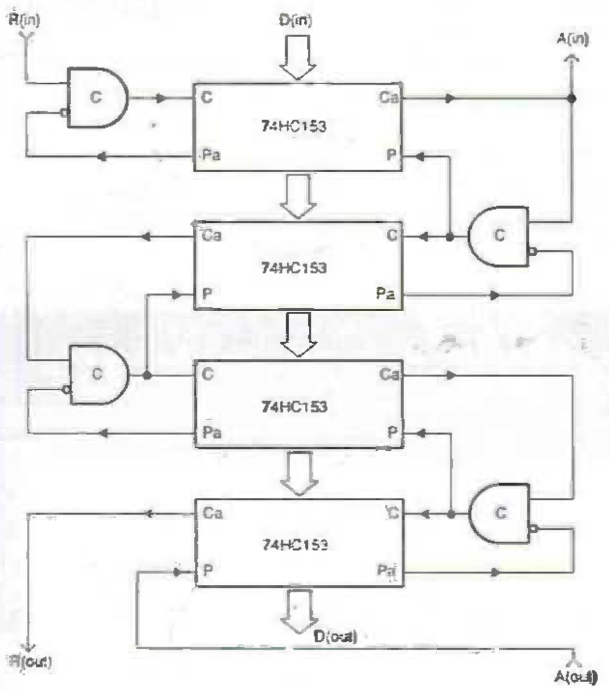


Fig 5b. Gate implementation of micropipeline

The asynchronous computer

In an asynchronous computer, the absence of a clock pulse means that there is no synchronisation between all the different components of the processor (a fact which immediately solves several problems, such as those of synchronisation with its requirements for a monolithic design, and clock slew with its need for massive clock drivers). Instead, each part of the processor operates using either its own clock or at maximum speed.

Data and instructions are transferred between different parts of the processor using a handshaking technique which will be familiar to anyone who has worked with asynchronous communications ports on a computer. When one part of the processor has data or an instruction available for another part to use it sends a signal to that part telling it that it is ready to send this data or instruction, it will only do this upon receipt of an acknowledgement signal from the part that is to receive the data or instruction.

This means that each part of the processor can work at maximum speed whenever instructions and data are available; there is no need to slow the overall operational speed down to match that of some worst case operation. In other words, an asynchronous processor will operate at very high speeds when performing simple commands and at a slower rate when performing more complex commands.

For readers familiar with computer programming, the asynchronous computer is analogous to object oriented programming. Here the rigid structure of procedural languages, as with synchronous computer designs, has given way to the very flexible collection of self contained objects. Each object is a programme in its own right; there are no global variables or procedure calls, simply the communication of data.

Object oriented programming has largely developed from the programmer's need to produce ever larger and more complex pieces of code. It allows the programmer to do this without the danger of the programme becoming untestable and so rigid in its structure as to be impossible to easily upgrade. By using the object oriented approach the individual component objects to be individually tested, verified, and updated with ease.

Similarly, with the asynchronous computer, it can be built from a large number of simple modules which can each be individually tested and verified with much greater ease than a large, rigidly structured processor. This means that an asynchronous system should be capable of being designed and tested very quickly. It also means that the system can equally easily be changed, updated or specially tailored for a specific application. Remember that, with an asynchronous system, there is no rigid synchronisation built into the design, only simple communications links.

This modularity of design using building blocks and ease of system testing and verification are both very important factors in a commercial world where getting a product on the market quickly is all important. It allows designers to construct a working implementation and then gradually refine the design in small increments as opposed to major design revisions.

In another similarity an object will only be activated when specific data is available either from other objects or from some external source. In an asynchronous computer, the only parts of the system that will be functioning are those parts which are actually processing data or instructions; any other circuitry is quiescent. This is in contrast to a synchronous system where every part is operating irrespective of whether it has any data or instructions to process.

This factor is an important thing in favour of asynchronous systems, since if such a system is fabricated in CMOS, there will be a substantial power saving. This is because, in such a circuit, power is only used when the circuit is actually switching data; in the quiescent state power requirements are infinitesimally small.

This close relationship between power use and the amount of processing to be done by the system means that an asynchronous computer will immediately change its power requirements in response to changes in processing requirement. At full processing capacity, the asynchronous processor will use as much power as a conventional clocked processor, but at lower processing capacity it will use less and less power, whereas the clocked processor will still be using the same power as it did at full capacity.

Of course, some modern processors do attempt to save power by shutting down unused sections of the processor, an extreme version of which is sleep mode. But the granularity of such control systems is very course and can not compare to the very smooth and automatic reduction in power use by an asynchronous processor, which will of course automatically go to 'sleep' when there is no processing to be done, and equally automatically will 'wake up' when processing is needed.

All of this means that since most processors spend a very large proportion of their time doing nothing, an asynchronous processor could be a very low power processor, making it ideal for the multitude of battery powered portable, hand-held devices which are being developed.

We can thus summarise a few of the advantages of an asynchronous design as:

- no problems with clock slew
- no need for large clock drivers
- no need for rigid synchronised designs
- highly flexible modular design
- easy updating of designs
- easier testing of designs
- maximised operation speed
- very low power consumption
- no problem with signal propagation delays

From this small list it can easily be seen why the design of an asynchronous computer has been considered by many to be the Holy Grail of computing.

But there is one negative; it has nothing to do with the technology, but rather with the people who will use it. The problem is that the concept of synchronous clocked computers has become so ingrained into the psyche of designers, computer scientists and users that it may be very difficult to get people to switch to clockless designs, despite the obvious advantages of such designs.

AMULET The Asynchronous ARM

The ARM microprocessor was originally developed over twelve years ago by the British company Acorn Computers Ltd (well known for their BBC Micro of which over 1.5million were sold worldwide). The ARM is a RISC (Reduced Instruction Set Computer) processor and was designed as a powerful, versatile replacement to the 8-bit 6502 used in the BBC machine. It is now produced by a separate company part owned by Acorn and Apple.

The ARM is a 32-bit processor and the worlds first commercial implementation of the pioneering RISC designs developed at Stanford and Berkley Universities in California. The first versions of the chip were fabricated using 3um CMOS with test samples being delivered in April 1985. Successive generations of the ARM have become faster and are fabricated using smaller geometries, the current ARM7 being fabricated in 0.8um CMOS with an 8K fully associative cache, and capable of

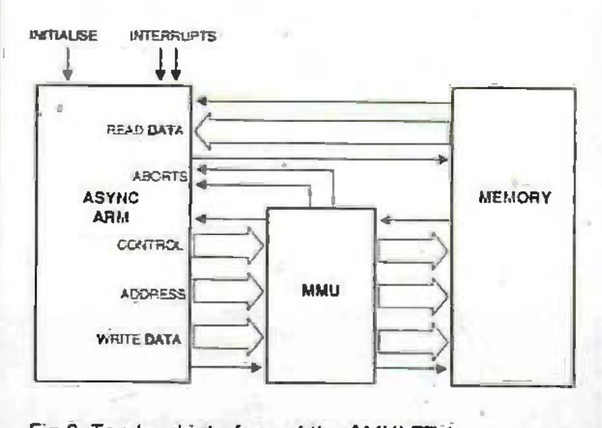


Fig.6. Top level interface of the AMULET 1

A similar problem faced programmers attempting to move from procedural languages to object oriented languages. It required an enormous, and extremely difficult intellectual change in the way that the programmer looked at problems and attempted to solve them. It took many programmers years to make this change; some never made it. A similar change will be demanded of electronics engineers and computer designers - they will have to learn to live without a clock, and that may prove very difficult.

Is the future clockless?

There are currently four major teams around the world, besides Professor Furber's at Manchester University, who are working on asynchronous computer systems. In the USA, work is being carried out at Caltech under Alain Martin on a 16-bit processor, whilst at SUN, Ivan Sutherland is working on an asynchronous implementation of the well known SPARC processor. In Holland, researchers at Philips Research under Kees van Berkel are working on asynchronous systems for use in audio electronics. Whilst in Japan a team at the Tokyo Institute of Technology under Professor Takashi Nanya are working on an asynchronous RISC processor

So far the Manchester team look like having a considerable lead over the others since they are the only ones to have actually produced a working asynchronous processor that re-implements a commercial device. Neither of the American teams have yet come up with a working device, whilst the team at Phillips have produced working asynchronous devices but are not working on an asynchronous processor.

This leaves the team in Tokyo who have just produced a very small 8-bit asynchronous processor. They are currently working on a larger version which will closely resemble the AMULET 1, and they expect to have a prototype available in 1997. This gives ARM about a two year lead on the other teams. This should be enough time to permit them to capitalise on this very important work and start to build a world leadership in this technology.

The work of all these researchers is being closely monitored by the big computer, telecommunications and semiconductor manufacturers, all of whom see enormous potential advantages in the use of asynchronous technology, particularly in the areas of low power systems and modular design.

Hand-held devices such as digital phones, the soon to be released hand-held satellite phone, personal digital assistants and global positioning systems now all incorporate increasing levels of intelligence. There is an enormous potential demand for powerful processors which can operate for a long time on battery power. Asynchronous devices with their smooth instantaneous decrease in power requirements as data throughput decreases are ideal, since in most such applications peak processing power is only required for a very short period, most of the time the processor will be doing nothing.

Similarly, the rapid increase in the number of applications is creating an increased need for highly integrated special purpose chips which incorporate intelligence; the boom in licensing agreements by ARM is evidence of this. The need to get such products on to the market quickly means that the rapid modular design potential of asynchronous systems will be enormously appealing. Indeed some of the first commercial applications for asynchronous systems will probably be as components within a more conventionally designed chip. For example, the consumer electronics products being designed by Phillips.

However, in the longer term, probably within the next five years, asynchronous processor technology is likely to become a major factor in the world computer market. And it is a fairly good bet that just as object oriented languages have swept into and now dominate computer programming, so clockless computers will sweep in and dominate the computer hardware of the future.

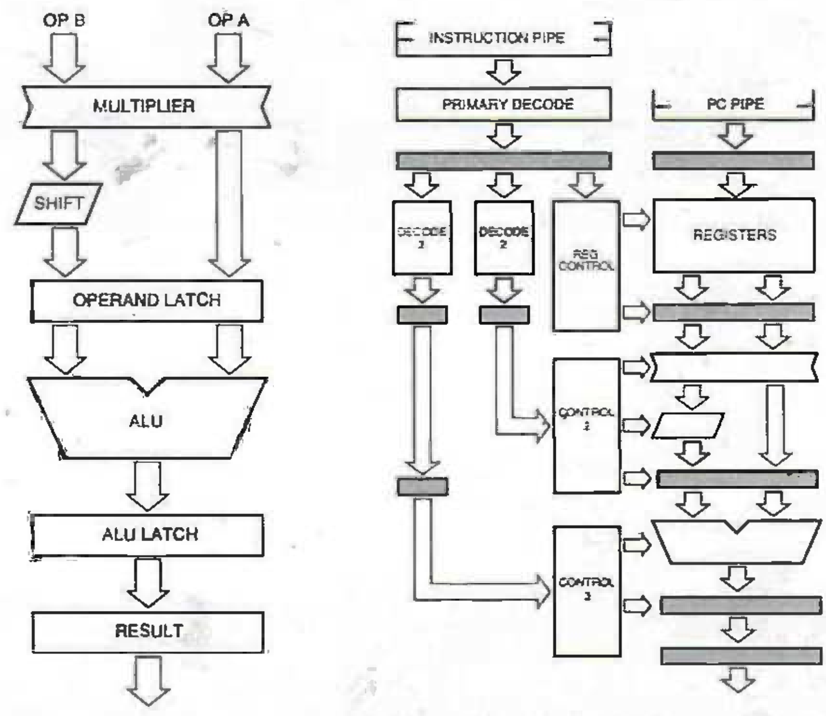


Fig.7. The functional units of the execution pipeline

operating at 33MHz.

When deciding to develop a working asynchronous processor, Professor Steve Furber and his team at Manchester University, in association with Advanced RISC Machines, decided to produce a device which was the equivalent of a standard commercial processor. This decision would enable them to use all the development software already available for the existing synchronous processor. The processor they chose was the ARM6, a device which has become the world standard RISC architecture for low-cost low power applications.

The ARM is built using what is known as a load/store architecture with 16 visible registers available to the programmer. In addition to these general purpose registers, there is a Current Programme Status Register available in every mode, and a Saved Programme Status Register for each non-user mode. In common with other RISC processors, ARM separates those instructions which perform data processing functions from those which move data between registers and memory.

This architecture is re-implemented on the AMULET 1 using a fully asynchronous design based upon micropipelines, and has resulted in a device which exactly copies the functionality of the ARM6, omitting only the coprocessor instructions and support for the 26-bit address space modes which the ARM6 has purely for backward compatibility with earlier versions. The processor used, however, a micropipelined interface between the chip and its environment.

This was done so that future versions could include a cache memory, and a micropipeline interface is a natural way to connect such memory to the processor core. (this choice of micropipelined interface made initial testing of the AMULET 1 very difficult, but on the AMULET 2 the interface circuitry will be placed on chip and so should not cause any problems) The top level interface of the AMULET 1 is shown in Fig.6. It shows how the AMULET is connected to the MMU and standard memory.

The functional units of the execution pipeline are shown in Fig.7. This diagram shows how the operands first pass through a multiplier. This unit either passes them on straight away or replaces them with partial product and partial carry outputs from a carry/save multiplication unit. One of the operands is then modified by a barrel shifter before placing both into a pipeline latch. The operands are then combined in the ALU which has a data dependent delay and a latch to allow a dynamic structure to operate with static external behaviour. The result latch then passes the output to its next destination.

The instruction decode and execution pipe control logic are also shown in Fig.7. Here the pipeline is shaded to highlight the structure. Prefetched instructions are queued before being passed to the primary decode logic which produces multiple pipeline bubbles for the more complex instructions, sends appropriate read/write addresses to the register bank for each bubble and passes information on to the secondary and tertiary decode logic.

The complete fully asynchronous pipelined structure of the AMULET 1 is shown in Fig.8. It was completely designed using computer aided design tools and tested thoroughly at component level using sophisticated computer simulations before committing the design to silicon. Despite some initial problems with the interface circuitry, the chip worked according to specifications with only a couple of very minor design flaws discovered so far in an extensive testing programme.

Fabrication of the chip was done at two sites using two different CMOS fabrication technologies. A 1um process was used by ES2 and a 0.7um process by GEC Plessey Semiconductors. The performance of these two versions and of a standard ARM6 are shown in the following table.

Table 1
AMULET & ARM performance figures

	AMULET 1 - ES2	AMULET 1 - GPS	ARM6
Process	1um	0.7um	1um
Area (mm)	5.5x4.1	3.9x2.9	4.1x2.7
Transistors	58,374	58,374	33,494
Performance	20.5k Dhrystones	40kDhrystones	31kDrhystones
Multiplier	5.3ns/bit	3ns/bit	25ns/bit
Conditions	5V,20C	5V,20C	5V,20MHz
Power	152mW	N/A	148mW
MIPS/W	77	N/A	120

Steve Furber's team at Manchester University, and Advanced RISC Machines have demonstrated with the AMULET 1 the world's first working asynchronous implementation of a real processor. In so doing, they have overcome many design hurdles and proved many of the conjectures about asynchronous systems; these all point to a very important future for such designs. They are now working on an enhanced version, AMULET 2, which will incorporate all the enhancements which they have developed as a result of working with the earlier version. The new version should be in silicon by the end of this year.

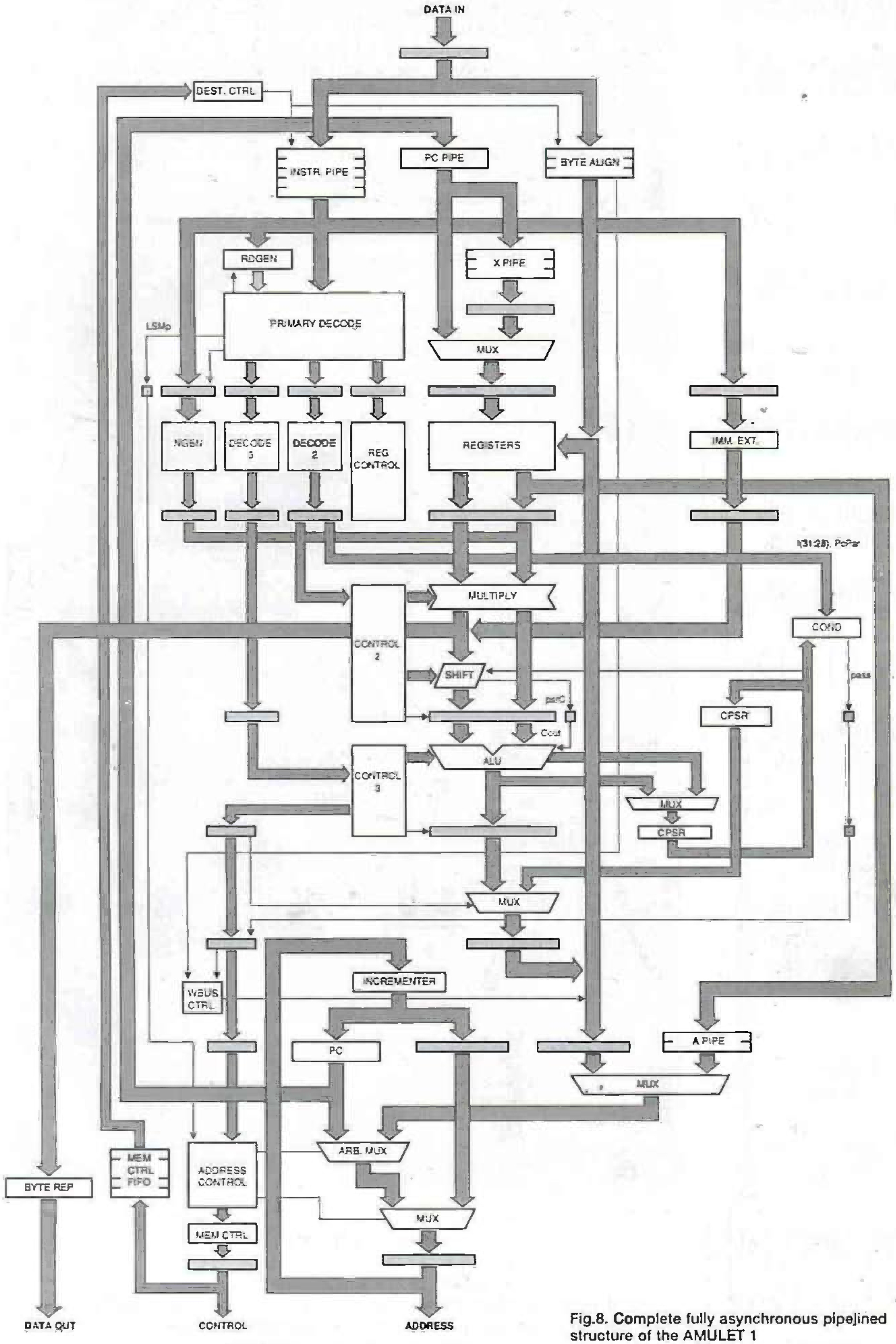


Fig.8. Complete fully asynchronous pipelined structure of the AMULET 1

Advanced RISC Machines

The ARM RISC processor was first designed and produced by Acorn Computer Group PLC exactly ten years ago. It was one of the first commercial RISC to be produced in the world and has since become one of the world's leading standard devices for use in high volume computing, communications and consumer electronics products.

The ARM processor and its family of derivative products is now designed and marketed by a three year old company called Advanced RISC Machines Ltd, or ARM Ltd. Acorn still own 42.78% of ARM, with an equally large shareholding being held by Apple Computer, with smaller 7% shareholdings by VLSI Technology, and Nippon Investment and Finance.

ARM Ltd do not manufacture the ARM chip; instead they design, develop and market the product at their Cambridge headquarters. The result is that ARM license a wide range of the world's leading semiconductor companies to produce both stand-alone ARM processors and other chip designs built around the ARM processor. The licensees who produce ARM based products include such as Texas Instruments, Samsung, Sharp, IBM, Digital Equipment Corporation, GEC/Plessey, Cirrus, VLSI, and AKM of Japan.

This strategy means that countless millions of ARM processors are being produced and used all around the world as part of some of the most sophisticated electronics products from the world's leading companies, with ARM getting royalty payments for each one produced. It is a strategy which has enabled the company to grow very rapidly and to become a leading force in the RISC technology world.

Indeed, one will find ARM processors all over the place, not just in the highly successful Acorn Archimedes range of computers. It is the processing heart of Apple's Newton and similar products produced by Sharp and Motorola. Schlumberger use the ARM in their data acquisition systems, and Spyrus and AT&T use it in their data scrambling systems. The ARM is also the main processor and controller in the highly acclaimed 3DO multimedia entertainment system produced by 3DO, Panasonic, Sanyo, Goldstar, and Creative Labs, whilst IBM use an ARM core embedded into its SSA interface chips. There are also a host of other applications which are still on the drawing board or in pre-production stages.

The success of ARM as a company can be demonstrated by the almost meteoric rise in its revenues, up from just £M1.2 in 1992 to £M7.2 in 1994, in the same period profits moved from a loss of £34,000 to a profit of £M3, and cash in the bank moved from £M1.3 to £M4.2. In the current year, the 1994 figures are expected to double. All of this has made ARM's parent company, Acorn, a darling of the City with a very bouyant share price.

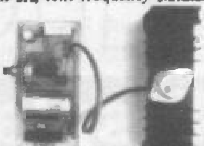
With patents to revolutionary world-beating technology, like the asynchronous ARM in their pocket, the company look set to take the world by storm. They have the technology, they have the right partners, and they have the City financiers behind them. Let's hope that they can show the world that British high technology companies are a force to be reckoned with!

Acknowledgements.

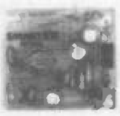
I would like to thank Professor Steve Furber of Manchester University for giving his time to explain a complex subject, and also the staff at Advanced RISC Machines in Cambridge for their assistance.

A mini FM transmitter, very high gain preamp, supplied complete with FET electret microphone. Designed to cover 88-108 Mhz but it is easy to change it to cover 63-130Mhz. Works with a common 9v (PP3) battery. 0.2W RF. £8.22 Kit no 1001.

Electronic siren kit with an impressive 5 watt power output. Ideal for car/bike alarms etc. 6-12vdc, max current 1A, tone frequency 1.2khz. £7.05 Kit no 1003.

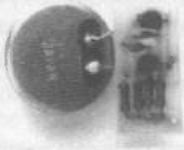


3-30v Power supply, variable, stabilized power supply for laboratory use. Shortcircuit protected, suitable for professional or amateur applications. 24v 3A transformer is also needed to complete the kit. £16.45 Kit no 1007.

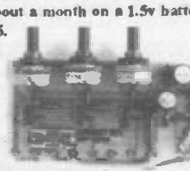


Powerful 1 watt FM transmitter supplied complete with piezoelectric microphone. 8-30vdc. At 25-30v you will get nearly 2 watts! £14.10 Kit no 1009.

FM/AM Scanner, well not quite you have to turn the knob yourself but you will hear things on this radio (even TV) that you would not hear on an ordinary radio!. Receiver covers 50-160Mhz both AM and FM. Built in 5 watt amplifier. £17.62 Kit no 1013.



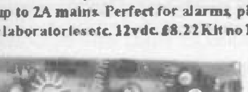
Mosquito repeller, modern way to keep midges at bay! Runs for about a month on a 1.5v battery. £8.22 Kit no 1015.



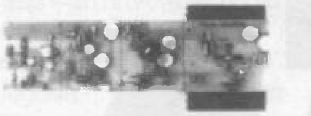
3 channel wireless sound to light system, mains operated, separate sensitivity adjustment for each channel, 1,200 watt power handling. Microphone included. £16.45 Kit no 1014.

Motorbike/cycle trembler alarm, adjustable sensitivity, preset alarm time, auto reset. Could be connected to bikes horn etc. £14.10 Kit no 1011

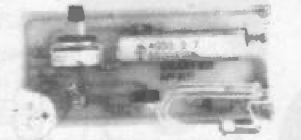
0-5 minute timer, adjustable from 0 to 5 mins, will switch up to 2A mains. Perfect for alarms, photographic laboratories etc. 12vdc. £8.22 Kit no 1020.



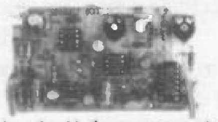
4 watt FM transmitter, small but powerful transmitter, 3 RF stages, microphone and an audio preamp include in kit. £23.50 Kit no 1028.



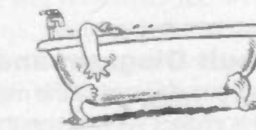
25 watt FM transmitter 4 RF stages, preamp required (our kit 1068 is suitable). Due to the complexity of the transmitter it is supplied in built up form only. £92.82 Kit no 1031.



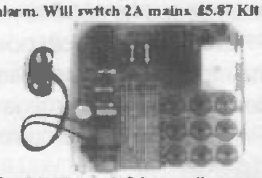
Strobe light, adjustable frequency from 1- to 60Hz (a lot faster than conventional strobes) mains operated. £18.80 Kit no 1037.



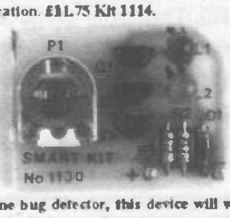
Ultrasonic radar ideal as a movement detector with a range of about 10 metres, automate your cat flap! 12v operation so ideal for cars, caravans etc. £16.45 Kit no 1049.



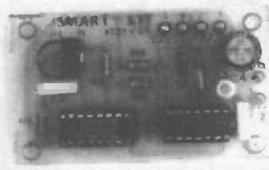
Liquid level detector useful for detecting fluid levels in tanks, fishponds, baths or as a rain or leak alarm. Will switch 2A mains. £5.87 Kit no 1081.



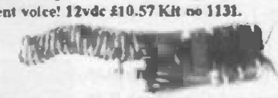
Combination lock 9 key, easily programmable. will switch 2A mains. Complete with keypad. 9v operation. £11.75 Kit 1114.



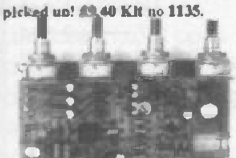
Phone bug detector, this device will warn you if somebody is eavesdropping on your phone line. £7.05 Kit no 1130.



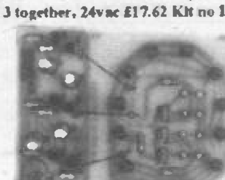
Robot voice, interesting circuit that distorts your voice! adjustable, answer the phone with a different voice! 12vdc £10.57 Kit no 1131.



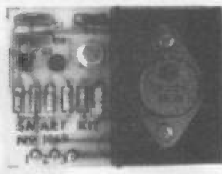
Telephone bug, small bug powered by the telephone line, starts transmitting as soon as the handset is picked up! £9.40 Kit no 1135.



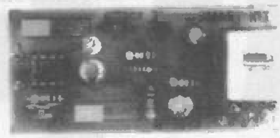
function generator, produces sinusoidal, sawtooth and square waves adjustable from 20hz-20khz, separate level controls for each shape. Will produce all 3 together, 24vac £17.62 Kit no 1008.



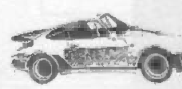
3 Channel light chaser, 800 watts per channel, speed and direction controls supplied with 12 leds and mains triacs, so you can use mains light bulbs if you want. 9-15vdc £19.97 Kit no 1026.



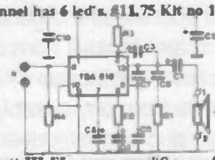
12v flourescent. A useful kit that will enable you to light 4' flourescent tubes from your car battery! (you will also need a 9v 2A transformer, not supplied) £9.40 Kit no 1069.



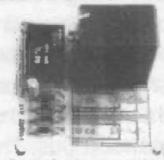
VOX switch, sound activated switch ideal for turning tape recorders on and off when sounds are heard. Makes the tape last a lot longer! adjustable sensitivity, built in delay. £9.40 Kit 1073.



Incar sound to light, Put some atmosphere in your car with this mini 3 channel sound to light. Each channel has 6 led's. £11.75 Kit no 1086.

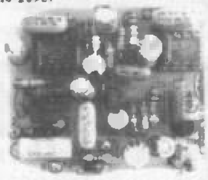


7 watt HI FI power amplifier useful, powerful, ideal for intercomms, audio systems, car use etc. 12-18vdc 500mA. £8.22 Kit No 1025.



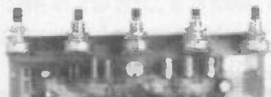
Phone call relay, useful device that operates a relay when ever the 'phone rings, could be used to operate more bells or signalling lights etc. Will switch mains at 2A. £11.75 Kit no 1122.

Lead acid charger, two automatic charging rates, visual indication of battery state, ideal for alarm systems, emergency lighting etc. 100mA 12vdc. £14.10 Kit no 1095.

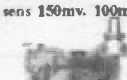


Car alarm system, works on voltage drop and/or vibration, entry and exit delays plus adjustable alarm duration. Good for cars, caravans etc. £14.10 Kit no 1019.

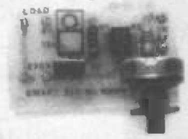
Portable alarm system, based on a mercury switch. The alarm continues to sound until the unit is disabled by the owner. Buzzer included. £12.92 Kit no 1150.



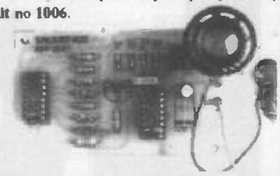
Preamp mixer, 3 input mono mixer, separate bass and treble controls plus independent level controls. 18vdc, input sens 150mv. 100mA. £17.62 Kit no 1052.



Mini metal detector, suitable for locating pipes in walls etc, range 15-20 cm, complete with case. 9v operation. £9.40 Kit no 1022.



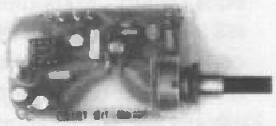
800 watt single channel sound to light kit, mains operated, add rhythm to your party for only £9.40 Kit no 1006.



Sound effects generator, produce sounds ranging from bird chips to sirens, complete with speaker, add sound effects to your projects for just £10.57 Kit no 1045.

Guitar preamp with tone controls, small enough to fit inside any guitar, based on TL082 1C, 9-12vdc, 50mA. £9.40 Kit no 1091.

15 watt FM transmitter, 4 stage high power, preamp required. 12-18vdc. Can use either ground plane, open dipole, or Yagi. Supplied in built form only at £81.07 Kit 1021.



Telephone amplifier, Very sensitive amplifier which uses a 'phone pickup coil (supplied) will let you follow a conversation without holding the phone. £12.92 Kit no 1059.

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3. Geiger counter kit, contains everything you need to build a working counter £22.32.
4. Solar energy kit, contains a solar panel, motor, buzzer and cable for experiments £5.87.
5. Electronic accupuncture kit, may help with migrane, poor circulation, backache etc. £8.22.
6. Electrifying apparatus kit, produces a weak adjustable high tension of 80-300v from a 9v battery, ideal for catching worms etc! £9.40.
7. Adapter bug kit, contains everything you need to build a professional bug built inside a standard 13A mains adapter! the bug is mains powered so it operates all the time the adapter is plugged in. Price is £16.45 for the complete kit including adapter. Hand tools and glue required.
8. Nicad charger kit automatic charger for cells from 1.2v to 15v, 7 settings 50600mA, transformer required 18-20v 600mA. £9.40.

9 & 10. Inverter kits, produce 240vac from a 12vdc supply, two versions are available a 15w one at £14.10, and an 80w version at £23.50.

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Large Scale Displays

Robin Abbott concludes his laser tag game project with a large character score display

This is the last part of the light gun project, but is of more general use as it addresses the general problem of driving large scale displays from a computer. It offers the following features: standard RS232 serial drive from any suitably equipped PC, computer or from the light gun central, driven on a 3 wire link (Power, Ground, and serial drive); it will drive four common anode or common cathode 7 segment displays driving up to 50mA/segment at up to 24v/segment; modules are stackable so that up to 16 digits can be driven from one serial port; stylised display of the entire ASCII character set; automatic scroll; command driven control of flash, dim, power up messages, display test, lower power mode. The prototype used 3" displays which are easily visible from a considerable distance, but any displays can be driven including the Velleman 8" high 7-segment display kits

Circuit Diagram and operation

The circuit diagram of the main circuit board is shown in figure 1. This project is based on the PIC16C84 which has on board EEPROM.The PIC uses a commonly available 3.58MHz colour crystal needed for accuracy on reception of serial data. The EEPROM is used to hold power up messages and the address of the module when modules are stacked. The PIC holds the code for a 7-segment image of the entire ASCII character set, an RS232 receiver and command decoder, and the display multiplexer.

The serial input signal is shaped and inverted by R1, TR15 and R2. The serial signal drives the interrupt input of the PIC. Incoming serial bytes are received and processed entirely on an interrupt routine. The multiplex driving routine is capable of executing entirely within the stop bit of a received character so that received serial data has no visible effect on the display. The

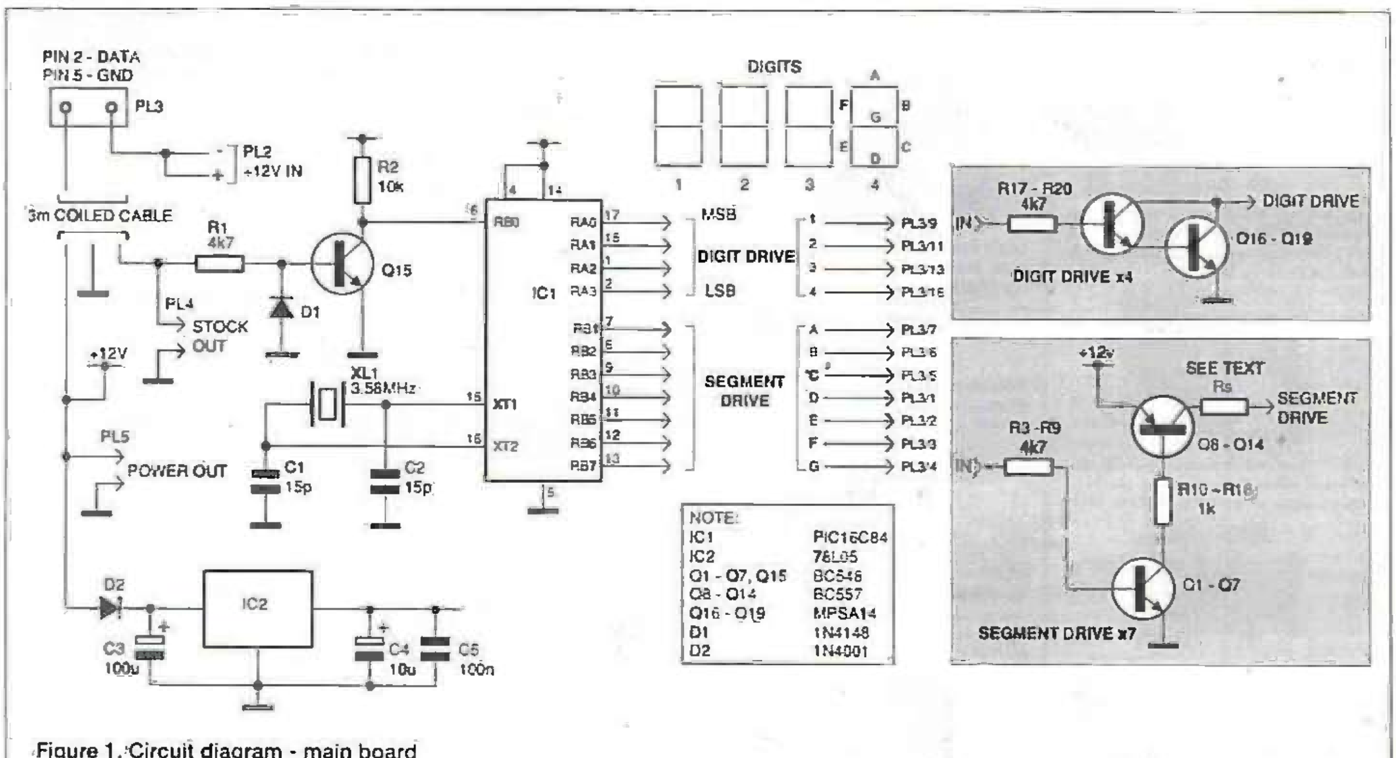


Figure 1. Circuit diagram - main board

module has an optional sleep mode which will turn off the display, reducing consumption to less than 5mA when no serial data has been received for four minutes, or immediately if commanded. In sleep mode, the majority of the power consumption is in IC2 (the power regulator); if IC2 is replaced by a 6v supply direct to the board then consumption will drop to around 40uA - the standard PIC sleep consumption. The PIC program supports watchdog operation which increases reliablity in brief power supply interruptions (which may not trigger the PIC reset circuitry); however if this is enabled (at program time) then the sleep mode will not be supported.

The displays are driven by a high going signal for both the segment and digit drivers. The segment drive for common cathode displays consists of an NPN and PNP transistor combination switching the positive supply rail, and a Darlington transistor switching the ground rail to the digits. Rs is the segment resistor which limits the current drive. The value of Rs is calculated as Rs=(Vs-Vl)/I, where Vs is the power supply to the module, Vl is the voltage drop across the LEDs and I is the required drive current per segment (V and I in volts and amps respectively). In the prototype, Rs was chosen as 160 ohms. For driving common anode displays, then the digit and segment drive circuits can be exchanged..In this case there will be seven Darlington transistors and four PNP/NPN pairs The segment drive resistors should be placed in series with the collectors of the Darlington transistors.

The displays are connected in parallel for the multiplexed drive to reduce the requirement for output drivers. The circuit diagram for the displays is shown in figure 2. Note that digit 1 is the least significant digit, on the extreme right.

The displays are driven on a 4mS multiplex cycle from the PIC. In dim mode, the displays are only driven for half the time, and in flash mode the displays are turned off for 250mS in every 500mS. When display modules are stacked, there is a power output socket and a serial output socket which are connected in parallel with the input power and serial data signals. The operation and addressing of stacked modules is described below.

Power supply to the PIC is from IC2, a 78L05. Power supply to the module can be from 10Vdc to 25Vdc dependant on the voltage requirement of the displays. At the higher levels, then the voltage rating of C3 should be increased. Power consumption of the prototype was 6mA when all displays were off, rising to 75mA when all segments were turned on in dim mode and 145mA with all segments turned on in bright mode. This was with Rs set to drive about 10mA per segment.

Construction

The PCB overlay for the main board is shown in figure 3. This is for the common cathode version. Use an IC socket for IC1 and an IC socket for display board interface cable. Construction is straightforward; there is only one wire link between IC1 and IC2. Fit this first, followed by resistors, diodes, transistors, capacitors, IC sockets and crystal.

The PIC should be programmed with the Intel Hex16 code shown in figure 4. This should be entered using a standard editor and saved as "LEDS.HEX" which can be read by any standard PIC programmer. The code includes checksums so that it should be impossible to enter incorrectly. Alternatively, the author is prepared to program PICs - see the end of the article for details. If your programmer is capable of programming EEPROM data area then the address can be programmed into EEPROM data location 00H, and the start up message into data locations 10H to 13H for digits 1 to 4 respectively. However, both these items may be programmed

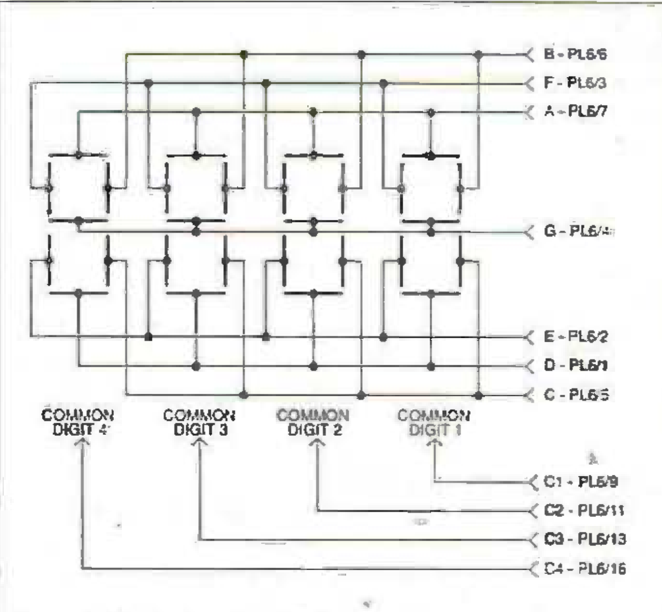


Figure 2. Circuit diagram - display

from the serial link as detailed below. If programming the device yourself, note that the WDT can be enabled or disabled at program time. If enabled, then the module will be more reliable at power up (crocodile clips on a battery seemed to upset the PIC power up reset circuitry spectacularly); however the sleep mode will not then be available

There is no PCB design shown for the display board as the module is expected to drive many different display types.The displays can be wired up on veroboard using hookup wire under the displays. PL6 should be mounted on the underside of the display board. If the Velleman 8" displays are used then use the common cathode version. Connect the input cathode signal on D1 of the display board to the positive on the display board with a 10K resistor, and drive the cathode pin with the digit drive. The segment drives can be connected directly to the module main board.

The link between the displays and the main board is a 16 way IDC cable with a 16 pin DIL header at each end which plugs into PL3 in the main board and into PL6 on the display board. In the prototype, the cable was soldered directly to the main display board connector pins and PL6 was not used.

The case used was Verobox type 201 painted black. The display board is mounted on the front face of the case and PL6 protrudes through a hole in the case. However, the case must be chosen to fit the displays used. The cable used to connect the module is 6m of coiled 3 way cable. Screen is ground, one conductor is for the serial link, and one conductor is for the power supply. As the prototype is intended for use with the light gun project, the serial data plug is intended to fit the central; pin 3 is the serial data output from the central. The power plug is wired into the coiled cable and connected inside the serial data plug. See figure 7. If the module is intended to be used for stacking, then PL4 and PL5 should be fitted into the case and wired to the input serial data and power supply connections.

For use with the light gun, the display module was intended for use in the field; it is fixed to a 2" belt with a clip for fixing to the nearest convenient tree.

Testing

Check the main module carefully, especially the segment drives - displays of the size used in the module are too expensive to blow too often!

Do not fit IC1. Connect the power supply and the display to the main board. Check that there is +5Vdc on pins 5 and 14 of the socket for IC1. Consult figure 1. Take a pair of stripped wires and short the digit drive pins of the socket one by one to +5V. Check that when the segment drive pins are shorted to +5V in turn, each of the segments on all of the displays illuminate and that there are no short circuits.

Remove power and insert IC1. Connect power and the display should immediately show 8888 for about 1 second before blanking; this is the power up diagnostic. Now wire the module to a computer. if you are not sure of the pin out of the serial port on your computer then measure the voltage on pins 2 and 3 of the serial port; the pin which has a voltage of around -8 to -12Vd

Computer connection

The module can be connected to a standard RS232 serial port using a three wire link (gnd, power and data); this should be connected to the module. Use a communications package on your computer, set to 9600 bits per second, no parity, one stop bit, no hardware flow control, no XON/XOFF signalling (the terminal program supplied free with Windows 3.1 is suitable on a PC). Check that characters typed on the PC are shown correctly on the display. The module runs at 9600 bits per second, and has not RTS/CTS (hardware) signalling. The module will operate with (but ignore) XON/XOFF

Commands

If characters from ASCII codes 32 to 127 are sent to the module, they will be displayed on the next digit as shown in figure 8. Text messages are stylised, but can be recognised fairly easily - avoid messages with X's and V's! When the module is powered up, the display position is set to digit 4; the next four characters received will be printed to digits 4, 3, 2 and 1 respectively. After this, the display is scrolled to the left and characters are printed to digit 1.

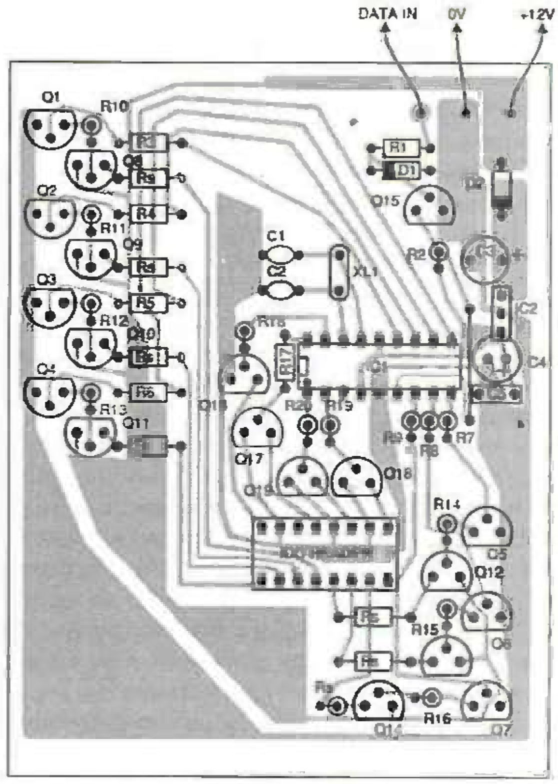


Figure 3. PCB overlay

Figure 9 shows the commands which can be sent to the module. Commands have ASCII numbers from 1 to 25. To send code 1 then the control and 'A' keys are pressed together; to send code 2 then control and 'B' are pressed etc. These control keys are shown in figure 9.

The following commands are of note. Command 10 (Ctrl+J) clears the display and sets the print position to digit 4.

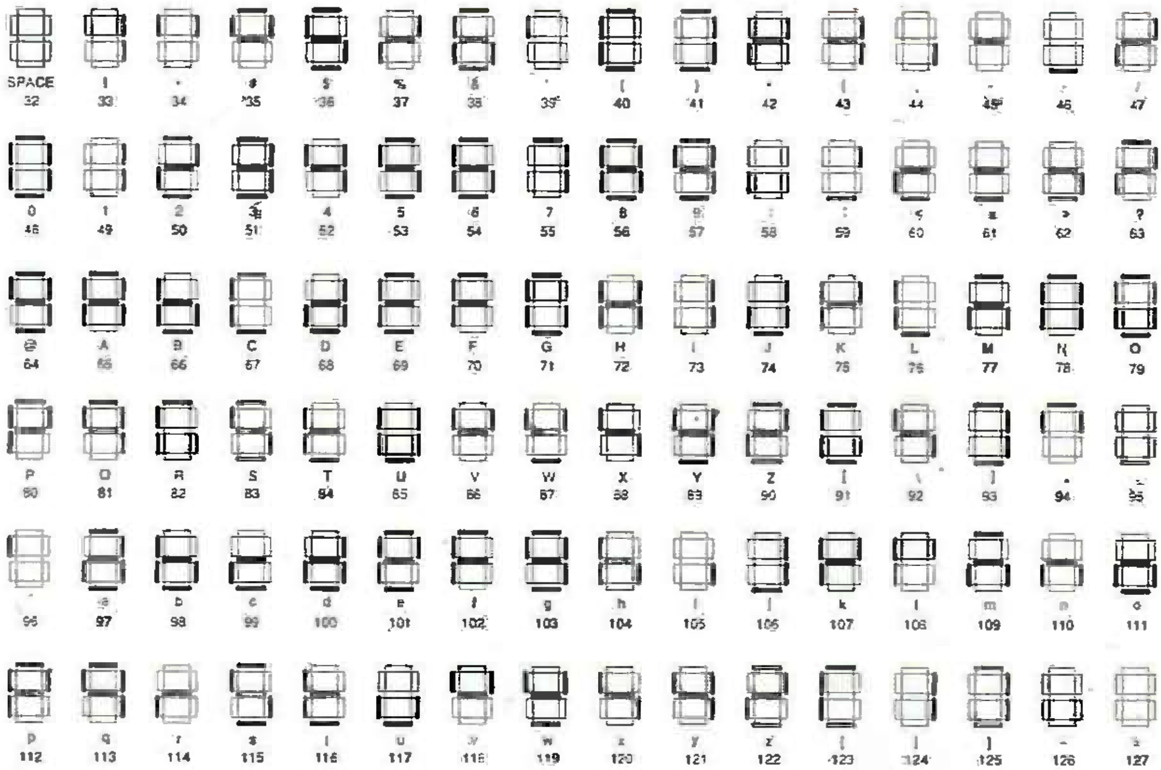


Figure 8. 7-segment display diagram

Command 14 (Ctrl+N) sends the module to sleep, turning the display off. However, if the watchdog timer is enabled, then this will not operate. Any character received will enable the display and wake up the module. Command 23 and 24 (Ctrl+W/X) will enable or disable flashing and dim mode respectively. Follow the command with the numbers 0 or 1 (ASCII code 48 or 49); 0 will disable the mode, 1 will enable it.

You can send any pattern you like to the display. Send commands 1 to 4 (Ctrl+A to D) for digits 1 to 4 respectively and follow the command with a data byte. The data byte should have a '1' set in each bit position to turn on a segment where bit 0 is segment 'A', and bit 6 is segment 'G'. So, to turn on segment 'G' of digit 4, send the ASCII codes 4 then 64. (Ctrl+D followed by by '@').It is possible to set a message to be displayed automatically after the power up display. To do this, set up the display to show the message displayed after power up using characters or the bit commands Ctrl A to Ctrl D. Then send command 25 (Ctrl+Y) This will write the bit pattern to EEPROM and it will be displayed after the power up display diagnostic. Note that this is the one command which causes the display to flicker momentarily as the program suspends execution whilst writing to EEPROM; incoming commands are also ignored for a maximum time of 40mS.

Multiple displays

In normal operation with one module, there is no need to worry about module addresses. The module powers up, responding to all commands and text. To use stacked modules, it is possible to operate in one of two modes. In the first mode, all commands are actioned by all stacked modules, in the second mode only one of the stacked modules will respond to commands.

To set the address of the module the command 5 (Ctrl+E) is used, followed by the address which is to be programmed into EEPROM. This address will now be held through a power down. The address can be any number from 1 to 255. Each module which is stacked should be set to a different address, and the address should be set with only one module connected to the PC (otherwise all connected modules will respond and set themselves to the same address!).

To select a specific module the command 6 (Ctrl+F) is used, followed by the address of the module to be selected. Now only that module will respond to any commands sent. The one command which will still be actioned by all modules is command 6, thus different modules can be selected. If module address 0 is selected then all modules will respond to all commands until a specific module is selected again.

As an example, if modules 1 and 2 are stacked then to set module 1 to display 1234, and module 2 to display 4567, the following bytes should be sent to the modules:6,1,49,50,51,52,6,2,53,54,55,56

Example control program

Fig 10 shows a simple example program which may be used to control one or more modules. It is not very sophisticated, but demonstrates the techniques used to communicate with the

PIC 16C84 Code for Large Display

```
:040000002B280200A7
:080008008C008C0E030E8D002C
:0800100008309800212029208E
:0800180003100618031497 0CF5
:080020000980B0B282F1F922200
:080028002F131B089C00FE30A1
:080030009605061C1928F830A2
:080038008B050D0E83000C0E78
:0800400009000B300000000074
:080048009900990B2528AF1166
:08005000080001A30242885 0184
:080058008601831664008230 6A
:08006000810000308500013031
:0800680086008312AF01013094
:080070009200FF308E008F00AA
:0800780090009100AF159A0100
:080080008101950196012F1585
:0800880002309B009C00000106
:08009000CC22A100A001903078
:080098008B00AF1E5628AF12C9
:0800A000850186012F176300A2
:0800A800031E5328811F5C2890
:0800B000AF1C5E20AF144D28C7
:0800B800AF104D286400950F04
:0800C0006828960A0319852047
:0800C800AF1D6828AF118B2069
:0800D00086010310920D0F30B0
:0800D800AF1BFF309205120876
:0800E0000319013092000F39F1
:0800E800850005180E088518BB
:0800F0000F080519100885191D
:0800F80011089300130D2F1CE9
:08010000832816180800860090
:0801080008002F1D08009C0BFC
:080110000800AF16080010300D2
:08011800CC228E000E0A03192F
:08012000522A890ACD228F004A
:08012800890ACD229000890A2A
:06013000CD229100562AC9
:08040000213422342434263497
:0804080028347F347A342134DA
:08041000213433345234383436
:0804180021345634583421341C
:080420005A3421342134213447
:0804280044344B3466346E3499
:080430007434853421342134B9
:08043800213421342134213468
:08044000820008000E30292A99
:080448000F30292A1030292A87
:0804500011309D002F162E3023
:080458009E0008001D0884004D
:080460001708800008009A0350
:080468009A1F08009A014B2ABB
:0804700004301A020319422AAC
:080478001A08003C113E84004B
:080480009A0A08000E30840006
:08048800100891000F0890001C
:080490000E088F0008000F08A0
:080498008E0010088F0011080E
:0804A0000900008008E018F019D
:0804A800900191019A01080086
:0804B000AF1608005E309E004B
:0804B8002F16080017089B0035
:0804C0002F15003C031D08008C
:0804C8002F1108006A309B00AC
:0804D0002F160800170803397C
:0804D8009A0008007030672A49
:0804E0002F1017182F1408005B
:0804E8007630672AAF131718E4
:0804F000AF1708007C30672AF9
:0804F8001708A0000800813084
:08050000672A1708A100890118
:08050800BD2A103089000E0825
:08051000BD22890A0F08BD227B
:08051800890A1008BD22890ABE
:080520001108BD2AA00803190F
:080528009F2A2F1AA12A0630B8
:08053000170203199F2A20089D
:080538002102031D08002F1E23
:08054000A62A2F1202308A00E6
:080548001E088200203017029A
:080550000318AF2A02308A00F3
:0805580017082022820038225E
:080560009713203097020 31CE1
:080568000800B8228000080021
:0805700003308A0017088038EF
:080578008200880083160812BE
:08058000081555308900AA306E
:08058800890088146400881842
:08059000C62A081183120800BD
:08059800890083160814831288
:0405A000080808003F
:08070000003406342234633496
:080708006D3452347D3420348D
:0807100039340F345234463431
:08071800043440340834523 46B
:080720003F3406345B344F3412
:0807280066346D347D340734A2
:080730007F346F3410340A34E9
:08073800583448344C345334AA
:080740006F3477347C34393446
:080748005E34793471343D3454
:08075000763406341E347234C5
:0807580038345534373 43F34C6
:080760007334673431346D3449
:0807680078343E3462346A3437
:0807700064346E345B3439344B
:0807780064340F34233408340B
:0807800020345F347C3458344E
:080788005E347B3471346F34E0
:08079000743404340E34723499
:080798003034553454345C3454
:0807A0007334673450346D34EA
:0807A80078341C3462346A3419
:0807B00064346E345B3439340B
:0807B80064340F3400340034F6
:00000001FF
```

module. It is written in QBASIC which is supplied with DOS on PCs (QBASIC is similar to other BASIC languages). It only supports ports COM1 or COM2. The program allows messages to be displayed, dim and flash modes to be toggled, and the start up message and module address can be programmed. It also supports message scrolling - long messages will be scrolled across the display repeatedly until commanded to stop. Note the line which reads:

```
FOR I=0 to 3000: NEXT I
```

This is a very crude time delay chosen for a 486/33, increase or decrease the value 3000 to match the scrolling speed with faster or slower PCs respectively.

Use with the Light Gun Central

The light gun central is set up to use this external display directly. Simply plug the display into the serial and power sockets in the rear of the central. The display must be enabled with the configuration menu option. (Press 'C' at the copyright prompt, enter the password '1986' and then reply 'Yes' to the external display prompt).

PIC programming

The author is prepared to program and test PICs with the code for this project. Send a PIC16C84, return packaging with postage, and a cheque for £4.00 to Robin Abbott, 37 Plantation Drive, Christchurch, Dorset. BH23 5SG. Please state whether the watchdog timer is to be enabled or disabled.

Programme 1

```
ln$ = CHR$(10): mdim = 48: flash = 48
COLOR 15, 1

CLS : PRINT ln$, "Enter COM Port Number (1 or
2)"
DO: a$ = INKEY$: LOOP UNTIL a$ = "1" OR a$ =
"2"
OPEN "com" + a$ +
":9600,n,8,1,bin,cd0,cs0,ds0,op0,rs" FOR
OUTPUT AS #1
CLS
DO
 CLS
 PRINT
 PRINT , "     EXTERNAL DISPLAY MODULE -
OPTIONS"
 PRINT , "
=================================" + ln$
 PRINT , "M - Scroll Message"
 PRINT , "D - Toggle Dim"
 PRINT , "F - Toggle Flash"
 PRINT , "C - Clear module"
 PRINT , "H - Choose module"
 PRINT
 PRINT , "S - Set current display as start up
message"
 PRINT , "A - Set Module Address into EEPROM"
 PRINT
 PRINT , "Q - Exit"
 DO: a$ = INKEY$: LOOP UNTIL a$ <> ""

 CLS : PRINT
 SELECT CASE UCASE$(a$)
 CASE "M": LINE INPUT " Message to scroll ? >
", ms$
          PRINT #1, ln$; MID$(ms$, 1, 4);
          IF (LEN(ms$) > 4) THEN
           CLS
           PRINT ln$; " Scrolling"; ln$, ">";
ms$; "<"
           PRINT ln$ + " .....Press key to
stop"
           ms$ = ms$ + " "
           ppos = 5
           WHILE (INKEY$ = "")
            PRINT #1, MID$(ms$, ppos, 1);
            ppos = ppos + 1: IF (ppos >
LEN(ms$)) THEN ppos = 1
            FOR i = 0 TO 3000: NEXT i
           WEND
          END IF
 CASE "D": mdim = mdim XOR 1: PRINT #1,
CHR$(24); CHR$(mdim);
 CASE "F": flash = flash XOR 1: PRINT #1,
CHR$(23); CHR$(flash);
 CASE "C": PRINT #1, ln$;
 CASE "S": PRINT #1, CHR$(25);
 CASE "H": INPUT " Choose Module to address (0
for all) ? > ", mn
          PRINT #1, CHR$(6); CHR$(mn);
 CASE "A": INPUT " Set Module Address ? > ",
mn: PRINT #1, CHR$(5); CHR$(mn);
 CASE "Q": EXIT DO
 END SELECT
LOOP UNTIL 0
```

PARTS LIST

Resistors

R1, 3-9, 17-20	4K7
R2	10K
R10-16	1K
Rs (7 off)	See text

Capacitors

C1-2	15pF (Ceramic)
C3	100uF (16V Electrolytic)
C4	10uF
C5	100nF (Ceramic)

Semiconductors

IC1	PIC16C84
IC2	78L05
TR1-7, 15	BC548
TR8-14	BC557
TR16-19	MPSA14
DISP 1-4	See text
D1	1N4148
D2	1N4001

Miscellaneous

Case	
PCB	
Coiled cable	3-way
PL1	16pin DIL IC socket
PL2	2.1mm power plug
PL3	9-way D connector
PL4	9-way D connector (optional)
PL5	2.1mm power socket (optional)
PL6	16 pin DIL IC socket
XL1	3.58MHz crystal
16-way IDC cable	
16-pin DIL IDC header	
Fixing hardware	
1.5m 2" belt	
Rucksack fixing clip	
18-pin IC socket (IC1)	

Table Of Multiple LED Display Commands

ASCII codes 1-31 - These are control codes with the following meanings:

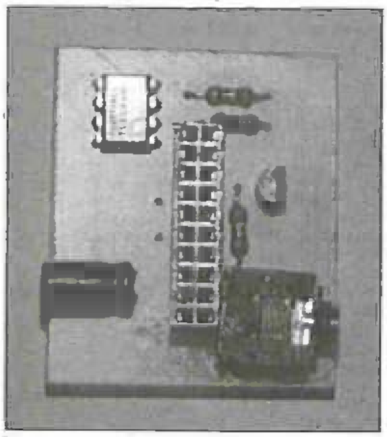
Code	Ctrl +	Extra bytes	Meaning
1	A	1	The following byte is printed directly as data to digit 1. Segment A is bit 0 (LSB), and segment G bit 6 (MSB). E.G. to send the numeral 2 to digit 1 then send the bytes 01H,5BH
2	B	1	As code 1 for digit 2
3	C	1	As code 1 for digit 3
4	D	1	As code 1 for digit 4
5	E	1	Set module address to the following byte (any number but 0 may be used). This address is written into EEPROM and is read every time the module powers up.
6	F	1	The following byte is the address of the only module which will respond to any following commands or text. The only command actioned by a module which does not have the specified address is this command - command 6. If the following byte is 0 then all stacked modules will respond to all following commands and text.
7	G	0	Not Used
8	H	0	Not Used
9	I	0	Move print position left one digit, if already at digit 4 then scroll right
10	J	0	Clear display, set print position to digit 4
11	K	0	Move print position right one digit, if at digit 1 then scroll left
12	L	0	Not Used
13	M	0	Set print position to digit 4
14	N	0	Send module to sleep - turn off display and enter PIC sleep mode, consumption, wake up and turn on display on receipt of next character. No effect if watch dog is enabled
15	O	0	Null - will not be used in future versions of the software, useful to wake up display
16	P	1	Set sleep time in units of about 2.5 minutes - if parameter is 0 then never go to sleep, if parameter is greater than 0 then send module to sleep after this time if no input occurs. E.g. time=2 will sleep after about 5 minutes.
17	Q	0	Not Used
18	R	0	Not Used
19	S	0	Not Used
20	T	0	Scroll display left one character - leave print position
21	U	0	Scroll display right one character - leave print position
22	V	1	Set print position to following number, 0 is digit 4, 3 is digit 1 etc.
23	W	1	Flash Mode, if following byte is even then turn flash mode off, if the byte is odd then turn flash mode on
24	X	1	Dim Mode, if following byte is even then turn dim mode off, if the byte is odd then turn dim mode on
25	Y	0	Write the information currently displayed to EEPROM for use as the start up message on power up.
26	Z	0	Not Used

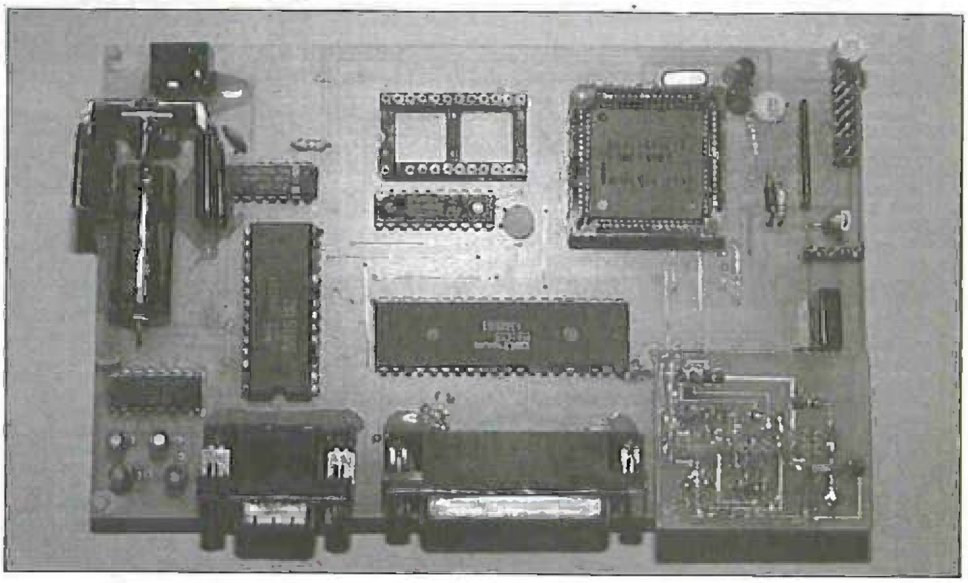
ASSCII codes 32-127

Characters which have codes from 32 to 127 are printed to the display. Printing starts at digit 4 and moves across to digit 1 at which point further characters are printed at digit 1 and the display is scrolled left.

Serial ADC for Virtual Instrumentation

Another add-on module for the ETI 80188 single board computer by Richard Grodzik





This analog to digital converter module, only two inches square, plugs directly onto the module connector pins of the 80188 embedded controller board. It provides a serial RS232 output at 9600 baud for an input voltage range of 0 - 5 volts. The raw RS232 data (00 - FFH),sent to the serial port (COM1) of a PC, represents an analogue input voltage with a resolution of 20 mV/bit; (FFH)255 decimal representing a full scale voltage of 5000 mV. In order to produce a meaningful representation of this data, a virtual instrumentation program is available which runs on any MSDOS machine.

What is Virtual Instrumentation? Well, it is a means of graphically representing, on a PC's screen, a measuring instrument such as a multimeter. In this case, a visual image of an analogue meter and pointer is presented to the viewer, as well as a precise digital indication. This combination of analogue and digital readouts is a real-time mimic of actual hardware meters which, of course do not exist, except on the PC's screen. Moreover, this is all achieved in software, so that the possibilities of facia appearance, size, colour, legend, scales and ergonomic considerations are infinitely variable, requiring only modifications in software. The need for stand-alone instruments is negated, since they can all be represented in pictorial 'mimic' form on the PC's screen.

Module Concept

The 80188 embedded controller board was designed to accommodate plug-in modules. For this purpose a dual row of 0.1 inch pitch connectors (10 x 10), is provided alongside the parallel port - the 'MODULE AREA'. These pins are connected to I/O lines as follows:

0v	0v
Timer out 1	Timer out 0
Timer in 1	Timer in 0
+5v	+5v
PC3	PC4
PB7	PB6
PB5	PB4
PB3	PB2
PB1	PB0
0V	0V

A mating socket (double row top entry 10 + 10), available from Farnell Electronics 148-526 or Rapid Electronics, is soldered to the module PCB, allowing easy interchange of modules. Note that the pin connections are 'mirrored' because the

Serial ADC

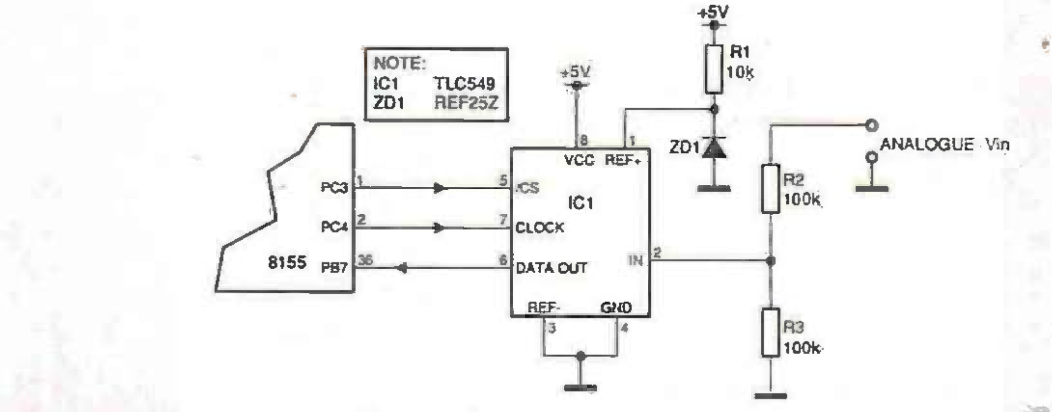


Fig.1. Circuit diagram for ADC module

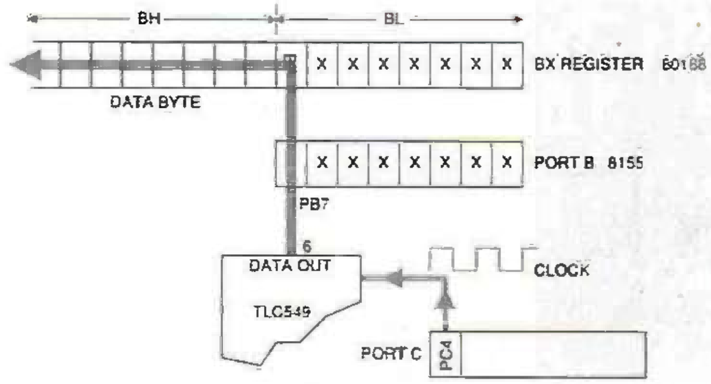


Fig.2. Data input

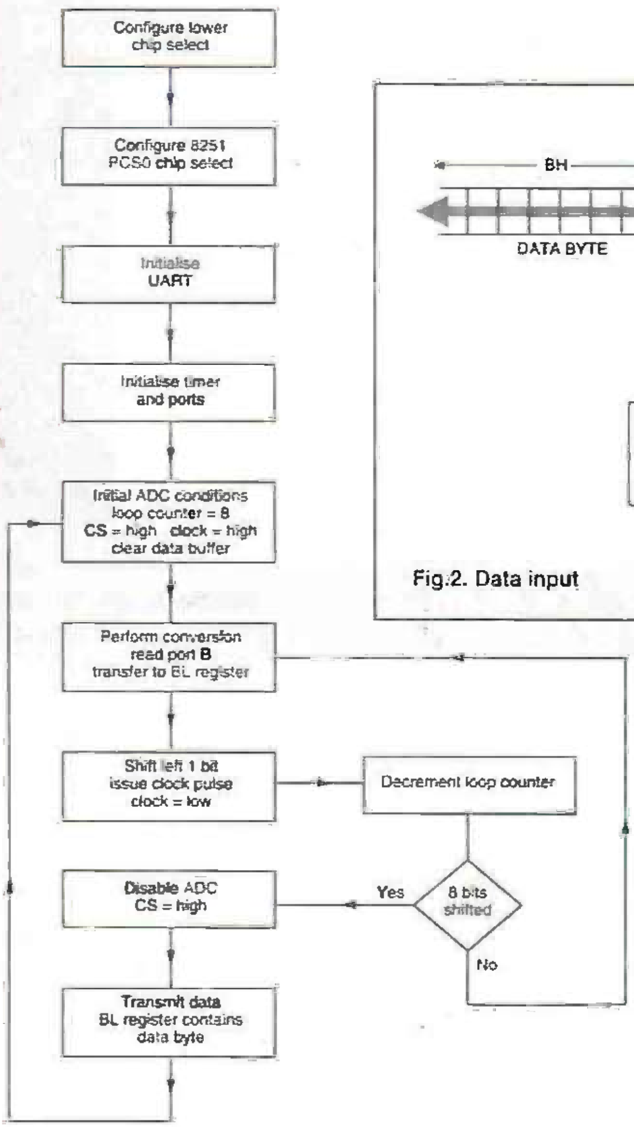


Fig.3. Flow chart of ADC code

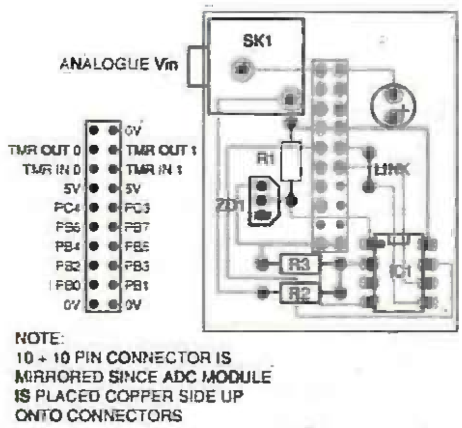


Fig.4. Component overlay and connector for ADC module

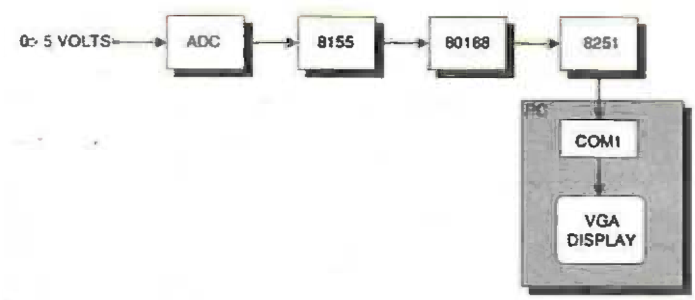


Fig.5. Data flow diagram

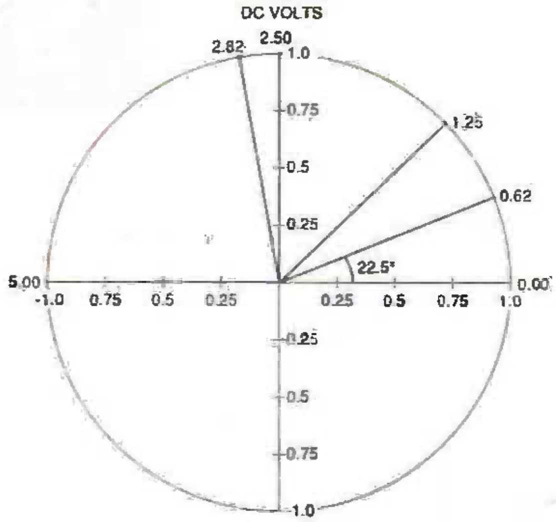


Fig.6. Rotating vectors

module board sits in the module socket in an inverted position i.e. copper side up.

Description

The A to D converter module is based on the TLC549 8 bit resolution 8 pin DIL IC with a serial output. A potential divider resistor network of two 100K resistors across the analogue input produce a voltage on pin 2 of half the input voltage. A reference diode REF25Z provides a 2.5 volt reference for the converter, giving a maximum input voltage of 5 volts. The reference voltage is sufficiently stable for most purposes and slight variations are easily offset in software.

Interfacing of the ADC chip consists of three lines: CS (chip select) - active low to enable the internal circuitry and allow conversion to take place; CLK IN (clock input)-eight clock cycles applied to this input shift out the eight bits of the conversion, the most significant bit (D7) being clocked out first, with least significant bits following; DATA OUT-The 8 bit serial data stream representing the converted analogue value (11111111B) for a maximum input voltage of 5 volts is fed to port line PB7 of the 8155 PIO.

There is a problem, however - how to convert the serial information to a parallel data byte which can then be easily manipulated and written to a memory location or register. Diagram ADC2 shows how this is achieved. Use is made of a 16 bit register (BX) by the 80188. As each data bit is clocked out of the TLC549, it is received by bit 7 of port B. This bit is copied to the BL register and a left shift operation is performed, pushing the bit into the BH register. This process is repeated eight times until the BH register is filled.

Note that when reading port B, all eight bits of port B are loaded into the BL register. However only the most significant bit (the serial bit) Bit 7 is valid and bits 0 to 6 are lost. Once the BH register if full, a conversion is completed, and the constructed byte is then sent via the 8251 UART to the serial port of the PC. No calibration is necessary, since again, all scaling and conversion is performed by the virtual instrumentation software (ADC_3.EXE).

Operation

Once the PCB has been populated and soldered, it is simply plugged onto the module pins - these should be phosphor bronze type since turned pins will break off easily. The source code (ADC.ASM) is assembled producing an object file (ADC.BIN) which is then sent to the EPROM emulator. Meanwhile, the MSDOS file (ADC_3.exe) is installed on the PC and run by typing ADC_3 <ENTER>. Connect the serial lead from the 80188 controller's serial socket to COM1 port of the PC. Applying an input voltage (d.c) to the ADC module will result in digital and analogue voltage being displayed on the monitor.

Programme 1

```
;ADC ROUTINE
;CONVERT INPUT VOLTAGE (RANGE 0-5V)
;AND SEND VIA RS232 LINE AT 9600 BAUD TO PC

CODE SEGMENT
ASSUME CS:CODE
ORG 0

ORG 0400H

   MOV SP,0FFH
   MOV DX,0FFA2H          ;LMCS 8155 CHIP SELECT
   MOV AX,038H
   OUT DX,AX

   MOV DX,0FFA4H          ;PCS0 8251 CHIP SELECT
   MOV AX,0F8H
   OUT DX,AX

   MOV DX,0FFA8H
   MOV AX,081B8H
   OUT DX,AX

   CALL USART             ;INITIALISE UART TO
                             TRANSMIT
   CALL TIMERPORTS        ;INITIALISE PORTS AND
                             TIMER

CYCLE:
   MOV BH,0               ;CLEAR DATA REGISTER
   MOV DI,0103H           ;PORT C
   MOV AL,08H             ;STOP ADC,CS HIGH
   MOV [DI],AL
   CALL DELAY

   MOV CX,8               ;LOOP COUNTER = 8

CONVERT:
   MOV DI,0103H           ;PORT C
   MOV AL,010H            ;CLOCK HIGH
   MOV [DI],AL

   CALL DELAY

   MOV SI,0102H           ;READ PORT B
   MOV BL,[SI]
   SHL BX,1               ;SHIFT DATA BIT LEFT

   MOV AL,0               ;CLOCK LOW
   MOV [DI],AL
   CALL DELAY

   LOOP CONVERT           ;REPEAT FOR 8 CLOCK
                             CYCLES
   mov al,08h             ;stop conversion
   mov [di],al            ;CS HIGH

CALL TRANSMIT             ;TRANSMIT BYTE FROM
                             USART
CALL TDELAY
   JMP CYCLE              ;REPEAT FOREVER

DELAY PROC NEAR
   PUSH CX
   MOV CX,10 EOC: LOOP EOC
   POP CX
   RET DELAY ENDP
   TDELAY PROC NEAR
   MOV CX,0FFFH EOCP:LOOP EOCP
   RET TDELAY ENDP
   TRANSMIT               PROC NEAR


   MOV DX,0C00H           ;USART DATA BUFFER
   MOV AL,BH
   ;REGISTER BH CONTAINS DATA BYTE
   OUT DX,AL              ;TRANSMIT


   POLL:MOV DX,0C01H      ;CHECK TO SEE IF TX
                             BUFFER IS EMPTY
   IN AL,DX               ;BY POLLING TXRDY FLAG
                             BIT
   AND AL,1
   CMP AL,1
   JNZ POLL
   RET
TRANSMIT ENDP

USART PROC NEAR           ;CONFIGURE RS232 PROTOCOL
   MOV AL,04FH
   MOV DX,0C01H
   OUT DX,AL

   MOV AL,3
   OUT DX,AL
   RET USART ENDP

TIMERPORTS PROC NEAR      ;CONFIGURE 8155 PORTS
   MOV DI,0105H
   MOV AL,040H
   MOV [DI],AL

   MOV DI,0104H
   MOV AL,9               ;8155 TIMER DIVISOR FOR
                             USART CLOCK
   MOV [DI],AL

   MOV DI,0100H           ;PORT COMMAND
   MOV AL,0CDH            ;PORT B INPUT,PORT C
                             OUTPUT
   MOV [DI],AL            ;PC3=CE
                             PC4=CLOCK
                                 PB7=DATA BIT
   RET
TIMERPORTS ENDP
   ORG 07F0H              ;80188 Reset vector
                             FFFF0H JMP
                                 0FFC0H:0000
   ORG 0800H              ;FILE SIZE=2048 (2
                             KBYTES)
CODE ENDS
```

A floppy disk (MSDOS 3-1/2 in.),containing all the source code,object code and printable PCB files for the 80188 embedded controller and add-on modules, is available from: R.Grodzik (MICROS), 53 Chelmsford Road, Bradford BD3 8QN. Price £12.50 P&P inc.

Next Month...

Next month we look at how to generate the virtual instrumentation display

Switch regulators

Last month, Dave Bradshaw looked at the design and construction of some simple switch regulators. Here, he looks at 6.3V and 25V versions, along with variable voltage regulators

In the last issue of ETI we looked at the design and construction of a simple switcher voltage regulator. Such regulators can for the basis of many efficient and versatile power supply systems. This month we look at the construction of 6.3V and 25V versions, as well as a variable switch voltage regulator. Continuing on from last month Figure 8 shows the slightly different circuits for these versions, and Figure 9 the required PCB layout. Tables 4 and 5 give the values for C1 and L1, and Table 6 gives the resistor values.

Since there are no fixed-voltage versions of the regulator IC for 6.3 or 25V, the circuit uses the LM2575-ADJ (1A max) or LM2576-ADJ adjustable voltage version with a fixed attenuator (R1-3) between the output voltage at C4 and the feedback input. The attenuator reduces the feedback voltage to 1.23V, which is equal to the IC's own reference voltage, generated by an internal band-gap diode. The attenuator uses three resistors to get the attenuation as close as possible to the value required.

If all the component values are spot on, the output voltages will be 6.27 and 25.01 volts (using 240ohm for R3 makes the first voltage 6.29V). However, the resistors have a finite tolerance (nowadays, 1% is usual) and the IC's internal reference voltage also has a tolerance of around 3%. The output voltages should therefore be within 5% of the target voltages; if this is not sufficiently accurate, an 'trimable' variable voltage version of the supply can be used.

Trimable and variable voltage regulators

The LM2576-ADJ will supply voltages as low as 1.23V and up to 37V, depending on the unregulated input and the other values used. The main difference is in the feedback, which replaces R2 with a variable resistor, RV1, so making the attenuator adjustable.

There are two ways of using this circuit:

•as a fixed but 'trimable' supply; in other words a supply that can be accurately adjusted to make up for

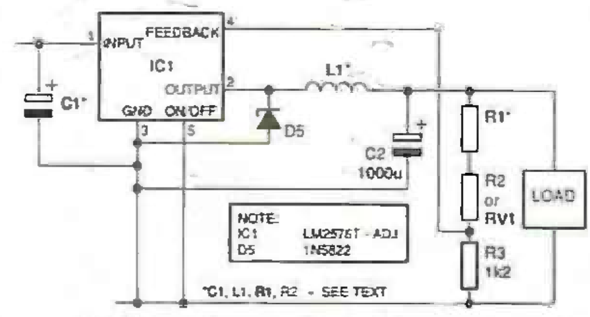


Fig 8. Modifications to the basic circuit to give adjustable voltages (and to give 6.3V output). The resistor network modifies the amount of the output voltage that is fed back to the sensor input.

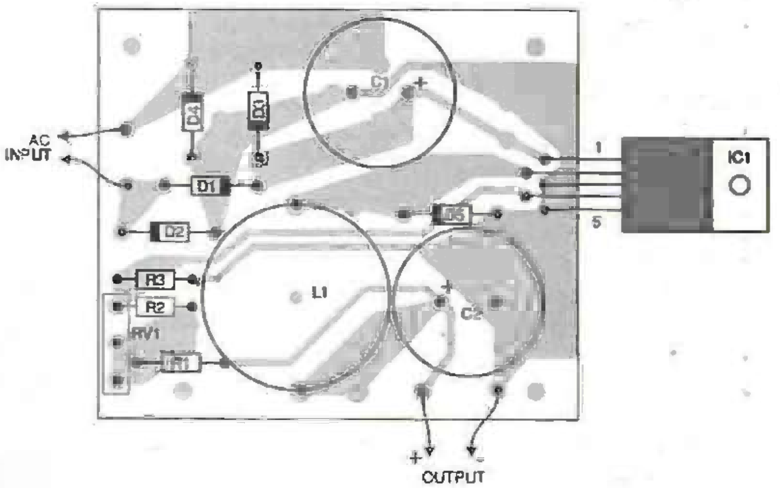


Fig 9. PCB layout for the variable voltage version. Note that RV1 can be a preset or full-sized potentiometer mounted on the board, or mounted entirely off board. However, leads should be kept as short as possible if it is mounted off board.

Table 1
C1 and L1 values for 5V

Transformer voltage	9	12	15	18	22	25, 28, 30
C1 for 1A (uF)	4,700	1,000	470	330	220	220
C1 for 2A (uF)	10,000	2,200	680	680	470	220
C1 for 3A (uF)	12,000	3,300	1,500	1,000	470	330
L1 for 1A (uH)	220	220	330	330	330	330
L1 for 2A (uH)	100	100	150	150	150	150
L1 for 3A (uH)	68	100	100	100	100	100

Table 2
C1 and L1 values for 12V

Transformer voltage	15	18	22	25	28,30
C1 for 1A (uF)	3,300	1,000	470	330	220
C1 for 2A (uF)	6,800	2,200	1,000	680	470
C1 for 3A (uF)	10,000	3,300	1,500	1,000	680
L1 for 1A (uH)	330	330	470	680	680
L1 for 2A (uH)	150	220	220	330	470
L1 for 3A (uH)	100	150	150	220	220

Table 3
C1 and L1 values for 15V

Transformer voltage	18	22	25	28,30
C1 for 1A (uF)	2,200	1,000	470	330
C1 for 2A (uF)	4,700	2,200	1,000	680
C1 for 3A (uF)	6,800	2,200	1,500	1,000
L1 for 1A (uH)	330	470	680	680
L1 for 2A (uH)	220	330	330	330
L1 for 3A (uH)	150	150	220	220

component tolerances
*as a wide output range supply, e.g. for a bench power.
The circuit for these two applications is quite similar, but the balance between the component values is very different.

Starting with the trimable supplies, Table 7 shows the values of RV1 and R1 for the different output voltages already. R3 is 1k2 for all the trimable versions, and all other component values are the same as for the fixed versions. Using the values shown, the potentiometer has a range of at least ±4%, and in some cases rather more.

The fully variable version uses a different value for R3 and no (or rather, short-circuited) R1. RV1 is 22k, and all the other component values are as the 25V fixed version. On paper, these values give an output range of 1.23V to around 28V. Of course, whether or not the top of the output range can be realised depends on the input to the regulator. If the input is up to it, you could try for the absolute maximum output with R1=1k5 and RV1=47k.

Regulators

This design is a straight-forward application of National Semiconductor's Simple Switcher TM series of step-down voltage regulators. At the expense of a few extra components, these regulators give higher output currents and less heat dissipation than the ubiquitous 78 series of linear regulators. NatSemi's regulators can supply fixed and variable voltages at maximum currents of 0.5, 1 and 3 amps; this design suits the LM2575 (1A) and LM2576 (3A) series. The LM2574 series (0.5A) have a different package and pin-out, but are otherwise very similar.
Voltage step-down is by no means the only way of using switching regulators. The LM2574/5/6 step-down regulators can be configured to generate negative outputs from positive inputs, although the available current is restricted. There is also a step-up version, the LM2577. These will be the subject of a future article.

Table 4
C1 and L1 values for 6.3V

Transformer voltage	12	15	18	22	25	28,30
C1 for 1A (uF)	2,200	470	470	470	220	220
C1 for 2A (uF)	3,300	1,000	1,000	1,000	470	470
C1 for 3A (uF)	4,700	1,500	1,000	1,000	470	470
L1 for 1A (uH)	220	330	330	330	330	470
L1 for 2A (uH)	150	150	150	220	220	220
L1 for 3A (uH)	100	100	100	150	150	150

Table 5
C1 and L1 values for 25V

Transformer voltage	25	28	30
C1 for 1A (uF)	3,300	2,200	1,000
C1 for 2A (uF)	6,800	4,700	2,200
C1 for 3A (uF)	10,000	4,700	3,300
L1 for 1A (uH)	470	680	680
L1 for 2A (uH)	220	330	330
L1 for 3A (uH)	220	220	220

Table 6
Resistor values
6.3 and 25 V versions

Output voltage	6.3	25
R1	4k7	22k
R2	240R	1k2
R3	1k2	1k2

Table 8
Component values
for 6.3V DC from 6.3V AC

C1	100uF
C2	1,000uF
C3,4	4,700uF
L1	100uH

Table 7
Resistor values - variable versions

Trimable versions Output voltage	5	6.3	12	15	25	Fully variable
R1	3k3	4k7	10k	12k	22k	SC
R2	Not used					
R3	1k2	1k2	1k2	1k2	1k2	1k0
RV1	1k	470R	1k	2k2	2k2	22k

Table 8
IC choice, LM2575/6T-?

Output voltage	5	6.3	12	15	25
Fixed version	5	ADJ	12	15	ADJ
Trimable or variable	ADJ	ADJ	ADJ	ADJ	ADJ

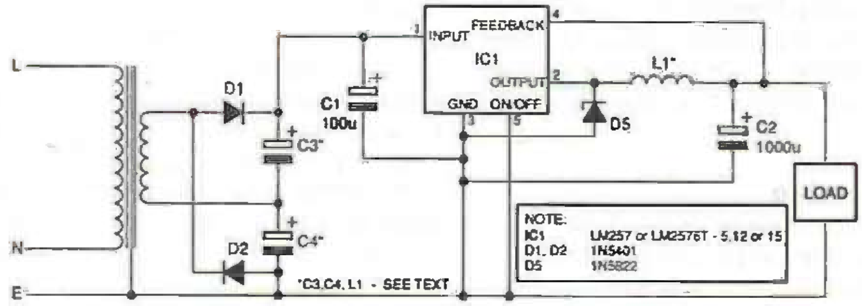


Fig 10. The switcher with a voltage doubler unregulated supply, so that it can use a lower voltage transformer. Note that C3 is still needed, but can be reduced in size to 100{SYMBOL 109 \f "Symbol"}F, and that D3 and 4 are not needed. This version can be fixed or variable. Note that the potential of the AC input is affected by this circuit, and this could cause problems if the same AC input is connected to other items

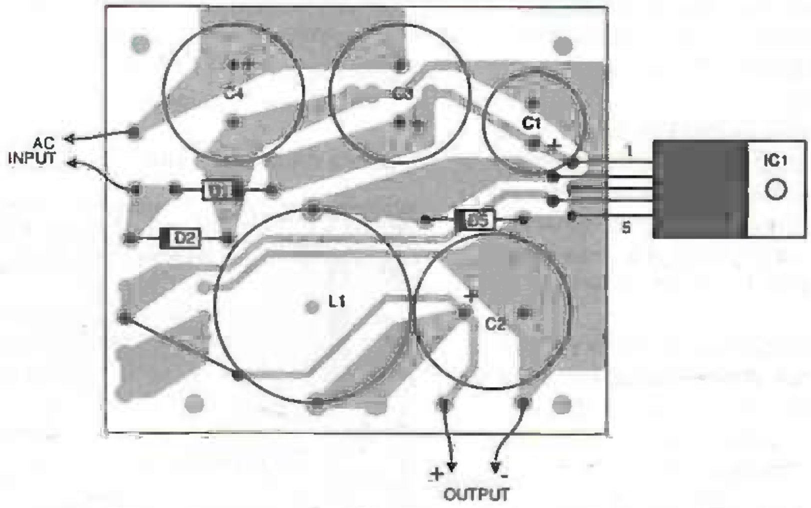


Fig 11. PCB layout for the voltage doubler option. Note the position of C3 and C4. C3 is oriented at 90 degrees to that of C1 in the conventional version.

Transformer voltage too low?

All is not lost! There is a voltage-doubling version shown in Figure 10, using only two rectifier diodes (D1 and 2) and two additional smoothing capacitors (C3,4). Capacitor C1 may seem redundant, but has to be retained for correct action of the IC; however, it is reduced to 100uF. The PCB overlay is given in Figure 11.

The circuit effectively doubles the transformer secondary voltage. To find the sizes of capacitors C3 and C4, double the value quoted for C1 in the conventional circuit and then use the next size up. Except for C1 which is 100uF regardless, all the other component values are the same.

For example, suppose I have a 9V 2A transformer and I want a 12V 1A regulated output. Table 2 lists 3300uF as the value for C1 for 3A, so I could use 1,100uF. To find the right size for C3 and 4, I double this to 2,200uF and choose the next size up: either 3,300 or 4,700uF, depending on what is available. C3 and 4 will have to take a peak voltage of 9x1.4=12.6V, so 15 or 16V types will be fine. According to the table, I will need a 330uH 1A inductor for L1. Both Maplin and RS/Electrovalue have 330uH 2.8A inductors, and Maplin also has a 1A inductor for around the same price. All things being equal, I'll go for the higher current capability because one day I may need a little extra.

This circuit can be used with transformer secondaries up to 14V; unfortunately, I cannot recommend use with a 15V secondary unless the circuit is going to be under load full-time (for the same reason that 30V secondaries are not advisable with the conventional version). Voltages higher than this will definitely damage the IC unless the 'HV' version is used.

Finally, Table 8 shows the values for the version that started the whole thing off. This is for 6.3V DC from a 6.3V heater transformer. Using a heater winding rated at 1.5A, this circuit delivers up to 1.2A at 6.3V. Ideally, there shouldn't be any other valve heaters directly connected to the same transformer heater winding, but if they are, the floating voltage, the heaters will be around +7V on average but with ripple of 7V peak-to-peak - not good for low-noise valves!

Construction and testing

The PCB is designed for all the options described above. Whatever option you choose, there will be some holes that are not used. Also notice that the placement and orientation of capacitors changes between the conventional and doubled versions of the circuit.

The first stage, as ever, is to check the components you are using fit the PCB and widen any holes as necessary. You may need to widen the fixing holes, and the hole for a non-magnetic bolt to go through the middle of a bobbin-type L1; this is only really necessary if the finished item is going to be portable. Fit the PCB pins, if you are using them for off-board connections.

Assemble the unregulated supply first. The mains side of the circuit isn't included on the PCB, so this will have to be done point-to-point. Include a switch and a fuse, if there isn't one already. I also like to add a mains neon directly across the mains input at the earliest possible point, as a warning that some part of the circuit is live (I remove the neon when the circuit is finished and fully tested).

Double, triple and quadruple check that the capacitor and diode polarities are right, then apply power. Check that the unregulated supply is giving the voltage you'd expect (around 1.4 times the transformer secondary voltage (and often a bit more because the transformer is designed to be under load). Then disconnect the mains and discharge the capacitors through a resistor.

Build the regulator circuit and attach a test load - say one that ought to draw around 100mA. Again, obsessively check that the diode and capacitors are the right way round, then apply power and check that the output voltage is as expected.

If you have access to an oscilloscope, check that the output does not have an excessive amount of 52kHz signal in it. If is has, consider replacing C2 with a superior type.

Attach the circuit to the load it is intended to supply, and check again the output voltage. If this is lower than you would expect by more than 250mV, there is probably ripple breakthrough on the output - check for this with an oscilloscope. The most likely reason for this is the transformer secondary having quite a high resistance. Try increasing the values of capacitor C1 (or C3 and 4 in the doubled version), but this may not work. If all else fails, reduce the current requirements or increase the voltage or current available from the transformer.

Component choices and sources

The Simple Switcher ICs are gradually getting more widely available. Maplin and RS/Electrovalue both carry a range. For a small charge, Maplin will also supply copies of the data sheets for the ICs.

The inductor L1 is a critical component. It is vital that it is rated for switched mode usage and for continuous usage at the full current being drawn. Again, Maplin and RS/Electrovalue carry suitable types. The PCB will accommodate Newport Components high-current bobbin-type inductors of 100uH/5.4A, 220/3.5 and 330/2.8 (Maplin codes AH21X, AH22Y and AH23A), a very similar series from RS/Electrovalue (same values, codes 228-416, 228-422 and 228-438, and a 470uH/2.3A type code 228-444), and the lower current Newport vertically mounted toroids of 100uH/2.2A, 220/1.2 and 330/1.0 (Maplin codes BU55K, BU56L and BU57M). Maplin also have a couple of unmounted high-current toroids, one 150uH/3A (code JL72P) and the other 300uH/5A (code JL73Q). In theory, there's no reason why you shouldn't make your own inductor. Personally, though, this is not something I'd risk.

The choice of capacitors is straightforward with one exception: C2. This can be a good quality conventional capacitor, but a special-purpose capacitor for switched mode supplies will give lower 52kHz ripple on the output. These have lower internal resistances, so attenuate ripple better; however, they are expensive and if your application will tolerate a little ripple, then you probably do not need one.

Capacitor voltages in general are common sense: at least 1.4 times the primary voltage for C1 (double this in voltage doubler circuits), C3 and C4 (if used). However, C2 needs to be rated at 1.5 times the maximum output voltage of the regulator.

For D5 be sure to use the device specified, or any Schottky or fast recover device rated at least 1.2 times the maximum load current with a peak inverse voltage of 1.25 times the peak input voltage on capacitor C1.

I have taken the precaution of using a heat-sink on IC1; for many applications, it does not need it, but there's no harm done in keeping it cool. The tab on the IC is at the same potential as the middle pin, the negative connection.

PARTS LIST

Resistors

• R1-3	See tables 6,7
• RV1	(if required) horizontal preset or normal potentiometer; see tables 6,7 for values

Capacitors

• C1	See tables 1-5 and text for values
• C2	1000uF low ESR type (voltage to suit maximum output voltage of regulator)
• C3*,4*	see text

Semiconductors

• IC1	LM2575 series (1A output) or LM2576 series (up to 3A); see tables for exact part number
• D1,2 3*,4*	1N4001 (1A) or 1N5401 (up to 3A)
• D5	1N5822

Miscellaneous

• L1	See tables 1-5 for values
• T1	Mains transformer to suit
• PCB, PCB pins, heat sink	

Fibre Optic Transceiver

Linking computers and peripherals using fibre optics can help overcome many problems, Ken Ginn shows how it can be done

All over the country, contractors are digging up the roads and installing fibre optic cable for cable TV systems. In this case, fibre optic cabling is used because of its high data transfer capability, but there are other reasons why fibre optic cables are used, and one of them is the cable's immunity to 'noise'. Trying to link computers together in an environment such as a machine shop filled with powerful electric motors emitting large amounts of electromagnetic noise can be extremely difficult. Well shielded coaxial cable is one answer, but a far better solution is to use fibre optic cable.

This project describes the construction and use of an interface which can be attached to an RS232 serial data port of a DTE (Data Terminal Equipment, e.g. computer) or DCE (Data Communicating Equipment, e.g. modem) and used to communicate at a speed of 19200 baud over a 20 metre optical fibre cable run. Communication between two computers for example, a serial printer connection, or to a

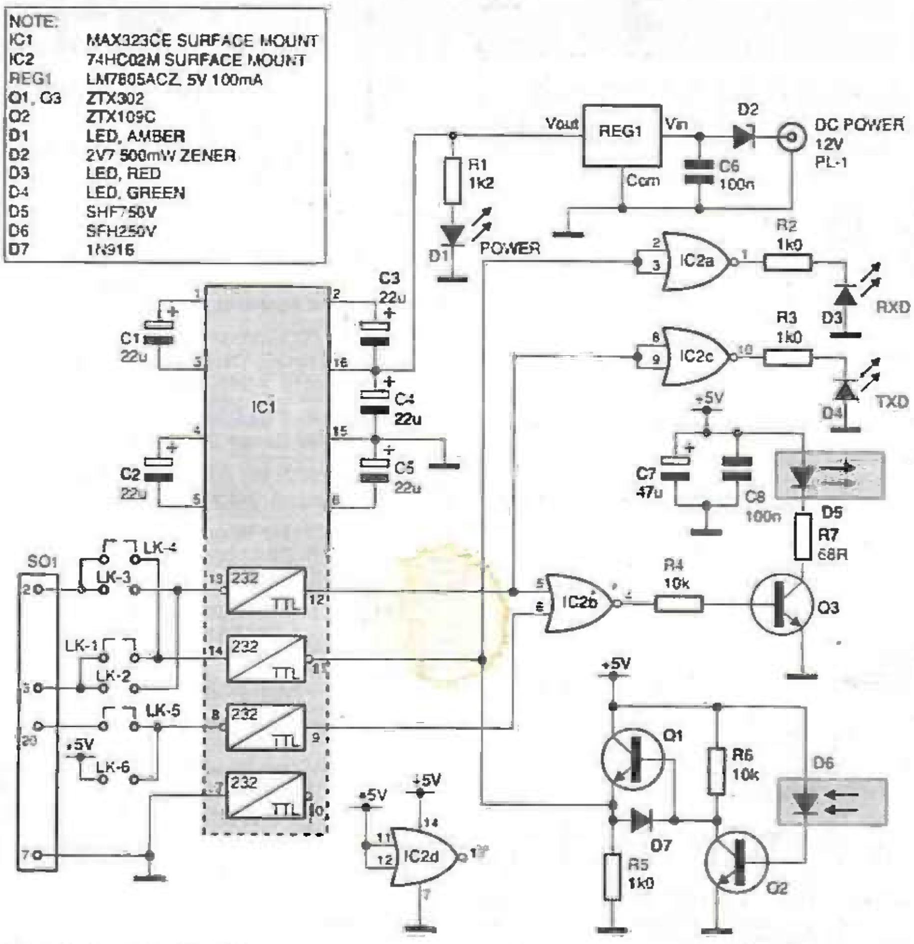


Fig.1. Optical transceiver circuit diagram

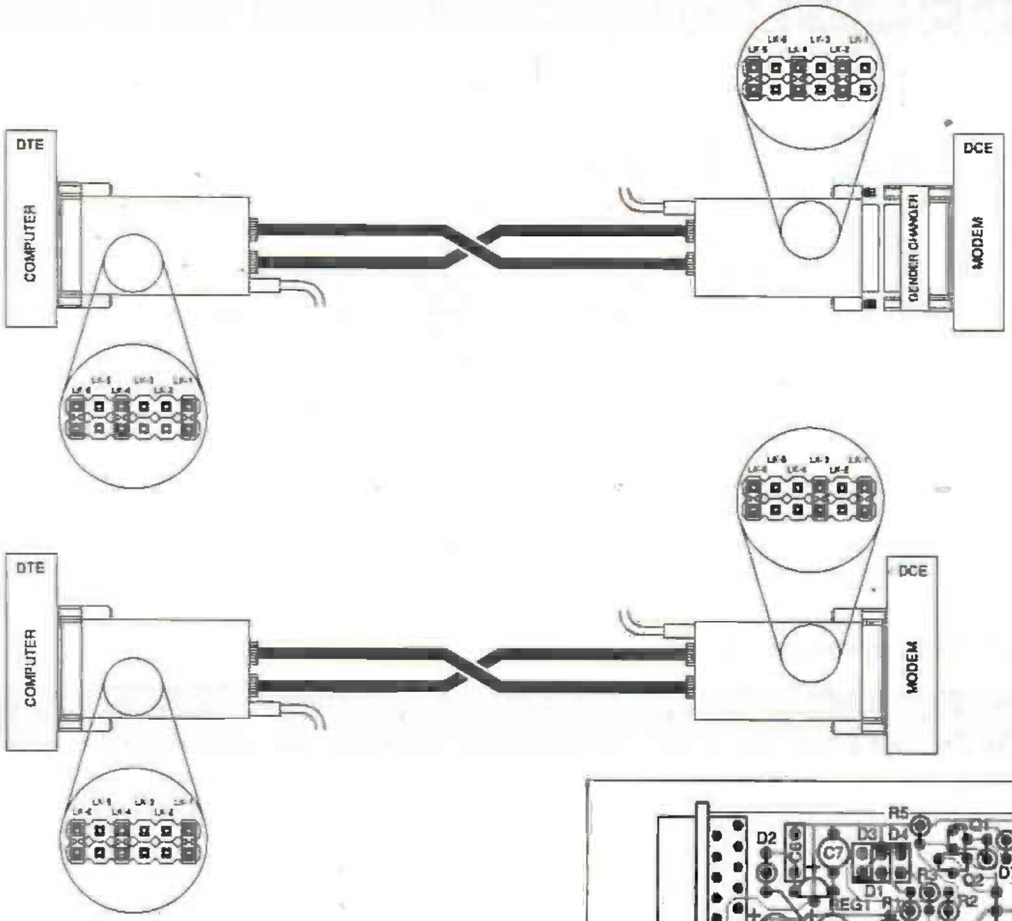


Fig.2. Optical transceiver link details

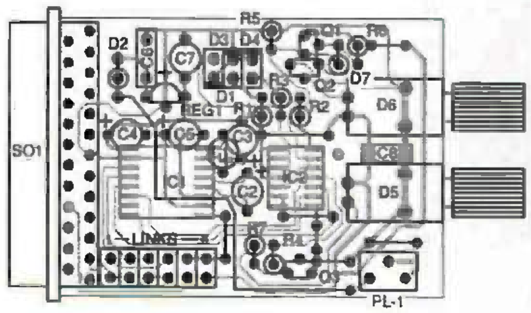


Fig.4. PCB component placements

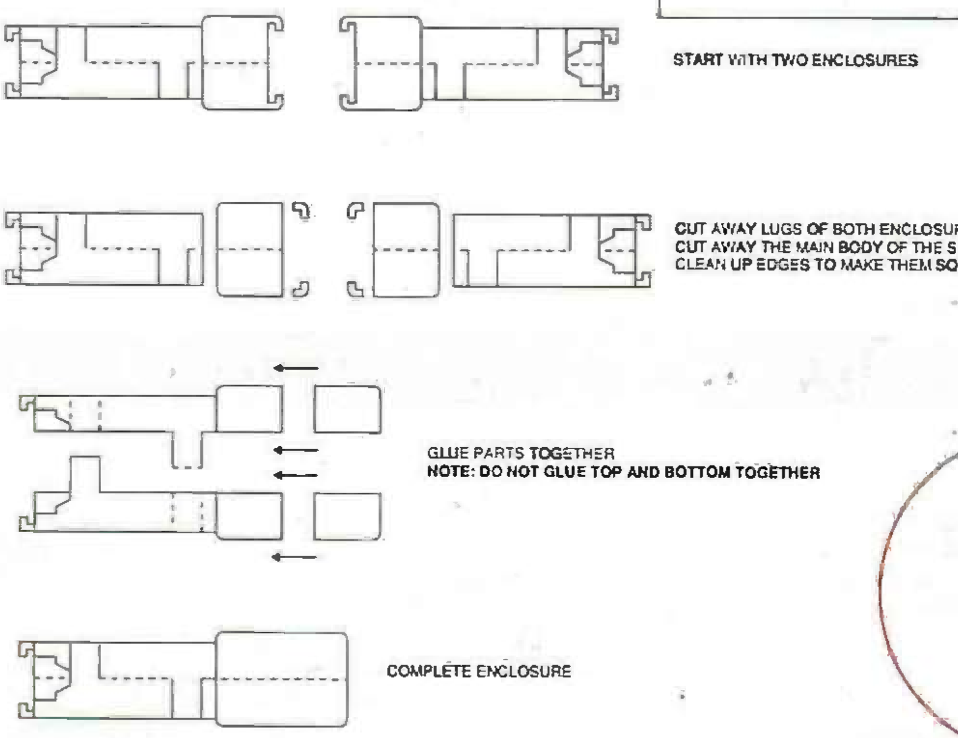


Fig.5. Construction of case

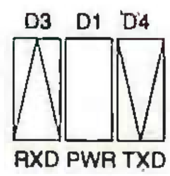


Fig.3. LED positions

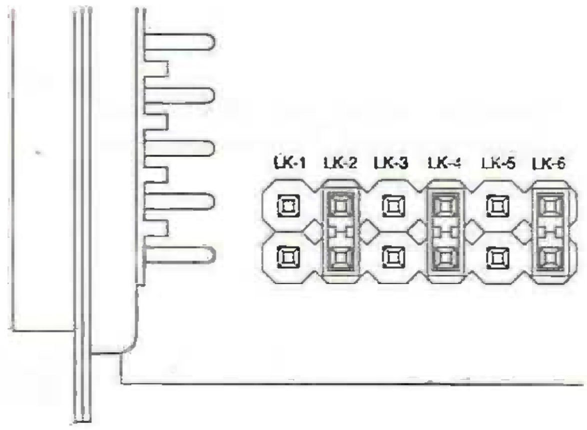


Fig.7. Optical transceiver link details

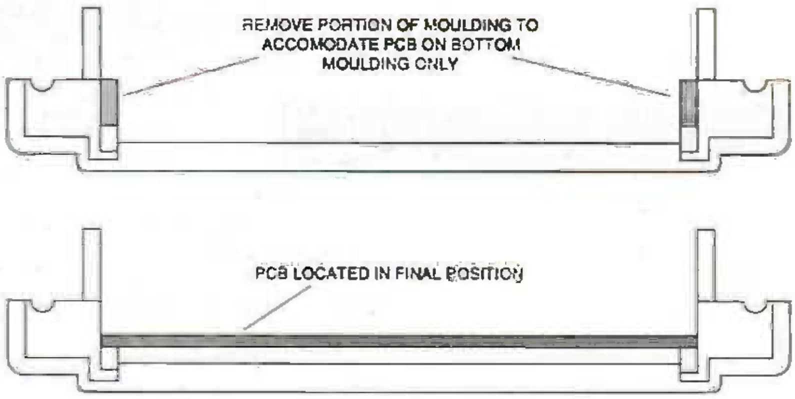


Fig.8. Case modifications

modem are possible. The original idea was to provide a suitable transceiver unit which is powered by an external power supply at each end of the fibre optic link. The unit itself, accommodated in a small enclosure, is simply configured accordingly before use and plugged into an RS232 serial port.

Power Supply

Power is supplied to the unit by either a commercially available plug-in power supply, or a PC's internal power supply. These external power supplies are available from suppliers such as Maplin. The power supply unit itself supplies sufficient current to the transceiver circuitry. The supply could alternatively be tapped off a PC to power the unit; in either case it should be able to provide 12 volts DC at 80mA under the maximum load conditions.

D2 is used as a series zener diode, reverse biased to protect the five volt regulator unit from being stressed when high currents are being drawn, i.e. when transmitted data from the serial TXD path enables the optical transmitter. This reduces the supply voltage to the regulator to about 9.3 volts - hence, the power dissipation in the regulator is reduced.

REG1 is a three terminal regulator which supplies the unit with the regulated five volt supply. D1 indicates power being supplied to the unit. IC1 contains its own power supply unit to provide the positive and negative power supplies needed for the RS232 data paths.

Transmit signal path

In this example, the transmitted data through the transceiver is presented at pin 13 of IC1 via the link LK-3 (more about that later). The signal is processed through the MAX232CBE which is inverted and presented at TTL levels at pin 12 of IC1. Should DTR on the DTE (e.g. computer) be used, then this signal line is picked off and processed through the MAX232CBE in the same way as the transmitted data and thus enables the transmit signal path to the transmit optical transmitter D5. The output of IC2b passes data when both inputs are at a logic "0" and drives the optical transmitter driver transistor TR3 on, which provides current to drive the optical transmitter D5. The drive current is limited by R7 to approximately 60mA. The TXD (transmitted data) LED D4 will illuminate to indicate a logic "1" being presented at IC1 pin 13, thus giving indication of transmitted data being launched from the unit down the optical fibre.

Receive signal path

Received signal in the form of light is received by the optical receiver D6. There follows a high gain, low-noise preamplifier stage. The output of TR1 (emitter) feeds IC2a which in turn drives current to D4, (RXD, received data), in the presence of a signal being received from the fibre optics. This indicates received data. The signal path splits from this pre-amp stage feeding both the LED driver IC2c, and also feeds ICl pin 11, which is presented with TTL logic levels, and converts this to RS232 levels at pin 14 of IC1. The RS232 signal is then sent through LK-1 and then on to pin 3 of the 25 way d-type SO-1.

Construction

The whole circuit is built on a single-sided PCB measuring approximately 2.0 by 1.5 inches. The majority of the components are mounted on the topside of the board, with the exception of ICl, IC2 and C8 (100n), which are all surface mount types. This saves an immense amount of space taken up by two of the principle components, IC1 and IC2.

Soldering the two surface mount components to the board may be the best choice with which to start construction, but thereafter careful consideration to the handling of the board would have to be observed with static sensitive devices already in place. When soldering the surface mount components onto the track side of the board, it would be wise to fabricate a simple device to hold the board steady and a way of applying pressure to the device holding both the board and component in position whilst being soldered onto the PCB. A fine tipped soldering iron designed for surface mount devices would be the best.

All of the remaining capacitors are PCB mounting types and are mounted onto the top side of the board. All the resistors are mounted vertically keeping their height above the board to a minimum. This will ensure that the assembled circuit will fit into the enclosure.

The transistors are mounted close to the board with lead lengths no more than 3mm. D2 is mounted in the same manner to all of the resistors, i.e. vertical. The tallest

PARTS LIST

Resistors

R1	1K2
R2	1K0
R3	1K0
R4	10K
R5	1K0
R6	10K
R7	68R

Capacitors

C1	22uF 16v tant
C2	22uF 16v tant
C3	22uF 16v tant
C4	22uF 16v tant
C5	22uF 16v tant
C6	100nF 63v polyester film
C7	47uF 16v sub-miniature radial electrolytic
C8	100nF surface mount

Semi-conductors

IC1	MAX232CBE surface mount
IC2	74HC02M surface mount
REG1	LM7805ACZ, 5v 100mA regulator
TR1	ZTX302
TR2	ZTX109C
TR3	ZTX302
D1	Amber LED, Maplin stock no.YY48C
D2	BZY88C2V7, 2.7v 500mW zener diode
D3	Red LED, Maplin stock no.YY57M
D4	Green LED, Maplin stock no.YY58N
D5	SHF750V, Farnell stock no.212-799
D6	SFH250V, Farnell stock no.212-805
D7	1N916

Miscellaneous

- PCB
- Cases (see text)
- 25 way d-type socket
- Gender changer (if required)
- Tinned copper wire
- Power socket
- Links,
- Single row header Farnell stock no. 176-370
- Superglue

components on the completed board should be the LEDs, which should be no more than 12mm or half an inch above the surface of the PCB.

Note the mounting of the three LEDs, the LED for TXD (red) is pointing the opposite way to the RXD. Figure 3 illustrates this; the middle LED being D1, indicating power.

The links LK-1, 2, 3, 4, 5 and 6 can either be made as simple wire links on the board, or can be made from removable links as shown in the prototype. The latter is the preferred as this will enable the unit to have its configuration easily altered if the unit's application is later changed.

The prototype is shown having a 25 way d-type solder bucket socket with short lengths of tinned copper wire bent at right angles and soldered to the board. Should a 25 way plug be required, a plug-plug gender changer can be employed to provide a plug connection to other equipment.

Once the board has been assembled, it is best to check the soldering for dry joints and solder bridges, in particular the surface mounted integrated circuits. Clean the track surface with a cleaning agent such as Isopropanol. This will make the inspection of the board much easier.

Testing

Initially connect the circuit to a variable regulated power supply where the current can be monitored as the supply voltage is brought slowly up to 12 volts. Under quiescent conditions a single unit should not take more than 40mA - typically 35 to 38mA. Switch off the power supply if the current is higher and check the component placements and the soldering on the track side of the board.

Check the voltage at the five volt regulator. The power LED D1 should be illuminated.

For the initial testing, configure the links as shown below:

LK-1
LK-3
LK-6

This will enable a transmitted signal path at pin 2 of the 25 way d-type on the unit, the receive path will return at pin 3. Installing LK-6 will enable the DTR line.

Connect pin 2 of the 25 way d-type to a positive ten volts supply via a 1K0 resistor. This will enable the optical transmitter and can be seen illuminated through the aperture for the fibre cable (as will D4, TXD). The total current drawn from the supply should be no greater than 80mA in this state. Connect this input to a negative ten volt supply, zero volts and the optical transmitter will extinguish, as will D4. This has proved the transmitter path is working under static conditions.

Repeat the tests with a short length of fibre optic cable connected from the optical transmitter to the optical receiver, D5 and D6. This time, monitor the output of the RS232 line driver, i.e. pin 3 of the 25 way d-type connector. D4 will illuminate to indicate received data, i.e. logic "1". Whatever logic voltage is presented at the input to pin 2 will be echoed at pin 3. This test provides a simple optical loop and can be repeated with a computer connected to the unit, using suitable communications software to drive the unit.

Note that during the static loopback tests, both the TXD and RXD LEDs should illuminate together.

Confirmation of the optical loop test can be carried out at speeds to 19200 baud. Proof of the test can be checked by disconnecting the optical fibre, and ensuring that the echo disappears.

Case Construction

The construction of a suitable enclosure can be fabricated out of two identical cases available from Maplin, stock no. JW56L. Figure 5 illustrates this. The case extension is stuck with superglue to form the completed case.

Apertures are made as shown in the photos which allow access to the links and the LEDs giving power indication and status of the signal lines.

Dressing the Fibre

When finally installing the units in situ, careful attention has to be paid to the fibre/transducer (optical transmitter or receiver) interface. Using the cheaper polymer cable has certain disadvantages over the more conventional glass fibre, which is more usually supplied with connectors terminated at each end of the cable, and this simplifies connection.

Take care when cutting the polymer cables and try to get a clean square cut at the transducer interface. This will ensure a good degree of coupling between fibre and transducer. A hot, sharp knife is recommended.

Using the Unit

To use the unit is simplicity itself. The links within the unit are configured to suit the need of the unit. If it is to be connected at DTE or DCE the internal links are configured accordingly.

To keep the unit common at either end of the fibre optical link, a 25 way gender changer is used to give the facility of a socket connection to a unit.

Links

Considering the connection of the unit to a DTE (i.e. a computer), data transmitted from the RS232 port is presented to pin 2 on the 25way d-type. The optical transceiver unit will interface with the computer direct, and plug straight to the computer's serial port. (i.e. 25 way d-type plug). Here, the links for data to follow the path to the optical transmitter will need to be in position, i.e. LK-3.

For DCE connection, pin 3 of SO-1 takes the transmit signal path and LK-2 is installed in place of LK-3.

Considering the receive data from the optical receiver in the unit, the received data follows a path to pin 3 of the 25 way d-type; again, the linking of the RS232 signal at this point has to be routed. LK-1 is put in position.

For DCE connection, pin 2 of SO-1 now takes the received signal path and LK-4 is installed.

Should the computer use DTR signalling, this can be enabled by putting LK-5 into position. To continually enable the unit, the link can be positioned to LK-6. This depends upon the computer using DTR in the software or not.

See figure 2. for linkage details.

Conclusion

These units have proved useful, linking two computers together enabling the much smaller and easier to install fibre optic cables to be laid. One of the major advantages of running fibre optic cables is their immunity to induced electrical interference and higher speeds over an equivalent cable run to conventional copper cables.

PIC Programmer

In part two of this project, Robin Abbott explains how to build an inexpensive PIC programmer

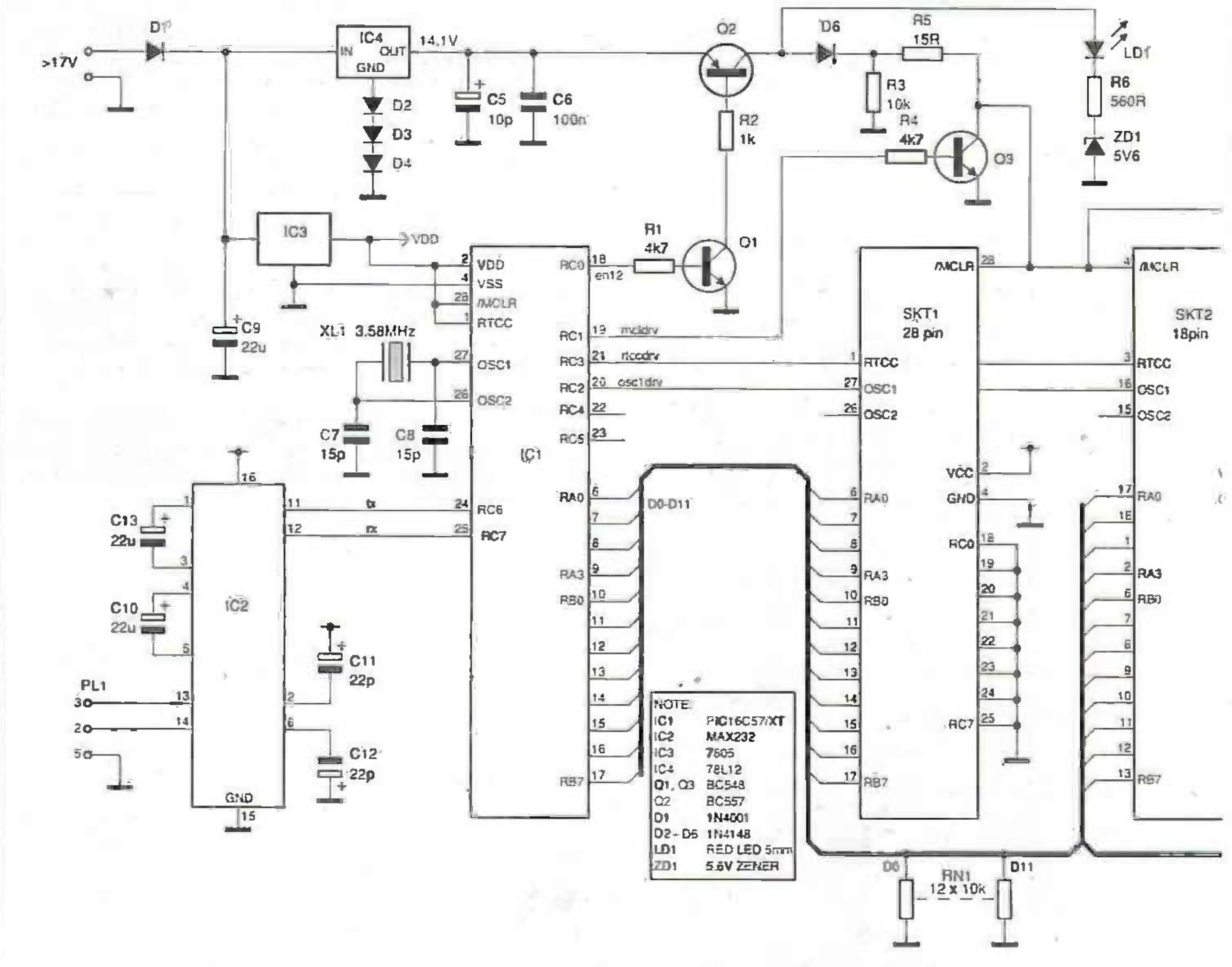
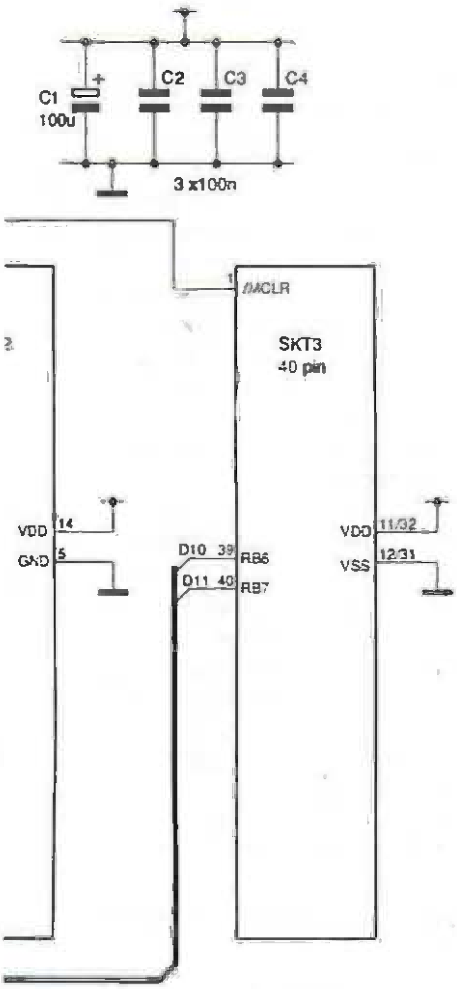


Fig.1. PIC programmer circuit

Last month we took an overall look at the design and operation of a programmer for the popular Microsystems PIC microcontroller chips. The programmer is connected to a PC and can be used with the PIC assembler and simulator included in the cover disk given away with February 1995 ETI. This month we conclude the project with a look at constructing and using the programmer.

The programmer is constructed on a fibreglass PCB with four rubber feet which prevent the PCB from scratching any surface on which it is used.

The PCB overlay is shown in figure 7. Construction is not complicated, insert all the jumpers and horizontally mounted components first, IC1 and IC2 should be socketed. Insert the capacitors, crystal, IC3 and PL1 last. Note the resistor network RN1. RN1 can be made up from one 9 way SIL resistor network and one 3 way SIL network. However as these appear to be unobtainable then RN1 can be made up from 12 individual vertically mounted resistors.



SKT1, SKT2, and SKT3 are the device programming sockets. Zero Insertion Force (ZIF) sockets can be used here. Howeve,r they are expensive and can be replaced with stacked DIL sockets. If this is to be the case, then ensure that the device programmed is inserted into a DIL socket, and that the board has at least two stacked sockets. This will ensure that sockets with bent pins can be replaced without unsoldering from the PCB. 18 pin ZIF sockets are hard to find, and the prototype used a 20 pin socket for SKT2. If ZIF sockets are used then they should be either long pin devices, or should be mounted on two stacked DIL sockets to raise them above the board and components.

A serial cable needs to be constructed, or a standard serial cable can be used. As there are a variety of serial ports connectors available then it is likely that different host PCs will need different connectors. If you choose to make up a cable for the host PC then follow the connections shown in figure 9.

The power supply is constructed in a small case with an integral mains plug. There are only three components in the power supply apart from the transformer. These are mounted on a small piece of veroboard. Ensure that the transformer and power supply board are bolted firmly into the case. In the prototype, the exposed mains pins were liberally smeared with silicone rubber sealant to insulate them.

Code

Figure 8 shows the code for the prototype in INTEL hex format. This is checksummed which should reduce the chance of programming a device in error. The author is prepared to program PIC devices which will guarantee the latest code version - see the end of this article for details.

Please note that this code is copyright, and although it may be used by individuals for personal experimentation it may not be used commercially.

Testing

Consult figure 1 and check that the PCB matches the circuit diagram and that there are no short circuits. Without inserting IC1 or IC2 check that with the power connected the supply pins on IC1, SKT1, 2 and 3 are at +5V. Check that the voltage on the emitter of TR2 is at 14V+/- 0.2V. Power down.

Insert IC2 and short pins 24 and 25 of the socket for IC1 and power up. Use a terminal emulator program on the host PC. Windows terminal is suitable for a PC. Set the emulator communications parameters to 9600 BPS, 8 bits, one stop bit, no parity, no flow control. In Windows terminal this is the menu option under "Settings - Communications". Check that characters typed on the terminal emulator are echoed back to the PC. This ensures that the serial link is working before trying any programmer functionality.

Power down, remove the link on IC1 socket, insert IC1 and power up. Now at the emulator enter 'D' (it is important that capitals are used). The programmer should respond with a 'K', this is the standard "are you there" diagnostic. Short pins 12 and 14 of SKT2 and enter a 'B' the programmer should respond with a large number of '@' characters followed by a

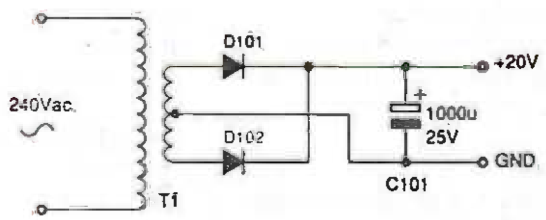


Fig.2. Circuit diagram of PIC programmer power supply

'K'. This is the programmer "read PIC" command and the link has forced the programmer to read bytes with the value 40Hex which is the '@' character. Remove the link. This completes testing of the serial interface.

Enter an 'F' character and LED 1 should illuminate, check that the voltage on pin 28 of SKT 1, pin 4 of SKT 2, and pin 1 of SKT 3 is about 13.25V. Check all the other pins of SKT 1 to 3 are at +5 or 0V, and that there are no other pins with a greater voltage on them. Enter 'K' and LED 1 should go out, now check that except for the power supply ALL pins of SKT1, 2 and 3 are at 0V.

Finally use the host PC programmer software to check that real PIC devices are successfully read and programmed. Please use erasable devices for the initial tests!

Using the programmer

It is highly recommended that the software developed for the prototype is used with the programmer which is available from the author (see the end of the article for details). This software has been fully tested and offers a number of advanced features. However, for those who do not own PCs with Windows software, or who own non-IBM compatible computers, a full programming specification is given below.

Windows host software

The programmer software runs under Windows 3.1 or 3.11. The software is generally self explanatory and has help facilities, however some of the features are explained here.

The program offers the following features:

- **Reads, verifies, checksums PIC devices.**
- **Allows user to set configuration fuses and user programmable areas.**
- **Allows examination and programming of EEPROM data areas in devices which have them.**
- **Supports Program Readable ID's (PRID's) see below.**
- **Displays programs read from PIC, or from files produced by the assembler.**
- **Blank checks devices**
- **Bulk erases EEPROM devices.**
- **Supports PC serial communication ports 1 to 4.**
- **Saves configuration information defined for a project so that configuration only needs to be defined once for each project.**

Figure 10 shows a screenshot of the programmer showing a loaded file. The programmer main screen always shows the buffer. The buffer can be loaded from a file or read from a PIC device in the programmer. The buffer can then be used to program a PIC, or can be saved. The buffer can be navigated using the up and down arrow and page keys.

At the top of the screen is the display showing the use of PRID's and user values; these are fully described below. The checksum is also shown. The checksum is a 16 bit value which is calculated by combining all the words in the buffer and the configuration fuse value. The user values are not included.

The screen also shows the currently set oscillator type, and the values of the configuration fuses. The oscillator type may be set as LP, HS, XT and RC, these types are low power crystal oscillator (e.g. 32KHz), High Speed crystal (>4MHz), normal crystal (1-4MHz) and resistor/capacitor oscillator types respectively. The user values, and configuration fuses may be programmed independently of the main buffer.

Configuration fuses

All the PIC devices of configuration fuses which set the mode of operation of the device - the type of oscillator and whether the watch dog timer, power up time, and code protection features are enabled. These are fully described in the PIC databooks; however, the use of the code protect fuse bears further examination.

The code protect fuse prevents any copying of the PIC. It does this by preventing programming of most of the PIC (including the code protect bit). Reading the PIC results in reading the value of the upper bits of the PIC XOR'd with the lower bits (exactly how this is done depends on the PIC type), and blanking the upper bits. Thus it is impossible to reconstruct the program, however each PIC program will read differently. Thus, to verify a code protected PIC, then the PIC should be programmed, and then read. The code protected file should then be saved. Now any PIC which needs verifying can be compared to the code protected file.

Erasing a device will reset the code protect fuse. The programmer will not allow any attempt to program a code protected device, although it will automatically bulk erase EEPROM devices before programming them.

User Words

The user words are an area of EPROM which is readable and programmable by the user, but is not accessible to the program running on the PIC. User words are not available on the latest devices - the PIC16C64 or the PIC16C74, suggesting that they may not be available on future devices. Different PIC device types have different sizes of user EPROM; however the programmer limits use of these words to entering a single 16 bit value as recommended by the Microchip programming reference. This is because the way that the 16 bit value is stored permits it to be read even in a code protected device.

The programmer permits the user words to be set to the following options:

1. User defined. With this option the user can enter a 16 bit value in hex which is used to program the user ID.

2. Program sequence. With this option the ID is set automatically to the number of times that a particular file has been used to program a PIC. Thus the user ID can be used to indicate the number of PIC's produced for a particular project. The file used must have the same directory and file name each time that a PIC is programmed for this feature to operate.

3. Use device sequence. This can only be used with EEPROM devices, and is a count of the total number of times that the device being programmed has ever been programmed - regardless of the file used to program it.

4. Use PRID. In this case the user ID is set to the same value at the lower 16 bits of the PRID - see below for a description of PRID's.

5. Use Checksum. In this case the user ID is set automatically to the checksum of the buffer.

Program Readable ID's (PRID's)

Program readable ID's (PRID's) are used to set an ID which is readable by the program running on the PIC. PRID's are useful for serialising projects or for setting values such as code words in alarm systems such that each PIC programmed will use a different value. PRID's are available on all the PIC devices. A

```
PIC Programmer - 16c84
File   PIC   Options   Help
PRID :: No PRID
USER :: 7FE6, using checksum
OSC  :: LP.   Checksum: 7FE6
FUSES:: Code Protect: N, Watch Dog: Y, Power Up Timer : N
C:\PIC\LITEGUN\LITEGUN

0000 : 2839 0023 3FFF 3FFF 0099 0E99 0E03 009A  - 9#......
0008 : 0A90 0810 390F 1903 16AE 13AE 19AD 2833  - ......-3
0010 : 1806 2817 18AF 2819 15AE 14AF 281C 10AF  - ../.././
0018 : 281A 14AF 1E06 17AE 1C2E 2822 0805 3A03  - ./...".. 
0020 : 0085 2833 1CAE 282C 0810 3903 1D03 2833  - .3.,...3
0028 : 0805 3A02 0085 2833 1FAD 2833 1C10 2833  - ...3-3.3
0030 : 0805 3A0B 0085 30F8 058B 0E1A 0083 0E19  - ...x....
0038 : 0009 3004 008C 301F 0085 0186 0189 1683  - ........
0040 : 1408 3007 0081 30F0 0085 301B 0086 1283  - ...p....
0048 : 0808 009D 0A89 1683 1408 1283 0808 061D  - ........
0050 : 3E01 1903 2855 3008 009D 01AF 20CE 0181  - ..U../N.
0058 : 019C 132E 1806 285F 172E 1185 2860 1085  - ..._..`.
0060 : 30A0 008B 1D86 293E 1AAE 20F2 192E 2862  -  ..>.r.b
0068 : 1BAE 2927 19AE 286D 2862 019C 11AE 082D  - .'.mb..-
0070 : 3930 1903 2875 1F2D 2862 0806 0091 1786  - 0.u-b...
0078 : 1506 15AD 0805 0093 39F5 0085 3003 0095  - .-...u..
```

Fig.10. Sample Pogrammer Screen

PRID may be from 1 to 4 bytes in length. To use a PRID then the program must use an array of RETLW instructions at a location defined by the user. It is suggested that these are somewhere obvious like at address 100Hex. The programmer will insert the values for the PRID into these instructions before programming each PIC. For example if the value 127 is to be inserted then the programmer will replace the current RETLW instruction with a "RETLW 127" instruction. If the user has defined a PRID area which does not contain RETLW instructions then the programmer will not proceed.

The following types of PRID may be used:

1. No PRID - the default. It is suggested that even if a program will use a PRID, then the PRID is not enabled until the program is fully debugged and devices are to be programmed for use.
2. User defined. With this option the user can enter a value of up to 8 hex digits, the user is prompted to enter this value each time that a PIC is programmed.
3. Program sequence. With this option the PRID is set automatically to the number of times that a particular file has been used to program a PIC - this guarantees that each PIC has a different ID, but ID's will be sequential. The file used must have the same directory and file name each time that a PIC is programmed for this feature to operate.
4. Random. With this option, the PRID is set to a random value. This option is best used for security systems when a 4 byte value is recommended.

Data EEPROM

The EEPROM PIC devices have an EEPROM data area which may be read or written from the program. The programmer can also read or write this area. In practice this is most useful for setting up device configuration in advance, or for debugging to check that the EEPROM data has been correctly written by an application program. Data may be read from, or written to, any of the standard file types.

This area is considered to be mapped at address 0, and information read from Intel hex format files is read to this area. This is slightly different from the Microchip programming specification which places the EEPROM data at logical address 2100H. The reason for the difference is to allow for any future expansion in EEPROM or program sizes.

Adding new PIC types

It is possible to add new PIC device types to the programmer software. New device types should have the same type of programming specification as an existing device type. That is, programming voltage should be on the MCLR pin, and for serial devices the clock and data should be entered on RB6 and RB7 respectively. For serial devices, the command numbers should match the 16C6XX or 16C7XX devices. Please feel free to consult the author in case of uncertainty.

New devices are entered into the file "PROCTYPE.INI" which is in the directory used to run the programmer. A new

FIGURE 9 Serial Cable from programmer to host PC				
Programmer	PC connector type:			
PL1	9way female	9way Male	25 way Female	25way Male
2	3	2	2	3
3	2	3	3	2
5	5	5	7	7

device should be added by putting the line "NAME=TRUE" where NAME is the device type in the section at the top, and then adding a definition section. An example definition section is shown for the PIC16C71 in figure 11- note the information shown after a ';' on each line describes the entry and should not be entered into the file. Please examine the supplied file for other examples as the definition may change as the software is enhanced. After entering new devices into PROCTYPE.INI they will then be available for selection in the programmer host software.

Programming Specification

For those users who wish to produce their own host software for the programmer this section describes the serial interface to the programmer.

Communication to the programmer relies on a command/acknowledgement protocol driven by the host machine. Commands are given as a letter from 'A' to 'Q', and any bytes required by the command follow the command letter. The programmer responds with any bytes to be sent as a result of the command followed by an acknowledgement byte. The acknowledgement byte is either a 'K' or an 'F'. 'K' indicates the command was successfully obeyed, 'F' indicates that an error occurred such as a checksum failure on data sent to the programmer. Commands may take up to 100mS before the acknowledgement byte is returned, and if this time expires then an error may assume to have occurred, the time-out in the prototype was set to 1S.

To initialise the programmer from any state, this sequence should be followed : Send 'D' 18 times, wait 1S and discard any bytes returned from the programmer. Send 'K' and wait for the acknowledgement - 'K', the programmer is now guaranteed to be in a waiting state. This sequence needs to be followed only at the beginning of an application program.

Figure 12 shows the list of commands which can be sent to the programmer, and the expected responses. The following paragraphs describe commands in more detail.

The Set mode command ('A') and the Size command ('I') should be sent before any other command is sent to the programmer. These set the type of PIC and the size of the program area. The Set mode command ('A') is followed by a single byte. Bit 0 of this byte is set for serial mode devices, bit 1 is set if the device is manufactured in EEPROM technology. For example, the PIC16C84 has the mode command definition value 3, the PIC16C57 has the value 0, and the PIC16C71 has the value 1.

All data words written to the programmer for programming (commands 'E', 'G', and 'L') are in PIC parallel format sent as the low byte followed by the high byte. This format has the upper 8 bits of the word in the upper byte, and the lower 4 or 6 bits in the lower byte which should be padded with 0's. Thus the hex word "1EC7" for a 14 bit device is written to the programmer as the byte "07" followed by the byte "7B". Regardless of the number of words written to the programmer they are always followed by a single byte checksum which is the 8 bit sum of the data words. If the checksum fails then the programmer will return 'F'.

All data read from the programmer in response to the 'B', 'C' or 'J' commands is in the PIC parallel format as for data written, but there is no checksum. All other 8 bit data is returned as a single byte. 16 bit data is returned in the normal low byte followed by high byte format.

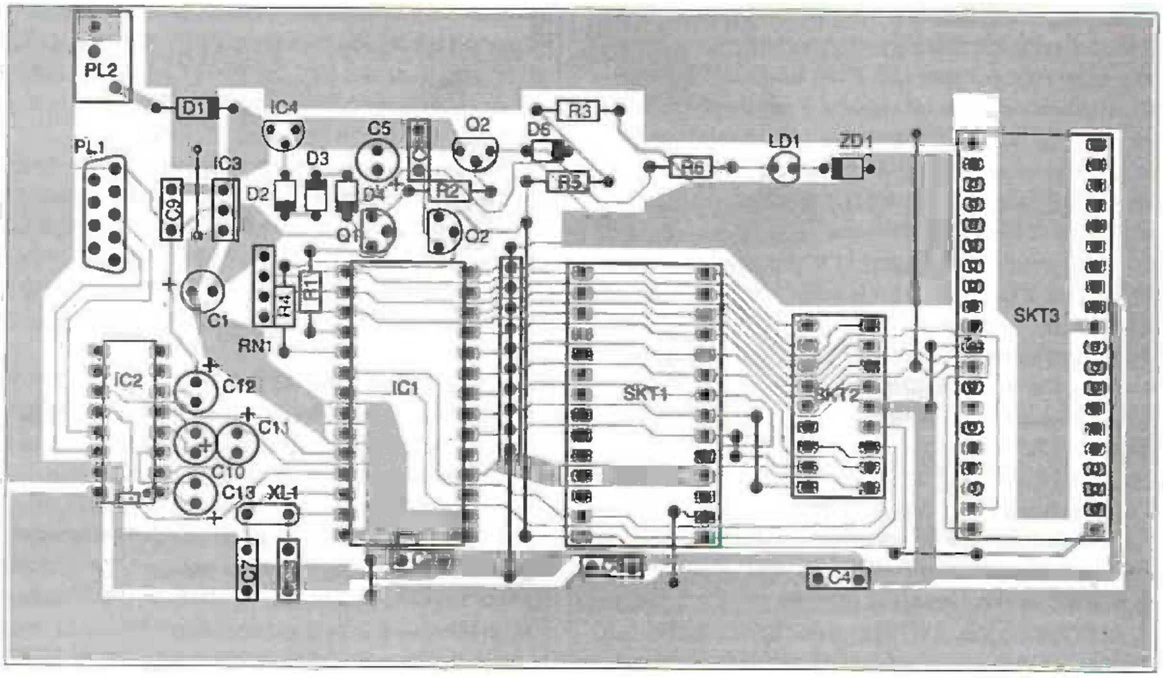


Fig.7. PCB component overlay

Fig.8 - 16C57 Code for PIC Programmer

```
:08000000010065006600420CDE
:08000800270068006900020CEA
:080010002A00000C0200FF0CA5
:0800180005000600800C070042
:080020004B0C1509E804160958
:08002800340A1D0B0C0B020B46
:080030000E0C2E00EE021A0A6C
:0800380000000008190C000093
:080040000000190A44085708EA
:080048005B084708610850083D
:080050006308590849085F0824
:080058005508650867085D0802
:0800600069086E086B0822001C
:08006800520C8B000306410A53
:08007000410CAB00EE06410A54
:08007800220CEB010B0233091D
:080080002200460C1509120ACA
:0800880016090B0228004B0CC5
:08009000420A16090B022900C7
:0800980016090B022A00470AB9
:0800A0000806BB090807A609C8
:0800A800470AAB09470AA30552
:0800B0004B0AA305800AA30519
:0800B8002F0AA305ED0AA305C0
:0800C000010AC305240AC3056F
:0800C800030AC305000AB10997
:0800D000470AC305A80AA305B5
:0800D800C305200AA305C305BE
:0800E000000A020C740A1C0C5A
:0800E8003B00FB02750A000851
:0800F0000D0C3C007B00FB023B
:0800F8007E0AFC027B0A0008F0
:080100000806940A4000050006
:0801080006000D0225000E02A5
:0801100026006704730967056E
:08011800FF0C0500060071094F
:080120006704B409670500083B
:08012800020CD409BF09080C08
:08013000D409280678097309BF
:080138000E0C2807D409ED0AA2
:08014000030CD409BF09080CEF
:08014800D409780A6705730968
:08015000490C270000084A0CCD
:080158002700FF0C06006704FC
:0801600000080806D30A470558
:0801680005020F0E2F00060234
:0801700031004704000866009D
:080178003F0C0600A60A4D032E
:08018000390079030E033A0077
:0801880039031904FA04100CFC
:080190003700E6043A033903CD
:080198000306E605C605C604D6
:0801A000F702C90A0008060C71
:0801A8003700060C3800E604E4
:0801B00037030306E605C6054E
:0801B800C604F802D70A000892
:0801C000FF0C2D002E00400091
:0801C800D409BF09070C39003E
:0801D000D309F902E80A050C4D
:0801D800EE0A040CD409BF0C6F
:0801E00006000F0C2400070CBF
:0801E80017092F032F033F0C40
:0801F0006F01110C2400080C42
:0801F8001709C605C6043F0CFF
:080200000600000083800C605E5
:08020800C6040304E606030529
:080210002003F802030B0008B3
:08021800E706160A080C2D0090
:0802200018091E090000030487
:08022800E70603052B03ED02BC
:08023000110B0B02E7071A0B8A
:0802380000082C00090C2D0048
:0802400003040307C7040306D1
:08024800C7051E092C03ED029D
:08025000210BC7051E0900087F
:08040000240B08061C0AA304EA
:08040800C304A6090902330038
:080410000A0234003302430725
:08041800B402A304C304B309FC
:08042000A304C304B309A30502
:08042800F302100AF402100AAD
:08043000040C3300B4025A0A67
:08043800A304C304BB09FF0C7F
:080440002D002E004000A30472
:08044800C304D409A304C3049A
:08045000BF09040C3300740025
:08045800B402A3056F0A0806B7
:080460003E0AA304C304A6092F
:08046800A304C304B3096300FF
:080470000F0215091102150924
:08047800A305670AA304C304F5
:08048000BB09A304C304E00959
:0804880063000F0215091102C7
:080490001509A305670A090222
:0804980033000A0234003302B4
:0804A0004307B40208066C0AD0
:0804A800A304C304A609A30488
:0804B000C304B309A304C30453
:0804B800B30963000F021509BE
:0804C00011021509A305F30266
:0804C8005A0AF4025A0AA304C7
:0804D000C304AB096300470AF5
:0804D800A304C304BB09A30443
:0804E000C304ED0963000F02E3
:0804E800150911021509A30416
:0804F000C304D309A305F302C4
:0804F8006F0AF4026F0A670AA3
:080500007500760009023300CA
:080508000A0234000806AD0AE6
:08051000B30233024307B402F9
:08051800A304C304A609A30417
:08052000C304B309A305C304E1
:08052800DE090F02F5010306D4
:08053000B6021102F601A30559
:08053800F3028F0AF4028F0A9E
:08054000A304C304AB0915027A
:08054800A304C3041509160207
:08055000A304C30415096300B4
:08055800470A33024307B40215
:08056000A304C304BB09A304BA
:08056800C304ED09A305C3045F
:08057000DE090F02F50103068C
:08057800B6021102F601A30412
:08058000C304D309A305F30233
:08058800B30AF402B30AA30454
:08059000C304AB09A304C3047A
:080598007809A304C304BB09A8
:0805A000A304C304E009A30554
:0805A800C304DE090F02F50196
:0805B0000306B6021102F60178
:0805B800A305A00A6F036F0305
:0805C000020C0806E60A6F03B5
:0805C8006F03040C3200030470
:0805D00031032F03F202E70AD8
:0805D8000008090233000A02C9
:0805E000340033024307B402AA
:0805E8000806110BA304C30473
:0805F000A609A304C304B3092A
:0805F800A304C304B309A30529
:08060000000943070C0BF30293
:08060800FC0AF402FC0AA30441
:08061000C304AB096300470AB3
:08061800A304C304AB09630055
:08062000410AA304C304BB0955
:08062800A304C304ED09A305BE
:08063000000943070C0BA304BE
:08063800C304D309A305F3027A
:08064000140BF402140B070B6C
:08064800C00C0807F00C2F01A3
:08065000AF0243070008B102EC
:02065800000898
:08080000E805020C250A0806B8
:08080800170A09023300B302D4
:080810000A0234003302430721
:08081800B402A304C304B309F8
:08082000C305F3020D0AF40206
:080828000D0A080C250AFF0C63
:080830002D002E004000A3047E
:08083800C304D409A304C304A6
:08084000BF09C305080C250ADD
:08084800100C2F003300030423
:080850003303300C24006C009E
:08085800A304C3041609C30543
:080860000B02EC012000A402D0
:08086800EF022C0AA304C304F3
:080870001609C3050B02AC00E0
:0808780043076E0AE8068E0931
:080880006400300C3200750029
:08088800010C340012022400EF
:0808900000022D00A402000289
:080898002E006400B202B2025E
:0808A000A304C3048009C30591
:0808A800F806630A0D02AF002F
:0808B00043065D0AE8066E0A2A
:0808B800630A0E02B1004306C1
:0808C000740AE8066E0A28061E
:0808C8006C0AB402640CE8079D
:0808D0001A0C94004307500AC2
:0808D800E806560A4000A304E3
:0808E000C30415096300410A7D
:0808E8001402F5012806820A42
:0808F000E806820AD401F401BC
:0808F800A304C3048009C30539
:08090000F4027C0AA304C30405
:08090800B109C305F302440A22
:080910001502A304C30415093C
:080918006300470A080700080C
:08092000300C240000022D0040
:08092800A40200022E0064008D
:080930004000A304C304D40934
:08093800A304C304BF09070C6E
:080940003200A304C304D30933
:08094800C305F202A10A000838
:0809500040002807DF0A080738
:08095800DF0AA304C304BB097C
:0809600067040A0CA304C304A0
:08096800D409C3053F0C250072
:080970002600400005000600 0E
:08097800EC09FF0CEC09BF0CB7
:08098000EC09070C3200060C23
:08098800260067056704E6057F
:08099000F202C30A010CEC099C
:08099800070CEC09020CEC094C
:0809A000FF0CEC09BF0CEC098F
:0809A800080CEC09A304C304D0
:0809B0007809C305010CEC09F4
:0809B800070CEC09010C3200F0
:0809C00065006600A304C304F6
:0809C800AB09FF0C0500630000
:0809D00032024306410A470A06
:0809D800260067056704E6052F
:0209E00000080D
:080C0000090233000A0234006E
:080C08003302 4307B402A30408
:080C1000C304BB09A304C304E3
:080C1800EB0963000F0215094E
:080C200011021509A304C3042D
:080C2800D309A305C305F30283
:080C30000A0AF4020A0AA304F7
:080C3800C304AB096300470A85
:080C4000100C2F00080C33001A
:080C4800300C24006C00A30431
:080C5000C3041609A305C30546
:080C58000B02EC012000A402D4
:080C6000EF02270AA304C304FC
:080C68001609A305C3050B02E8
:080C7000AC004307540A6400C4
:080C7800300C320012022400CE
:080C800000022D00A402000295
:080C88002E006400B202B2026A
:080C9000A304C304A009A3049E
:080C9800C304B109A305C30563
:080CA000F3023E0A6300470A5B
:040CA8006300410A9A
:020FFE00010AE6
:00000001FF
```

To program data locations the Enter Program command ('F') is given. This sets the program counter to address 0. Now 8 words can be programmed at a time using the Program Data command ('E'). Each command returns the overprogram count (a single byte) followed by the acknowledgement. The overprogram count is the total number of pulses required to initially program the 8 words. Thus, if the first seven words all required one pulse to initially program the word, and the eighth word required 2 initial pulses, then the overprogram count returned will be 9. After each word is programmed the internal counter is incremented ready to write the next 8 words. After the entire program area is written then the End Programming command ('K') is given. Note for parallel programmed devices then when the data locations are to be programmed the initial 'F' command must be followed by a single 'M' command. This increments the program counter past the configuration word in these devices.

In similar fashion the user words may be programmed by sending the Enter Program ('F') command followed by the Program ID locations command ('G'), followed by the End Programming command ('K').

The User configuration fuses are programmed by sending the Enter Program ('F') command followed by the Program configuration fuse command ('L'), followed by the End Programming command ('K'). Note if the Code Protect fuse is set to 0 (entering protect mode) then the program command may fail due to the inability to read back the correctly programmed value. Fuses must always be programmed after the program and user words.

Data EEPROM is written in the same way as program EEPROM, using the F, Q and K commands. Note that data sent for data EEPROM is still be sent and received as 8 words in PIC parallel format even though only 8 bit bytes are being sent. Thus the byte "FF" is sent as the byte "3F" followed by the byte "03". Note for reading and programming data EEPROM the size command must be used to send the size of the EEPROM data area, and not the program area. Also there is no check of EEPROM data after it has been written - use the read command to verify it.

File Formats

The host software accepts the following file types:

Intel Hex

This format is the standard Intel hex form consisting of data records with checksums followed by an end record command and is produced by the Microchip MPASM assembler. There are two types of Intel hex file supported by the programmer. The first is merged 8 bit format described by Microchip as INHX8M format (.HEX extension). This is a single file containing words in low high format. All addresses are doubled. The INHX8S format consists of two files, a file with a .HXL extension and a file with a .HXH extension. The first file consists of the lower 8 bits of each word to be written to program memory, the second file contains the upper 4 or 6 bits of each word. The old 16 bit hex format used for the proprietary Microchip PICPRO programmer is not supported.

Hex Text

The Hex Text format is most useful for producing data files for the EEPROM data memory. Hex Text format files can be created with a standard text editor. The records consist of a single word written on each line of the file which has a ".TXT" extension. Thus the file consisting of the four bytes, 05, 6B, 1A

PARTS LIST

Resistors

- R1,4 — 4K7
- R2 — 1K
- R3 — 10K
- R5 — 15R
- R6 — 560R
- RN1 — 12x10K (see text)

Capacitors

- C1 — 100uF 10V Electrolytic
- C2,3,4,6 — 100n Ceramic
- C5 — 10uF 16V Electrolytic
- C7,8 — 15pF Ceramic
- C9 — 22uF 25V Electrolytic
- C10,11,12,13 — 22uF 16V Electrolytic

Semiconducors

- IC1 — PIC16C57/XT
- IC2 — MAX232
- IC3 — 7805
- IC4 — 78L12
- TR1,3 — BC548
- TR2 — BC557
- D1 — 1N4001
- D2, 3 ,4 ,6 ,1N4148
- LD1 — Red LED, 5mm
- ZD1 — 5.6V Zener diode

Miscellaneous

- XL1 — 3.579545MHz crystal or ceramic resonator
- PCB
- PL1 — 9-pin D socket
- PL2 — 2.1mm PCB mounted power socket
- IC sockets
- SKT1,2,3 — 28, 18, 40 pin sockets (see text)
- 4mm high rubber feet

Mains Supply

Capacitors

- C101 — 100uF, 25V Electrolytic

Semiconductors

- D101, 102 — 1N4001

Miscellaneous

- TRANS1 — 15-0-15V 250mA transformer
- Veroboard
- Case with integral mains plug
- 3m two core cable
- 2.1m power plug
- Fixing hardware

Figure 12
Table of commands and responses used by the programmer

Command Letter	Function	Input data	Returned data
A	Setmode	Single byte mode data - see text	Acknowledgement byte
B	Read entire PIC	None	Size* words + Acknowledgement byte
C	Read configuration word	None	Configuration word + Acknowledgement byte
D	Check programmer	None	Acknowledgement byte
E	Program 8 words at the current location, move the current location onward 8 words	8 words + single byte checksum	Single byte count of overprogram pulses for all 8 words + Acknowledgement byte
F	Enter programming mode, set current location to 0	None	Acknowledgement byte
G	Program user words	4 words + single byte checksum	Acknowledgement byte
H	Checksum entire PIC and configuration word, excludes user words	None	16 bit checksum in low -high format + Acknowledgement byte
I	Set PIC program size	Size of program area in low - high format	Acknowledgement byte
J	Read User words	None	4 user words + Acknowledgement byte
K	Leave programming mode	None	Acknowledgement byte
L	Program configuration fuses	Single configuration word + single byte checksum	Acknowledgement byte
M	Increment program location (only needed to step past configuration in parallel devices when programming data - see text)	None	Acknowledgement byte
N	Blank check PIC	None	Return 'K' if the PIC is blank, 'F' if it is not blank.
O	Bulk erase EEPROM device program and data	None	Acknowledgement byte
P	Read EEPROM data	None	Size* words + Acknowledgement byte
Q	Program 8 bytes at the current EEPROM data location, move the current location onward 8 bytes	8 bytes sent as words in PIC parallel format, followed by a single byte checksum	Acknowledgement byte

* Size is programmed by the Setsize command ('I')

and A7 is written as follows:

05
6B
1A
A7

Binary
Binary information files are stored as bytes. Where words of more then 8 bits are written then the lower byte is written followed by the higher byte. The file extension is ".BIN".

Developing with PICs
It is recommended that all development projects should use the erasable (/JW) versions of the PIC series. There have been recommendations that the simulator (MPSIM) is sufficient to fully evaluate code prior to blowing a PIC. However in practice it is difficult to use MPSIM to exactly simulate external devices - particularly those driven using serial protocols.
The PIC16C84 EEPROM device is much cheaper than the erasable versions of the 18 pin 16C5XX devices and offers a code superset of these devices. It also erases in less than one second and is recommended for development of programs on 18 pin devices.

Programmer Software
The author is prepared to program PICs as well as to supply host software. Send a blank PIC16C57/XT or PIC16C57/JW which will be returned together with the host software. The host software is supplied on 3.5" High Density floppy disk suitable for use with Microsoft Windows version 3.1 or 3.11 - the software will probably operate with Windows 3.0, but has not been tested. Send the PIC together with an SAE and a cheque for £20.00 to Robin Abbott, 37 Plantation Drive, Christchurch, Dorset, BH23 5SG. The author is also happy to answer any queries on the use of the programmer.

Figure 11
Example Processor definition in "PROCTYPE.INI"

[16c71]	
bitlength=14	; Number of bits in program word
eeprom=0	; Set to 1 if device uses EEPROM technology
serial=1	; Set to 1 if device uses serial programming
proglength=1024	; Size of program in device
put=1	; Set to 1 if the device has a power up timer
rc=3	; value of fuse bits for Resistor/Capacitor oscillator
hs=2	; value of fuse bits for High speed crystal oscillator
xt=1	; value of fuse bits for Medium speed crystal oscillator
lp=0	; value of fuse bits for Low power crystal oscillator
wdtbit=4	; value of fuse bit for watch dog enable
putbit=8	; value of fuse bit
for power up timer enable	
cpbit=16	; value of fuse bit for code protect feature
cfmask=16352	; Mask for unused bits in fuse area
udosc=1	; Set to indicate all devices can have oscillator type programmed
retlw=13312	; Value of 'RETLW 0' instruction
eedatasize=0	; Size of EEPROM data area

STAMP PROJECT

Here, we explore several applications for the BASIC Stamp's unique pulsin command, which measures the duration of incoming positive or negative pulses in 10-microsecond units

The BASIC Stamp's pulsin command measures the width of a pulse, or the interval between two pulses. Left at that, it might seem to have a limited range of obscure uses. However, pulsin is the key to many kinds of real-world interfacing using simple, reliable sensors. Some possibilities include:

- **tachometer**
- **speed trap**
- **physics demonstrator**
- **capacitance checker**
- **duty cycle meter**
- **log input analog-to-digital converter**

Pulsin works like a stopwatch that keeps time in units of 10 microseconds (µs). To use it, you must specify which pin to monitor, when to trigger on (which implies when to trigger off), and where to put the resulting 16-bit time measurement. The syntax is as follows:

pulsin pin, trigger condition, variable

Pin is a BASIC Stamp input/output pin (0 to 7). Trigger condition is a variable or constant (0 or 1) that specifies the direction of the transition that will start the pulsin timer. If trigger is 0, pulsin will start measuring when a high-to-low transition occurs, because 0 is the edge's destination. Variable can be either a byte or word variable to hold the timing measurement. In most cases, a word variable is called for, because pulsin produces 16-bit results.

Figure 1 shows how pulsin works. The waveform represents an input at pin 7 that varies between ground and +5 volts (V).

A smart feature of pulsin is its ability to recognise a no-pulse or out-of-range condition. If the specified transition doesn't occur within 0.65535 seconds (s), or if the pulse to be measured is longer than 0.65535 s, pulsin will give up and return a 0 in the variable. This prevents the program from hanging up when there's no input or out-of-range input.

Let's look at some sample applications for pulsin, starting with one inspired by the digital readout on an exercise bicycle: pulsin as a tachometer.

Tachometer

The most obvious way to measure the speed of a wheel or shaft in revolutions per minute (rpm) is to count the number of revolutions that occur during 1 minute. The trouble is, the user probably wouldn't want to wait a whole minute for the answer.

For a continuously updated display, we can use pulsin to measure the time the wheel takes to make one complete revolution. By dividing this time into 60 seconds, we get a

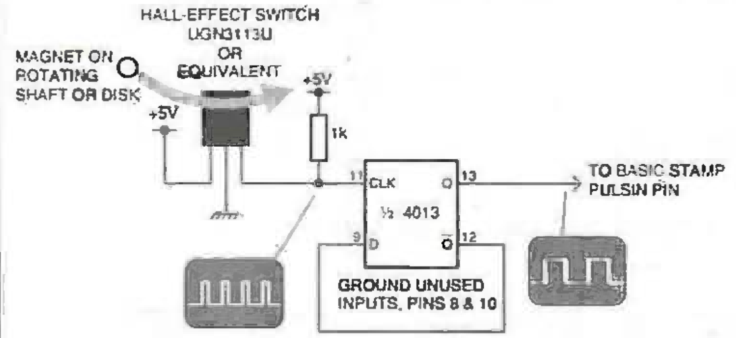


Figure 1. Timing diagram for pulsin 7,0,w3.

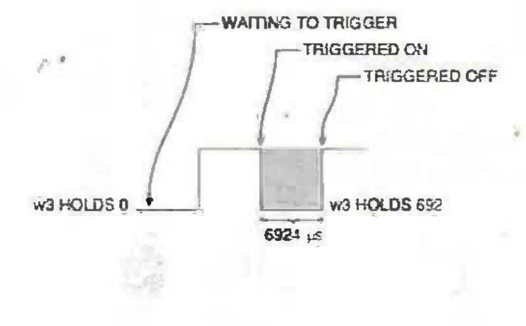


Figure 2. Schematic to accompany listing 1, tach.bas.

quick estimate of the rpm. Listing 1 is a tachometer program that works just this way. Figure 2 is the circuit that provides input pulses for the program. A pencil-eraser-sized magnet attached to the wheel causes a Hall-effect switch to generate a pulse every rotation.

We could use the Hall switch output directly, by measuring the interval between positive pulses, but we would be measuring the period of rotation minus the pulses. That would cause small errors that would be most significant at high speeds. The flip-flop, wired to toggle with each pulse, eliminates the error by converting the pulses into a train of square waves. Measuring either the high or low interval will give you the period of rotation.

Note that listing 1 splits the job of dividing the period into 60 seconds into two parts. This is because 60 seconds expressed in 10-µs units is 6 million, which exceeds the range of the Stamp's 16-bit calculations. You will see this trick, and others that work around the limits of 16-bit math, throughout the listings.

Using the flip-flop's set/reset inputs, this circuit and program could easily be modified to create a variety of speed-trap instruments. A steel ball rolling down a track would encounter two pairs of contacts to set and reset the flip-flop. Pulsin would measure the interval and compute the speed for a physics demonstration (acceleration). More challenging setups would be required to time baseballs, remote-control cars or aircraft, bullets, or model rockets.

The circuit could also serve as a rudimentary frequency meter. Just divide the period into 1 second instead of 1 minute.

Duty cycle meter

Many electronic devices vary the power they deliver to a load by changing the duty cycle of a waveform; the proportion of time that the load is switched fully on to the time it is fully off. This approach, found in light dimmers, power supplies, motor controls and amplifiers, is efficient and relatively easy to implement with digital components.

Listing 2 measures the duty cycle of a repetitive pulse train by computing the ratio of two pulsin readings and presenting them as a percentage. A reading approaching 100 percent means that the input is mostly on or high. The output of figure 2's flip-flop is 50 percent. The output of the Hall switch in figure 2 was less than 10 percent when the device was monitoring a benchtop drill press.

Capacitor checker

The simple circuit in figure 3 charges a capacitor, and then discharges it across a resistance when the button is pushed. This produces a brief pulse for pulsin to measure. Since the time constant of the pulse is determined by resistance (R) times capacitance (C), and R is fixed at 10k, the width of the pulse tells us C. With the resistance values listed, the circuit operates over a range of .001 to 2.2 µF. You may substitute other resistors for other ranges of capacitance; just be sure that the charging resistor (100k in this case) is about 10 times the value of the discharge resistor. This ensures that the voltage at the junction of the two resistors when the switch is held down is a definite low (0) input to the Stamp.

Log-input analog-to-digital converter (ADC)

Many sensors have convenient linear outputs. If you know that an input of 10 units (degrees, pounds, percent humidity, or whatever) produces an output of 1 volt, then 20 units will produce 2 volts. Others, such as thermistors and audio-taper potentiometers, produce logarithmic outputs. A Radio Shack thermistor (271-110) has a resistance of 18k at 10° C and 12k at 20°C. Not linear, and not even the worst cases!

While it's possible to straighten out a log curve in software, it's often easier to deal with it in hardware. That's where figure 4 comes in. The voltage-controlled oscillator of the 4046 phase-locked loop chip, when wired as shown, has a log response curve. If you play this curve against a log input, you can effectively straighten the curve. Figure 5 is a plot of the output of the circuit as measured by the pulsin program in listing 4. It shows the characteristic log curve.

The plot points out another advantage of using a voltage-controlled oscillator as an ADC; namely, increased resolution.

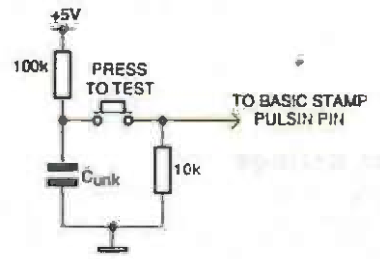


Figure 3. Schematic for listing 3, cap.bas.

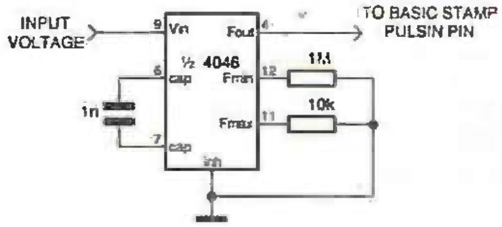


Figure 4. Schematic for listing 4, vco.bas.

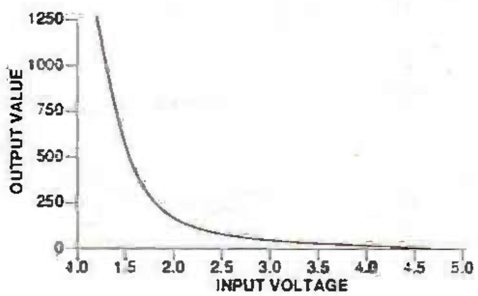


Figure 5. Log response curve of the VCO.

Most inexpensive ADCs provide eight bits of resolution (0 to 255), while the VCO provides the equivalent of 10 bits (0 to 1024+). Admittedly, a true ADC would provide much better accuracy, but you can't touch one for anywhere near the 4046's sub-£1 price.

The 4046 isn't the only game in town, either. Devices that can convert analog values, such as voltage or resistance, to frequency or pulse width include timers (such as the 555) and true voltage-to-frequency converters (such as the 9400). For sensors that convert some physical property such as humidity or proximity into a variable capacitance or inductance, pulsin is a natural candidate for sampling their output via an oscillator or timer.

Program listings

```
' Listing 1: TACH.BAS
' The BASIC Stamp serves as a tachometer. It accepts pulse input through
' pin 7, and outputs rpm measurements at 2400 baud through pin 0.
        input 7
        output 0
Tach:   pulsin 7,1,w2          ' Read positive-going pulses on pin 7.
        let w2 = w2/100        ' w2/100 divided into 60,000 equals
        let w2 = 60000/w2      ' 6,000,000/w2 (60 seconds in 10-us units).

' Transmit data followed by carriage return and linefeed.
        serout 0,N2400,(#w2," rpm",10,13)
        pause 1000          ' Wait 1 second between readings
        goto Tach

' Listing 2: DUTY.BAS
' The BASIC Stamp calculates the duty cycle of a repetitive pulse train.
' Pulses in on pin 7; data out via 2400-baud serial on pin 0.
        input 7
        output 0
Duty:   pulsin 7,1,w2                ' Take positive pulse sample.
        if w2 > 6553 then Error      ' Avoid overflow when w2 is multiplied x10.
        pulsin 7,0,w3                ' Take negative pulse sample.
        let w3 = w2+w3
        let w3 = w3/10               ' Distribute multiplication by 10 into two
        let w2 = w2*10               ' parts to avoid an overflow.
        let w2 = w2/w3               ' Calculate percentage.
        serout 0,N2400,(#w2," percent",10,13)
        pause 1000             ' Update once a second.
        goto Duty

' Handle overflows by skipping calculations and telling the user.
Error:  serout 0,N2400,("Out of range",10,13)
        pause 1000
        goto Duty

' Listing 3: CAP.BAS
' The BASIC Stamp estimates the value of a capacitor by the time required
' for it to discharge through a known resistance.
        input 7
        output 0
Cap:    pulsin 7,1,w1
        if w1 = 0 then Cap  ' If no pulse, try again.
        if w1 > 6553 then Err        ' Avoid overflows.
        let w1 = w1*10
        let w1 = w1/14               ' Apply calibration value.
        if w1 > 999 then uF ' Use uF for larger caps.
        serout 0,N2400,(#w1," nF",10,13)
        goto Cap

uF:     let b4 = w1/1000     ' Value left of decimal point.
        let b6 = w1//1000    ' Value right of decimal point.
        serout 0,N2400,(#b4,".",#b6," uF",10,13)
        goto Cap

Err:    serout 0,N2400,("out of range",10,13)
        goto Cap

' Listing 4: VCO.BAS
' The BASIC Stamp uses input from the VCO of a 4046 phase-locked loop
' as a logarithmic A-to-D converter. Input on pin 7; 2400-baud serial
' output on pin 0.
        input 7
        output 0
VCO:    pulsin 7,1,w2          ' Put the width of pulse on pin 7 into w2.
        let w2 = w2-45         ' Allow a near-zero min value without underflow.
        serout 0,N2400,(#w2,10,13)
        pause 1000    ' Wait 1 second between measurements.
        goto VCO
```

Note about the Program Listings

All of the listings output results as serial data. To receive it, connect Stamp pin 0 to your PC's serial input, and Stamp ground to signal ground. On 9-pin connectors, pin 2 is serial in and pin 5 is signal ground; on 25-pin connectors, pin 3 is serial in and pin 7 is signal ground. Set terminal software for 8 data bits, no parity, 1 stop bit.

TEC200

Terry Balbirnie looks at a new, easy way to make PCBs

When I was given the opportunity to review TEC200 Film, I was eager to try it out. This material promises to be a real help for the hobbyist wishing to make the occasional printed circuit board (PCB). TEC200 simplifies the procedure by eliminating the need for an ultra-violet exposure box, sensitized board and developer. Instead, plain copper-clad board is used in an iron-on process.

Modern trends

It was once common for magazine projects to specify stripboard as their means of construction. Although designs still appear in this form from time to time, the trend is now towards proper PCBs. By using a PCB, there is much less chance of error. Readers will note foils for this issue reproduced near the back of ETI.

Many constructors have a problem in transferring the master foil pattern on to copper-clad board. This must be in a form which can be etched to produce the pads and tracks. It is possible to copy the artwork direct on to plain board using an etch resist pen or rub-down transfers. However, this is very time-consuming and is not appropriate to anything but simple designs. The conventional ultra-violet process involves making a transparent acetate copy and using this in conjunction with ultra-violet sensitive board and special developer. Exposing the board to ultra-violet involves the use of a U.V. light box and this, together with the developer and sensitized board, is fairly expensive. The cost is therefore not justified for occasional work.

TEC200 provides a short cut. Here, an image is made direct on the special film using a photocopier or laser printer. This image is subsequently transferred to copper clad board using the heat of a domestic iron. The resulting image turns out to be an effective resist so that conventional etching material may be used on it.

A good image

If a photocopier is used, this must be of the "dry" type where the toner is heat-fused on to the material. This method will be useful to the many readers wishing to work from the master foils reproduced in a magazine. I found that not all copiers are suitable - mine, for example. My best results were obtained by using the services of a photocopy shop. They only charged 10p to copy on to my own material. You need to explain that the film is made to run through the machine and that ordinary acetate will not do. They are understandably very sensitive about damaging their equipment.

Unfortunately, it is not possible simply to make a photocopy from the magazine in one step. This is because the image is the correct way round - that is, as the board will finally appear. This would produce a similar (correct way round) image on the surface of the film. If this image were to be transferred to the board, it would be reversed - that is, a mirror image would be produced.

To overcome the problem, a conventional transparent (acetate) copy is first made. This is then turned over and re-copied on to the TEC200 film. This will produce a mirror image of the design on its surface and,. when this is ironed on to the copper-clad board, it will be the correct way round. Since the image goes through two processes, it is even more important to maintain a good image quality. The photocopy shop charged 50p to make the acetate intermediate copy

The CAD

Some constructors create their own PCB artwork using CAD software. This may be printed direct on to the TEC200 film using a laser printer. The software will provide the necessary mirror image. Note that other types of printer such as bubble-jet and matrix varieties are not suitable.

My NEC laser printer did not produce a satisfactory image. Even darkening it to maximum did not help much. The problem appeared to be in the toner material itself. Some laser printers will work well, others will not and readers wishing to use this approach will need to experiment.

Assuming a good image has been formed on the film, it is now necessary to transfer it to the copper-clad board. The board must be perfectly clean for successful transfer to take place. The best way to clean it is to use a non-metallic domestic cleaning pad. This should be followed by washing with a little liquid detergent and warm water, rinsing and drying. From this point, the board should be handled by the edges only to avoid finger marks.

The iron (an ordinary domestic type) is adjusted to about 140 degrees C (cotton or linen setting). The TEC200 film, image side down, is then placed on top of the copper clad board and heated with the iron. The toner melts and adheres to the board. This seemed fiddly to do and I preferred an alternative method. This involves placing the hot iron on the board until the copper surface reaches the correct temperature. The film, image side down, is then applied to the board and rolled with a rubber roller. A firm, even pressure is required and it is essential to keep the film still while doing it or the image will smear. When cool, the film is peeled away and the board examined for blemishes. If any are seen, they should be touched-in with a fine etch resist pen. Note that the transferred image is easily rubbed off so the board should be etched straight away. This is done in a conventional etchant bath such as ferric chloride solution.

Obtaining a really good transferred image was not successful on my first few attempts. I would advise readers to buy several extra sheets of TEC200 to start with because a little practice is needed to get the technique right. Irons vary in their temperature settings and it will be necessary to do a few tests (using small pieces of film) to find the best one. Too cold and the image will not transfer properly. Too hot and the film curls.

The film should be left completely clear after the transfer. If the image fails to transfer completely on the next try wipe the surface of the film and/or the board with alcohol. I did not find this necessary.

I found TEC200 a very satisfactory product especially for readers wishing to use published designs. My most important advice is to use a photocopier which produces a really good image. The black parts should be opaque and free from blemishes. It may be best to use a photocopy shop - the Sharp machine used in mine gave excellent results but others will, presumably, be just as good. Those using CAD design software must bear in mind that not all laser printers are the same - some work much better than others. Remember, during the ironing-on process that "practice makes perfect".

The bottom line

TEC200 film is supplied in A4 sheets at 75p each (up to 20). There is also a postage and packing charge (75p for 10 sheets, for example). The unit price reduces as the number increases - 100 sheets cost 42p each. A rubber roller costs £5. Acetate sheets for the intermediate copy are supplied at 25p although a photocopy shop will provide them. The total cost per PCB will be a little more than £1 plus, of course, the cost of the copper-clad board and etching chemicals.

Materials

All the above materials (including the roller) are supplied by:
PSS Services,
217 Prestbury Road,
Cheltenham,
Gloucester.
GL52 3ES
Tel: 01242 254108

Designing a MICROCONTROLLER based project

In Part 1 of this short tutorial series Bart Trepak shows how he set about building a PIC based alarm clock

During the last economic recovery - the one where the first green shoots of recession were just becoming visible by the light from the end of the tunnel - the author - along with many other electronics engineers, programmers, accountants and even one or two politicians - found himself in the situation which actors euphemistically call "resting between jobs".

One of the problems when one is (to use that well known DSS phrase) "actively seeking employment", is that apart from not having any money, the routine imposed by simply having a job is missing. There is no need to get up at a certain time to get to work so the day tends to get shifted with late mornings following ever later nights. Before long one can find apathy and then depression setting in.

One way out of this dilemma is to set your alarm clock the night before when you are still full of good intentions, to wake you at the usual time early in the morning. Unfortunately, when morning comes and the alarm goes off, you realise that you don't really need to get up so early, so you reach for the snooze button. This cancels the alarm and gives you another ten minutes or so before the buzzer goes off again. You may do this a few times but eventually, unless you have a strong will, you will probably switch the alarm off altogether, roll over and go back to sleep, particularly if you went to bed late the night before. When you finally wake up at 11.30 am, you may grab a quick breakfast (or is that lunch?), peruse the papers for any job (you still have hope) and then as there is not much else to do, settle down to watching afternoon TV with endless antipodean soap operas and re-runs of old black and white films - and what could be more depressing than that?

But even in the depths of this gloom, electronics can provide the answer. An alarm clock that allows you to snooze - just once (you are allowed some luxuries even when you are unemployed) but after this it continues to sound the alarm, disabling the alarm cancel and snooze buttons until you actually get up.

The clock has an input which can be connected to a pressure mat of the type used in burglar alarms which is placed under the mattress and is used to sense the presence of your body in the bed. To foil any clever attempts to fool the clock by jumping out of bed, cancelling the alarm and then getting back in again, the alarm remains potentially active for a further ten minutes, during which time it will sound again if you do decide to get back into bed.

By this time you should be wide awake and ready to face the new day. Of course you could fool the clock by setting the alarm for 11.30am in the first place, but the answer to that problem is beyond the scope of this article.

Although designed originally for myself, this device has since found a use for other members of the family - namely the children, whose sense of responsibility is even less well developed than that of their father, and who find getting up for school, especially on Monday mornings, extremely difficult.

Another digital clock!

You could be forgiven for wondering why ETI is publishing yet another digital clock project when so many have been published before and it is quite possible nowadays, to buy a perfectly good clock for a few pounds albeit without the useful additional feature described above. The real reason is to introduce readers to designing circuits using micro-controllers which are destined to virtually replace conventional logic in many applications and have already featured in many designs published in electronics magazines.

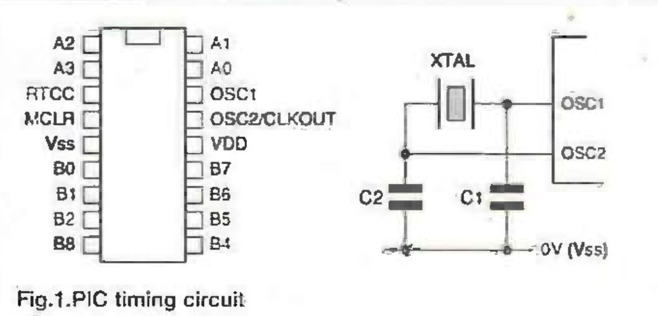


Fig.1.PIC timing circuit

This series of articles will deal with designing a project from scratch and a digital alarm clock was chosen because it is an item with which everyone is familiar and we will not need to spend too much time on describing in detail what the finished circuit is required to do, but rather how it does it. As well as this, a digital clock needs a display, a keyboard and a buzzer and therefore provides a good vehicle for describing how these devices which are often used in other projects, and the software routines to drive them, can be used in a micro-processor based design.

The series will deal with the hardware design and, perhaps more importantly, with how the software is developed and programmed into the device. No previous familiarity with any other processor is assumed but the reader should have a basic knowledge of electronics and how a computer works.

At the end of the series you should be able to at least modify the design to meet some real or imaginary extra requirement (such as would be caused by getting a job for example if you would like a lie-in at weekends) and from this it is but a short step to designing your own project - an all singing all dancing temperature/lighting controller to keep your pet reptiles in the style to which they are accustomed - - or perhaps an automatic lawnmower/sprinkler system with a digital display showing the time, amount of grass cut, average rainfall, distance walked and the date at which the lawn was last cut at the touch of a button - the choices are limited only by your imagination!

The circuit will be developed with specific reference to the PIC16C54 microcontroller which is available for under £4 in some versions (and that includes the Chancellor's piece of the action) so many circuits and applications which would otherwise not be viable because of cost or complexity are now perfectly feasible. Because this device has some unusual features compared to more conventional microprocessors, the series will start by examining the chips themselves but for fuller information the data sheets for the devices should be consulted.

Take your pic

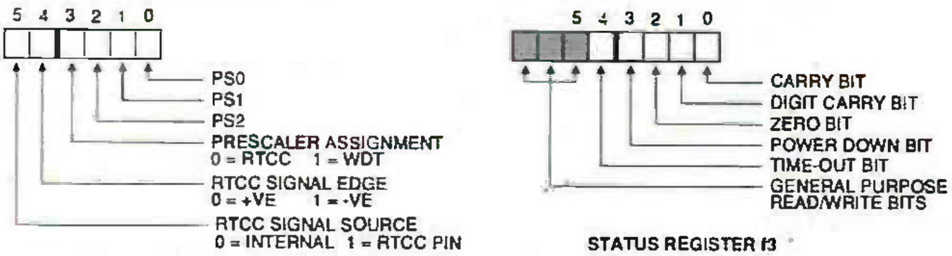
The PIC contains all the basic elements normally associated with a micro-computer system: an Arithmetic/Logic Unit (ALU), which executes the various instructions, a Read Only Memory (ROM or in this case an EPROM) to store the programme, a Random Access Memory (RAM) to store the results of the various operations as well as programmable Input/Output (I/O) lines for connecting the micro-controller to external devices. As well as this, it also contains other elements such as a clock oscillator, a counter/timer and watchdog timer and the only difference is that, unlike the computer on your desk, all of this is contained in one chip.

The PIC16C5X series of micro-controllers consists of four basic types (the PIC16C54, C55, C56 and C57) which differ only in the number of input/output (I/O) lines and EPROM and RAM size. These are available in the UV erasable versions and come in an 18 or 28 pin ceramic package. The cheaper windowless plastic versions of these four devices are identical to their EPROM counterparts except that once programmed they cannot be erased and are available with the suffixes RC, XT, HS and LP. These determine the type of oscillator used and the frequency range which, of course, determine the speed of operation.

The RC versions use a simple resistor - capacitor network to define the clock frequency giving a frequency range of DC to 4MHz and are useful where the execution time of instructions is not critical but the cost is. Where this timing is of importance, such as in our clock project where the oscillator is used as a time base for example, the XT, HS or LP versions should be used. The XT will run with a 100kHz to 4MHz and the HS with a 4 to 20MHz crystal or resonator, while the LP version is a lower power device for use with a low frequency crystal such as the popular 32kHz watch crystal.

The OSC1 and OSC2 pins are connected to the crystal or resonator and in the case of the RC oscillator mode only OSC1 is used with OSC2 functioning as a clock output producing a squarewave with a frequency of Fosc/4 where Fosc is the oscillator frequency measured at OSC1. In this mode, although the circuit will operate with no external capacitor, one of at least 20pF is recommended for noise and stability reasons. The value of the external resistor should be between 5 and 100kOhm. The ceramic "windowed" versions can be programmed and re-programmed to operate in any of these modes so that only one device needs to be purchased for development

The other features common to all devices include 12 - 20



PS2	PS1	PS0	RTCC RATE	WDT RATE
0	0	0	1:2	1:1
0	0	1	1:4	1:2
0	1	0	1:8	1:4
0	1	1	1:16	1:8
1	0	0	1:32	1:16
1	0	1	1:64	1:32
1	1	0	1:128	1:64
1	1	1	1:256	1:128

Fig.2. Pictorial representation of data mempry in PIC

fully programmable I/O lines which can easily drive seven segment LED displays even without driver transistors, an 8-bit real time clock/counter (RTCC), an 8-bit programmable prescaler, a power on reset circuit, a watchdog timer (WDT) and a security EPROM fuse which when blown prevents anyone from reading the contents of your EPROM and copying your programme.

The pinouts for the dual in line version of the PIC16C54 is shown in Fig 1. Vdd and Vss are the positive and negative supply rails and can be anything from 3.0 to 5.5 Volts making the device eminently suitable for battery operation. The current consumption is less than 3.3mA (except for the HS version when operated at 20MHz) and this can be further reduced to less than 15uA by executing a SLEEP instruction which disables the clock and halts operation until the device is "woken up" either by the watchdog timer timing out or by a reset pulse.

The MCLR pin is connected to Vdd (+5V) for normal operation and doing so will RESET the microcontroller when the device is powered up. If it is required to reset the device at any other time during operation, this pin should be connected to Vdd via a resistor and the pin taken momentarily to 0V. In some cases, especially with certain crystals which take longer to stabilise, a resistor and capacitor may be connected to this pin to ensure a longer reset period when the device is first switched on. On reset, all I/O lines are set to input mode and certain registers preset to various values. In particular the programme counter is set to 1FF (HEX) and since this is the highest EPROM address it overflows to 000h and executes the instruction stored there. For reasons which will become clear later, this is usually a GOTO instruction causing the programme to jump to the beginning of the programme which normally starts at a higher address.

The RTCC pin is the external input to the RTCC register which will be described later and can be used to enable the device to count external events such as mains cycles for example. If this input is not used, the pin should be connected to one or other of the supply rails to prevent unintended entering of test modes.

The 28 pin device has three I/O ports; PORT A, PORT B and PORT C while the 18 pin device has only two (A and B). These are 8 bits wide except for PORT A which has only 4 bits and each pin can source 20mA or sink 25mA so that LEDs can easily be driven although care should be taken to ensure that the maximum power dissipation is not exceeded. After a RESET, all ports are in the input mode and must be programmed to output if they are required to drive external devices.

Since this can be done under program control, a pin may be used as an input in one part of the program and as an output in another as long as the external circuit can handle this. Remember that an output should never be driven high or low by another output or an external device such as a logic gate or a switch.

Internal architecture

The PIC16C series of microcontrollers are unusual in that they use the so called Harvard Architecture which features a separate programme memory (which holds the instructions or programme for the computer to carry out and is usually stored in EPROM) and data memory which holds the results of these operations (and is normally RAM) together with separate connections or busses to transfer the data between the two memories and the arithmetic logic unit (ALU) which carries out the instructions.

Contrast this to most other microprocessors which use the Von Neumann architecture where the EPROM and RAM share the same address and data bus and form a continuous memory space within the range that the processor can address. This enables the PIC to execute one instruction while it is fetching the next one with a resulting faster execution of instructions. Because this architecture also permits a different width of bus to be used for both memories (the EPROM is 12 bits wide in the PIC16C5X series for example while the data memory is only 8 bits) this enables all instructions to be carried out in one cycle except branch instructions which require two. This makes it easy to work out how much time a section of programme will take to execute because a single cycle is simply the oscillator period multiplied by four. A 4MHz clock will therefore execute instructions at 1MHz so that each instruction will take 1uS while branch instructions such as GOTO or CALL will take 2uS.

Fig 2 shows a pictorial representation of the data memory of the PIC series microcontrollers. The RAM is organised as a series of 8-bit file registers numbered from 00 to 1F (hex) giving 32 registers for the basic devices with further 3 banks of 16 registers (i.e. 48 registers) for the PIC16C57. (These registers are selected by the FILE SELECT REGISTER or FSR which is register 04 but as this chip will not be used this will not be discussed further and the user is referred to the data sheet for more information on this.)

All the registers can be loaded, read and operated on in various ways by the program and are in this respect all identical. Some of them have fewer than 8-bits actually implemented and these are shown dotted. In these, the state of the missing bits as far as read operations are concerned are shown. Any write operation carried out on these registers will, of course, not alter the status of these bits. Some of the registers have special functions and cannot therefore be used as general purpose registers by the programmer and these are described below together with their file addresses:

Indirect register - 00

This register is not in fact implemented on the chip but is used in indirect addressing. By specifying this register in an instruction, the computer will use the register "pointed to" by the FSR (see later) to execute the instruction. Thus if the FSR contains 1Fh (hex) then the instruction will use register 1F.

RTCC - 01

This register is the REAL TIME CLOCK/COUNTER register which can be incremented by either the internal instruction cycle clock or by an external signal edge applied to the RTCC pin mentioned earlier. In addition, an 8-bit programmable prescaler counter can be assigned to the RTCC by setting various bits in the OPTION register (see later). As long as clock pulses are applied to the RTCC register (from the internal or external source, with or without the prescaler) the register will increment and will simply roll over to 00 hex when the value reaches FF hex. Since the PIC does not handle interrupts as do other processors which have built-in counter/timers, the RTCC register must be read periodically to see if it has reached zero if this function is required in the programme. To ensure that the count is not affected during this process, it is recommended that the MOVF RTCC,w instruction is used (see later).

PROGRAM COUNTER - 02

This register is actually 9 bits wide (10 and 11 bits in the PIC16C56 and '57 respectively) and keeps track of the next instruction to be executed. At reset, it is set to all 1's so that program execution for the PIC16C54/55 will start at address 1FF hex.

STATUS REGISTER - 03

This register is a collection of bits which are used to indicate the results of some of the instructions which the processor executes (see FIG 2A).

Bit 0 is the carry bit which goes to a logic 1 if an addition or subtraction operation results in an overflow i.e. if two numbers are added and the result is greater than 255 (FF hex) this will not fit into the 8 bits of a register so a carry is generated. Bit 1 has a similar function except that this bit is set if there is a carry from the 4th bit. This is useful in operations on BCD numbers but will not be dealt with here.

Bit 2 is the zero bit and is very important because this bit is set if the result of an operation is zero. This can be used to "test" a register to see if it contains zero and has many applications in programming.

The other bits in the STATUS register will not be used in our project and the reader is referred to the data sheet for more information on their function.

FILE SELECT REGISTER (FSR) - 04

Bits 0-4 of this register are used in selecting one of the 32 registers in the indirect addressing mode by specifying register f00 (INDIRECT register) in any of the instructions. These bits then act as a pointer to the register which is the object of the given instruction. If no indirect addressing is used in the programme, the FSR may be used as a general purpose 5-bit register. Bits 5-7 are read only and are always set to 1. In the PIC16C57, these three bits are also available and are used to select memory banks 1, 2 or 3 (see data sheet).

I/O REGISTERS - 05, 06 and 07

These registers are connected to the output port pins PORT A, B and (if it exists) C and may be read or written to just like any other register in the file. If the port is defined as an output, writing a "1" will cause the corresponding pin to go to +Vdd while a "0" will result in the pin going to 0 Volts. Read instructions however will result in the status of the pin being read irrespective of whether the pin has been defined as an input or output.

Note that since PORT A is only 4 bits wide, the high order bits of f05 (bits 4-7) do not exist and will be read as "zeros". In the 18 pin device there is no PORT C so register f07 can be used as a general purpose register and writing to it will, of course, not affect any of the I/O pins.

All the other registers are general purpose 8-bit registers for use in programmes to store the results of various operations. These have addresses ranging from 08h to 1Fh in the basic types (and to 7Fh in the PIC16C57 See data). As well as these there are a number of other registers which have special functions.

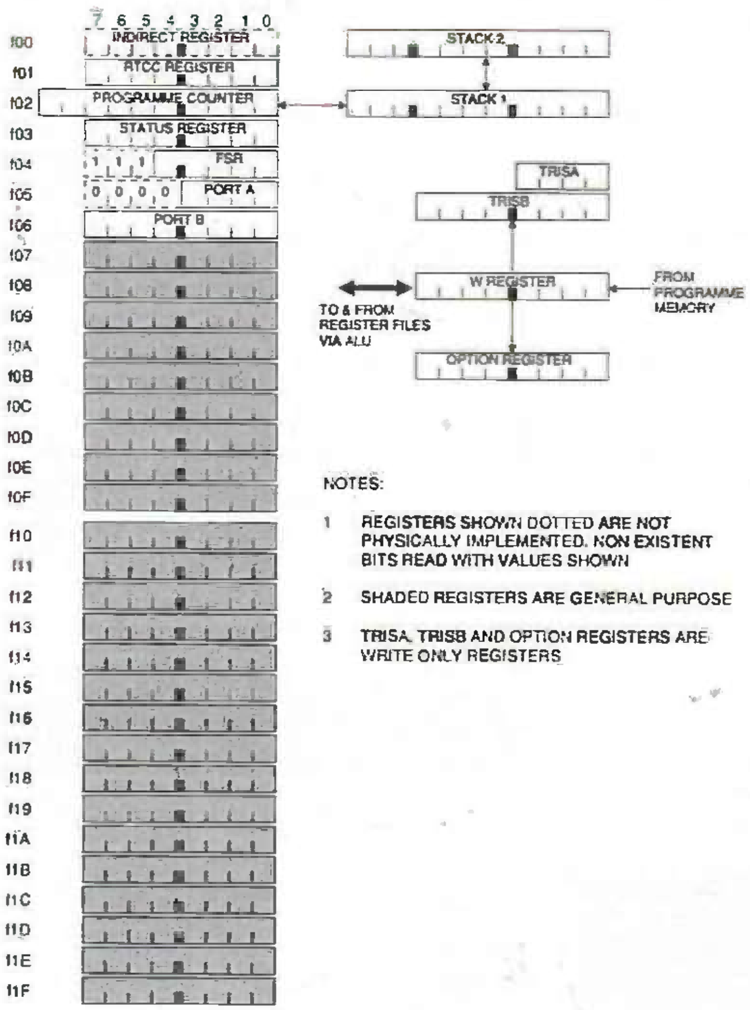


Fig.3. I/O registers

W (or WORKING) REGISTER

This register holds the second operand in two operand instructions and supports internal data transfer. It can also hold the result of an operation. TRISA, TRISB (and TRISC) are the I/O control registers for the corresponding ports and are used to define whether the pin in a port is an output or an input. This is done by loading a "1" into the corresponding bit of the register where an input is required and a zero for an output. Thus if port B pins 0,1,2,3 and bit 5 were to be inputs and the other pins outputs, TRISB register would be loaded with the value 0010 1111 or 2F in hex.
Note that since PORT A is only 4 bits wide, only bits 0 to 3 are available in the register TRISA so loading 2Fh into this register would result in only the "F" being moved so port A would become an input. The TRIS registers are write only and cannot be read.

OPTION REGISTER

This register determines the prescaler division ratio as well as defining the RTCC signal source (RTCC pin or internal instruction clock), the signal edge (positive or negative transition) and prescaler assignment (RTCC or watch dog timer). In our project this will be loaded with 07h which means that the division ratio will be 1:256 with the prescaler assigned to the RTCC register with the internal instruction clock as the signal source. For more details on this register refer to FIG. 2A and the data sheet.

STACK1, STACK2

Very often in a programme it is necessary for the processor to execute a series of instructions to do a specific job such as display the contents of a register on an LED display or read a keyboard. Since these functions are likely to be required a number of times in a programme, it makes sense to store them in a part of the memory only once and "call" them up as they are required. Indeed, whole programmes may be written by simply calling various subroutines as they are required which makes the programme easier to write and to understand as each subroutine performs a separate function.

Such subroutines are normally given a name such as DISPLAY or KEYBOARD and in the course of a programme a CALL DISPLAY or CALL KEYBOARD instruction is inserted when this is required. The processor then replaces the current address in the programme counter with the start address of the subroutine and executes it. When it has done this it needs to return to the point in the programme from which the subroutine was called to continue the operation and this return address is stored in a special register called the STACK register when the routine is called. As there are two STACKs in the PIC, it follows that a programme can contain a CALL instruction and the subroutine called can itself contain another CALL instruction enabling another subroutine to be executed (or nested) from within the first subroutine and both return addresses would be stored correctly. If another subroutine were to be called before the second one had been finished however, the programme would fail as the processor would "lose its way".

For those readers familiar with other micro-processors, the absence of any interrupt handling capability may seem to be a serious omission as once the programme is running, it would seem that the processor cannot be interrupted to cope with external events such as a pin going high or low and would therefore be unable to respond to them. This is not really a problem and simply means that the programmer must be careful to remember to read an input as often as necessary if its status is relevant to the operation of the programme. The speed with which programmes are executed usually means that inputs from external devices such as keyboards or other sensors can be read many times per second and the maximum delay before the system responds even assuming it "just missed" the actual input on the first pass would normally be insignificant.

If the input is a regular event such as a 50Hz mains input which is required for timing and which therefore cannot be missed, the programme must be written in such a way that it waits until the input occurs, does what needs to be done and then returns to wait for the next input, ensuring that all inputs are counted.

Next Month...

we will look at the instruction set of the PIC16C5X series and design of the hardware for the clock project.

Practically SPEAKING

BY TERRY BALBIRNIE

The unwary or weak-willed electronics enthusiast will always become the general dogsbody. Every non-working electrical appliance from kettle or iron to car radio or CD player will be brought along with a hurried: You know about electronics, don't you? Have a quick look at this!

To these people, "knowing about" electronics is an unskilled craft where a dab with the soldering iron will always put matters right. Not only are they prepared to put you down by implying that they could do the job themselves if they had the time but they don't want to pay the proper rate. If I had charged the commercial price for all the repairs I have had a "quick look at" over the years I would probably be a millionaire. The "quick look" has a habit of turning into the long slog. Even finding out how to part the plastic case of a ghetto blaster can take half an hour or more.

Of course, it is a different matter if you are helping out a member of the family, a charity organisation or a friend and there will be many repair jobs which the hobbyist will wish to carry out in the workshop. Sometimes a quick soldering job to repair a detached connection is, indeed, all that is required. Even so, if you are wanting to impress your partner/boss/friend by repairing a cassette player or fixing the PC - if you want to be seen as the electronics expert - you must have a selection strategy. This should enable you to attempt only those jobs which you are likely to tackle successfully, safely and quickly. You may get a little praise if you succeed but you will pick up a great deal of scorn if you fail. Also, you can easily make matters worse so that the eventual professional repair becomes much more expensive. You could even end up in trouble with the law if a botched repair to a piece of mains equipment resulted in injury.

Good sign

You need to assess what is being asked of you. If it is simply a matter of replacing a PP3 battery snap, this would seem a safe repair job to tackle. If the fault is not obvious, do you have any knowledge of this type of equipment? Have you done a similar job before? Do you have the time?

It is often a good sign if the equipment does not work at all. This often indicates a power supply problem such as a broken or detached wire, blown fuse or faulty switch. Wiggling controls and wires sometimes gives a spurt of life and a clue to the problem. Strange symptoms such as unusual noises from an amplifier often indicate a more deeply-seated problem and may require expert knowledge and access to the service manual. If tentative tests lead you to suspect that you may get out of your depth or that the job is likely to take too long - refuse straight away. Simply say that without a circuit diagram to follow or special test gear, it is impossible for you to repair it. You will not then lose face.

Extensive dismantling

I was once handed a car radio cassette player on the "quick look" basis. The fault turned out to be the on-off switch which was built into the volume control potentiometer - a common arrangement. Because it was a stereo pot it had six tag connections plus two for the switch. The whole assembly was extremely small and mounted on a miniature PCB of its own. Getting down to this PCB involved much dismantling and took two hours. Because I did not know the job, I dismantled more than was actually necessary but this was only clear in retrospect. Uprooting the PCB took another half hour including drawing a diagram with the colours of the various connecting wires on it.

Because the pot was a "special" component, it had to be ordered from the manufacturer and proved to be very expensive. There was an additional "small order" charge plus carriage. It was not supplied with a new PCB and the old pot had to be removed so that the original PCB could be re-used. This caused damage to the tracks which had to be virtually re-made using soldered bridge wires.

After re-assembly, the radio/cassette worked perfectly and the owner was delighted. Being realistic though, my labour would have cost more than a new unit. The agent's repair department could have done the job in a fraction of the time because they would be familiar with the model.

Next Month...

we shall look at some of the special problems in tackling - or refusing - repairs to mains-operated equipment.

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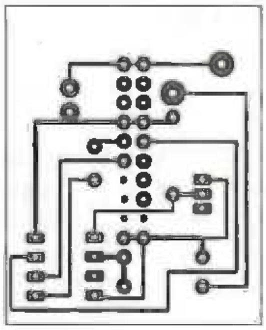

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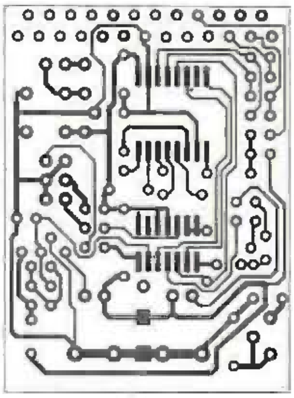

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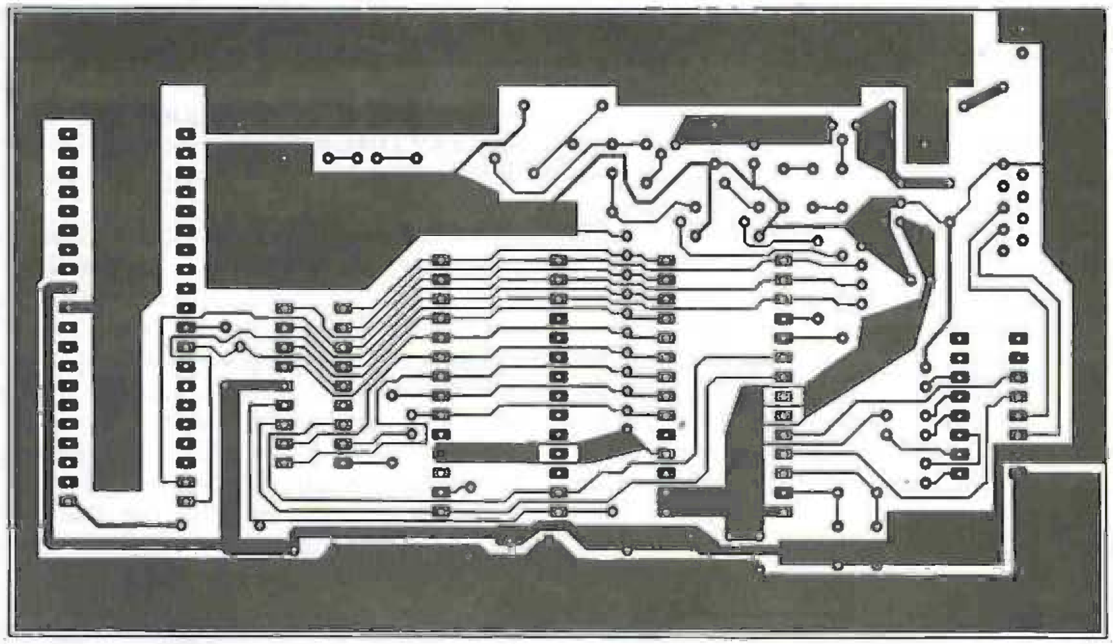
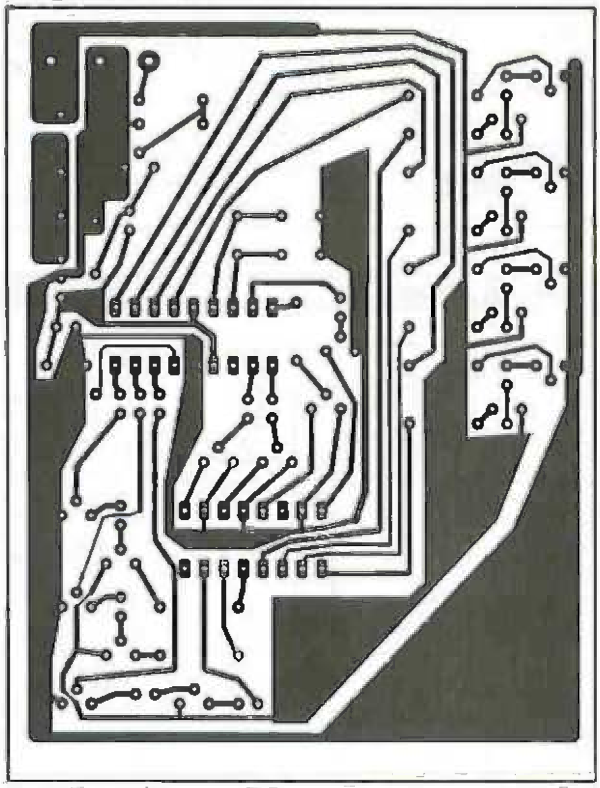
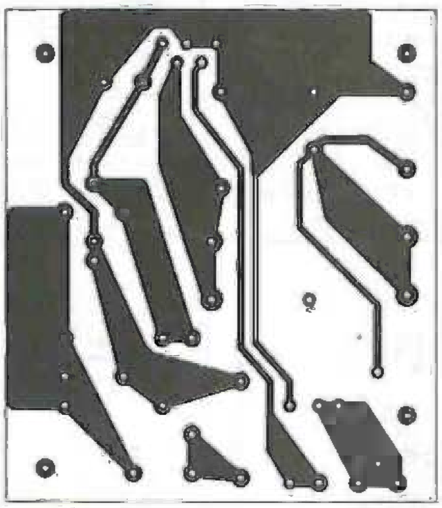


Pic Programmer



Light Gun



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Open Forum

According to figures just released by the Central Statistical Office, the economic recovery in Britain is being led by manufacturing industry rather than by a consumer or property price boom as in previous recovery periods. The figures show that the fastest growing areas of the economy are exports of high technology electrical and electronic engineering equipment, news that should gladden all of us who are involved in electronics.

Some of this growth is accounted for by booming sales for UK made personal computers, and allied equipment, areas where the UK is especially strong in Europe. But a lot of the growth comes from the new electronics based technology companies which have sprung up all over the country during the last ten years.

Robert Madge's Madge Networks, founded with very little financial backing in 1986 is now a major player in the world market for Token Ring networks, and wrestling market share from IBM amongst others. With a current turnover of nearly £150million per year, and profits of over £30million, the company is a major UK success story.

Another example is Advanced RISC Machines, the creators of the asynchronous computer featured in this issue of ETI. In the last four years, this company has become a world leader in RISC processor design and has seen turnover, profits, number of employees, and cash in hand roughly double every year over the last three or four years.

These are the new high technology companies which are revitalising the UK manufacturing industry and providing the impetus behind the current economic recovery - a recovery which is infinitely more sound and potentially durable than any based on retail sales or house price increases, for it is a recovery which will generate real wealth and real employment.

These are companies which are using the intellectual talent that exists within this country rather than relying on cheap labour and large government grants. They are companies which are looking towards the construction of true global markets for their products and which are investing heavily in research and development to ensure that their position can not be challenged.

At Madge Networks the company have just opened a new UK based research centre employing 200 computer scientists and electronic engineers, At ARM they now employ over 110 people, well over half of whom are development engineers, plus they are funding basic long-term research at Manchester University.

A lot of forecasters say that the rapid expansion of such companies will be restricted in the long term as a result of a shortage of skilled personnel. In the very long term, they may be right, and we as a country do desperately need to educate more engineers, but what is noticeable about such companies is that they regard talent as being international.

The thing is that the people who run such companies realise that you need the best brains working for you in order to succeed in the cut-throat world market for high technology. They know that they must recruit the best, and to keep them they must pay them well and, if necessary, give them stock options. The wealth generated by these new high technology companies must be shared with those whose skills have been used to generate that wealth.

Only if we can encourage this attitude will this country succeed in high technology industry. For tomorrow's success stories will be companies created by the employees of today's success stories. It is a self-perpetuating system that is fuelled by recognising talent and remunerating it well, and in so doing allowing that talent the freedom to recognise new opportunities and create new wealth.

Next Month...

In the August 1995 issue of Electronics Today International we will be starting an interesting range of new projects. One of these is the start of a new computer construction project, an 8088 interrupt based control computer from Richard Grodzik. Dr Pei An shows how to build a computerised radio digital transmission system and Robert Penfold offers an analogue shutter timer project.

Tim Parker describes how to build a pocket-sized multipurpose tester that will be a handy addition to any test bench. Continuing on from his Raydor project in ETI a few months ago Pat Alley describes a few add-on features, including a remote radio controller. Continuing his practical approach to designing with the PIC microcontroller Bart Trepak continues his quest for the perfect alarm clock.

The two feature articles in next month's ETI are a detailed look by Dave Clarkeson at DC and electrically commutated electric motors, and an investigation into the future of digital interactive television - Will it bring the information superhighway into everyone's homes? Will we become a nation of old movie addicts, home shoppers, and teleworkers?

ETI

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ABC CONSUMER PRESS

ISSN 0142-7229

ETI is normally published on the first Friday in the month preceding the cover date.

Subscription rates-UK £25.80 Europe £34.70 Sterling Overseas £36.20 US Dollars Overseas $54.00

Published by Nexus Special Interests, Nexus House, Boundary Way, Hemel Hempstead HP2 7ST. Telephone (01442) 66551. UK newstrade distribution by SM Distribution Ltd, 6 Leigham Court Road, London SW16 2PG. Telephone 0181-677 8111. Overseas and non-newstrade sales by Magazine Sales Department, Argus House, Boundary Way, Hemel Hempstead, HP2 7ST. Telephone (01442) 66551. Subscriptions by Nexus Subscription Services, ETI, Queensway House, 2 Queensway, Redhill, Surrey RH1 1QS. Telephone (01737) 768611.
US subscriptions by Wise Owl Worldwide Publications, 4314 West 238th Street, Torrance, CA90505 USA. For Visa/Mastercard orders in USA - Telephone (310) 375 6258 Fax (310) 375 0548. Pacific Time: 9am-9pm Weekdays, 10am-6pm Weekends.
Typesetting and origination by Ebony, Liskeard, Cornwall. Printed by Wiltshire Ltd, Bristol.

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