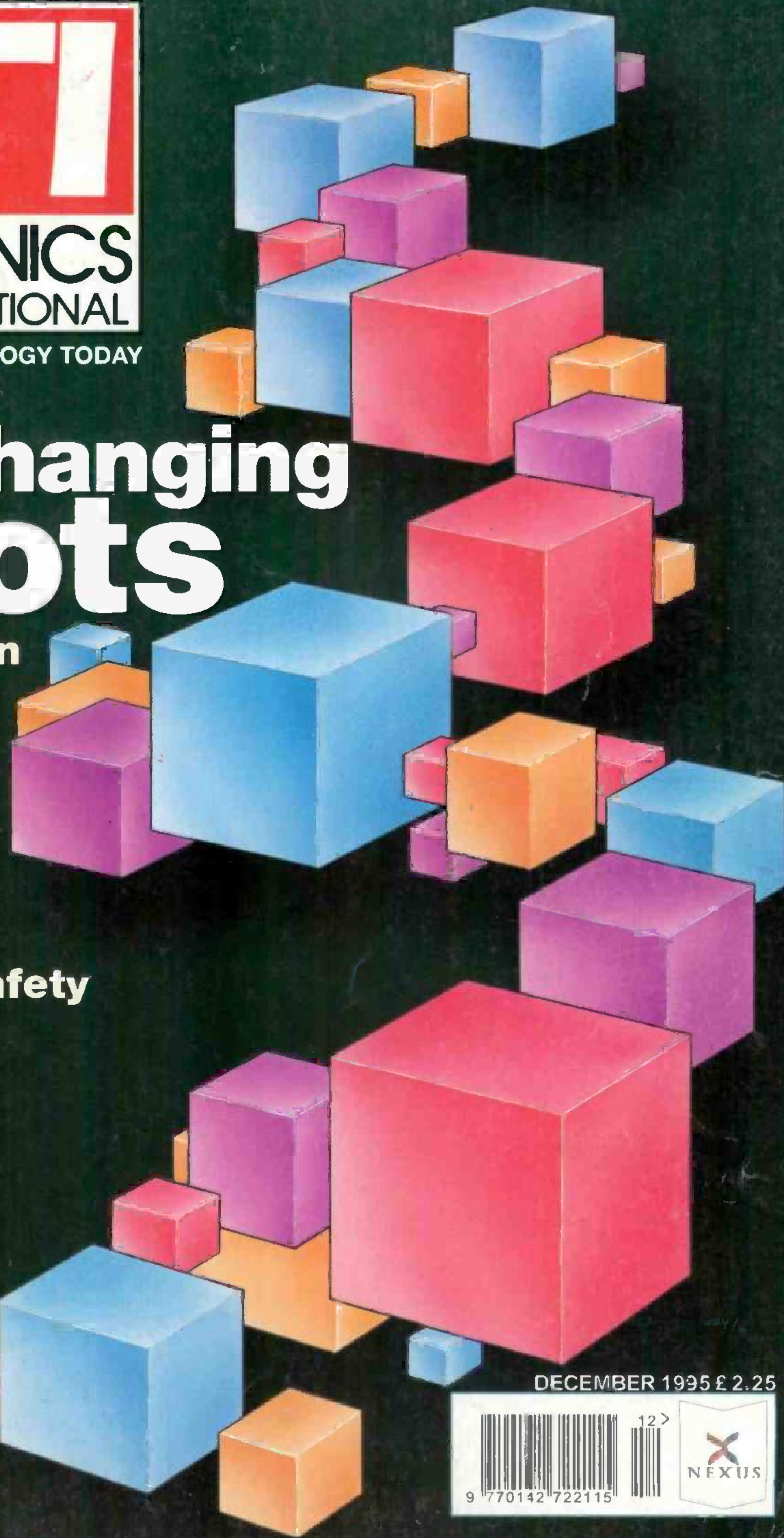
ETI
ELECTRONICS TODAY INTERNATIONAL

TOMORROW'S TECHNOLOGY TODAY



Shape changing robots

science fiction or reality?

Noise masker for a quieter life

Switching off on time for safety

Stop thief cycle alarm

Plus

- The ETI Basic microcontroller
- The PIC tutorial
- Electronics Workbench a review

DECEMBER 1995 £ 2.25

Contents

Volume 24 No.12

& Features Projects

Shape changing robots 10

A look at the potentially revolutionary work of a British inventor which could have an enormous impact on the lives of all of us

Bar-code reader 18

Dr Pei An has developed a system which allows a PC to read any bar-code, even the one on the front cover of ETI!

The Electronics Engineer's PC 28

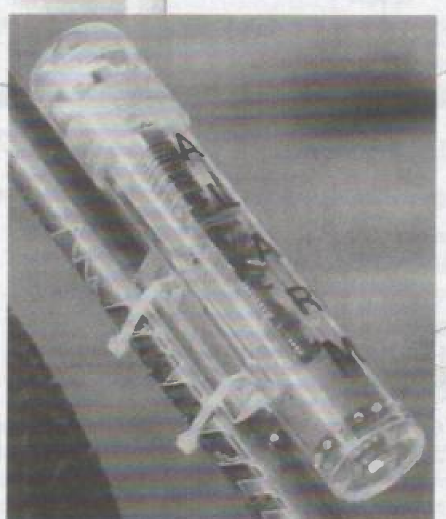
In this new series, Paul Stenning takes a look at Electronics Workbench, an electronic circuit simulation package

Noise Masker 34

Robert Penfold devises an electronic solution to the increasingly pervasive problem of noise pollution

Electronic Cycle Alarm 40

Worried about having your bike stolen? Then Simon Brown's cycle alarm may be the solution to your worries

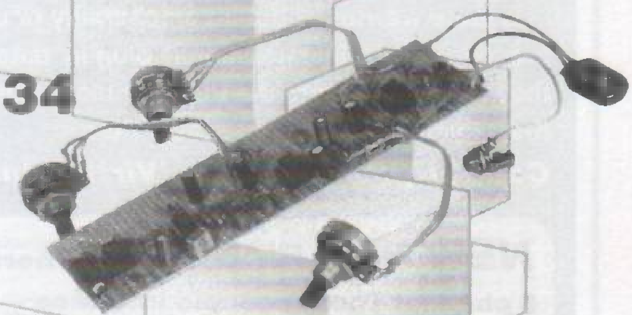


Timed Isolator 44

A useful device which will automatically switch off mains equipment after a specified period

The ETI Basic microcontroller 52

In part 3 of this premier project, Robin Abbott looks at some other versions of the ETI PIC based controller module, which offer the user a range of additional options



Designing a PIC microcontroller based project 56

In Part 6 of this short tutorial series, Bart Trepak concludes his look at the circuit and design of a PIC based alarm clock

Regulars

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PORTABLE X RAY MACHINE PLANS Easy to construct plans on a simple and cheap way to build a home X-ray machine! Effective device, X-ray sealed assemblies, can be used for experimental purposes. Not a toy or for minors! £6/set. Ref F/XP1.

TELEKINETIC ENHANCER PLANS Mystify and amaze your friends by creating motion with no known apparent means or cause. Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect. Excellent for science projects, magic shows, party demonstrations or serious research & development of this strange and amazing phychic phenomenon. £4/set Ref F/TKE1.

ELECTRONIC HYPNOSIS PLANS & DATA This data shows several ways to put subjects under your control. Included is a full volume reference text and several construction plans that when assembled can produce highly effective stimuli. This material must be used cautiously. It is for use as entertainment at parties etc only, by those experienced in its use. £15/set. Ref F/EH2.

GRAVITY GENERATOR PLANS This unique plan demonstrates a simple electrical phenomena that produces an anti-gravity effect. You can actually build a small mock spaceship out of simple materials and without any visible means- cause it to levitate. £10/set Ref F/GRA1.

WORLDS SMALLEST TESLA COIL/LIGHTENING DISPLAY GLOBE PLANS Produces up to 750,000 volts of discharge, experiment with extraordinary HV effects, 'Plasma in a jar', St Elmo's fire, Corona, excellent science project or conversation piece. £5/set Ref F/BTC1/LG5.

COPPER VAPOUR LASER PLANS Produces 100mw of visible green light. High coherency and spectral quality similar to Argon laser but easier and less costly to build yet far more efficient. This particular design was developed at the Atomic Energy Commision of NEGEV in Israel. £10/set Ref F/CVL1.

VOICE SCRAMBLER PLANS Minature solid state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit. Use on telephone to prevent third party listening and bugging. £6/set Ref F/VS9.

PULSED TV JOKER PLANS Little hand held device utilises pulse techniques that will completely disrupt TV picture and sound! works on FM too! DISCRETION ADVISED. £8/set Ref F/TJ5.

BODYHEAT TELESCOPE PLANS Highly directional long range device uses recent technology to detect the presence of living bodies, warm and hot spots, heat leaks etc. Intended for security, law enforcement, research and development, etc. Excellent security device or very interesting science project. £8/set Ref F/BHT1.

BURNING, CUTTING CO2 LASER PLANS Projects an invisible beam of heat capable of burning and melting materials over a considerable distance. This laser is one of the most efficient, converting 10% input power into useful output. Not only is this device a workhorse in welding, cutting and heat processing materials but it is also a likely candidate as an effective directed energy beam weapon against missiles, aircraft, ground-to-ground, etc. Particle beams may very well utilize a laser of this type to blast a channel in the atmosphere for a high energy stream of neutrons or other particles. The device is easily applicable to burning and etching wood, cutting, plastics, textiles etc £12/set Ref F/LC7.

MYSTERY ANTI GRAVITY DEVICE PLANS Uses simple concept. Objects float in air and move to the touch. Defies gravity, amazing gift, conversation piece, magic trick or science project. £6/ set Ref F/ANT1K.

ULTRASONIC BLASTER PLANS Laboratory source of sonic shock waves. Blow holes in metal, produce 'cold' steam, atomize liquides. Many cleaning uses for PC boards, jewllery, coins, small parts etc. £6/set Ref F/ULB1.

ULTRAHIGH GAIN AMP/STETHOSCOPIC MIKE/SOUND AND VIBRATION DETECTOR PLANS Ultrasensitive device enables one to hear a whole new world of sounds. Listen through walls, windows, floors etc. Many applications shown, from law enforcement, nature listening, medical heartbeat, to mechanical devices. £6/set Ref F/HGA7

ANTI DOG FORCE FIELD PLANS Highly effective circuit produces time variable pulses of accoustical energy that dogs cannot tolerate £6/set Ref F/DOG2

LASER BOUNCE LISTENER SYSTEM PLANS Allows you to hear sounds from a premises without gaining access. £12/set Ref F/LLIST1

CRAWLING INSECT ROASTER PLANS Harmless high frequency energy pulses destroy pests as they crawl into the energy field! £4/set Ref F/RCR1

LASER LIGHT SHOW PLANS Do it yourself plans show three methods. £6 Ref F/LLS1

PHASOR BLAST WAVE PISTOL SERIES PLANS Handheld, has large transducer and battery capacity with external controls. £6/set Ref F/PSP4

INFINITY TRANSMITTER PLANS Telephone line grabber/ room monitor. The ultimate in home/office security and safety! simple to use! Call your home or office phone, push a secret tone on your telephone to access either: A) On premises sound and voices or B) Existing conversation with break-in capability for emergency messages. £7 Ref F/TELEGRAB.

BUG DETECTOR PLANS Is that someone getting the goods on you? Easy to construct device locates any hidden source of radio energy! Sniffs out and finds bugs and other sources of bothersome interference. Detects low, high and UHF frequencies. £5/set Ref F/ BD1.

ELECTROMAGNETIC COIL GUN PLANS Projects a metal object a considerable distance-requires adult

ELECTRIC MAN PLANS, SHOCK PEOPLE WITH THE TOUCH OF YOUR HAND! £5/set Ref F/EMA1

PARABOLIC DISH MICROPHONE PLANS Listen to distant sounds and voices, open windows, sound sources in 'hard to get' or hostile premises. Uses satellite technology to gather distant sounds and focus them to our ultra sensitive electronics. Plans also show an optional wireless link system. £8/set ref F/PM5

2 FOR 1 MULTIFUNCTIONAL HIGH FREQUENCY AND HIGH DC VOLTAGE, SOLID STATE TESLA COIL AND VARIABLE 100,000 VDC OUTPUT GENERATOR PLANS Operates on 9-12vdc, many possible experiments. £10 Ref F/HVM7/ TCL4.

WOLVERHAMPTON BRANCH NOW OPEN AT WORCESTER ST W'HAMPTON TEL 01902 22039

MINI FM TRANSMITTER KIT Very high gain preamp, supplied complete with FET electret microphone. Designed to cover 88-108 Mhz but easily changed to cover 63-130 Mhz. Works with a common 9v (PP3) battery. 0.2W RF. £7 Ref 1001.

ELECTRONIC SIREN KIT Impressive 5 watt power output. Ideal for car/bike alarm etc. 6-12v dc max current 1A, 1.2khz £6 Ref 1003.

3-30V POWER SUPPLY KIT Variable, stabilized power supply for lab use. Short circuit protected, suitable for profesional or amateur use 24v 3A transformer is needed to complete the kit. £14 Ref 1007.

1 WATT FM TRANSMITTER KIT Supplied with piezo electric microphone 8-30vdc. At 25-30v you will get nearly 2 watts! £12 ref 1009.

FM/AM SCANNER KIT Well not quite, you have to turn the knob your self but you will hear things on this radio that you would not hear on an ordinary radio (even TV). Covers 50-160mhz on both AM and FM. Built in 5 watt amplifier, inc speaker. £15 ref 1013.

MOSQUITO REPELLER KIT Modern way to keep midges at bay! Runs for about a month on one 1.5v battery. £7 Ref 1015.

3 CHANNEL SOUND TO LIGHT KIT Wireless system, mains operated, separate sensitivity adjustment for each channel, 1,200 w power handling, microphone included. £14 Ref 1014.

MOTORBIKE/CYCLE TREMBLER ALARM KIT Adjustable sensitivity, preset alarm time, auto reset. Could be connected to horn etc. £12 Ref 1011.

0-5 MINUTE TIMER KIT adjustable, will switch up to 2A mains. Perfect for alarms, photography, etc. £7 Ref 1020.

4 WATT FM TRANSMITTER KIT Small but powerful FM transmitter, 3 RF stages, microphone and audio preamp included. £20 Ref 1028.

STROBE LIGHT KIT Adjustable from 1-60 hz (a lot faster than conventional strobes). Mains operated. £16 Ref 1037.

ULTRASONIC RADAR KIT Ideal as a movement detector with a range of about 10 metres, automate your cat flap! 12v dc. £15 Ref 1049.

LIQUID LEVEL DETECTOR KIT Useful for tanks, ponds, baths, rain alarm, leak detector etc. Will switch 2A mains. £5 Ref 1081.

COMBINATION LOCK KIT 9 key, programmable, complete with keypad, will switch 2A mains. 9v dc operation. £10 ref 1114.

PHONE BUG DETECTOR KIT This device will warn you if somebody is eavesdropping on your line. £6 ref 1130.

ROBOT VOICE KIT Interesting circuit that distorts your voice! adjustable, answer the phone with a different voice! 12vdc £9 ref 1131

TELEPHONE BUG KIT Small bug powered by the 'phone line, starts transmitting as soon as the phone is picked up! £8 Ref 1135.

FUNCTION GENERATOR KIT Produces sinusoidal, saw tooth and square waves from 20-20khz, separate level controls for each shape. Will produce all 3 together. 24vac. £16 ref 1008.

3 CHANNEL LIGHT CHASER KIT 800 watts per channel, speed and direction controls supplied with 12 LEDS (you can fit triacs instead to make kit mains, not supplied) 9-12vdc £17 ref 1026.

12V FLOURESCENT LAMP DRIVER KIT Light up 4 foot tubes from your car battery! 9v 2a transformer also required. £8 ref 1069.

VOX SWITCH KIT Sound activated switch ideal for making bugging tape recorders etc, adjustable sensitivity. £8 ref 1073.

INCAR SOUND TO LIGHT KIT Put some atmosphere in your car with this mini 3 channel sound to light. Each channel has 6 led's. £10 ref 1086.

7W HI FI AMPLIFIER KIT Useful, powerful, ideal for audio systems, intercoms etc. 12-18vdc £7 ref 1025.

PHONE CALL RELAY KIT Useful device that operates a relay whenever the 'phone rings. Switches mains at 2A. £10 ref 1122.

LEAD ACID CHARGER KIT Two automatic charging rates, visual indication of battery state, ideal for alarm systems etc, 100mA 12vdc £12 ref 1095.

CAR ALARM KIT Works on voltage drop and vibration, entry/exit delays, adjustable alarm duration, ideal caravans etc £12 ref 1019.

PORTABLE ALARM KIT Based on mercury switch, alrm continues to sound until reset by owner. Buzzer inc. £11 ref 1150.

PREAMP MIXER KIT 3 input mono mixer, sep bass and treble controls plus individual level controls, 18vdc, input sens 100mA. £15 ref 1052.

METAL DETECTOR KIT Range 15-20cm, complete with case, 9vdc. £8 ref 1022.

SINGLE CHANNEL SOUND TO LIGHT KIT Mains operated, add rythum to your party for only £8 ref 1006.

SOUND EFFECTS GENERATOR KIT Produces sounds ranging from bird chips to sirens. Complete with speaker, add sound effects to your projects for just £9 ref 1045.

GUITAR PREAMP KIT Complete with tone controls, small enough to fit in any guitar, based on TL082 IC, 9-12vdc £8 Ref 1091.

15 WATT FM TRANSMITTER (BUILT) 4 stage high power, preamp required 12-18vdc, can use ground plane, yagi or open dipole. £69 ref 1021.

TELEPHONE AMPLIFIER KIT Very sensitive amplifier which uses a pickup coil (supplied) will let you follow a conversation with out holding the 'phone. £11 ref 1059.

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

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FAX 01273 323077

HUMIDITY METER KIT Builds into a precision LCD humidity meter, 9 ic design, pcb, lcd display and all components included. £49

PC TIMER KIT Four channel output controlled by your PC, will switch high current mains with relays (supplied). Software supplied so you can program the channels to do what you want whenever you want. Minimum system configeration is 286, VGA, 4.1,640k, serial port, hard drive with min 100k free. £24.99

DIVINING RODS Expensive technology cannot challenge the fool proof art of water divining, passed down from generation to generation. Seeing is believing. Use in the home, garden, countryside or desert, it's divinely simple! £4.99 a pair ref E/3.

HUGE BUBBLE MAKING KIT You'll be amazed at the the size of the bubbles you can acheive with this bubble making kit. Once you have got the knack it is possible to make bubbles of up to 40 feet long. £11.99 ref E/9.

FM CORDLESS MICROPHONE This unit is an FM broadcasting station in minature, 3 transistor transmitter with electret condenser mic+fet amp design result in maximum sensitivity and broad frequency response. 90-105mhz, 50-1500hz, 500 foot range in open country! PP3 battery required. £15.00 ref 15P42A.

MAGNETIC MARBLES They have been around for a number of years but still give rise to curiosity and amazement. A pack of 12 is just £3.99 ref GI/R20

STETHOSCOPES A fully functioning stethoscope for all those intricate projects. Enables you to listen to motors, pipes, heartbeats, walls, insects etc. £6 ref MAR6P6.

NICKEL PLATING KIT Proffesional electroplating kit that will transform rusting parts into showpieces in 3 hours! Will plate onto steel, iron, bronze, gunmetal, copper, welded, silver soldered or brazed joints. Kit includes enough to plate 1,000 sq inches. You will also need a 12v supply, a container and 2 12v light bulbs. £39.99 ref NIK39.

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

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
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HY1260M, 12vDC adjustable from 0-60 mins. £4.99
HY2460M, 24vAC adjustable from 0-60 mins. £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

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

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.

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

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

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

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

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

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

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.

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

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

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

3' by 1' AMORPHOUS SOLAR PANELS 14.5v, 700mA 10 watts, aluminium frame, screw terminals. £44.95 ref MAG45.

ELECTRONIC ACCUPUNCTURE KIT Builds into an electronic version instead of needles! good to experiment with. £7 ref 7P30

SHOCKING COIL KIT Build this little battery operated device into all sorts of things, also gets worms out of the ground! £7 ref 7P36.

FLYING PARROTS Easily assembled kit that builds a parrot that actually flaps its wings and flies! 50 m range £6 ref EF2

HIGH POWER CATAPULTS Hinged arm brace for stability, tempered steel yoke, super strength latex power bands. Departure speed of ammunition is in excess of 200 miles per hour! Range of over 200 metres! £7.99 ref R/9.

BALLON MANUFACTURING KIT British made, small blob blows into a large, longlasting balloon, hours of fun! £3.99 ref GI/E99R

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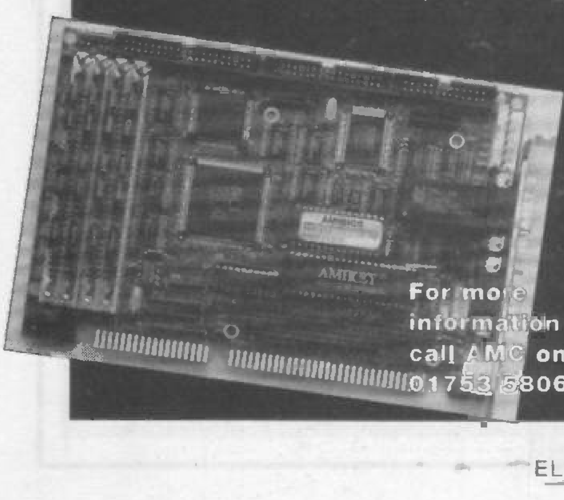
ETI ELECTRONICS TODAY INTERNATIONAL News...

Halfsize Industrial Single Board PC

The AMC-350A comes equipped with a 80386SX-40 or 80486SLC-33 CPU. Also included are two serial RS-232 ports, a bi-directional parallel port, an IDE hard disk drive interface (which controls up to two hard disk drives), and a watchdog timer. The watchdog timer ensures that the CPU will be reset if it stops due to a program or EMI problem, allowing the AMC-350A to be used in stand-alone systems or unmanned environments. With its industrial grade reliability, the AMC-350A can operate continuously at up to 140°F (60°C) temperatures.

The AMC-350A is specifically designed as a compact all-in-one CPU card which incorporates a PC/104 connector into its design, making non-passive backplane applications possible. The 4-layer CPU card turns any system into a 16-bit 386 compatible computer. Its highly compact form and numerous features make it an ideal cost/performance solution for high-end commercial and industrial applications where CPU speed and mean-time-to-repair are critical. In addition, its all-in-one configuration frees up valuable expansion slots. Built using CMOS technology, the AMC-350A consumes very little power.

The AMC-350A provides 4 SIMM (Single In-Line Memory Module) sockets for its on-board system DRAM. Each socket accepts one 256KB 1MB or 4MB SIMM. Total on-board memory can be configured from 1MB up to 16MB.



For more information call AMC on 01753 580660.

Car Battery Booster Charger

The latest in car products from Maplin Electronics is the Car Battery Booster/Charger. Costing £39.99, it is a high quality, powerful battery charger which supplies a useful 15A charge and is also capable of providing a short boost charge or even starting a car.

The compact charger will prove a useful tool to anyone who uses machinery, such as the building and farming industries, or the motor trade. It will also prove valuable to most car owners in winter when engines and batteries are cold and indifferent towards starting - thanks to its ability to supply a healthy 12V 100A boost for up to 5 seconds.

The charger is housed in a robust case with a built-in handle and can be wall-mounted. Two sturdy leads, terminating in heavy-duty crocodile clips, carry the charge to the battery. Built-in overload protection is provided and reset with a push switch.

For further information, telephone (01702) 552911.

Gang Programming for Microcontrollers & SIMM Modules

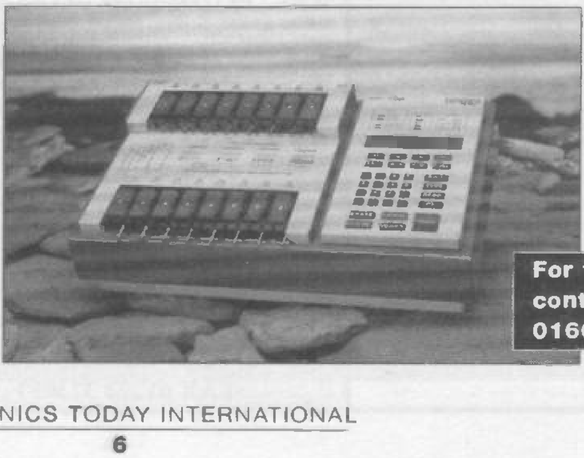
MQP Electronics has announced support for many more devices in their range of production devices programming equipment.

Support is now available for the full range of microcontrollers from several leading manufacturers. The microcontrollers can typically be programmed 8 at a time, at very high speeds. Manufacturers supported include Motorola with their 68HC705 and 68HC711 series and NEC with the popular 75P and 78P series. A gang module is also available for the SGS-Thomson ST6 family.

This year, for the first time, MQP also offers gang programming of FLASH SIMM modules, up to 128Mbit and beyond, as well as in the PCMCIA format.

Another recent addition to the S2000 gang programming system is a single site universal programming module. This makes the system arguably the most versatile production programming system available.

MQP Electronics provides programming solutions for both development and high volume production. All MQP programmers offer comprehensive PC software support, with batch controlled modes to automatically deal with the special programming options required by users and converters are available to deal with all package variants.



For further details, contact MQP on 01666 825146.

BULL CLEAROUT SALE

WIRELESS VIDEO BUG KIT Transmits video and audio signals from a minature CCTV camera (included) to any standard television! All the components including a PP3 battery will fit into a cigarette packet with the lens requiring a hole about 3mm diameter. Supplied with telescopic aerial but a piece of wire about 4" long will still give a range of up to 100 metres. A single PP3 will probably give less than 1 hours operating time. £98 REF EP79. (probably not licensable!)

GOT AN EXPENSIVE BIKE? You need one of our bottle alarms, they look like a standard water bottle, but open the top, insert a key to activate a motion sensor alarm built inside. Fits all standard bottle carriers, supplied with two keys. SALE PRICE £7.99 REF SA32.

GOT AN EXPENSIVE ANYTHING? You need one of our cased vibration alarms, keyswitch operated, fully cased just fit it to anything from videos to caravans, provides a years protection from 1 PP3 battery, UK made. SALE PRICE £4.99 REF SA33.

DAMAGED ANSWER PHONES These are probably beyond repair so they are just £4.99 each. Mainly response 200 machines. REF SA30.

COMMODORE GAMES CONSOLES Just a few of these left to clear at £5 ref SA31. Condition unknown.

COMPUTER DISC CLEAROUT We are left with a lot of software packs that need clearing so we are selling at disc value only! 50 discs for £4, thats just 8p each!!(our choice of discs) SALE PRICE £4 ref EP66

IBM PS2 MODEL 160Z CASE AND POWER SUPPLY Complete with fan etc and 200 watt power supply. SALE PRICE £9.95 ref EP67

DELL PC POWER SUPPLIES 145 watt, +5,-5,+12,-12, 150x150x85mm complete with switch, flyleads and IEC socket. SALE PRICE £9.99 ref EP55

1.44 DISC DRIVES Standard PC 3.5" drives but returns so they will need attention SALE PRICE £4.99 ref EP68

1.2 DISC DRIVES Standard 5.25" drives but returns so they will need attention SALE PRICE £4.99 ref EP69

PP3 NICADS New and unused but some storage marks. SALE PRICE £4.99 ref EP52

SOLAR PANELS 3v output with two flyleads, 100x60 mm pack of 10 SALE PRICE £6.99 ref EP56

DELL PC POWER SUPPLIES (Customer returns) Standard PC psu's complete with fly leads, case and fan, pack of two psus SALE PRICE £5 FOR TWO!! ref EP61

GAS HOBS AND OVENS Brand new gas appliances, perfect for small flats etc. Basic 3 burner hob SALE PRICE £24.99 ref EP72. Basic small built in oven SALE PRICE £79 ref EP73

BITS AND BOBS We have a quantity of cased modems, multiplexers etc different specs but ideal strippers. SALE PRICE £4 each ref EP63

RED EYE SECURITY PROTECTOR 1,000 watt outdoor PIR switch SALE PRICE £9.99 ref EP57

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, SALE PRICE £9.95 ref SA12. SAVE £120!!!

MINI MICRO FANS 12V 1.5" sq SALE PRICE £2. Ref SA13.

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 90 degC. SALE PRICE £9.95 REF SA29

12V 2AMP LAPTOP psu's 110x55x40mm (includes standard IEC socket) and 2m lead with plug. 100-240v IP. SALE PRICE £6.99 REF SA15.

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 £89.00.

SOLAR PATH LIGHTS Low energy walklights powered by the sun! built in PIR so they work when you walk past. Includes solar panel & rechargeable bat. SALE PRICE £19.9REF EP62

BIG BROTHER PSU Cased PSU, 6v 2A output, 2m o/p lead, 1.5m input lead, UK made,220v. SALE PRICE £4.99 REF EP7

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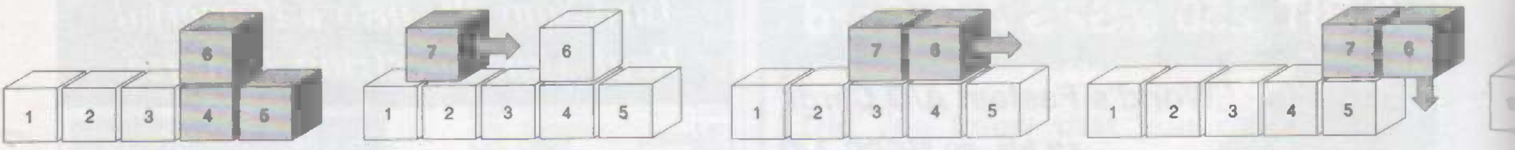
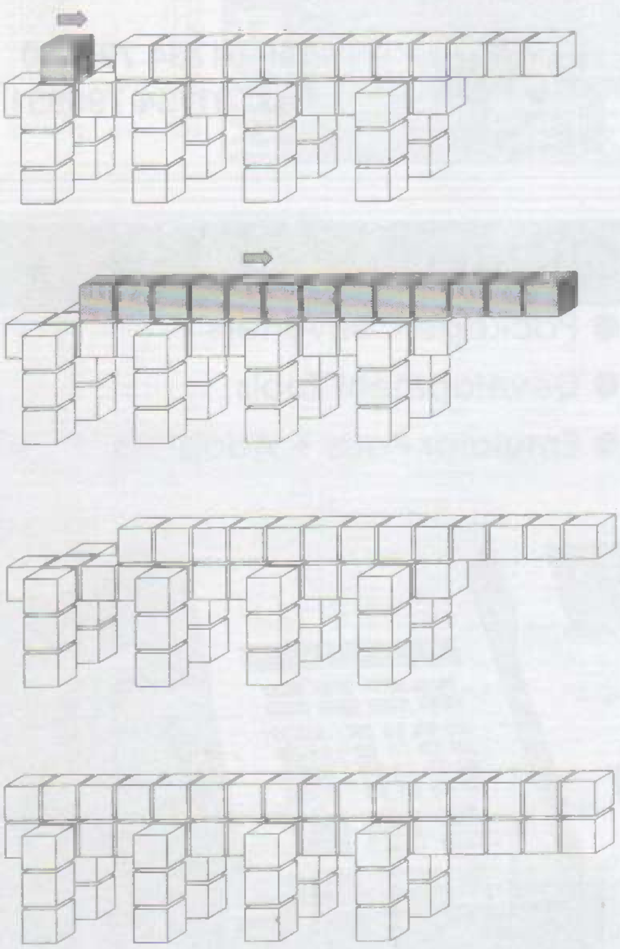


Shape Changing Ro

A look into the future as envisioned by a British inventor, a future filled with robots ranging in size from smaller than a grain of sand to as big a a skyscraper, yet all created using a single simple cubic unit.



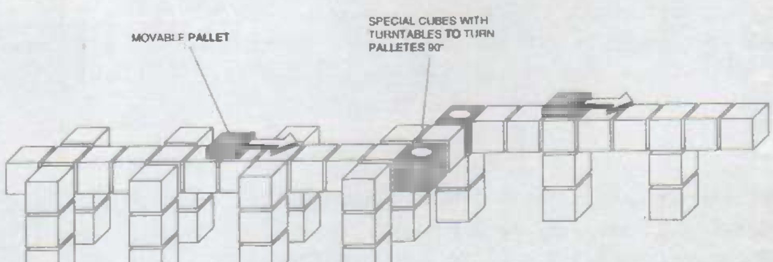
Walking mechanism with legs

For the past 17 years, a North London electrical engineer and computer programmer, Joe Michael, has had a dream - a dream which started when he was still a student, a dream to design and build the world's first shape-changing robot.

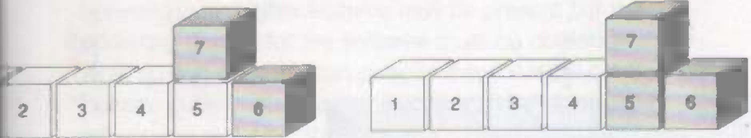
The shape-changing robot idea was initially conceived as some way of moving atoms and molecules to create new types of matter, but as a student of biochemistry he quickly realised that such a technique was either impossible or, at best, extremely difficult to implement. It was then that he hit on the idea of using a fractal-like system of small interlocking cubes that can slide over each other and, in so doing, form any desired shape.

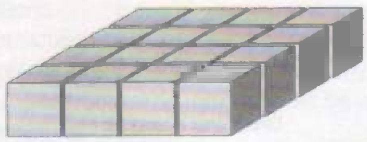
In pursuit of this idea, he studied electrical engineering and computing, spending most of his time and money working on the idea and developing it to a stage where he could demonstrate its practicality. After years of work, and the expenditure of over £35,000 in securing world-wide patents, his dream will become a reality when the first prototype units are completed in early 1996.

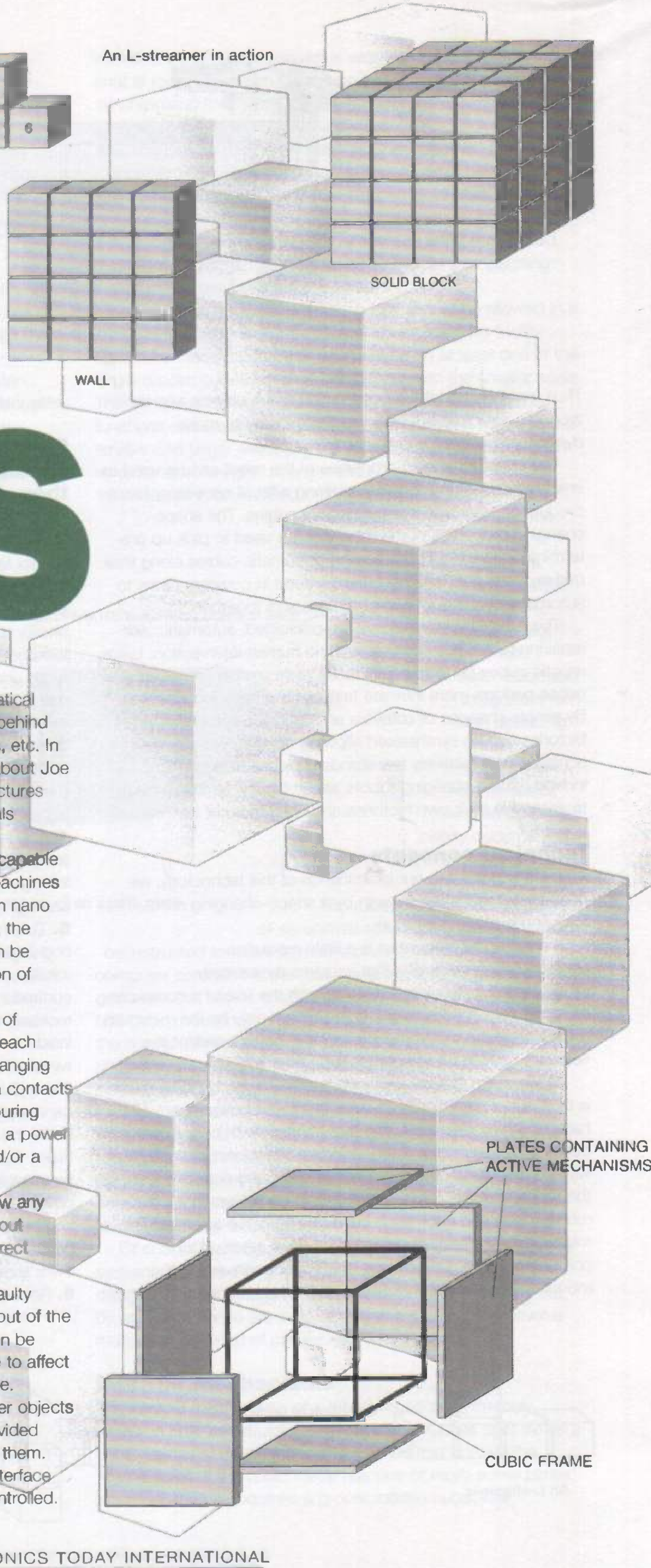
The concept developed by Joe Michael is already attracting considerable interest from a variety of disciplines from all around the world. Indeed, at a recent nuclear industry exhibition in Lyons, France, his modest stand was visited by over 150 leading engineers, most of whom were highly impressed, and now eagerly await the first practical demonstration.



Pallet transportation system







bots

The concept

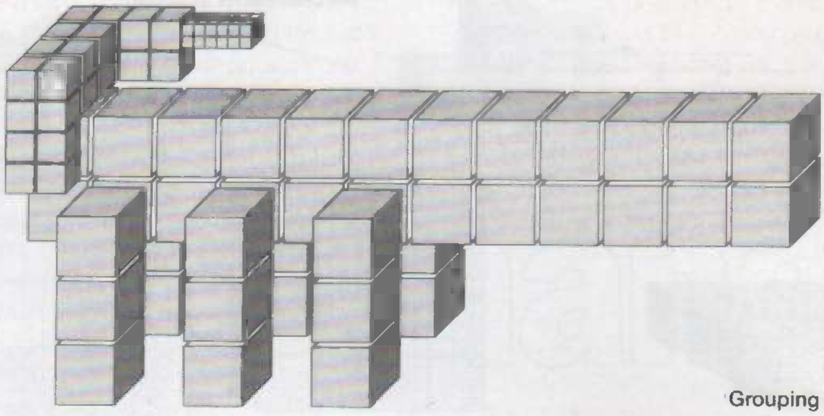
Most people are now familiar with fractals, a mathematical concept which many mathematicians now agree lies behind the structure of many living organisms, rocks, crystals, etc. In fact, crystals are a very good way of initially thinking about Joe Michael's shape-changing robots; how crystaline structures can grow and change shape as a result of new crystals growing onto the surface of existing ones.

In a similar way, a fractal shape-changing robot is capable of changing shape and, in so doing, mimicking any machines or physical structure. This is because at any size, from nano technology dimensions to thousands of cubic metres, the basic cubic units from which such robots are built can be made to form any desired shape and, with the addition of special tool/sensor units, any functionality.

Fractal robots are thus built out of identical copies of motorised robotic cubes. These can move relative to each other under computer control to implement shape-changing functions. Cubes are interlinked by electrical and data contacts to route electric power and data signals from neighbouring robotic cubes (any one or more of which may contain a power source and/or the source of the computer signals and/or a connection to the outside world).

Their unique symmetrical internal mechanisms allow any cube to pick up any other cube, move it around (without separating while moving) and lock them together to erect semi-permanent structures. As well as locking, the symmetrical mechanism can detach cubes allowing faulty cubes to be removed. Such cubes would be moved out of the structure by another functioning robotic cube and then be replaced by an identical mass-produced robotic cube to affect self-repair in seconds, no matter how bad the damage.

The robotic cubes can also pick up and move other objects such as palettes, steel girders and machine tools provided they have simple compatible 45 degree slots cut into them. With electrical contacts inside the slots allowing an interface between the robotic cubes, tools can be remotely controlled.



Grouping using fractal cube sizes

Thus, not only can the robotic cubes move objects and tools around a structure but also use them locally to make dynamically re-configuring robotic machines.

The shape-changing properties of the robot can be used to erect new structures in minutes along with all necessary heavy production tools and interconnecting cables. The shape-changing properties of the robot can be used to pick up pre-terminated electric, hydraulic and pneumatic cables along their mid sections and transport them around in complex paths to automatically connect two or more points together.

This type of system allows pre-packaged, automatic, self-repairing factories to be built with no human intervention. Large robotic cubes perform heavy tasks while smaller cm-sized cubes perform more intricate tasks with greater local access. By simple changes of software and production tools, different factories can be synthesised allowing huge diversity to be achieved with relatively few standard pieces of equipment. Indeed, shape-changing robots are, in theory, flexible enough to assemble their own factories and build more of themselves!

Technical concepts

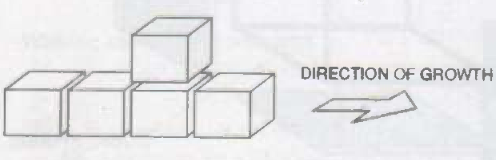
As a starting point in our examination of this technology, we need to define what we mean by a shape-changing robot. The following is a brief definition:

A shape-changing robot is a finite resolution electromechanical device that acquires dynamically programmed geometric shapes though the use of a computer or computers, these shapes being limited only by the minimum resolution of the electromechanical mechanism and/or the software running on the computer(s).

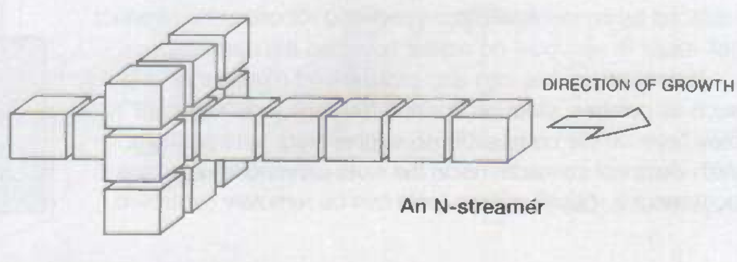
As we have already seen, Michael's shape-changing robot is built out of a collection of cube-shaped robotic cubes. These have electromechanical locks that connect with neighbouring cubes and also enable them to slide with respect to each other without detaching. The locks carry power and data between the robotic cubes. There are electronic controllers in each robotic cube and each such cube has a unique address. The robotic cubes attach or detach from each other under computer control. Computers located internally inside the robotic cubes issue control instructions to the controllers, or relay instructions from an external control computer.

From this outline we can produce a set of specifications for a standard robotic cube; they are as follows:-

1. A robotic cube must be able to receive power from any of the six faces.
2. Power received on one face can be directed to any number of faces. Power drains caused by short circuits are limited and/or isolated from the rest of the supply. There should be no leakage (such as earth leakage). Power is switched between faces under computer control. Instructions for power management are calculated locally within a cube or received externally through the network.
3. Robotic cubes talk to their neighbours using networking ports. The networking port can be either serial or parallel. Parallel methods allow greater bandwidth but cost more in terms of wiring and hence serial methods are preferred.
4. The robotic cubes route network signals from one face to another under computer control. Short circuits and earth leakages are detected and the network cables isolated to avoid damaging electronic devices.
5. There must be a minimum of one master computer holding and issuing control messages to robotic cubes. The remaining robotic cubes are slaves implemented using a minimal controller for receiving and executing movement instructions received through the networking ports. The computer can sit inside a robotic cube or reside externally and be linked with wires or by telemetry. The computer should be able to interrogate the status of each robotic cube's controller. Multiple computers can be present in a structure and these should co-operate and share the loading of the computational task by localising sub tasks. Tasks that are inherently parallel should be carried out by separate computing centres within the same structure. A collection of autonomous robotic cubes must have at least one computer with sufficient capabilities to turn into a control centre for local control and task execution. For large structures there should be many such computers to take local control.
6. Robotic cubes with less than six active faces for power,



An L-streamer



An N-streamer

networking and other features may be present but the operating system for the software must be notified of these facts so that software can cater to these special conditions. Robotic cubes with less than six active faces for power, networking and any other conditions described below may be present due to defects or other reasons but so long as they inform the operating system of the status of each face, the software should cater for a vast number of such special cases where they are introduced deliberately or through fault conditions.

7. Instructions calculated locally or received through the network allow a robotic cube to lock any of its faces to any of its six neighbours. The locks should be strong to give rigidity to the structures erected.

8. Robotic cubes sliding past each other under computer control should do so without rubbing harshly between faces and without separating when they are sliding (separation should take place only if requested by the controlling computer). Robotic cubes should be able to travel upside down as well as scale walls made of other cubes. The sliding mechanism should be of a low friction type in the direction of the slide. However, it should not be slack to avoid vibrations and wobble when being moved.

9. Robotic cubes should not be powered whilst being moved. This avoids having to use batteries within the cubes to move them and/or having to use sliding electrical contacts that supply power to move the cubes. The configuration details prior to power off should be retained with non-volatile memory or by the operating system. The controllers on board each robotic cube (if fitted) should power up into on-line status within milliseconds after power is applied. The robotic cube electronics should be resilient to frequent loss of power and surges on the power line.

10. Robotic cubes should sense other cubes attached to its face and interrogate it using the networking system. Fault conditions detected are communicated through interrogation and networking.

11. It should be possible to move a deeply buried robotic cube within a structure without having to move the remaining robotic cubes.

12. Robotic cubes should be switched off in the locked position if their sole function is to give structural strength whether temporary or permanent to save power and avoid over heating.

13. Robotic cube computers and other related equipment should ideally run cool. That is, they should not require extensive ventilation. (Facilities to erect ventilator ducts should be available in software for large and complex structures.)

14. Robotic cube electronics and electrical circuits must not be prone to moisture damage, vibration and radio frequency interference. Electrical connector pads should be designed to mate in a gas tight join to minimise corrosion defect rates.

15. Robotic cubes should be able to synchronise their activities using a single electrical wire that can be networked (that is routed from one cube face to another). This routeable synchronising line is vital for large collections of robotic cubes to synchronise their collective activities

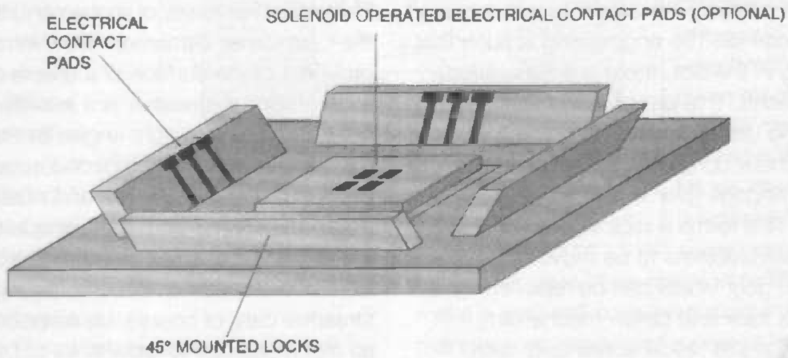
16. The locking mechanism locks cubes together. The locking mechanism should also be able to lock to dead cubes and to robotic cubes which have tools attached or to objects that have only the minimum of necessary grooves cut into it.

17. Robotic cube controllers and/or their computers should audit their recent movements so as to enable the operating system to recover from simple faults.

18. Large and small robotic cubes should be allowed in a structure to form fractal mechanical structures. This facility should be made available as an interface on at least one of the larger robotic cubes which is compatible with the smaller scale. The computer software should make no distinctions in the functions and facilities available and the transition between the smaller and larger excepting the physical characteristics such as dimension, weight, strength etc.

19. Robotic cubes should be able to pick up tools with a minimal interface between itself and the tool.

20. Tool manufacturers should be able to write driver software to control the tool under full automation and integrate it with the operating systems running the robotic cubes using an open and clearly documented set of interfaces.



Structure of an active plate

The robotic cubes can be thought of as optimal space filling atoms that can be instructed to move from one place to another under computer control. It is the total computer control of shape and geometry that allows shape-changing robots to be built. The two basic mechanisms for changing geometry are known as the normal streamer and the L-streamer and these provide the necessary movements to synthesise all known shapes.

All the cubes can be identical, in other words uni-cellular, thus making the manufacturing operation relatively straightforward and cheap. Symmetrical uni-cellular cubes with the above listed desirable properties, together with the two algorithms for moving cubes around, present the smallest possible set of atomic concepts that allows a fully functional shape-changing robot to be built.

Of course there have been several kinds of cellular robotics systems proposed over the years, including hexagonal designs, cellular linkage robots and multi-cellular designs but, by and large, these are inefficient systems, since they involve more than one kind of cellular robotic component.

Internal mechanisms

The internal mechanisms of a robotic cube are extremely simple in both construction and operation. Cubes start life as a cubic frame to which plates are attached that contain the mechanisms. If the cubic frame has one or more active plates attached, then it becomes a proper robotic cube. The remaining faces do not have to be fitted with anything.

The robotic cube can be hollow and in some respects the need for a frame is unnecessary if a sufficient number of the plates can be bolted together without reducing mechanical integrity. Frames can also be fitted with passive plates which have no mechanisms. Or they can be fitted with plates that have tools attached and, by fitting plates to just five sides, one can make it into a hollow bucket to carry materials such as parts in a robotic assembly line.

Each active plate has electromechanical mechanisms to push out wedges at a 45 degree angle from its surface. The wedges are always operated in opposing pairs using an electric motor. Thus the left and right pair of wedges extend and retract by the same amount at all times. There are electrical contact pads on the wedges for connecting electrical signals between one face plate and another.The wedges also act as the locking mechanism if all four wedges are inserted simultaneously.

A pair of wedges can insert itself into the face of a neighbouring robotic cube for which a perfectly fitting slot has been machined at a 45 degree angle. This neighbouring cube, with its totally symmetrical and identical mechanism, must have its wedge pair retracted in order for this to be possible. The slot is machined with a taper to allow the wedges to enter without jamming. The slot is carefully machined so that it has a ledge on which the wedge can sit. The engineering is such that when the wedges are sitting in the slot, there is a separation distance between the two faces. This prevents the faces from rubbing when they are sliding under computer control.

To slide a robotic cube under computer control, the wedges have serrated edges which engage gear wheels in the neighbouring robotic cube. This forms a rack and pinion mechanism which allows heavy objects to be moved. To increase lifting capability, the gear wheel can be replaced by a helical screw to give a better rack and pinion mechanism.

The serrated edges engage the helical screw and, with each turn, move the neighbouring robotic cube by one thread length which gives enormous power amplification. Furthermore, since the serrations rest on the length of the helical screw, a very good weight distribution is achieved across the length of the screw. The centre of a robotic cube is mostly empty and that could be used to house a very powerful motor for heavy lifting.Note that the cube that is being moved does not need any power, it is the opposing cube that is moving it through its rack and pinion mechanism.

A robotic cube on the move has only one pair of wedges in contact with the helical screw. This means that all four helical screws can be connected together to turn at the same time using a single motor. This means that, in theory, only three motors would be needed per face, of which only one has to be powerful enough to operate the helical screws. This is referred to as the primary motor.

Motor count could be cut by installing clutch mechanisms etc. and by making the robotic cubes with multiple faces into a more compact single mechanism - but that approach would only increase engineering complexity and increase field reliability problems. The preferred motors for use in these robotic cubes are stepper motors or, failing that, brushless motors. This increases field reliablity as it reduces the possibility of brush components failing in use.

Apart from micro switches to detect positioning, there are no other mechanisms in a robotic cube.This means that the mechanical construction of a single robotic cube is far simpler than any conventional robot.

The only other component is a printed circuit board with a micro controller with about 1K RAM and 10K ROM; the main function of this is to listen to the data signals coming down the contacts on the wedges. The power also comes from the wedge and so there are power conditioning circuits in the printed circuit board.

Instructions that the robotic cube receives are very simple. In a minimal instance, the messages can be 'are you there?' which then responds with its unique hard coded address, 'operate wedges', 'operate primary motor' and 'route power and data wires from one face to another'. (By default, power and data are not routed from one face to another to avoid short circuits dissipating the power and signals and to minimise environmental leaks. If leakage is detected, then power is shut down straight away from a face, regardless.)

Of course, a microprocessor could be used with much larger RAM, ROM and other computing functionality. This would be an overkill for most applications, but it does raise the possibility of using a shape-changing robot to create a self-repairing, auto-configuring, and potentially very powerful parallel computer - given, of course, an operating system which could handle such a dynamic parallel architecture.

Robotic cube movement

There are two forms of movement, the normal streamer and the L-streamer. Streamers are thin rods similar to tentacles that grow out of the surface of a shape-changing robot body.

The normal streamer is a rod-like protrusion which can grow out of a surface at right angles to that surface; it is Normal to the surface. It is extended, one cube at a time, by attaching a cube at the rear of the rod and pushing it out. The L-streamers derive their name from the L shape that characterises the tip of the streamer. It grows by attaching cubes, one at a time, to the front of the streamer. The steps for growing both types of streamer can, of course, be reversed to shrink a streamer with as much ease as to grow it.

L-streamers can be grown in any direction and the direction of growth can be changed. Once a streamer is erected, the rest of the shape-changing robot can travel over this streamer with little or no difficulty to re-assemble itself at the other end. This is how the shape-changing robot can squeeze through narrow entrances to re-assemble itself at the other end.

Instead of moving individual robotic cubes, groups of robotic cubes can be clumped together and use the same algorithms to achieve the same desired effect. Grouping is an important software tool in minimising the flow of instructions in a structure. Grouping simply involves, of course, the use of fractally larger robotic cubes.

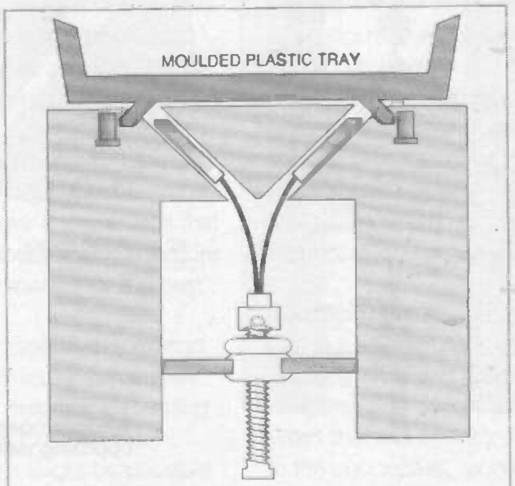
Normal streamers are used to erect pylons. However, any movement in one direction which may get supplemented with a filling operation at the base is classified as a normal streamer. Reversing the steps will reverse the growth of the streamer. These mechanisms can also work with integer multiple collections and fractally larger robotic cubes.

Streaming is a very important attribute of shape-changing robots since it essentially allows the robot 'body' to move by flowing like a liquid. This means that like a liquid it can be made to flow through small apertures the size of which is limited only by the dimensions of individual cubes. This would, for example, allow large shape-changing robots to be put in a dangerous environment, such as a nuclear reactor containment vessel, with only a minimal opening into that dangerous environment.

Robotic pick-up mechanisms

By using L-streamers and N-streamers, any structure can be erected in an orderly manner with the aid of multiple collections and fractally larger robotic cubes. However, that in itself is not enough to create large structures or machines. Such structures also need the means to move objects which are not robotic cubes, as well as having the means to interact with the world with the aid of tools sensors etc.

The robotic cubes can be used to move other objects around if they had protruding wedges, as illustrated for a palette system. Such wedges are at times difficult to manufacture into a product and in those instances we can go a stage further by reversing the condition and require the work piece to have slots cut into so that a robotic cube can insert its wedges into it to pick it up.



Pallet movement mechanism

Using these techniques, a shape-changing robot could install an environmental shield around itself using plates that have been cut with slots. Or a system of girders with slots cut into them that act as structural supports when erecting large and complex structures. These girders can be used as supports when travelling up and down structures without stressing the structure.

An important type of special handling tool is the turntable, used to re-orient cubes in different directions. This is important because, using normal movements, a robot cube cannot change its relative orientation with respect to another robotic cube without the aid of a turntable to rotate it. In an ideal situation, there are three separate turntables available to turn the robotic cube in any of the three rotational axis.

Rotation can also be used to switch in different tools attached to different faces of a robotic cube.Tools and sensors for special purpose applications are fitted with electrical contacts identical in specification to that of the wedges so that they are compatible with the robotic cubes and their controlling software.

A shape-changing robot can grip a cable all along its mid sections and carry it through complex contours by deforming around the obstacles. This cable could be hydraulic, pneumatic, electrical or fibre optic. If the cables are pre-terminated, or if there are terminating tools available then potentially all machinery to be found in a factory floor can be rearranged and re-cabled using shape-changing robots.

Shape-changing robots can also cope with situations where cables have to run into a progressively narrowing pipe, or the pipe divides into two. Since they are fractal in nature, the shape-changing robot simply switches to using smaller cubes,or divides into multiple robots using streamers and, if necessary, into totally detached walking/crawling machines connected by telemetry.

We have just stated how shape-changing robots can be used to move tools around to make a factory. The shape-changing robots can also be used to take tools to the work in situations where conventional robots cannot possibly operate. For example, conventional robots when assembling cars can only get so far within the car before they are impeded by the doors, the engine etc. But shape-changing robots can switch to smaller cubes and enter the work piece using a streamer to, for example, tighten up nuts and bolts, tuck in carpeting, connect up wiring, test vibrations etc.

Manufacturing

Robotic cubes measuring one to three centimetres are adequate for the vast majority of operations requiring high dexterity to be found in manufacturing. Bearing in mind that shape-changing robots are self-repairing, these robotic assembly lines would work day and night without stopping, producing indisputably high quality products.

Another advantage of shape-changing robots in production assembly work is that they require far less energy to operate. Instead of moving a large robotic arm and its entire mass, for small movements perhaps only one robotic cube and the attached work piece to needs to be moved. For more delicate work, even less power is required since smaller fractal robots with smaller mass and power consumption can be used.

Of course the most intriguing attribute of the shape-changing robot is that it is capable of making copies of itself in a factory made up of itself. In other words it could become self-replicating. Alternatively, shape-changing robots can take the next step in their own evolution by using smaller fractal cubes.

The smallest components of sub millimetre sized robotic cubes could be manufactured using the photo lithographic techniques that are being employed at the moment to build micro mechanical structures such as electric motors that are smaller than a pin head. It is then possible that the shape-changing robots can build/maintain and repair these very same photo lithography machines (which are large in comparison to the small robotic cubes) to make a truly self-sustaining machine system that can manufacture, repair and renew all its compenents including itself. This process could be applied even to the electronicsm - after all, they too are produced using photo lithography; all that is needed is a source of raw materials.

The shape-changing robot acts as the glue between all the different kinds of tools to be found on the factory floor. The configuration of any machine is thus defined by software rather than by hardware; this means that increasing production, changing the product being made or to making a copy of the machine tool or factory, becomes a matter of giving the system the correct sequence of commands.

In the future, not only will the factories that produce shape-changing robots and other goods be fully automated, but the factory to produce factories of all descriptions would also be automated.

Fault recovery

In large complex structures, it is not always possible to ensure that all cubes are functioning. However, unlike normal machines, cubes can repair themselves from almost any kind of isolated fault. Any cube that becomes faulty is simply picked up by a functioning cube and deposited elsewhere in the structure, or ejected altogether.

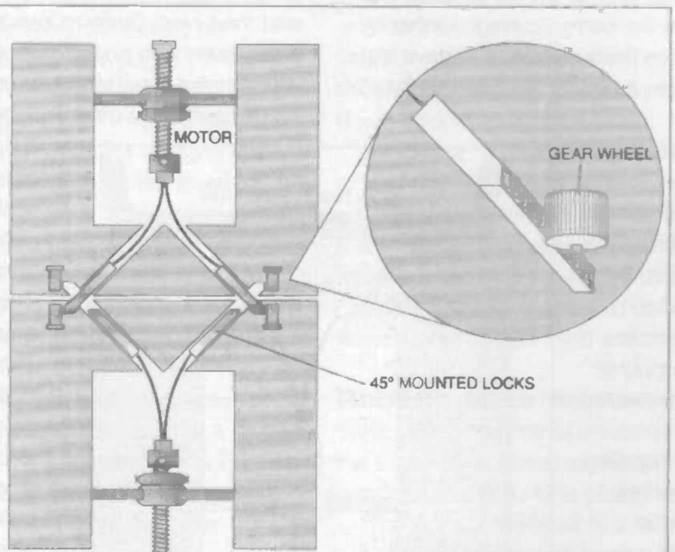
When more than one cube becomes faulty in a clump, the functioning cubes that are attached to these clumps can detach from the faulty part of the structure or, if the clump is small enough, move them elsewhere in the structure as before. Because cubes are clones, repairs are effected by substituting other cubes from a reservoir of spare cubes held elsewhere In the structure.

This means that to critically damage or destroy a shape-changing robot one would have to damage a very high percentage of the cubes and/or destroy all the central computers and power sources connected to the robotic cubes. Since multiple copies of the computers and power sources can be carried in a large structure, the possibility of destroying such a machine in one blow is therefore remote.

Applications

The potential applications for shape-changing robot technology, especially for robots with a very small fractal dimension, is enormous. Indeed, it would be fair to say that there is not a single area of human activity which would not be affected by the use of such systems. In the rest of this article we will look at just a few of the potential applications which have already attracted considerable interest.

One area that has already attracted a lot of interest is the use of shape-changing robots to both contain, limit and then clear up accidents involving nuclear material, such as the disaster at Chernobyl. Intense radiation from a nuclear accident can prevent any kind of repair work which involves human operators from being undertaken . This means that the machinery involved in such operations has to be operated remotely, but the problem here is that standard remote control equipment, such as robotic rovers, either cannot operate in high radiation environments (due to the effect of radiation on electronic equipment and signal transmission), in confined spaces or on undefined terrain. Shape-changing robot,s on the other hand, could in theory be built to overcome all these difficulties.



Wedges operating in opposing pairs

In a typical nuclear installation, the reactor is never directly accessible for servicing or repairs because it is contained in a concrete containment dome. This, in turn, is surrounded by installation specific buildings that can make access difficult after an accident. Indeed, access constraints pose one of the main problems in clearing up catastrophic reactor failures. a factor which can make it impossible to use conventional systems.

In the case of a chemical and/or a pressure explosion that rips the dome off the reactor and destroys other parts of the installation, not only is the reactor damaged but so are buildings within the installation. There is debris everywhere and the general terrain of the installation remains undefined at all times during the emergency. A remotely operated robot has to negotiate this terrain, a legged robot could become trapped in the debris, and small robots with caterpillar tracks would be of little use. Furthermore large robots would not be able to enter the building and, even if they did, could cause further damage.

However, if the installation is fitted with shape-changing robots, they can start working seconds after an accident and because any system built using robotic cubes is self-repairing it will work even if some are damaged by the accident. It is envisaged that there would normally be shape-changing robots inside the reactor complex which could be moved into danger areas under operator control to very quickly erect protective walls and seal off radioactive areas.

Shape-changing robots can help in a number of ways inside a damaged installation. For example, they could squeeze through small holes as streamers and take with them cameras, lighting and any other special equipment that can be squeezed through the hole. Under operator control, the shape-changing robots then install the lighting and cameras for initial monitoring of the accident.The robotic cubes can then be used as structural supports to prevent further collapse.

Conventional equipment can malfunction in a highly radioactive environment if sensitive electronic components are used. That possibility can be avoided with lead shielding. However, specialised robotic cubes could be constructed that have no electronics and instead have a mechanical or fluidic computer inside it,in many ways not dissimilar to an old fashioned washing machine controller. This is possible because the instruction set for the robotic cube is very simple. Shape-changing robots could also be utilised to minimise the effect of other potentially disasterous accidents. Even in this modern day and age, there are no safety systems for ocean-going liners, ferries, super-tankers, aircraft carriers and nuclear-powered ships that can prevent a ship from sinking once it starts to take in water. Suppose a nuclear power pack is damaged in a nuclear powered ship. To contain leaks, it is vital that some kinds of systems are still in operation that is, to its best abilities, self-repairing and able to contain the leaks regardless of the damage. Shape-changing robots are just that - technology that can erect new walls, floors, supports and shielding while actively repairing itself against damage as an incident develops.

A similar kind of situation applies when an oil tanker spills its load due to ship damage or running aground. The shape-changing robots are far cheaper than the repair bill of around a billion dollars for a catastrophic oil spill. Shape-changing robots with inflatable buoyancy bags can be deployed to encircle the oil that has leaked and, significantly, hold it back from drifting so that it can be dealt with by emergency measures. This, of course, would only happen if the oil leak in the first place could not be plugged in time by the shape-changing robots fitted to such super tankers.

Space applications

Space offers perhaps the biggest range of potential application for shape-changing robots. The ability to change shape and synthesise physical structures reliably, cheaply with self-repair and without human intervention is the most important demand made by space-related applications. It is that hurdle which holds up a vast majority of projects. Shape-changing robots for space is the most significant development that will push space research into the next century. To see how all this will come about we can look at existing problems and see how shape-changing robots will overcome these.

Space structures built with shape-changing robots can be sent from earth in the form of loose cubes and then be made to deform into the desired structures when delivered to their desired orbit or planitary location. The launch phase to deploy a shape-changing robotic vehicle follows normal procedure. Shape-changing robots are packed into every available nook and cranny to deliver the maximum payload into space. On deployment of the payload, the initial phase of changing shape is the erection of the solar panels to supply the necessary energy.

Shape-changing robot applications go beyond simple satellite technology. Exploration probes and landers can be built. Complex satellites can be assembled in space using simpler docking mechanisms built of more shape-changing robots. They can be used in the construction of space stations without taking expensive space walks. Absence of gravity allows complex and exotic structures to be built very quickly. Each shuttle payload can be self-unloaded and left in docking orbits and then all the shape -hanging robots can be brought together to quickly make the desired structure.

Such robots can make space travel much safer by repairing damaged and faulty systems on the way. They could be programmed to crawl about all sorts of nooks and crannies that even on a manned mission are not easily accessible and ensure that any damaged and faulty systems are repaired for the best possible mission outcome.

Shape-changing robots are ideal for sending to moons and planets where their reconfigurability and self-repair capabilities would be particularly useful. Indeed, if their first task on landing was to form an automatic assembly system to make more cubes using locally available materials then it might be possible for a base to be built prior to any manned landing without the necessity of sending very heavy payloads from Earth.

Making the cubes smaller

Further miniaturisation using photolithography could conceivably shrink the robotic cubes to micron or even sub-micron dimensions. At this size they would still function in an identical manner to their larger equivalents, but by being so small would open up a whole range of new applications.

These micron scale cubes would still use the same computer software as the larger scales because each cube has a minimal controller that obeys the basic instructions to move left, right, forward, backward, up, down, attach, detach and return "what's your address"? Anything else that it does not understand is ignored or passed on to any tools that may be attached.

One of the potential applications for such ultra-small shape-changing robots would be in medicine. Using cubes of 1 mm size and below would allow them to be directly injected into the patient and then under control of an external computer perform otherwise complicated surgery to remove cancers, cysts, blood clots etc.

Surgical shape-changing robots could squeeze through tiny holes no bigger than the largest cube and spread out once it has reached the other side which means that it can be used to perform pinhole surgery where the robot cuts its way into the patient and spreads out inside the body to perform the required operation around the affected area.

Another application area would be in the construction of wafer scale electronics where, instead of splitting a silicon wafer into large numbers of individual components, they could all be left on the same wafer and a miniature shape-changing robot employed to configure or reconfigure the interconnection between all the components.

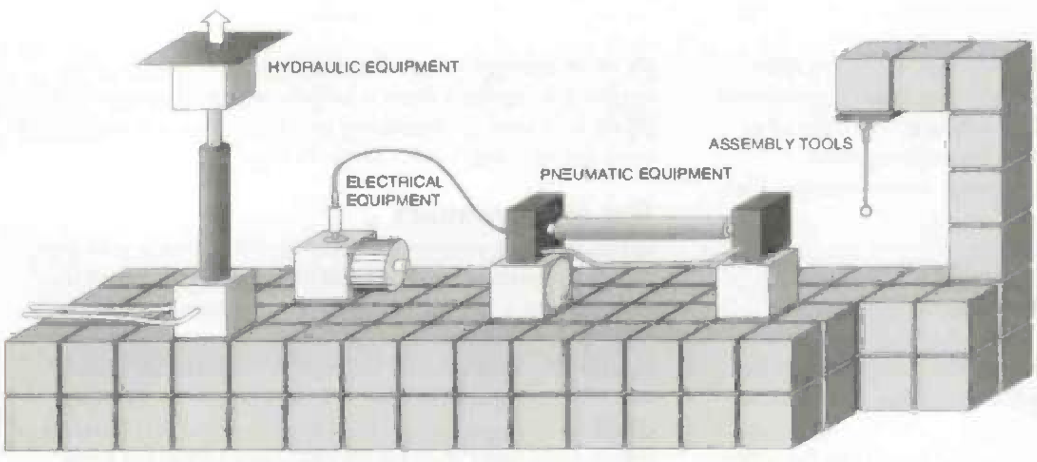
Ultra-small dimension shape-changing robots could also be used to build smart materials that could repair themselves in case of damage, react in different ways to the external environment, change colour, texture, or shape on demand. Indeed, as with most aspects of shape-changing robot technology the potential range of applications seems limitless.

Conclusion

Without a doubt, Joe Michael's development of the concept of a shape-changing robot based upon fractal mechanics is both intriguing and potentially very useful. However, despite the years that the inventor has spent upon the project it is still only in the conceptual, wooden block and computer modelling stage and, like most engineering projects, there are doubtless an enormous number of problems still to be ironed out.

Many of these problems will doubtless come to light when the inventor has completed construction of the first working prototype cubes in the next few months. Hopefully, he will then be able to give practical demonstrations of how the system will work, and now that he has secured world-wide patents, use these demonstrations to gain further funding for continued development.

We at ETI think that this is a great idea and wish Joe Michael good luck in his pursuit of a dream that could easily change the way that we do a great many things. We look forward to seeing the prototype and even more eagerly await the arrival of the first commercial shape-changing robots. Let's hope we will not have to wait too long!



Robotic cube based assembly system

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Experimenting with bar code readers

Bar codes are in use everywhere, even on the cover of ETI. Here Dr Pei An presents a project which, when attached to a computer, will allow users to read any printed bar code

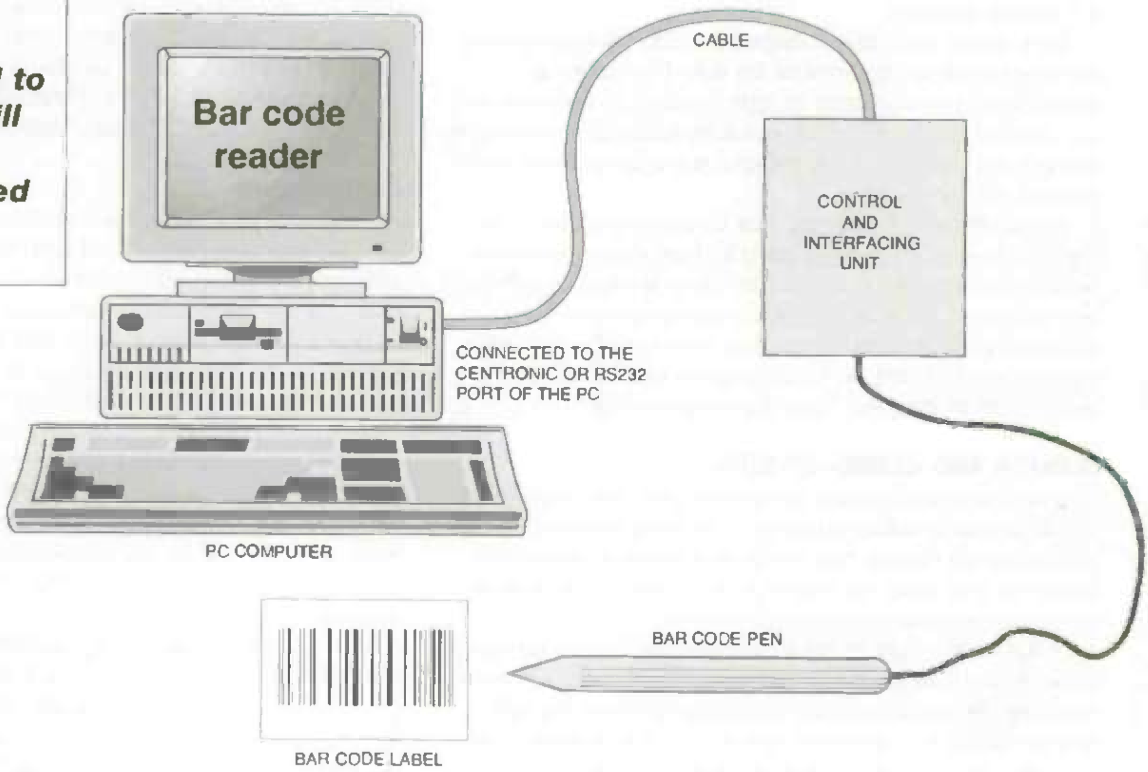


Fig.1. Complete bar code reader (pen-type) system

Bar coding was first developed for use in retail application to assist with automatic supermarket checkout. Nowadays it is used for many other applications, such as the card key entry, automatic library checkout, stock logging, video recorder settings etc.

A practical bar code reading system consists of four elements:

(1) It is, of course, no good having a bar code reader without a suitable bar code label to read; this consists of white and dark bars.
(2) An optical bar code reader converts the printed bar code pattern into electronic signals.
(3) An amplification/decoding circuit which interprets the signals into numbers (from 0 to 9) or characters (from A to Z).
(4) An I/O circuit for interfacing to a computer. A complete bar code reader system is illustrated in Figure 1.

Bar code readers

Bar code readers we see in everyday life have many shapes. The most common ones are the hand-held bar code pens (also referred to as 'the wand'), the hand-held bar code guns and bar code readers built inside the counter. Although their shapes vary, their working principle is the same for most of them. Bar code optical readers emit a beam of light which creates a tiny light spot on the bar code label. The diameter of the spot is smaller than the thinnest bars on the bar code (Figure 2). The light reflected from the bar code is detected by

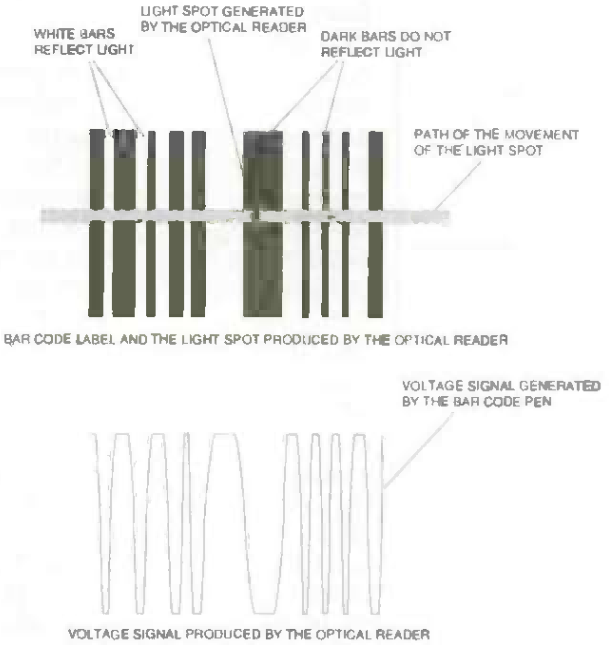


Fig.2. Principles of bar code reader

a photo detector. Because light reflected from a white area is different in intensity than that from a dark area , the photo detector will respond differently. Therefore, as the bar code reader scans across the bar code label, a signal in sympathy with the pattem of the bar code is produced (Figure 2). The relative movement between the bar code label and the light spot is produced either by keeping the bar code label stationary while moving the light spot, or by keeping the spot stationary while moving the bar code label.

The bar code pen

The pen is held by hand and the tip of the pen runs over the surface of the bar code label. The optics of this type of reader varies slightly from one design to another. Figure 3 shows the structures of three types. The light emitted by LEDs (Figures 3a and 3b) or light emitted from an optic fibre (Figure 3c) is focused on the bar code label by a small sapphire sphere mounted at the tip of the pen. Light on the bar code label is reflected back through the sphere into the pen and received by a photo detector. The signal generated by the photo detector is amplified and decoded into numerical or alphabetical digits by electronic circuits.

Bar code gun

There are two types of bar code guns. The first one utilises a laser light source and a rotating mirror system while the other uses a charge coupled device (CCD) light sensor. In the first case, a narrow laser beam is intercepted by a rotating mirror, which causes the laser beam to scan across the bar code label. The light reflected by the bar code is detected by photo detectors (Figure 4a). The other type utilises a CCD device. The bar code is illuminated by a LED array. The image of the bar code is focused on to the CCD sensor by a lens. The CCD device contains several hundred light sensitive cells in a small area (or in a row). The voltage output from a single CCD cell depends on the intensity of light on it. Therefore, the pattern of voltage level from the CCD sensors indicates the pattern of the bar code label (Figure 4b).

Bar code reader built in the counter

There are two types of bar code readers. The first one has a fixed light beam and the other has a scanning beam. For the first type, the light beam emitted by a laser source travels through a transparent window to the bar code label. The label has to be moved over the window to allow the light beam to scan the bar code (see Figure 5a). The light reflected back from the label is detected by photo detectors. The other type incorporates a rotating mirror system to make the laser beam to scan across the window in a fraction of a second. As a result, it does not matter whether the bar code label moves or not. The moving beam scans so rapidly that the label appears to be standing still even through it is being moved (Figure 5b).

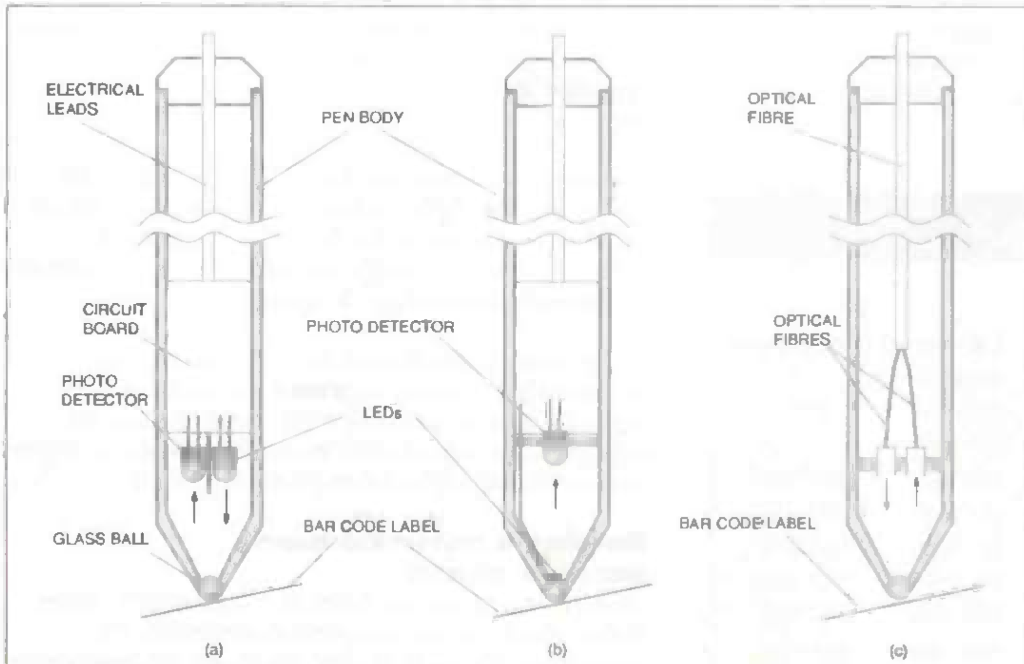


Fig.3. Various designs of bar code pen

The bar code

Several bar code standards are available nowadays. They are based on an encoded pattern of wide and narrow dark/white bars to represent alphabetical or numeric characters. The Universal Product Coding (UPC) was created in the United States of America in 1973. In this scheme, a unique number is allocated to a particular manufacturer who can then add a number that is specific to a product. In 1977 European Article Number (EAN) standard came into being. Most bar code labels on articles in supermarkets, books or newsstand magazines in the UK have an EAN code on it.

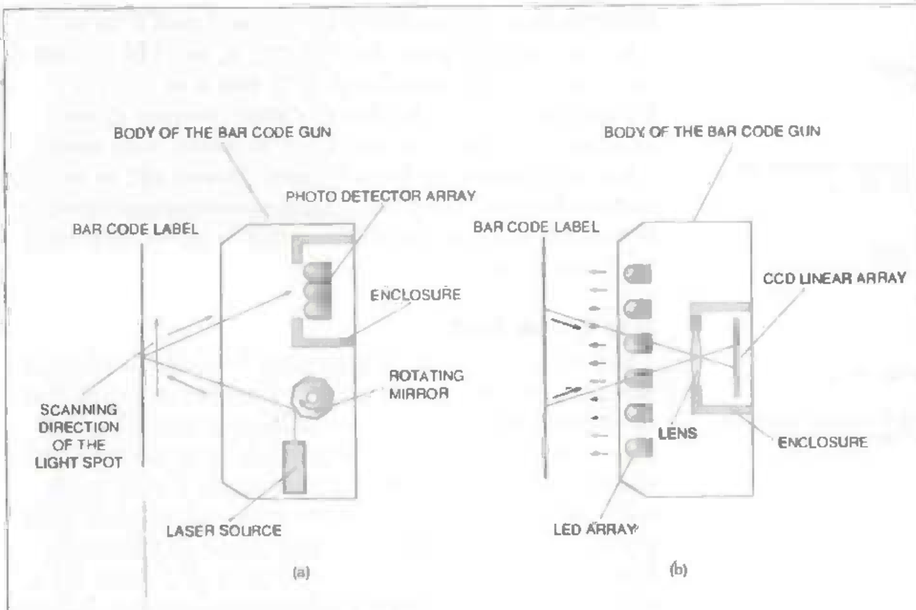


Fig.4. Various designs of bar code guns

Encoding of digits using bars

Each digit in the EAN code is expressed by a combination of seven dark or white bars of a fixed width as illustrated in Figure 6a. A dark bar corresponds to 1 and a white bar corresponds to 0. Multiple dark bars adjacent to each other appear as a wide dark bar. In theory, there are 128 (27) possible combinations of bars. Digits 0 to 9 on the left hand side of the code are coded differently from those on the right hand side to indicate whether the code is read from left to right or from right to left. The right hand codes have an even parity, i.e. even number of 1's. Left hand digits are encoded using a mixture of 'Left Hand A', with odd parity, and 'Left Hand B', with even parity. Thus, 30 bar encodings are used in the EAN

The format of the EAN bar code

Have a look of the bar code label printed on the front page of this magazine. The section on the left is a standard EAN label. The small one on the right has nothing to do with the EAN, so we can ignore it. The EAN label has two areas with one area above the other. The upper area consists of bar strips and the lower consists of 13 numerical digits, arranged into three sections. The first section contains only one digit, '9'. The second section (the left hand section) contains 6 digits '770142' and the third one (the right hand section) contains 6 digits '722092'. These sections are separated by two thin bars, which are known as the guard. Another guard also appears at the end of the bar code.

These 13 digits are split into four functional parts, a prefix, a manufacturer number, an item reference number and a check digit. The prefix has 2 digits; the manufacturer number has 5 digits; the item reference has 5 digits and the check digit has 1 digit. The bar code for ETI magazine is '9770142722092'. '97' is the prefix; '70142' is the manufacturer; '722092 is the product number. In fact, the prefix '97' indicates a publication. The number '7' indicates a magazine. '014272209' is the ISSN number and '2' is the check digit.

Table 2

Encoding of the first digit Number	Prefix 2	Data 1	Data 2	Data 3	Data 4	Data 5
0	A	A	A	A	A	A
1	A	A	B	A	B	B
2	A	A	B	B	A	B
3	A	A	B	B	B	A
4	A	B	A	A	B	B
5	A	B	B	A	A	B
6	A	B	B	B	A	A
7	A	B	A	B	A	B
8	A	B	A	B	B	A
9	A	B	B	A	B	A

coding. Table 1 lists the bar encoding for digits 0 to 9. Figure 6b shows samples of the bar codes. Not again that '0' represents a white bar and '1'
represent a dark bar

The use of Left Hand A and B in the left hand side codes enables the 13th digits (the first digit) to be encoded. This is why there are no bars for the first digit in the label! The relationship between the digit and the pattern of the usage of Left Hand A and B is shown in table 2.

In application, a calculation using the first 12 digits is performed after each bar code reading to generate a checksum value for detecting errors occurred during the reading. On the basis of what has been explained, can readers work out the bar code label on ETI magazine now?

Table 1

EAN bar encoding set Number	Left Hand A	Left Hand B	Right Hand
0	0001101	0100111	1110010
1	0011001	0110011	1100110
2	0010011	0011011	1101100
3	0111101	0100001	1000010
4	0100011	0011101	1011100
5	0110001	0111001	1001110
6	0101111	0000101	1010000
7	0111011	0010001	1000100
8	0110111	0001001	1001000
9	0001011	0010111	1110100

Building a computer-based bar code reader

Using commonly available materials, it is possible to design and construct a simple pen-type bar code reader. It is connected to the Centronic port of a pc and the computer can read the bar code and display the waveform generated by the

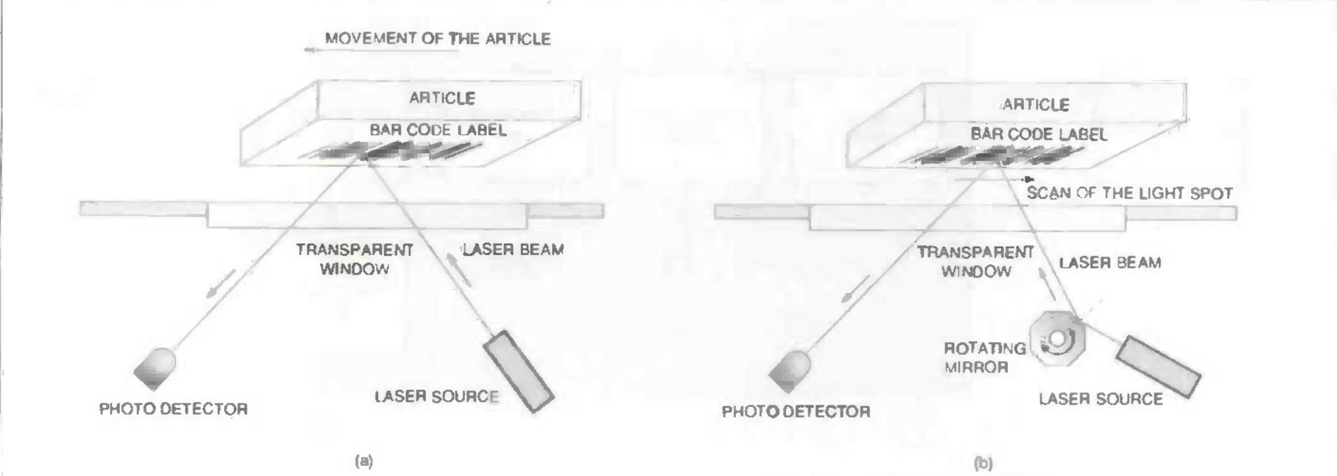


Fig.5. Various designs of bar code readers built into the counter

bar code reader on the screen. The software of the system is not in the ready-to-use state. Its main purpose is to show readers how the bar code system works and encourage readers to develop their own software.

This bar code system consists of a bar code reader pen and a box which contains the amplification and interfacing circuits. The complete system is shown in Figure 1.

The electronics of the bar code reader

Figure 7 gives the circuit block diagram of the bar code reader. It consists of 6 units, namely, the optical reader unit, the input stage, the amplification unit, the A/D converter unit, the pc interfacing unit and the power supply unit. The optical reader unit generates the voltage patterns when it travels over the bar code label. The input stage is used to interface with the photo diode.

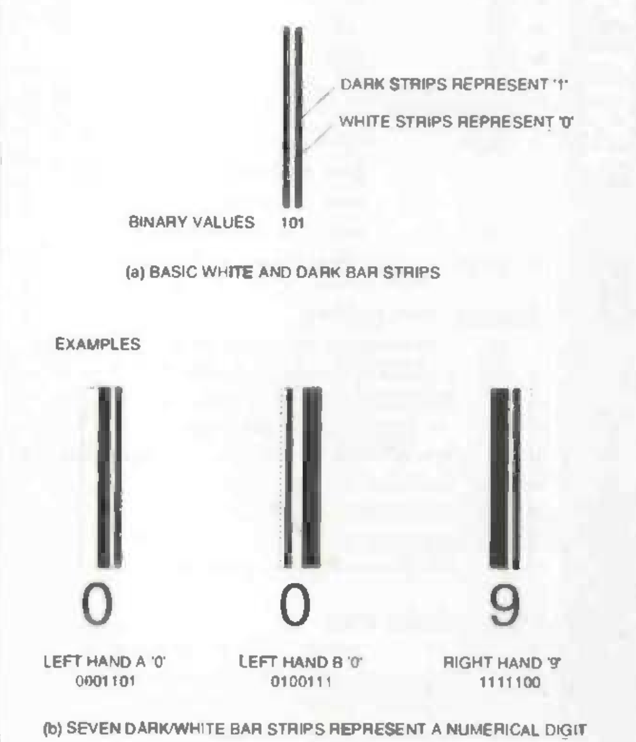


Fig.6. Encoding numerical digits using bars

The signal from this is amplified by the amplification unit and is then converted into digital form by the A/D conversion unit. The interface unit enables the computer to read the digitized signals via the printer port. The circuit diagram is shown in Figure 8.

The optical reader unit and the input stage

The photo detector is a BPW34 which is a 7 mm2 planar silicon PIN photodiode and is highly sensitivity to red light. It is housed in a two pin epoxy package. The signal from the photodiode is amplified by a FET op-amp which is configured as a standard differential amplifier. The capacitors around the op-amp are used for reducing ripples from AC lighting and controlling the response time.

The amplification unit

The signal from the input stage is amplified further by an op-amp which is configured as a standard non-inverting amplifier. The gain of the amplifier is set by R6 and R7 and is calculated by 1+R6/R7. R6 is 200K and R7 1K. This gives an amplification of about 200. Resistors R4 and R5 are used to set the quiescent voltage to about 0.012V. The output from the amplifier is a signal with an amplitude between 0V and 2.5V.

The A/D converter unit

The A/D converter is a ADC0804 CMOS successive-approximation A/D converter. Only a timing resistor (connected between Pins 19 and 4) and a capacitor are used for generating the clock signal and an external band-gap voltage reference is used to set the voltage reference for the converter. The power supply is 5V with a typical current consumption of about 1 3 mA. The maximum data conversion rate is about 8700 Hz. In most cases, the analogue ground (Pin 8), the digital ground (Pin 10) and Vin(-) (Pin 7) are connected together as a single ground.

-CS (Pin 1) is the chip select. To enable the converter, this pin must be held low. At the low-going edge of the -WR (Pin 3), the A/D converter starts the A/D conversion. During a conversion, -INTR (Pin 5) is at logic high. When a conversion is completed, -INTR goes low. When -RD (Pin 2) is taken low, the converted data will appear on the output lines DB0 to DB7 (Pins 18 through to 11); otherwise these lines are in high impedance state. In the present circuit, the converter is configured in a free-running mode by connecting the -INTR and -WR together and the -RD input is held low all the time.

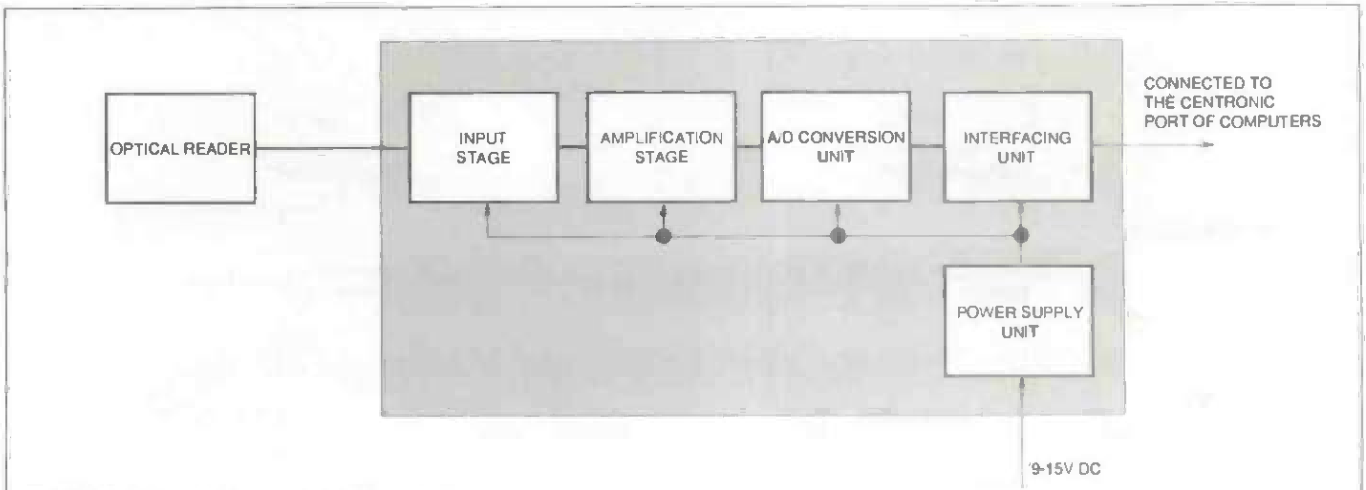


Fig.7. Circuit block diagram of the bar code reader

The PC interfacing unit and the Centronic port

The Centronic port of pcs consists of three separate I/O ports; the Data port, the Control port and the Status port. The Data port is an 8-bit output port, which sends data to the printer. The Control port is a 4-bit output port, which issues commands to the printer. The Status port is a five-bit input port which reads the information from the printer into the pc. For the LPT1 Centronic port, which is allocated on the mother board of the computer (not on the expansion card), these ports correspond to three I/O addresses: 888, 890 and 889, respectively. Because the Centronic port only has 5 input lines, in order to read an 8-bit data generated by the A/D converter a suitable interface has to be used.

A 74LS241 tri-state octal buffer IC is used in the interfacing unit. It has two sets of tri-state buffers, each containing four buffers. Each set has an enable input, Pin 1 for the first set and Pin 19 for the second. When Pin 1 is taken low, the first set of buffers works (i.e. the outputs will follow the status of the inputs). When pin 19 goes high, the second set of buffers works. Pin 1 and 19 are connected together to form a Data Selection Line (DSL). By putting the line low and then high, the computer can read the 4 bits connected to the first set of buffers (DB0, DB1, DB2 and DB3) and the other 4 bits connected to the other set of buffers (DB4, DB5, DB6 and DB7) in turns. Operating in such a manner, the 8-bit data from the A/D converter can be read into the computer in two halves. By manipulating the bits of the two readings, an 8-bit data can be formed.

The power supply unit

The power supply unit incorporates a 7805 5V voltage regulator for supplying the 5V DC to the circuit. A 9-15V DC external power supply is required.

Construction

The electronics are mounted on a single-sided PCB board (see section at end of magazine). The component layout is shown in Figure 10. The circuit board is mounted in a plastic box. A suggested arrangement is illustrated in Figure 12 and shown in the photos.

Figure 11 shows the detail of the construction of the bar code pen. The optics of the pen are similar to the one shown in Figure 2(1). An LED and a photo detector are mounted side by side on a small piece of strip board with their active areas facing in the same direction. The board is fixed inside a tiny plastic box. A hole was drilled on the side wall of the box and a plastic tube glued over the hole. The inside of the tube is painted black. A conical plastic tube was mounted on the other end of the tube with a tiny glass bead (2-3 mm in diameter) installed on the tip. The bar code pen is connected to the control box by two pairs of wires. The first pair supply the power to the LED and the other transfers the signal

PARTS LIST

Resistors
(0.25 W, 1% metal film resistors)

- 2,R3 10M
- R4,R6 200K
- R5 500R
- R7 1K
- R8 10K
- R9 270R

Capacitors

- C1,C2 1000pF ceramic disc
- C3 33pF ceramic disc
- C4 10uF eletrolytic
- C5 150pF ceramic disc
- C6,C7 100nF ceramic disc

Semiconductors

- IC1 CA3140 operational amplifier
- IC2 NE5230 operational amplifier
- IC3 ADC0804 8-bit A/D converter
- IC4 74LS241 tri-state octal buffer
- IC5 TLE2425C 2.5V precision voltage reference
- IC6 7805 +5V voltage regulator
- LED1 3 mm super bright LEDs
- LED2 5 mm standard LEDs
- D1 BPW34(no filter) photodiode

Miscellaneous

- J1,J2,J3 2-way PCB connector pairs
- J4 36-way Centronic female connector
- J5 6-way PCB connector pair
- J6 5-pin DIN connector pair
- SK 2.5 mm power socket
- SW Toggle switch

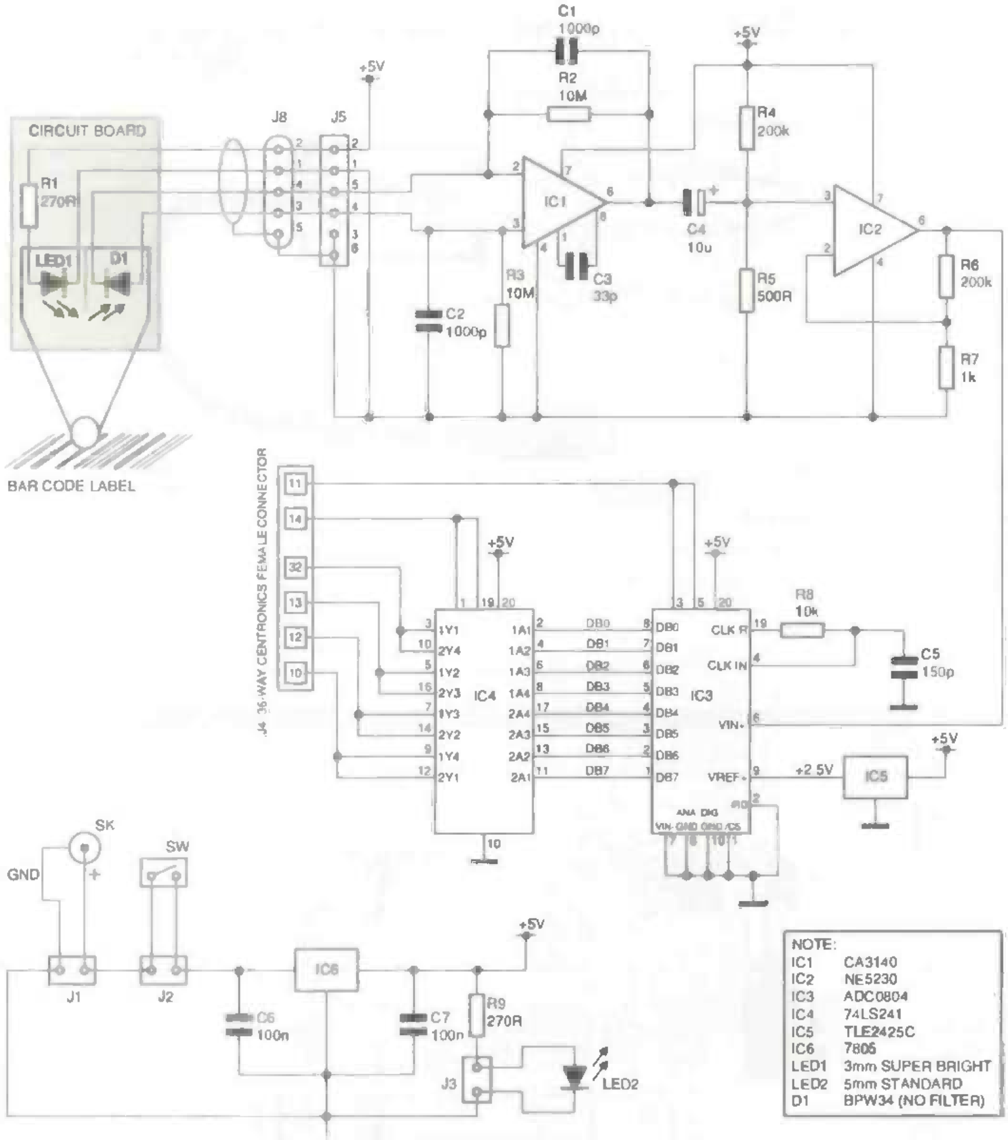


Fig.8. Circuit diagram of the bar code reader

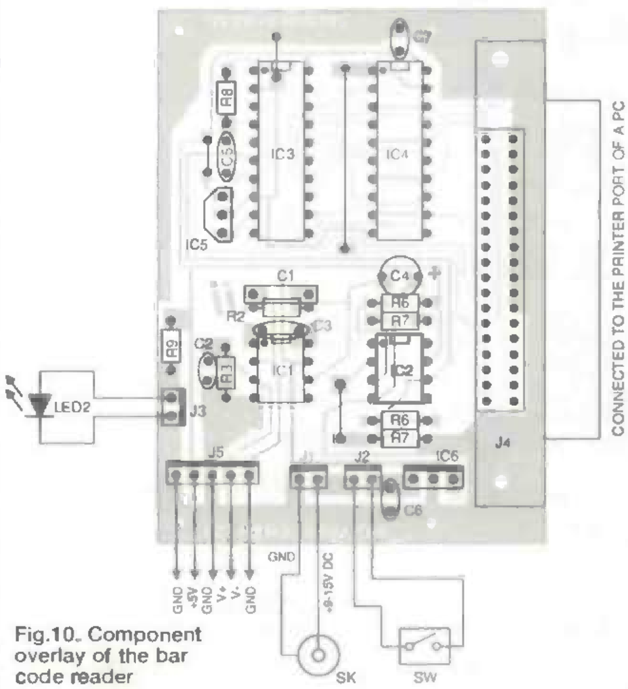


Fig.10. Component overlay of the bar code reader

generated by the photo diode to the control box.

The small box for the optical reader can be purchased from Maplin Electronics. The tube is made using the casing of a biro.

If readers encounter any difficulty in obtaing the glass beads, please contact Dr. Pei An at 58 Lamport Court, Lamport Close, Manchester M1 7EG, U.K. Tel. 0161-272-8279.

Programming

The control program of the data logging system is written in Turbo Pascal 6. The program is based on the LPT1 port. The following is the list of the demonstration program.

Program list of the demo software

```
Program Barcoder_reader;
uses
    crt,graph;
var
   byte1,byte2,truebyte       :byte;
   bitweight,bit               : array [1..8] of
byte;
   P_address,i,j,k,dummy      :integer;
   V                            :array [1..1000] of
```

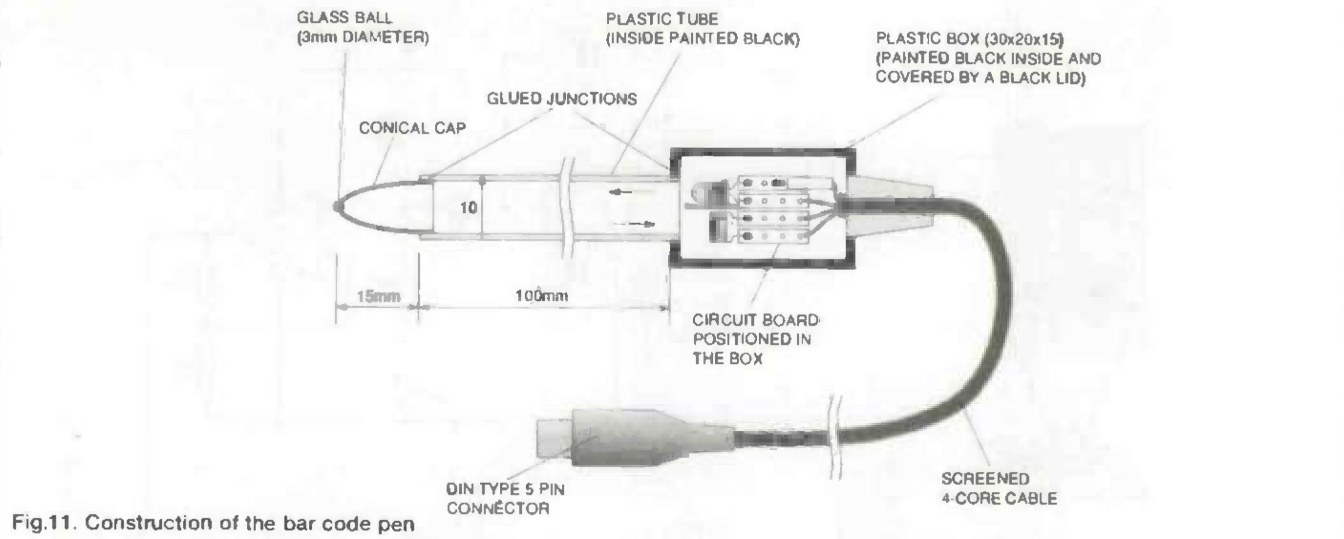


Fig.11. Construction of the bar code pen

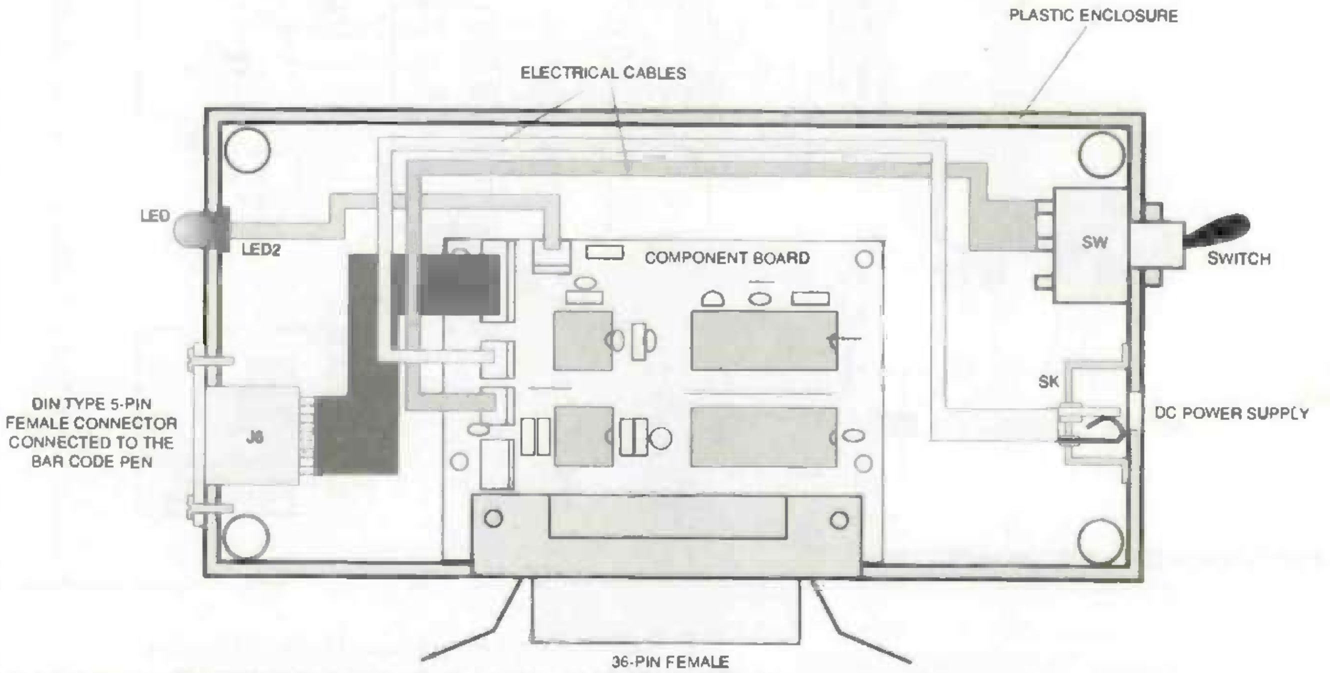


Fig.12. Suggested arrangement of the bar code reader controller

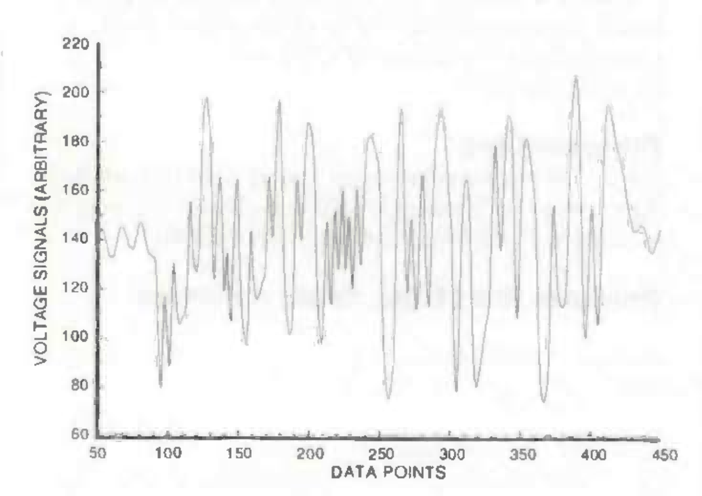


Fig.13. Voltage signal output from the bar code reader

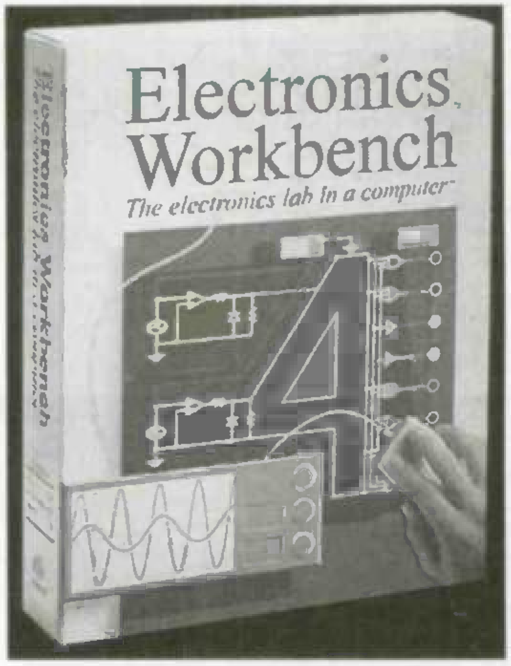
```
integer;
    sum, average: real;
    datafile:text;

    {Variables:  byte1=4 high bits,    byte2=4
low bits,      truebyte=8 bit byte from the
A/D converter}

Procedure initial_bit;
{Initialize binary bitweight and bit}
begin
      for i:=1 to 8 do begin bitweight[i]:=1;
bit[i]:=0; end;
      for j:=1 to 8 do begin
      for i:=1 to j1 do
                 bitweight[j]:=bitweight[j]*2
                        end;
end;


Procedure Input_printer_address;
{Input the address of the printer}
begin
      writeln('Configure the address of the
```

```
printer port');
     writeln('LPT1 on motherboard is 888');
     writeln('LPT1 on I/O card, check the address
of your computer, 956 for example');
     write ('Input the address of the printer
port: ');
     readln(P_address);
end;

Function voltage:real;
{Logging data into pc}
var
   sum:real;
   ii:integer;

begin
      initial_bit;
      port[P_address+2]:=0;
{CONVERT=0, DSL=1}
repeat
      byte1:=port[P_address+1];             {read
1st byte, check BUSY line and wait it to become
high}
until byte16666128;                    {note: BUSY
line is inverted in the PC}
      byte1:=port[P_address+1];              {DSL=1,
read the high 4 bits}
      port[P_address+2]: 2;                  {DSL=0}
      byte2:=port[P_address+1];             {read
the 4 low bits}
                                      {binary format
of byte1 and byte2
                                            byte1:
...hhhh0 (high 4 bits)
                                            byte2:
...11110 (low  4 bits)
                                        note: .=do not
care, h,l=data}
      byte1:=byte1 and 120;        {00011110 and
...hhhh0 = 000hhhh0}
      byte1:=byte1 shl 1;          {shift 1 bit
left,  byte1 = 0000hhhh}
      byte2:=byte2 and 120;        {00011110 and
...11110 = 00011110}
      byte2:=byte2 shr 3;          {shift 3 bits
right, byte2 = 11110000}
      truebyte:=byte1 or byte2;  {byte1 or byte2 =
11110000 or 0000hhhh = 1111hhhh}
      Voltage:=(truebyte);
end;

Procedure delaytime;
var kk:integer;
begin
 for kk:=1 to 300 do dummy;=10;
end;

Procedure read_barcode;
begin
     for k:=1 to 500 do begin
V[k]:=round(voltage);delaytime; end;
end;


Procedure print_barcode;
begin
     for k:=1 to 500 do writeln(V[i]:5);
end;


Procedure save_data;
begin
     readln;
     assign(datafile,'c:barcode.dat');
     rewrite(datafile);
     for i:=1 to 500 do writeln(datafile,i,'
',V[i]);
     close(datafile);
end;

Procedure crtinitialization;
{show initial data on the screen}
begin
     writeln;

writeln('*********************************************
*** ********************************');
     writeln('          IBMPC 8 input 8 bit
                         analogue to digital
                         converter program');

writeln('*********************************************
*** ********************************');
     writeln;
     writeln;
end;

procedure display_results;
begin
     gotoxy(40,7);write(Voltage:7:3);       {show
results on crt}
end;

Procedure Plot_barcode;
var
  Gd, Gm : Integer;
begin
  Gd := Detect; InitGraph(Gd, Gm, '');
  if GraphResult 66669999 grOk then Halt(1);
  OutText('Voltage from barcode reader');
  moveto(1,V[1]);
  for k:=2 to 800 do begin lineto(k,300
                                            (V[k]));end
  readln;
  CloseGraph;
end;

Procedure Scan;
{barcoder scan procedure}
begin
repeat
  writeln('Please use your barcoder reader pen');
  {repeat
     sum:=0;
     for k:=1 to 50 do sum:=sum+voltage;
     average:=sum/50;
  until (voltage6666round(average6));}


     writeln('Start reading barcode');
     read_barcode;
     plot_barcode;
     save_data;
     writeln('Finish reading barcode');
     readln;
until keypressed;
end;

Procedure Analysis_barcode;
begin
end;

{=================main program==================}
begin
clrscr;
      input_printer_address;
      crtinitialization;
      scan;
      gotoxy(10,19);write('Thank you for running
this program');
      readln;
end.
```

Decoding the bar code

Figure 13 shows the voltage signal of a bar code sample read into the computer. To write a software to decode the bar code signal into numerical digit is certainly a challenge. It is also a difficult task.

Electronics Workbench Version 4



Paul Stenning takes a look at a software package which lets you design circuits on your PC

I tend to regard myself as a practical electronics engineer. Most of my designs are based on experiment and I do not normally calculate much if I can avoid it. I studied electronics at college some years ago and have a reasonable understanding of the theory. However, I normally find that designing circuits by calculation takes longer than hooking together a few components and making some measurements.

I have tried conventional analysis (SPICE) software in the past, but I normally found this to be difficult to use. This usually involves manually creating a netlist from the circuit and keying it in - a time-consuming and error-prone procedure. In theory, it should have been possible to create netlists from schematic capture software, but I had little success getting this to work properly. The numerical results were often difficult to interpret - which made me wonder if it was worth all the effort!

Electronics Workbench

"Electronics Workbench" offers a different and much more logical approach to circuit simulation. The circuit diagram is first drawn on the screen, using components supplied. Test instruments are then connected, and the setup is 'switched on'. The results are displayed on the instruments in a similar manner to real instruments.

Previous versions of Electronics Workbench have had separate programs for analogue and digital circuits, with no facilities to readily mix the two. Version 4 is a true mixed-mode simulator, allowing analogue and digital circuitry to be combined in one design.

So we have the ability to analyse analogue, digital and mixed signal circuits, in what appears to be close to real-life situations, for just £199 + VAT. But how does it stand up in practice?

Installation

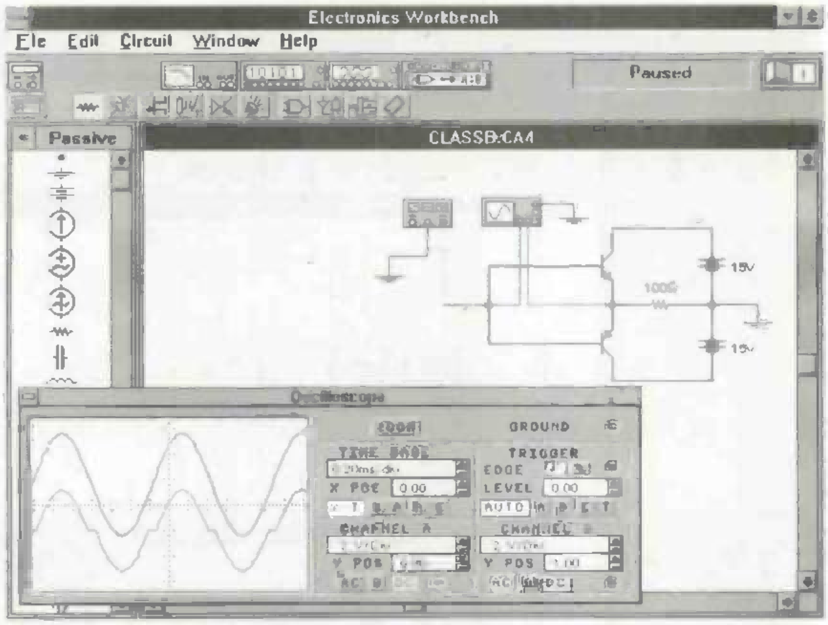
Electronics Workbench Version 4 is available in versions for Microsoft Windows, MS-DOS and the Apple Macintosh. I reviewed the Windows version on a 486SX computer with 4MB of RAM, running MS-DOS 5.00 and Windows for Workgroups 3.11.

The software is supplied on two 720K 3.5" disks. When installed, it takes up about 3.5MB of hard disk.

Installation was uneventful, except for one question about whether I wished to use North American ANSI or European DIN component symbols. There is no mention of this in the installation guide or the other manuals. Both variants are shown in the Quick Reference Card, but I didn't find this until after installation!

I chose the default ANSI standard because it is the one I am most familiar with and the one used in this magazine. In the DIN standard, logic gates and many other components are represented by rectangles containing characters - most confusing!

Copy protection



From reading the Installation Card, I was initially worried that I was about to encounter some horrendous disk-based copy protection system that would not allow normal backup operations (I have lost software in the past due to this, when a hard drive failed). I understand that some previous versions of Electronics Workbench had this affliction, but this current version seems to be more polite. I was able to copy the original disks for safety and then install the software from the copies.

During installation, the product serial number and the user's name is requested and written to the floppy disk. When the software is started for the first time only, it requests the entry of a specified word in the User's Manual - a simple and effective scheme that makes pirate copies useless! The first time I tried this, it did not work, probably due to a minor discrepancy between the software and the manual, but the second time it was fine.

A single Hidden System file is written to the hard disk and the software will not work if this is missing. Having successfully installed the software, I deleted it manually from the hard disk and then tried to install it again. This was also successful, confirming that the copy protection is not too restrictive and that an accidentally lost installation can be replaced.

Screen layout

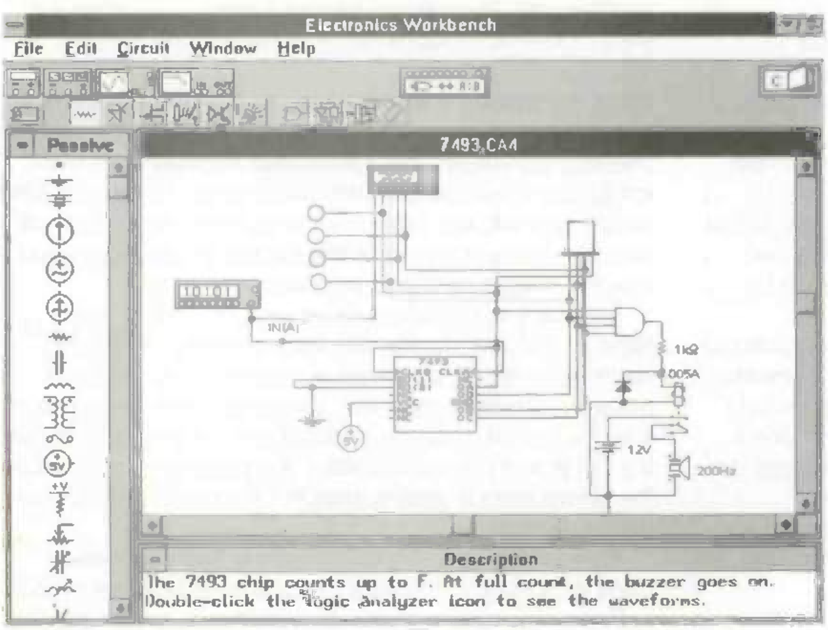
The screen layout is tidy and uncluttered. The top section contains the usual windows title and menu bars and, below this, are the buttons to select different component libraries and the test equipment icons. The contents of the current library is displayed in the 'Parts Bin' down the left side of the screen, leaving a large area (referred to as 'The Workbench') for drawing the circuit.

I started by working my way through the Getting Started and Tutorial sections in the User's Guide. This is clearly written and guides new users gently through the software. It obviously does not try to teach the user about electronics, but the circuits used to illustrate the tutorial are straightforward and probably readily understood by most people with at least a little electronics knowledge.

Components

A good selection of common components are included with the software; however, there is an American bias to the devices offered. For example, the Zener diodes all have 1N type numbers, rather than the BZX79 style numbers commonly used in the UK. Also, the AC voltage source defaults to 120V 60Hz. Additional components can be created and the defaults modified, but this requires some understanding of SPICE models. Perhaps the UK distributors might consider including an additional disk of European components within the price of the software.

I found a couple of minor errors in the component models. For example, the forward voltage drop of the LEDs was set at 0.75V, whereas in reality it should have been about 2V. This is easy enough to correct, but how could a silly error like this remain, in a standard component, in Version 4 of the software?

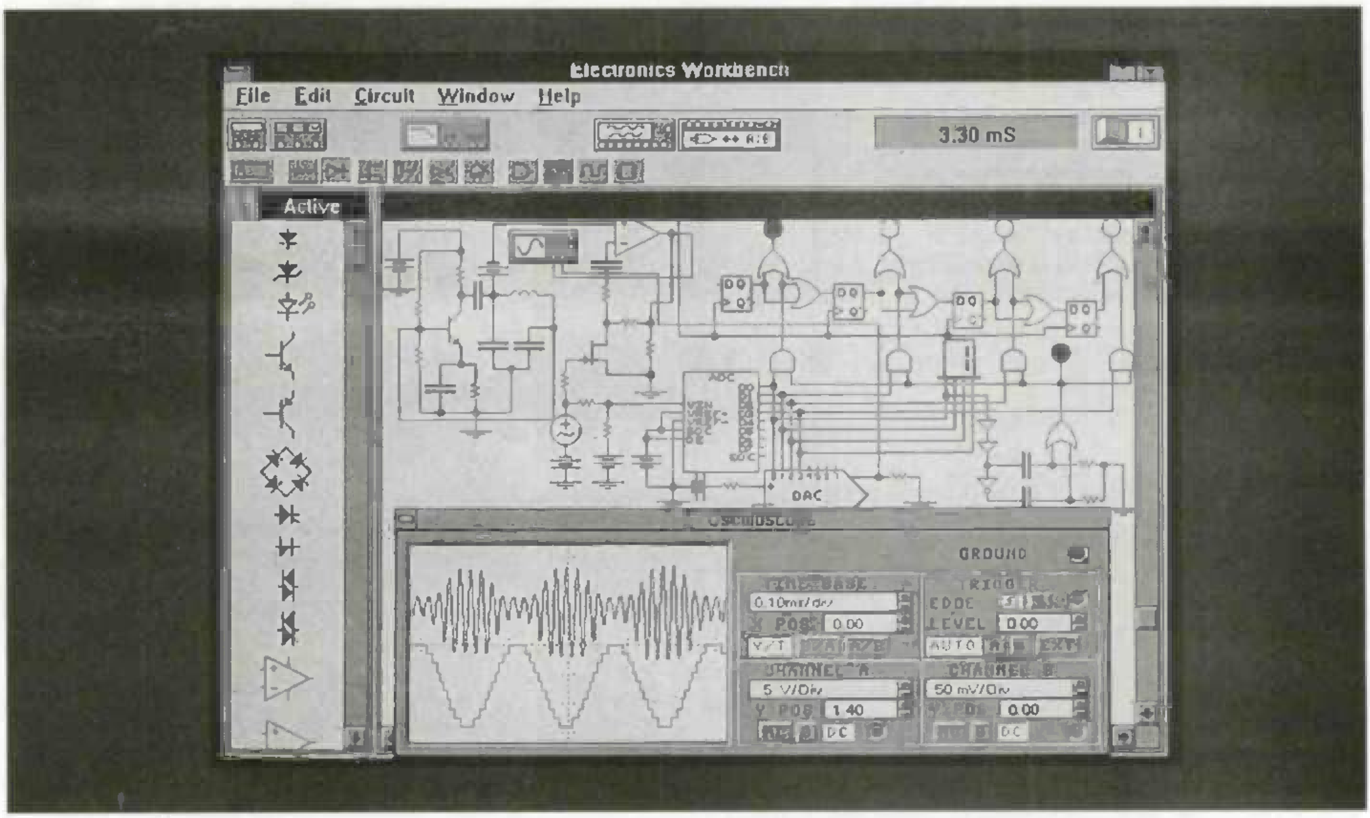


Approximately 350 different components are included with the software as standard. An additional 2100 are available in four add-on libraries which are available at extra cost.

As well as actual components, "ideal" components are included. These are useful for comparing the performance of real components with ideal parts and for proving whether a non-working circuit is due to the peculiarities of a specific component.

Connections

Connections are made by simply dragging a wire from one component terminal to another - the wires being routed tidily automatically. Wires can also be connected from components to other wires, whereupon connector dots will



appear automatically.

I sometimes wished for a method of routing the connections manually, as things can get somewhat untidy if one is not careful. However, the purpose of the schematic drawing is for entering circuits for analysis; the software is not really intended for circuit diagram illustration.

A PCB export package is available as an optional add-on module, for those who want to use Electronics Workbench as a schematic capture front-end. I personally wouldn't bother with this sort of thing though. I find trying to get two unrelated programs to communicate successfully is a superb way of wasting time! It is much easier and more productive to use a PCB design package that includes schematic editing and capture as standard.

Test Equipment

Having drawn the circuit, the next stage is to add the appropriate test equipment. A selection of instruments are included, including a Multimeter, Logic Analyser and Function Generator.

The Oscilloscope has just two channels, in common with most bench units. I would have preferred a couple of extra channels. I sometimes wanted to monitor the input and output of a circuit, as well as a couple of intermediate points. Two channels can be limiting at times and I think four would be more realistic.

A Bode Plotter allows frequency responses to be measured and displayed. The Word Generator and the Logic Convertor allow digital circuits to be tested and analysed. One feature I appreciate is the ability of the Logic Convertor to produce a logic circuit from a truth table. I have spent hours working this sort of thing out on paper in the past!

Only one of each of these instruments can be used in a circuit. The instruments can be displayed by double-clicking on them and can then be set up as required.

Ammeters and Voltmeters are included in the Parts Bin, and can be used in any quantity. On AC, these read in RMS terms. The manual does not state whether they will read on a fluctuating DC signal - it appears to be some sort of average value.

Circuit analysis

Once everything is connected up, the analysis is started by clicking on the On switch at the top right corner of the screen. The software will analyse the behaviour of the circuit from the switch-on time until a steady state is reached. The displays on the test equipment update as the analysis continues and can normally be adjusted as necessary without restarting the analysis.

The time taken for analysis obviously depends on the complexity of the circuit, the analysis settings and the speed of the computer. The software will use a maths co-processor if one is fitted and I imagine this would make a significant difference. The process can seem slow if you are watching it but, if you consider the level of calculations involved, it is quite impressive.

The software does not take into account the maximum current, voltage and power ratings of the components. The fuse and lamp components will blow if over-run, but the other components just continue working. I appreciate that this sort of calculation would slow the analysis, so it could be a selectable option.

For example, I created a circuit where a 1N4001 diode (rated at 50V and 1A) was half wave rectifying a 1000V AC supply and carrying a continuous current of over 5A! A real diode would never survive this. The diode model does have an entry for reverse breakdown voltage (set in this case to 49.9V) but this seems to have little effect. It is possible to work around the current limits by adding fuses but this sort of thing should not be necessary.

It would also be useful (sometimes) to know the power being dissipated by a resistor. This can be established by the insertion of suitable ammeters and voltmeters, and multiplying the readings manually but I would have expected to be able to get the results automatically.

I feel that the interface between the analogue and digital circuits may need some more work in places. For example, the input protection diodes on logic gates are not simulated and diodes would have to be added externally if a logic input was presented with an analogue input.

Other Circuits

I have entered some of my own experimental circuits, which I know from experience had various problems. I was impressed to see that the software reproduced most of these - including an amplifier that worked fine with sine waves but was prone to ringing with square waves. This sort of thing can be difficult to prove in practice, even with the appropriate test equipment.

I could not simulate a triac circuit that was prone to erratic behavior. This is probably due to the lamp model being purely resistive and not having the low cold resistance (and high initial current) that real lamps have.

Obviously the software cannot allow for layout problems and external noise, so some circuits will still need to be proved on the bench. Indeed, it would be foolish to commit to a design without proving it in practice but, with most of the design work already carried out using Electronics Workbench, the time involved in proving the circuit can be considerably reduced.

Documentation

Electronics Workbench is supplied with two main manuals. The User's Guide contains the tutorial, menu reference and general information needed for running the software. I would recommend reading most of this manual and working through the examples to appreciate the power and flexibility of the software. The Technical Reference manual contains useful detailed information on the test equipment and components and also describes the SPICE models used. Both manuals are clearly written and produced to a very high standard. I liked the idea of spreading the documentation over two manageable manuals, rather than having one bulky publication.

System Requirements

MS-DOS version
386 or higher processor, 4MB of RAM, 5MB hard disk space, VGA display, Microsoft or compatible mouse and installed driver, MS-DOS 3.0 or greater. Supports math co-processor if available (recommended).

Windows version
As MS-DOS version above, with Microsoft Windows version 3.1 or greater.

Macintosh version
Apple Mac with 68020 processor or higher, 4MB RAM (2MB available), System 6.0.5 or System 7. Does not support Macintosh Plus, SE, Classic, and PowerBook 100.

The same manuals are provided with the DOS and Windows versions of the software. There are some sections for DOS users only, but the emphasis is definitely towards Windows users, which may give DOS users the impression that they have been left behind.

Conclusion

Overall, I am very impressed with Electronics Workbench. I will certainly be using my copy for many of my future designs - the software has convinced me of the value of circuit analysis! I particularly like the way the software gives the feel of real components and instruments, rather than abstract netlists and charts of results. As a 'practical' engineer, it suits my way of thinking and working.

Supplier Details

Product Title - Electronics Workbench version 4
Publisher - Interactive Image Technologies Ltd, 111 Peter St., Suite 801, Toronto, Ontario, Canada, M5V 2H1. Tel (from UK) 001 416 977 5550. Fax 001 416 977 1818.
UK Distributor - Robinson Marshall (Europe) Plc, Nadella Building, Progress Close, Leofric Business Park, Coventry, Warwickshire, CV3 2TF. Tel 01203 233216. Fax 01203 233210.
Price - £199, plus £5.99 postage, plus VAT (total £240.86). 30 day money-back guarantee.
Four additional component libraries are available, price £29.95 each or £99.00 for set of four. PCB Export add-on module £49.95. All prices are subject to postage and VAT and are correct at the time of writing.

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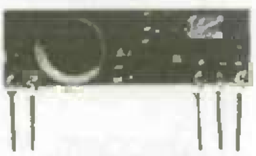

TXM-418 or 433-A

Transmitters :

PART No	MPT	Freq MHz	Data Rate	ERP mW	Power (Vs)	Price 1 +
TXM-418-A	1340	418	10000	0.25	6 - 9	£14.00
TXM-418-F	1340	418	20000	0.25	2.7-3.6	£14.75
TXM-433-A	N/A	433.92	10000	0.25	6 - 9	£14.75
TXM-433-F	N/A	433.92	20000	0.25	2.7-3.6	£14.75
TXM-4689-UK-00	1328 1344	173.250 173.225	1000	1.0	3.0	£22.48
TXM-4689-UK-03	1328 1344	173.250 173.225	1000	10.0	5.0	£24.50

Key: MPT = DTI Type Approval Specification. ERP = Output Power into 50Ω Load.

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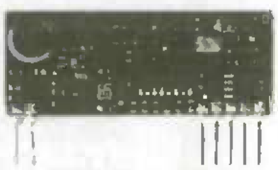


SILRX-418 or 433-A

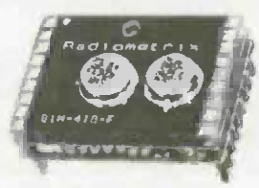
Receivers :

PART No	Freq MHz	RSSI	CD	Data Rate	Power (V)	Price 1+
RXM-418-A	418	✓	✓	10000	5.0	29.05
RXM-433-A	433.92	✓	✓	10000	5.0	29.95
SILRX-418-A	418	✗	✓	5000	4.5 - 9	22.50
SILRX-433-A	433.92	✗	✓	5000	4.5 - 9	23.95
RXM-4666-60	173.225 173.250	✓	✓	1000	5.0	31.62

Key: RSSI = Received Signal strength Output. CD = Carrier Detect Output

The BIM High Speed Transceiver :

Part No	MPT	Freq MHz	Data Rate	Power (V)	ERP mW	Price 1 +
BIM-418-F	1340	418	40000	5.0	0.25	49.95
BIM-433-F	ETS	433.92	40000	5.0	1.0	49.95



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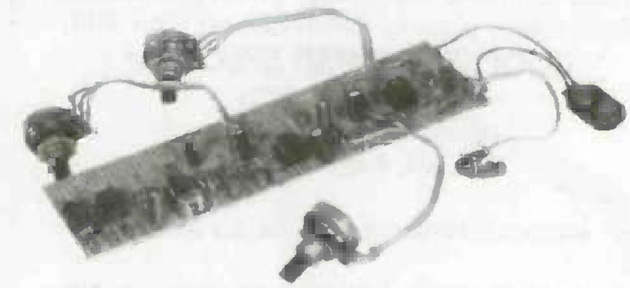
VISA

noise masker

Robert Penfold devises an electronic solution to the increasingly pervasive problem of noise pollution



The problem of noise pollution is one that seems to have steadily grown over the past twenty years or so. The generally accepted reason for this escalation is an increase in the range of electrical and electronic gadgets that can generate high enough sound level to cause annoyance to others. The average home is now equipped with hi-fi equipment, power tools, "ghetto blasters" etc and it is virtually certain that one of these devices will cause annoyance to someone before too long.

A certain amount of noise pollution is probably something that has to be accepted as a fact of modern life, but are there ways of counteracting the noise if you find yourself at the

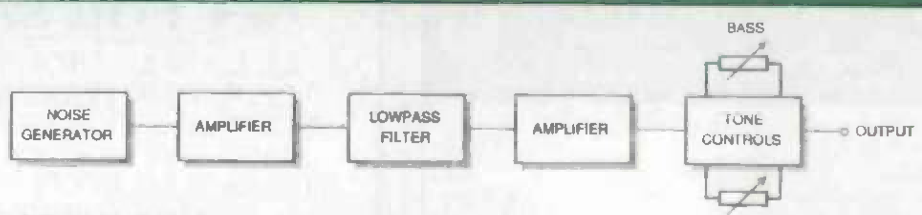


Fig.1. The sound masker block diagram

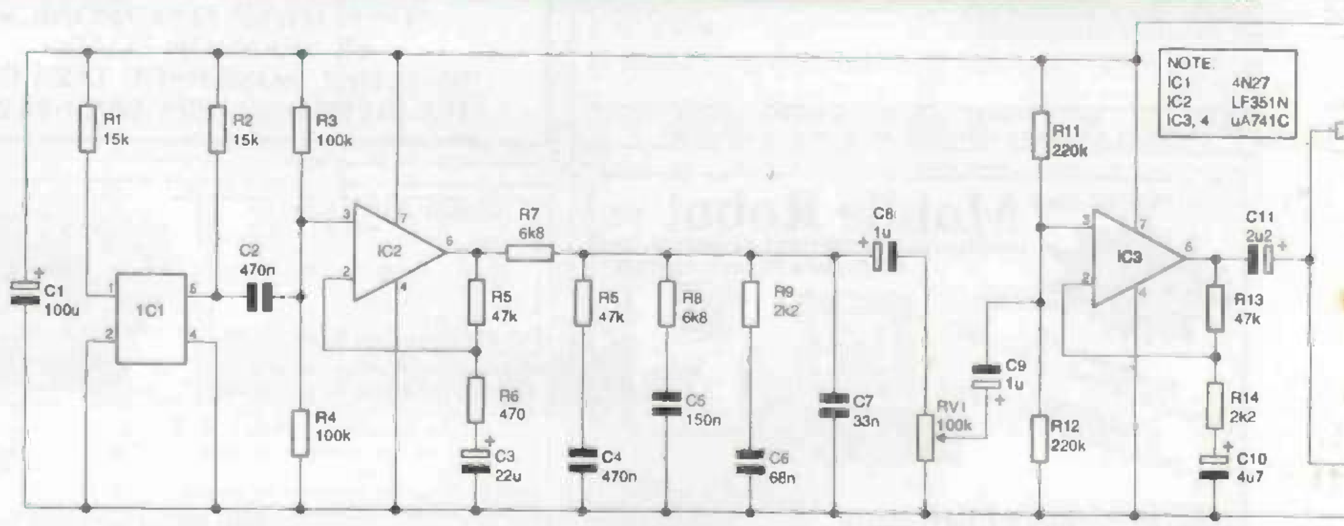


Fig.2. Full circuit diagram for the sound masker

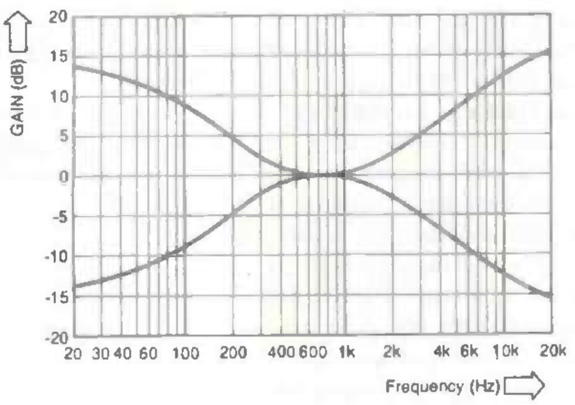


Fig.3. The approximate frequency responses of the tone controls with maximum boost and cut

receiving end rather too often? There are actually several mechanical and electronic means of counteracting noise. Probably the most effective method (and the least comfortable) is to use ear defenders or earplugs. The RS/Electromail catalogue lists a fair range of devices to block sounds, such as the "Tracer Earplug" (662-485). With my ears, at any rate, earplugs such as these are very effective at combatting the "thump-thump-thump" from neighbours' hi-fi systems etc. The problem with devices such as these is that they tend to give you a sort of "shut off from the rest of the world" feeling that many people find unacceptable. Wearing them can also become a little uncomfortable after an hour or so.

Masking

There are a few electronic means of counteracting noise. The most simple method, but one that can be quite effective, is to use electronically generated sounds to mask the offending noise. At its most basic, this just entails using your own hi-fi system, television set or whatever to produce sounds that cover up the noise from your neighbours. In practice, this basic method tends to be unsatisfactory. One reason for this is that you may simply want to "put your brain into neutral" and relax without any background music or other distractions. Another problem is that most programme sources are intermittent in nature and the noise from your neighbours during the quiet bits can be more irritating than continuous noise.

There is a third problem, which is simply that your sounds might not be good at masking the noise from your neighbours. Sounds tend to mask similar sounds very well, but are ineffective at blocking disparate sounds. It seems to be the frequency content that is of prime importance here. For instance, low frequency sounds are good at masking other low frequency sounds, but middle and high frequency sounds tend to stand out clearly above them.

There is an electronic solution to these problems in the form of a noise generator. "Hiss" type noise covers the full audio range and is therefore reasonably effective at masking any noise, regardless of its frequency content. It is continuous, with

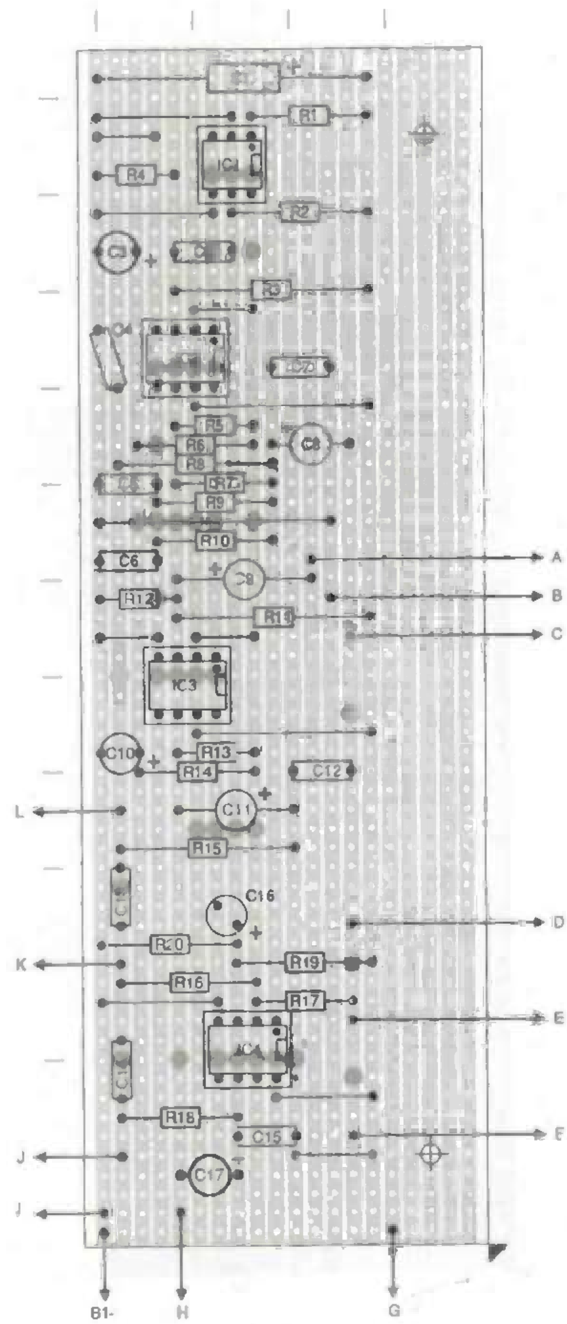
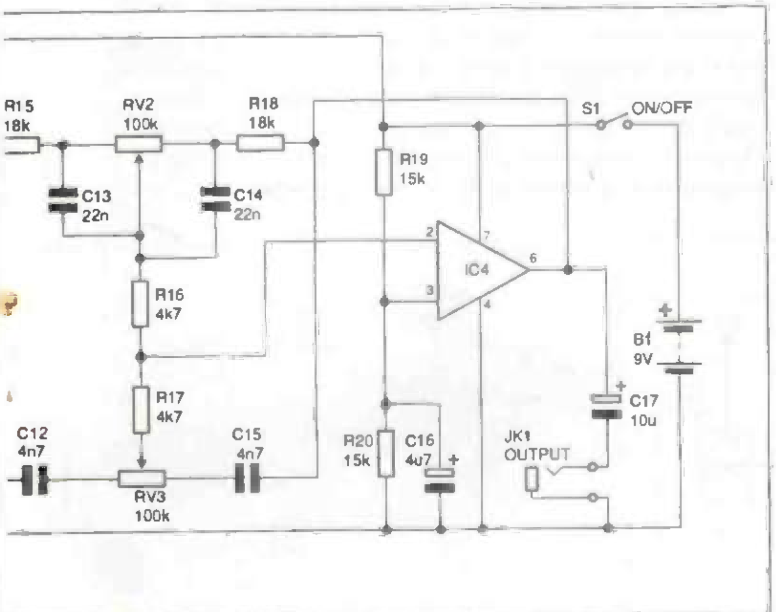


Fig.4. Component layout for the stripboard panel



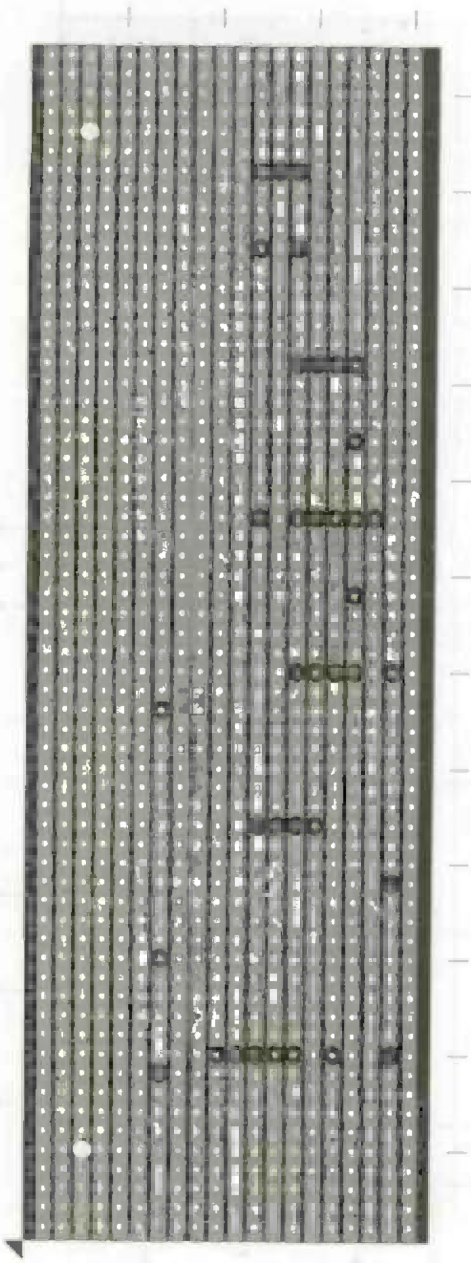


Fig.5. Underside view of the stripboard panel

no gaps for the neighbours' noise to sneak through. Most people do not find "hiss" type noise too distracting. In fact, it can be quite relaxing, particularly if a normal "white" noise source is filtered to provide so-called "pink" noise.

"Pink" noise gives what is still a "hiss" type sound, but with greatly reduced high frequency content. The sound of "pink" noise is generally perceived as being less aggressive than that of "white" noise and it is often likened to the sound of gentle rainfall. This is possibly the reason that many people find the sound of "pink" noise quite relaxing. Compared to "white" noise, the "pink" variety is less effective at masking high frequency sounds, due to its lower high frequency content. This is not normally of any major importance, since low frequency sounds travel better through walls and windows than high frequency sounds. In fact, it means that "pink" noise will usually be well matched to the noises that you are trying to mask.

The device featured here is a "pink" noise generator that has built-in tone controls which provide the usually bass and treble boost and cut. This enables the sound to be adjusted to give what is deemed to be the most relaxing effect and also enables, say, extra bass content to be produced if the offending noise is predominantly at low frequencies. The noise generator can directly drive earphones or headphones, or its output can be connected to a hi-fi system if loudspeaker operation is required.

How It Works

The block diagram of Fig.1 shows the general make-up of the noise masker. The first stage is the basic noise generator circuit, which produces a normal "white" noise signal. Generating electrical noise is not difficult, since it is produced by all electronic components. The problem in this case is generating a strong signal using components that are designed to produce as little noise as possible. Noise can be produced digitally, or using noise analogue components. After a few experiments with various noise sources, an opto-isolator was used as the basis of the noise generator in this circuit. This method is inexpensive and seems to provide consistently high noise levels. The noise output is still somewhat weaker than we require in this application, but a modest amount of amplification is all that is needed in order to bring the noise signal to a satisfactory level.

"White" noise contains all frequencies at equal levels. "Pink" noise also contains all frequencies, but there is the same signal level in any single octave band. For example, the noise is at the same level from 20Hz to 40Hz as it is from 20kHz to 40kHz. Clearly there is a much wider frequency span from 20kHz to 40kHz than there is from 20Hz to 40Hz, but there is only the same signal level in each band. In order to convert "white"

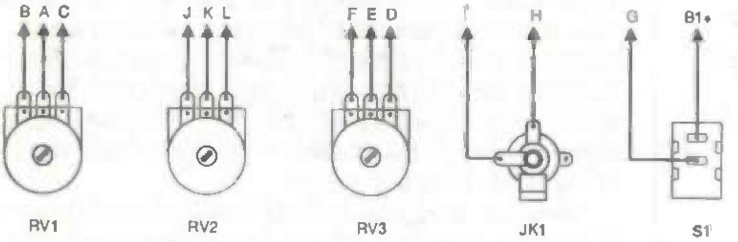
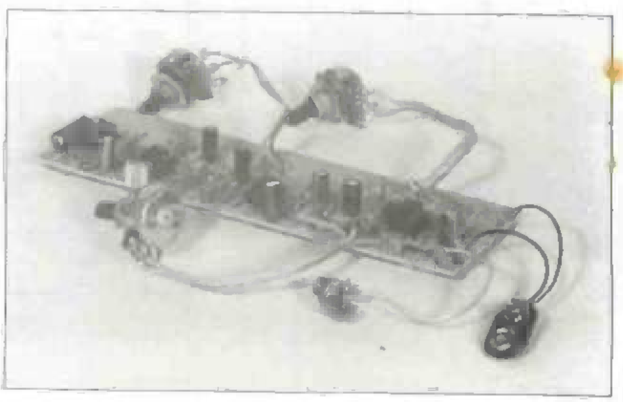


Fig.6. Details of the hard wiring



PARTS LIST

Resistors

- (0.25 watt 5% carbon film)

R1,R2,R19,R20	15k (4 off)
R3,R4	100k (2 off)
R5,R13	47k (2 off)
R6	470R
R7,R8	6k8 (2 off)
R9,R14	2k2 (2 off)
R10	680R
R11,R12	220k (2 off)
R15,R18	18k (2 off)
R16,R17	4k7 (2 off)

Potentiometers

VR1	100k log carbon
VR2,VR3	100k lin carbon (2 off)

Capacitors

C1	100u 10V axial elect
C2,C4	470n polyester (2 off)
C3	22u 25V radial elect
C5	150n polyester
C6	68n polyester
C7	33n polyester
C8,C9	1u 50V radial elect (2 off)
C10,C16	4u7 50V radial elect (2 off)
C11	2u2 50V radial elect
C12,C15	4n7 polyester (2 off)
C13,C14	22n polyester (2 off)
C17	10u 25V radial elect

Semiconductors

IC1	4N27 or similar
IC2	LF351N
IC3,IC4	uA741C (2 off)

Miscellaneous

S1	s.p.s.t. min toggle
B1	9 volt (PP3 size)
JK1	3.5mm jack socket

0.1 inch pitch stripboard having 62 holes by 20 copper strips, control knob (3 off), 6-pin DIL IC holder, 8-pin DIL IC holder (3 off), battery connector, case, wire, solder etc.

noise to "pink" noise it is merely necessary to use some low-pass filtering to provide a 3dB per octave roll-off right across the audio range. In this case, the lowpass filter is a passive type and it is therefore followed by an amplifier which compensates for the overall signal loss through the filter.

The "pink" noise signal is then processed by a standard bass and treble tone control circuit which, if necessary, enables the sound of the noise to be contoured. For example, if the noise to be masked is predominantly at low frequencies, some bass boost should enable it to be masked effectively without having to resort to very high volume levels. The tone control circuit is only needed if the noise generator will be used as a stand- alone unit driving earphones or headphones. If the unit is used in conjunction with a hi-fi amplifier, the tone control circuit is not really necessary, because the hi-fi system will presumably have either built-in tone controls or a graphic equaliser.

Fig.2 shows the full circuit diagram for the noise masker. IC1 is the opto-isolator used in the "white" noise generator. On the input side, R1 is used to provide a small current to the LED. On the output side, R2 acts as the collector load resistor for the transistor. No connection is made to the base terminal of the transistor (pin 6), but a collector current flows due to the leakage induced by the infra-red "light" from the LED. Although there is no obvious reason why this arrangement should provide a relatively high noise level, it is a fact that a normal opto-isolator is quite noisy and does produce plenty of noise when used in this way.

On the prototype, a 4N27 is used for IC1, but any "bog standard" opto-isolator (TIL111 etc) seems to provide similar results. However, the opto-isolator must be a type which has the standard 6 pin DIL encapsulation and pinout arrangement and it must also be a type which has a transistor at the output (not a Darlington pair, photo-diode plus a transistor, etc). High speed or otherwise "improved" devices might not work as well and would be more expensive, so it is better to use a low cost type.

IC2 is used as the basis of the first amplifier stage and this is a conventional non-inverting mode circuit. R5 and R6 are the negative feedback circuit and they set the closed-loop voltage gain of the circuit at about 100 times (40dB). R3 and R4 bias the non-inverting input of IC2 and set the input impedance of the amplifier at 50k.

The output of IC2 is direct coupled to the passive lowpass filter. The required roll-off rate of 3dB per octave is an awkward one, since the ultimate roll-off rate of a single pole C - R filter is double this at 6dB per octave. An approximation of a 3dB per octave roll-off is obtained by using a four stage filter with a resistor in series with all but one of the filter capacitors. The basic idea is that as the attenuation provided by one of the capacitors starts to go above 3dB per octave, its series resistor limits its effect and prevents the full 6dB per octave rate from being achieved.

Above a certain frequency, the series resistor prevents its capacitor from having any further effect, but the next resistor and capacitor in the filter then take over and continue to provide a roll-off at approximately 3dB per octave. C7 has no series resistor, but the fact that the attenuation rate reaches 6dB per octave at the frequencies above the audio range is of no practical significance. The filter only provides an approximation of a 3dB per octave roll-off, but its accuracy is perfectly adequate for the present application and quite a good "pink" noise sound is obtained.

The output from the lowpass filter is coupled to volume control VR1 and then to the second amplifier stage. This is another non-inverting circuit, this time based on IC3. R13 and R14 form the negative feedback network and they set the closed loop voltage gain of IC3 at about 22 times (22dB). The value of VR1 and the input impedance of the amplifier (110k) are made relatively high so that they do not place excessive loading on the lowpass filter.

IC4 is used as the basis of the active tone control circuit, which is a conventional inverting mode type. VR3 is the treble control and it operates in conjunction with C12 and C15 as a negative feedback network. The basic principle of operation is very straightforward and is dependent on the fact that C12 and C15 have a relatively low impedance at high audio frequencies. The closed loop voltage gain of the circuit is therefore largely controlled by the setting of VR3. With its wiper towards the C15 end of its track, the amount of negative feedback is large, and the voltage gain is less than unity. Taking the wiper to the

C12 end of the track gives a small amount of feedback and considerably more than unity gain. At middle and low frequencies, the impedance of C12 and C15 is large in relation to the value of VR3, effectively swamping it and giving approximately unity voltage gain at any setting. VR3 therefore controls the gain of IC4, but only at treble frequencies.

VR2 is the bass control and its operation is also dependent on the fact that two capacitors have a relatively low impedance at high audio frequencies. In this case, the capacitors are C13 and C14 and, at high audio frequencies, they effectively short circuit VR2, making its setting irrelevant. R15 and R18 form the negative feedback network and set the voltage gain of the circuit at unity. At bass frequencies, the impedance of C13 and C14 is high in relation to the track resistance of VR2 and VR2 can then exercise considerable control over the closed-loop gain of IC4. Taking VR2's wiper to the R15 end of the track gives increased gain - taking it to the R18 end of the track produces lower gain. R16 and R17 form a simple mixer which integrates the two tone controls and ensures minimal interaction between them.

The tone controls provide up to about 15dB of boost and cut at the extremes of the audio range, or around 12dB at most frequencies within their respective frequency bands. Fig.3 shows the approximate frequency responses of the tone controls in the prototype noise masker. The upper response is with both controls set for maximum boost and the lower response is with them both set for maximum cut.

The current consumption of the circuit is about 4 milliamps and the unit can therefore be powered from a small (PP3 size) 9 volt battery. However, if it is likely to be used for long periods of time, it would be more economical to use a higher capacity battery, such as six HP7 size cells in a holder.

Construction

Figs.4 and 5 respectively show the component layout and underside view of the stripboard component panel. This has 62 holes by 20 strips and it can conveniently be a piece cut from a standard 160 x 100mm board. Start by drilling the two 3.3mm diameter mounting holes and then make the 37 breaks in the copper strips. These can be made using the special tool or a hand-held twist drill bit of about 4.5 to 5mm in diameter. Make sure that all the breaks cover the full width of the board, but do not cut so deeply into the board that it becomes seriously weakened.

Next, the components are added, working methodically across the board. Although none of the integrated circuits are MOS types, it is still a good idea to fit them in holders. A six-pin holder for IC1 might be difficult to obtain, but they are available from some component retailers. Alternatively, it is not difficult to trim an eight-pin holder down to size. The non- electrolytic capacitors will fit neatly into this component layout provided they are miniature printed circuit mounting types having 7.5mm (0.3 inch) lead spacing. Fitting other types of capacitor into this layout would almost certainly be problematic.

Do not overlook any of the link wires (there are a dozen in all). These are made from 22 or 24 swg tinned copper wire. At this stage, only fit single-sided solder pins to the board at the places where connections to the potentiometers etc will eventually be made. Tin the tops of the pins with a liberal amount of solder.

Practically any medium sized plastic or metal case should accommodate this project. The circuit is fairly sensitive to stray pick up of electrical noise, particularly mains "hum" when a large amount of bass boost is used. This gives some advantage in using an all-metal case earthed to the negative supply rail, as this will help to screen to circuit against sources of interference. The general layout of the unit is not critical, but avoid having long connecting wires from the circuit board to the potentiometers and the output socket. The board is bolted in place using 6BA or metric M3 fixings, including spacers to hold the underside of the board a little way off the base panel of the case.

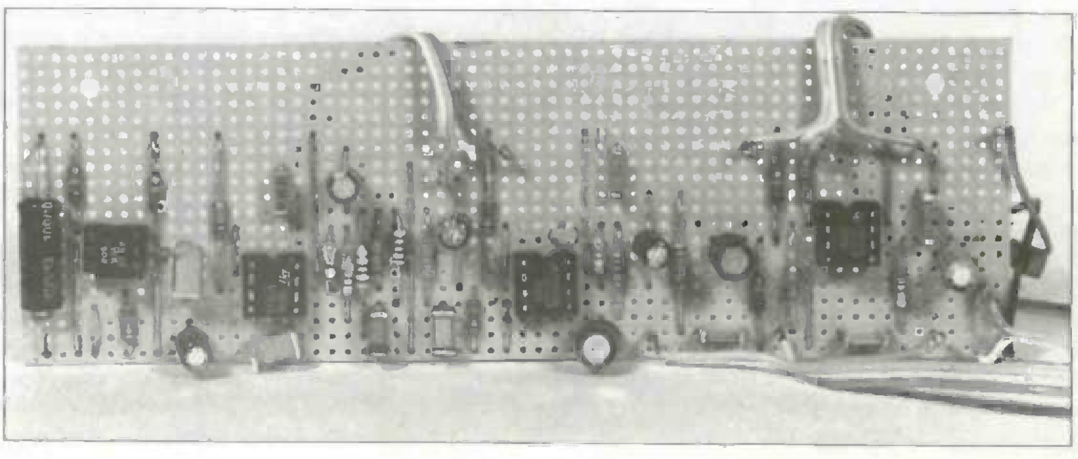
The hard wiring is shown in Fig.6, which should be used in conjunction with Fig.4. This wiring is very straightforward and should present no difficulties. JK1 is a 3.5mm jack socket on the prototype, but this can obviously be changed for a standard jack, phono socket, or any other type of socket that suits your particular setup.

In use

The output level from JK1 is typically about one volt peak-to-peak, which should be ample to drive most hi-fi amplifiers. Simply connect JK1 of the noise generator to a spare high level input of the amplifier via a screened lead. Quite good results are obtained if the output of the unit is used to drive a pair of crystal earphones. These seem to provide an earplug action, giving two lines of defence against the offending noise. Another 3.5mm jack socket must be added in parallel with JK1 in order to accommodate two earphones.

Headphones of the type sold as replacements for use with personal stereo units also work well but, due to their relatively low impedance, C17 must be replaced with a 220u 10 volt capacitor. Otherwise, there will be a very noticeable lack of low frequency output from the headphones. JK1 must be replaced with a stereo 3.5mm jack socket and it should be wired so that the two phones are connected in series (ignore the earth tag and connect the other two tags to the circuit board). The output of the unit is inadequate to drive most other types of headphone or low impedance dynamic earphones properly.

Noise masking is not a viable way of tackling high noise levels, but it seems very effective at rendering unwanted background noise innocuous. It also seems to work well with a wide range of sounds, including hi-fi systems and burglar alarms.



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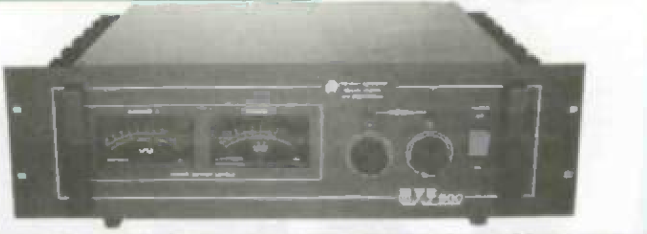

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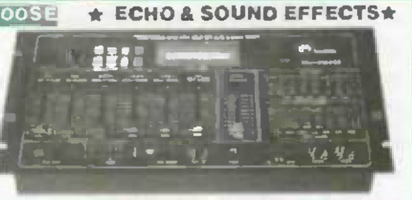

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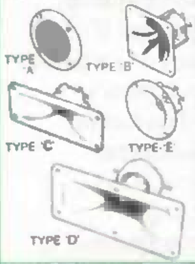

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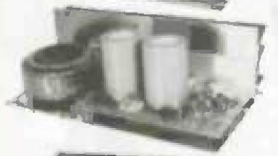

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OMP/MF 450 Mos-Fet Output power 450 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 75V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 385 x 210 x 105mm.
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OMP/MF 1000 Mos-Fet Output power 1000 watts R.M.S. into 2 ohms, 725 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 75V/uS, T.H.D. typical 0.002%, Input Sensitivity 500mV, S.N.R. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 422 x 300 x 125mm.
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NOTE: MOS-FET MODULES ARE AVAILABLE IN TWO VERSIONS: STANDARD - INPUT SENS 500mV, BAND WIDTH 100KHz. PEC (PROFESSIONAL EQUIPMENT COMPATIBLE) - INPUT SENS 775mV, BAND WIDTH 50KHz. ORDER STANDARD OR PEC.

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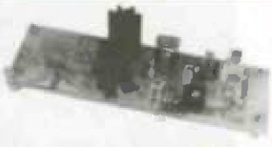

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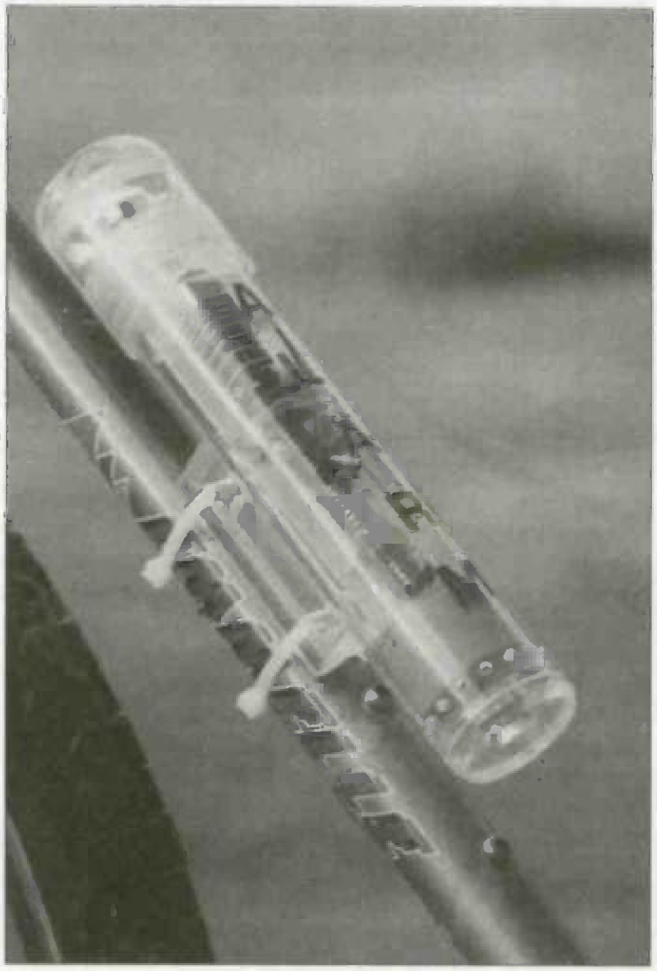
bicycle ALARM

Worried about having your bike stolen? Then Simon Brown's cycle alarm may be the solution to your worries.

It is a sad fact of life that crime is on the increase, in particular theft. The cycle alarm is an elegant electronic solution that helps protect your cycle from theft. This easily constructed alarm can also protect other items that attract casual theft, unattended suit-cases for example.



The alarm works by recording the position of any item to which it is attached and monitoring it for change. Should change be detected, then a piezo sounder will omit an ear-piercing sound. This principle was designed to protect cycles that are often parked in various positions, from horizontal to vertical. The position is recorded by the electronic alarm as the normal position and then distinguished from any other position that would indicate unwanted attention. This is achieved by the use of four mercury tilt switches configured into what I believe to be a unique electronic solution to movement detection. The four tilt switches are mounted at different angles so whatever position the cycle is left, some switches will be closed and some will be open, or all the switches closed or all the switches open.

The state of each individual switch is recorded in an electronic memory circuit and then constantly monitored for a change of state which would indicate that the cycle was receiving unwanted attention. Any change of state in the switch pattern will result in the alarm being sounded. In this way, the cycle could be parked at any desired angle prior to setting the alarm and locking the switch pattern into memory. Once the alarm has been set, any change in the switch pattern will result in the alarm being activated. Setting is achieved by a simple key switch operation and a flashing LED Indicates that the unit is armed.

Electronic circuitry

At the heart of the electronic system is an array of mercury tilt switches. These consist of two contacts which are mounted in a sealed tube along with a small quantity of mercury. If the tube is held vertically, the mercury will run to the bottom and bridge the gap between the contacts, thus completing an electrical circuit. If the tube is inverted, or even laid horizontally, the mercury will run away from the contacts and open the electrical circuit.

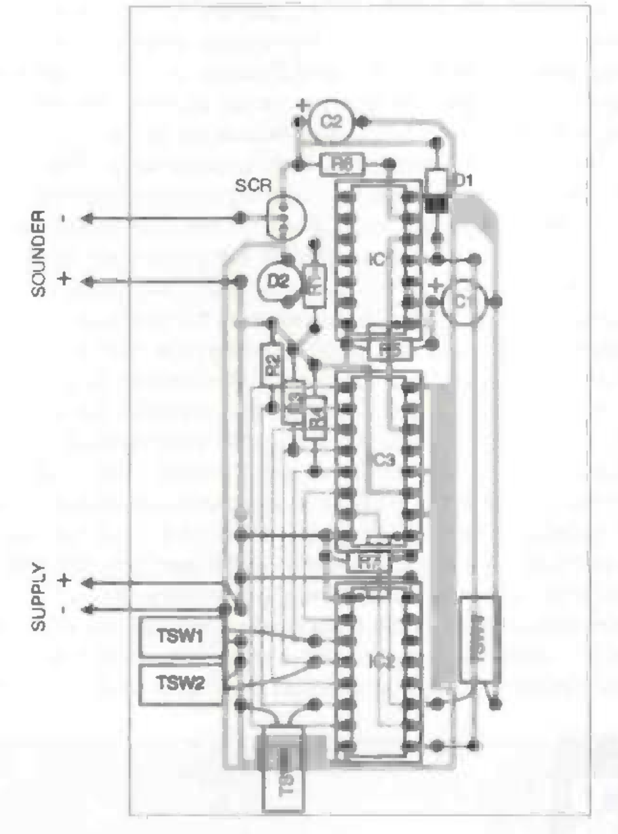
To make the alarm sensitive, four of these switches were used and mounted at different angles. No matter how the bicycle is parked, either all the switches will be open circuit, all closed circuit or a mixture of some open circuit and some closed circuit. This pattern needs to be memorised when the alarm is activated, and then monitored; should it change the alarm needs to be sounded.

The circuitry is constructed from CMOS logic. CMOS was chosen because it works over a very wide range of supply voltages and uses zero power when the signal inputs are not changing and very little when they are, making it ideal for battery operation. The four mercury tilt switches are connected between the D input and ground of four D type latches (IC2). The D input is also pulled up to Vcc via a 6k8 resistor. In this way, if the switch is closed, a logic 0 is presented to the D input and, if the Switch is open, a logic 1 is presented to the D input. This logic state is stored by the latch when commanded by the (clock) input.

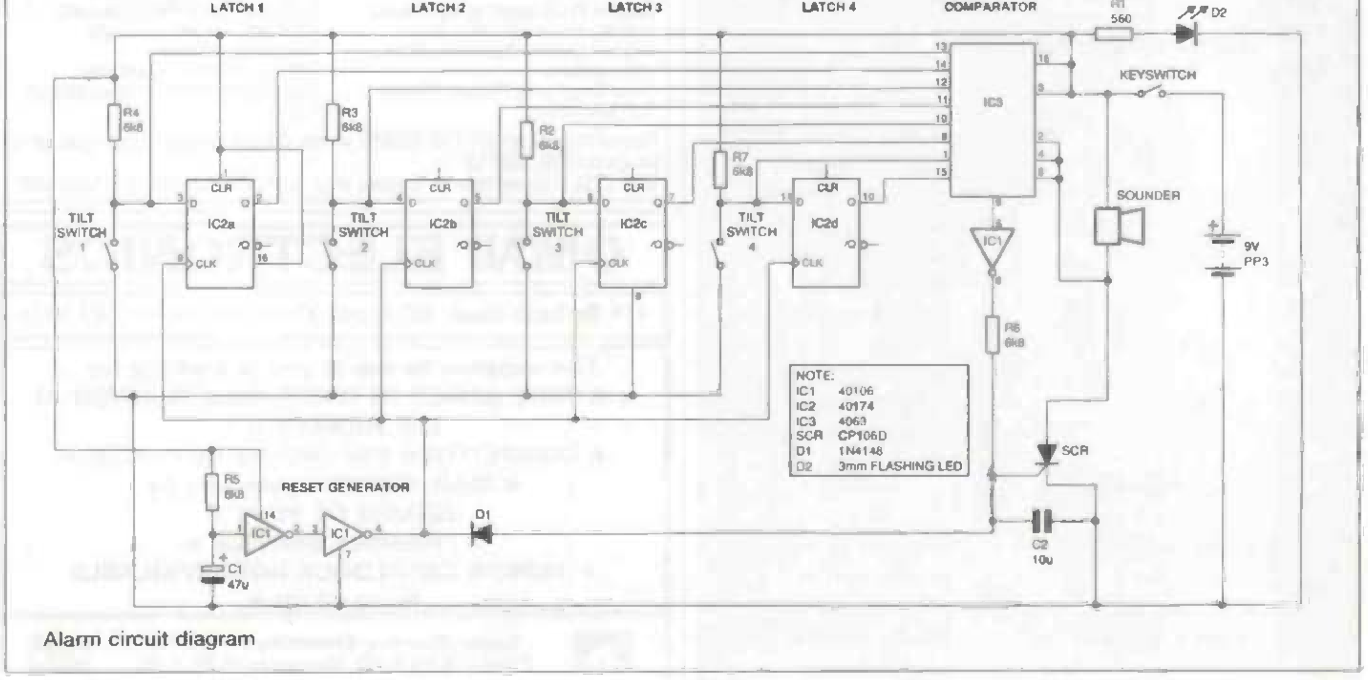
This input is activated by a transition of a logic 0 changing to a logic 1 (pulse). This pulse is generated at switch on by the reset generator.

The reset generator is constructed from two logic gates - a single capacitor and a resistor. When the alarm is switched on, the capacitor is in a discharged state and soon charges via the resistor (electrolytic capacitors are very poor at holding a charge in the absence of power). The values shown take about one second for the capacitor to charge - the resulting waveform can best be described as a ramp. This ramp is converted into a pulse and inverted by the first logic gate (inverter) and further sharpened by the second logic gate and inverted back to the same direction as the ramp only with sharp edges. The CMOS inverters will ignore the ramp until it reaches half the supply rail and then they will change state very quickly. Thus, the reset command is generated about one second after the alarm is switched on and the tilt switch states are then locked into the D latches.

The latched logic and the logic produced by the tilt switches is then monitored for change in IC3 (magnitude comparator). This chip has eight inputs arranged as four A inputs and four B inputs. It can compare them and detect if they are equal or not. The chip is designed to compare two four bit binary numbers and indicate if A is greater than B, if B is greater than A or if they are equal; hence its name, magnitude comparator. The A greater than B and B greater than A outputs are not used in this design. The A=B output connects pin 3 A=B input to A=B output when A=B. This should always be the state if



Component overlay



Alarm circuit diagram

the alarm has been set, the latches loaded with the switch pattern and the bicycle not moved. If the bicycle is moved, then the switch pattern will change and not equal the pattern latched in the D types. A will not equal B on the magnitude comparator and a logic 0 will be presented for our circuit configuration i.e. pin 3 at Vcc. This logic is inverted by the Logic gate and will turn on the SCR which will sink current and develop a potential difference across the sounder. This will produce a high pitched 103 dB (decibels) of sound.

The SCR was necessary so as to latch the alarm. The alternative would have been a switching transistor, but this would enable the alarm to be silenced if the cycle was moved to such a position that the original switch pattern was restored. Once the SCR is switched on by the logic, it will function as a transistor and sound the alarm, but it will not switch off, no matter what logic state is presented to its gate, even if the original switch pattern is restored. D1 is necessary to stop the SCR from being activated when the alarm is switched on, because the switch pattern is not latched until the reset pulse. During this time, the D types are set to random states that may or may not match the switches so the alarm would sound until C1 charges and latches the switch pattern. D1 stops the input to the SCR going to Logic 1 until the reset pulse has occurred. This is because it conducts when the reset generator is producing a logic 0, and therefore stops the SCR gate going to logic 1, when the reset generator is producing a logic 1 (i.e. after the latches have been loaded D1 is biased to open circuit).

C2 delays this pulse because the D latches and the magnitude comparator response is not instant. This is called propagation delay and is very small and is measured in nanoseconds

Construction

The ICs were installed using sockets but this is not necessary. The switches are wire-mounted devices that can be bent into their final position. It is important that all the positions are different to get the best performance out of the alarm - some experimenting with the final positions is inevitable. Any flux left on the PCB after soldering In the components should be cleaned off with flux remover as CMOS logic works at very high impedances and can easily be upset by any residue on the PCB. The on/off switch was the key operated kind for obvious reasons as the alarm would be less than useless if an ordinary toggle switch was used, enabling the thief to disarm the alarm

Battery life

This depends upon a number of things; in particular, how often the alarm is sounded and the quality of battery used. If long periods of duty are required, use an Alkaline battery. The battery life can be extended by omitting the LED. Further battery economies can also be made by increasing the value of the tilt switch pullup resistors R2, R3,R4, and R7. Values approaching 100k should still provide a logic 1 when the tilt switch is open

Case

The case is down to individual choice. The prototype was housed in transparent acrylic tube with a pair of suitable engineered end caps. The unit was then fixed to the cycle with tie wraps. But there are numerous other solutions.

PARTS LIST

Resistors

- R1 — 560ohms
- R2 TO R7 — 6K8 ohms

Capacitors

- C1 electrolytic — 47Mfd radial (MAPLIN FF083)
- C2 electrolytic — 10 Mfd radial (MAPLIN FFO4E)

Semiconductors

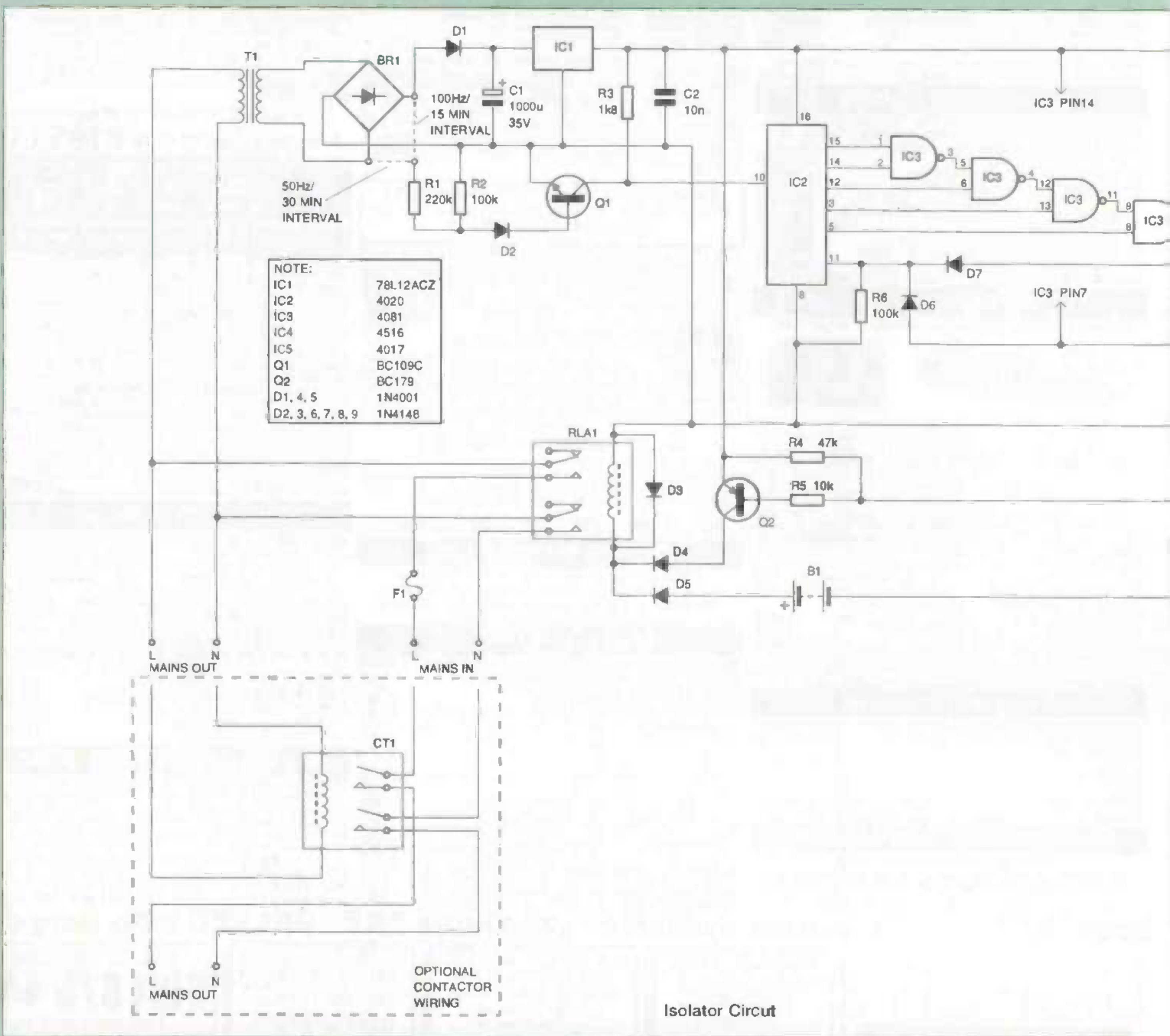
- IC1 — 40106 HEX INVERTER WITH SCHMITT INPUT (MAPLIN QW46U)
- IC2 — 40174 HEX D LATCH (MAPLIN QW46U)
- IC3 — 4063 MAGNITUDE COMPARATOR (MAPLIN QW41U)
- SCR — CP106D (MAPLIN UM74R)
- L.E.D. — FLASHING 3mm (MAPLIN UK33L)

Miscellaneous

- SW1 toSW4 — miniature tilt switches (Maplin FE11N)
- Battery clip to suit PP3 — (Maplin HF28F)
- Piezo sounder — (Maplin UM47R)
- Key switch — (Maplin FE44X)

Timed Isolator

This unit was designed by David Geary to provide automatic safety isolation of an appliance after a preset period



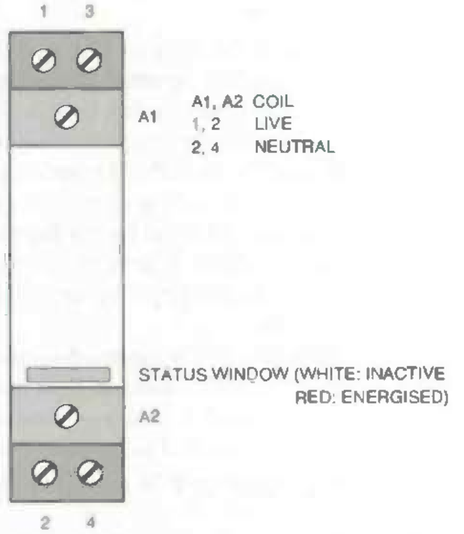
Isolator Circut

In my own case, I have a tumble dryer in my garage to which my two year old son can, on occasion, get access. Although the switched socket outlet feeding it is too high for him to reach, it is often left plugged in and switched on - therefore my son could operate the dryer. Before now he has managed to put one of our cats in the machine but thankfully has not then switched it on!

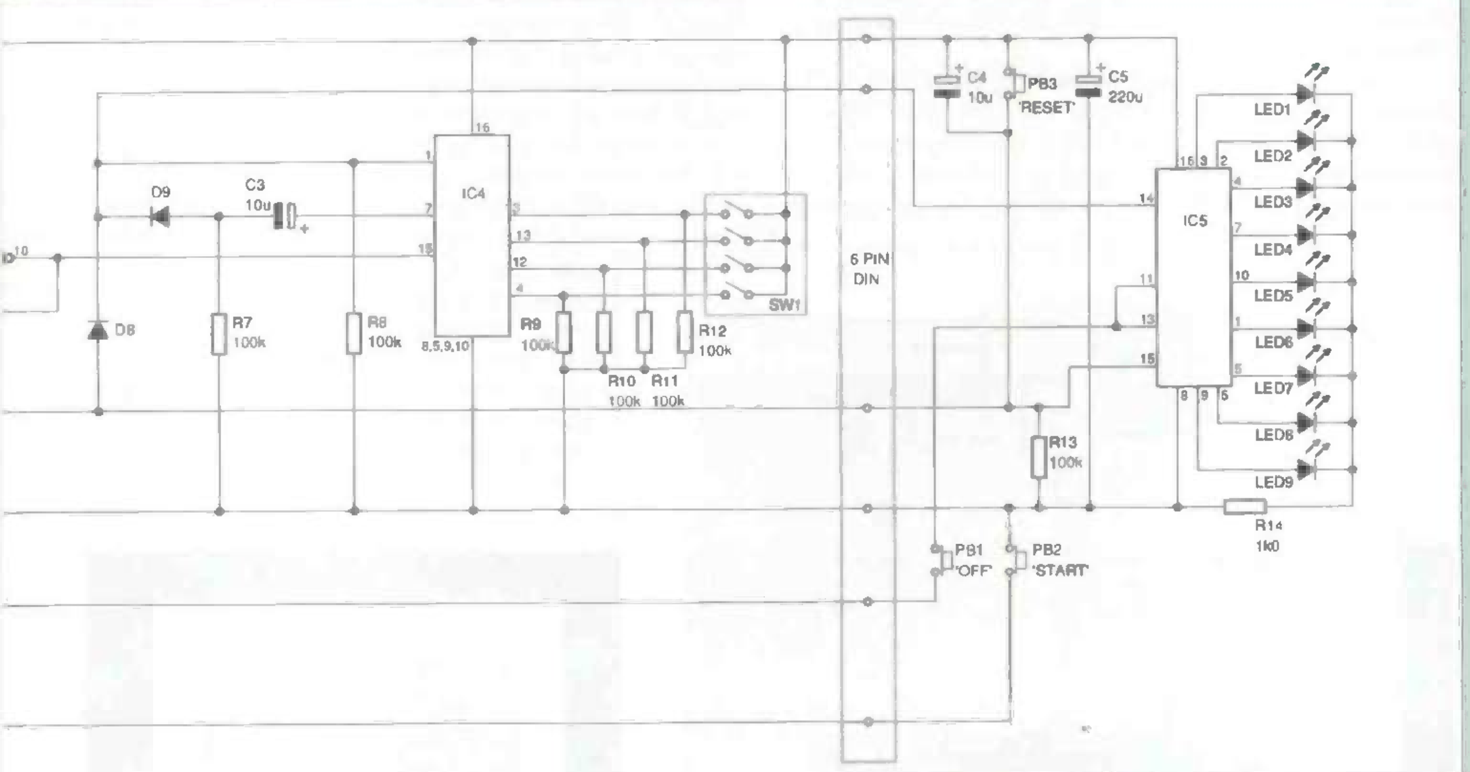
We also have a washing machine in the kitchen where similar risks are apparent. Electrical isolation rendering the appliance inoperative would mean (in our case) the door could not even be opened.

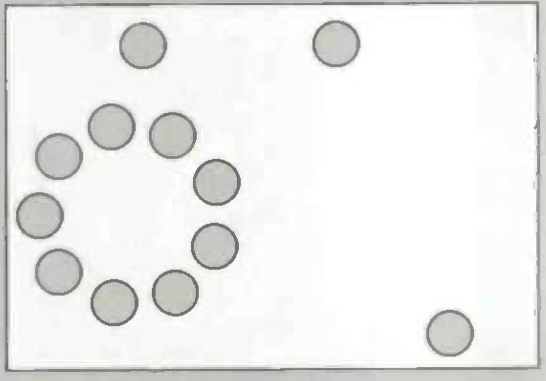
A secondary risk is that garages (particularly wooden ones such as mine) and similar outbuildings can suffer from leaks, flooding floors, and other sources of moisture.

The purpose of the design outlined here is to provide power to the appliance for just the necessary amount of time. Isolation is double-pole, i.e. both live and neutral. Maximum loads with the standard design are limited by the relay, around 5A resistive. Use of a contactor extends capability to a full 13A



Hager E220 detail





Remote unit panel layout

load with an inductive content, e.g. the aforementioned tumble dryer, or a washing machine.

An added benefit is that the three controlling pushbuttons are also isolated from the mains, operating at low voltage (12v). An advantage is to allow another use in a kitchen where, for example, a dishwasher or washing machine is installed next to the sink. The IEE Regulations state that it must be impossible to both have a hand in the sink area and on a socket outlet at the same time. The isolator unit could be mounted under the sink with the ring main outlet and a remote control box or panel with the pushbuttons and optional countdown LEDs mounted in any convenient position.

Continuing the theme of isolation, in the quiescent state the transformer primary is double-pole isolated from the mains by a relay. An alkaline battery is used to provide power for the "ON" pushbutton and the relay coil while the transformer is isolated, thereby allowing the timing cycle to be initiated. However, a double-pole mains-rated (override) pushbutton can also be provided on the main unit to short circuit the isolator, thereby starting the timer if necessary without the battery.

This article shows the timed isolator made up as two units, the main unit and the remote control. There is no reason why these cannot be combined; the LEDs are optional as are the "Reset" and "Off" controls.

Delay is set by a DIL switch on the PCB, in multiples of 15 minutes or 30 minutes depending on the wiring of the PCB, giving maximum delays of 4 or 8 hours. The delay period is determined by counting mains cycles and is therefore quite accurate and predictable, helping to eliminate the risk of power being removed until, for example, the washing machine has completed its cycle.

Changing the delay time means opening the case and changing the DIL switch setting to a calculated value or consulting a reference table (given later). This feature is quite deliberate and improves the tamperproof qualities of the system. However, there is no reason why four small toggle switches or similar could not be used, if desired.

The project also presents an opportunity to provide MCB (Miniature Circuit Breaker) or better still RCD (Residual Current Device) protection to the appliance, more on which later.

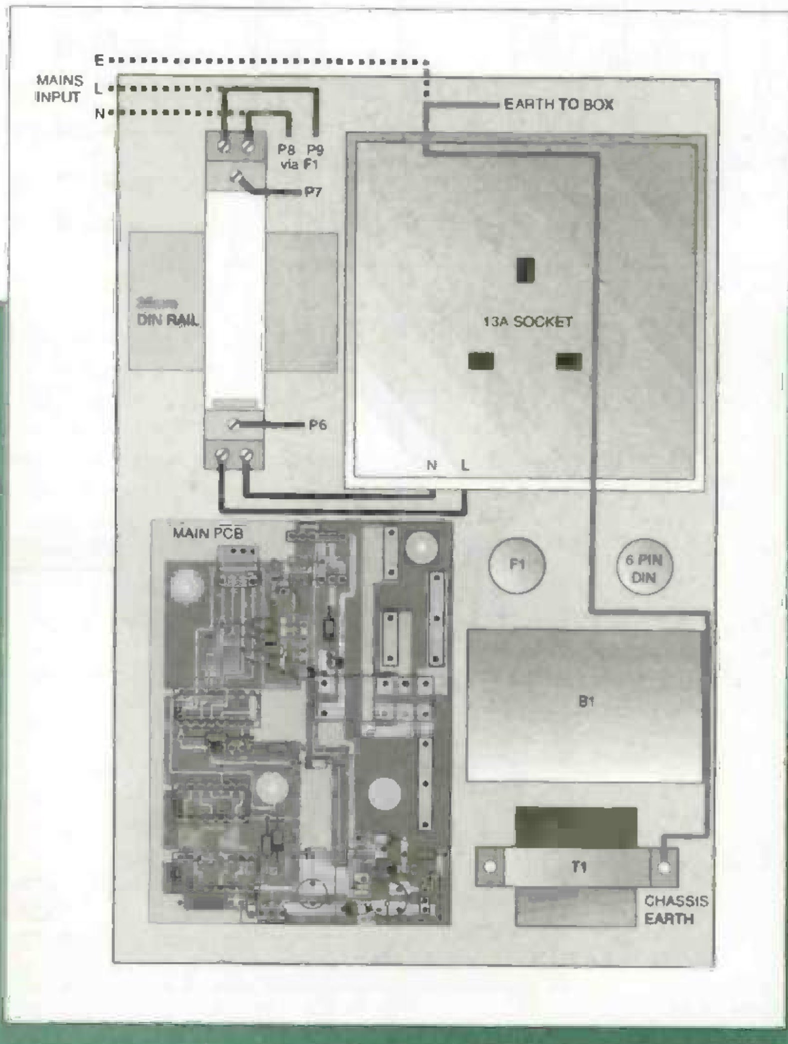
How It Works

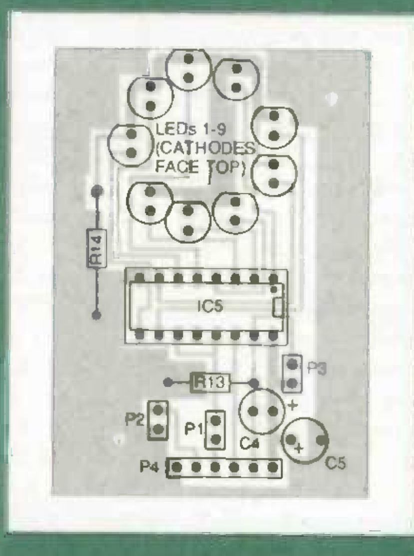
In the quiescent state, relay contacts RLAI isolate the mains transformer and the load from the supply. Pressing pushbutton PB2 connects battery BI to the relay coil via D5. The relay contacts then energise T1 and the load. D5 is included to prevent reverse current through B1, a potentially explosive situation in the case of an alkaline battery.

C4 and R13 provide a reset pulse to IC2 and IC5, and a preset enable pulse to IC4 to load data from SW1. Mains waveform pulses are fed to TRI via potential divider R1, R2 and diode D2. TRI is wired as a collector follower with R3, forming a high gain amplifier. The effect is to limit both polarity and amplitude to within the bounds of the power supply. IC1, CI, and C2 form a l2v regulated supply.

Pulses from TR1 of either 50Hz or 100Hz are counted by IC2. The 100Hz frequency is produced by BR1 full wave rectifying the 50Hz sinewave from T1. On reaching a count of 10000, IC2 is reset by the AND-gate network built around IC3. Diode OR-gate D6, D7, R6 is necessary as the reset pin is shared by the "on-reset" configuration C4, R13.

This reset pulse on 10000 is also fed to 1C4, which is wired as a down counter. IC4 therefore counts down on every 10000 pulses from TR1 until reaching zero, having been preset to "n" (set by SW1) on power-up. At this point R8, C3,





Above: Component overlay LED display board

Left: Main unit internal unit with optional contractor

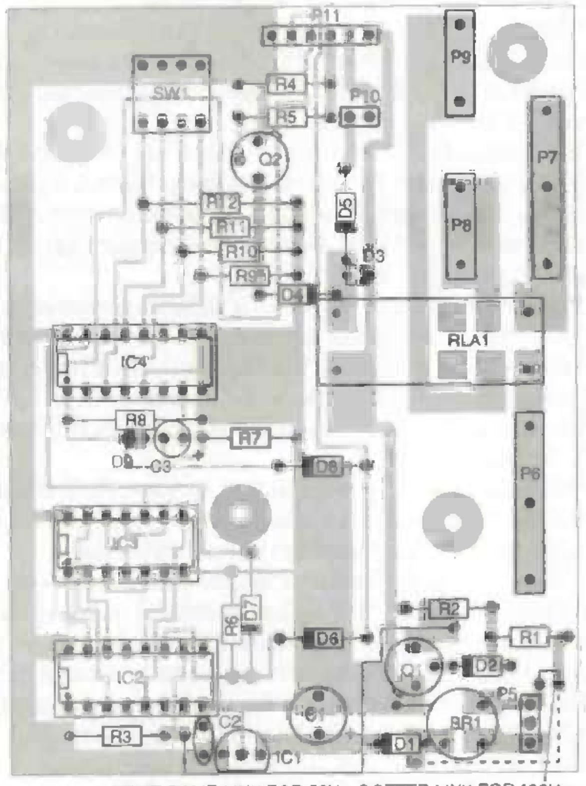
R7, D9 produces a pulse from the "CARRY-OUT" pin of IC4, presetting IC4 to repeat the cycle and clocking IC5. In this way IC4 is connected as a modulo-n divider depending on the binary number set up on SW1.

IC5 counts from 0 to 9; outputs 0 to 8 are connected to an LED moving-dot display formed from LED1 to LED 9. When the "9" output goes high, it takes the clock inhibit pin of IC5 high to prevent further counting. TR2 has been kept turned hard on by the path to ground via R5 and IC5. When IC5 pin 11 goes high at the count of "9", TR2 turns off, releasing the relay contacts. Power is therefore withdrawn from the circuit. As smoothing capacitors C1 and C5 discharge, the fact that the clock inhibit pin of IC5 is kept high by the "9" output as the supply voltage falls helps prevent any nuisance retriggering of the circuit.

At any time during the counting cycle, pressing PB3 pulls the reset/preset line high by shorting C4. The count on all chips therefore starts again and a new timing cycle is initiated. Pressing PB1 interrupts the ground path from TR2's base via R5, ending circuit operation immediately. R4 is included to stop TR2's base floating.

TR2 is a small signal, high gain transistor which would not normally be used to switch such a large load as RLA1. However, it is always hard on or completely off, and therefore power dissipation is minimised. D1, D4, and D5 are specified as 1N4001 where the current requirement is approaching the 75mA maximum of the 1N4148.

B1 should last quite some time as only a brief pulse is required on each occasion the unit is activated. An alkaline battery is recommended as they tend to be leak-resistant and capable of maintaining p.d. and current capability for some years.



MAKE SOLID LINK FOR 50Hz, DOTTED LINK FOR 100Hz

Component layout for main PCB

Output devices

The relay used in the prototypes were from Maplin, who state the contacts are rated at 5A resistive. Some of this capability is used by T1, a very small although inductive load. A 5A limit would restrict use of this project to small loads, e.g. my computer printer which I have a habit of leaving switched on. A number of the electrical accessory manufacturers have made available larger relays (contactors) designed to fit into modern consumer units. They are available from specialist electrical outlets and electrical wholesalers, and are made by such names as Mk, Merlin Gerin, Hager, Crabtree, etc. This type tends to be DIN-rail mounting, and so to use them you need to obtain some DIN rail. RS/Electromail can supply, but it might be worth asking your source of contactor if they can supply the rail as well, if only to save the postage! Alternatively, some contactors made for industrial use are screw mounting, but tend to be rather larger and more expensive. The prototype used the DIN-rail mount Hager E220 which, with a 20A rating, is perfect for controlling large appliances. Figure 2 shows the six connections to the Hager device, looking at the front of the unit.

Industrial contactors may provide more facilities which may be of use under special circumstances. For example, normally closed contacts would mean the timer could interrupt supply for a given period of time. This could be achieved using the spare Normally Closed contacts on RLA1, but would mean the contactor coil remaining energised for most of the time. Auxiliary contact blocks can often also be fitted in combinations of Normally Open (N.O.) and Normally Closed (N.C.).

If you use DIN-rail, you have the opportunity to include a Minature Circuit Breaker (MCB), which is effectively a very fast overcurrent protection device. The 5916s (16A), 5910s (10A), or even 5906s (6A) could be included here depending on your application.

Alternatively, you could install a Residual Current Device (RCD), which monitors current flow in both Live and Neutral supply lines. A difference (a RESIDUAL of (Live Current - Neutral Current)) indicates a current to earth, the only other path available. A fault condition is likely to exist under these circumstances, and therefore the RCD will trip, isolating the supply. There are various types, some combining over-current with residual current protection, often known as an "RCBO". These only break the live side of the supply, and therefore do not provide full isolation. A double-pole type, with a sensitivity of 30mA or better still, 10mA, is recommended. Examples are the Mk 6316s and Mk 5716s. My preference for double-pole isolation is based upon the possibility that Live and Neutral connections can be reversed. This could be due to an error by the constructor or whoever installed the house wiring. How many of us have checked?

You are recommended to consult a qualified electrician if you have the slightest doubt.

Construction

There are two PCBs which are very straightforward to construct, following the usual rules of orientation, etc. I tend to use PCB connectors (as listed in the Parts List) as they make for a very neat job and easy removal of the PCB if necessary. However, when constructing the remote PCB, Pl, P2, and P3 are best connected to pushbuttons directly with flexible wire due to lack of space.

Remember that D1, D4, D5, BR1 and RLA1 require larger holes than most components, as do all of the PCB connectors. It is much easier to drill out an "empty" PCB.

Start by soldering the IC sockets in place, followed by resistors, capacitors (except C1), connectors and then semiconductors. Fit C1 and RLAI last as they make the board unwieldy if installed at an early stage.

Don't forget the link from R1 to either T1 or BR1 depending on your chosen clock frequency/time delay. There is only one other link in the project, connecting to the "south" side of R3.

Beware of P4 and P11; although they connect together the order of connections is mirror image.

If you mount the remote PCB in a separate enclosure, use a six-pin DIN plug and socket with some six-core "signal" cable to make the interconnection. The following table is based upon the colours in the Maplin cable as per the components list. References for P4 and P11 are counting from 1 to 6, starting from the top.

The DIN socket is not numbered at the back. Pin 6 is the centre pin. If you look at the socket with the chassis connection nearest, count anticlockwise from bottom right as pin 1.

The project can be used in a number of different ways so the choice of case and final layout will depend on the intended use. I have not included a fuse (other than FI to protect T1 and RLA1) as it is anticipated that the unit will be connected to the mains supply via a fused plug. If this is not the case, you must include a fuse to suit the total load at the mains input. My layout is shown in Figure 5, and allows for the optional contactor.

If you follow my example and purchase a 9 x 6 x 3 black enamel "Adaptable Box" for the main unit from an electrical wholesaler you will find you have a box of remarkable quality for a relatively small outlay. Prices vary, so shop around. The size I have used is the smallest that is realistically suitable but it is not the most common, you will more easily get 9 x 9 x 3 or 12 x 12 x 3. Note that a larger case will be required if adding MCB or RCD protection as described earlier. The boxes are steel and highly suitable for mounting in the back of cupboards, under workbenches etc. I mounted all of the

Table 1
References for P4 and P11

Signal	Colour	P11	6-pin DIN	P4
Ov	Black	6	Pin 6 (centre)	1
Start	Blue	5	Pin 1	2
Out	Green	4	Pin 2	3
Clock	White	3	Pin 3	4
Reset	Yellow	2	Pin 4	5
+ve	Red	1	Pin 5	6

electronics on the reverse of the lid, bringing only the incoming supply through the box itself. This makes it easier to mount the box on a wall, but please remember to earth the box and lid. Another advantage of this method is that it is a lot easier to assemble the project and inter-wire on a fairly flat steel sheet than in a box 3" deep!

The range of adaptable boxes come in galvanised or black enamel finishes, the latter being cheaper. They are also available "plain" or "knockouts". I use the knockout type as they have 20mm holes available all round, and are the same price. When buying your box ask for a Pirelli 251 cable gland, or an equivalent "stuffing gland", and make sure you get a locknut or lockring for it. You can then press out one of the knockouts using a blunt tool in the centre of the knockout and a hammer, install your gland through it, and secure your incoming flex cable very neatly.

The remote unit, if built in the specified case, is an exercise in small, neat construction! The PCB as been designed to just fit. With the height of the LED's there is no need to secure the board in the case. There are knockouts in the side of the case where the lid can trap the cable once fitted. Two holes are provided in the base for screw fixing, but remember to stick some insulating tape or other material over the screw heads to prevent a short circuit with the bottom of the PCB. You will

Table 2
100Hz clock (dotted link on Overlay)

DIL Switch Setting Minutes	Total Delay (Hrs:Min)	LED count every Seconds	(Min:Sec)	
0 (0000)	15	(0:15)	100	(1:40)
1 (0001)	30	(0:30	200	(3:20)
2 (0010)	45	(0:45)	300	(5:00)
3 (0011)	60	(1:00)	400	(6:40)
4 (0100)	75	(1:15)	500	(8:20)
5 (0101)	90	(1:30)	600	(10:00)
6 (0110)	105	(1:45)	700	(11:40)
7 (0111)	120	(2:00)	800	(13:20)
8 (1000)	135	(2:15)	900	(15:00)
9 (1001)	150	(2:30)	1000	(16:40)
10 (1010)	165	(2:45)	1100	(18:20)
11 (1011)	180	(3:00)	1200	(20:00)
12 (1100)	195	(3:15)	1300	(21:40)
13 (1101)	210	(3:30)	1400	(23:20)
14 (1110)	225	(3:45)	1500	(25:00)
15 (1111)	240	(4:00)	1600	(26:40)

Table 3
50Hz clock (solid link on Overlay)

DIL Switch Setting	Total Delay Minutes	LED count every (Hrs:Min)	Seconds	(Min:Sec)	
0	(0000)	30	(0:30)	200	(3:20)
1	(0001)	60	(1:00)	400	(6:40)
2	(0010)	90	(1:30)	600	(10:00)
3	(0011)	120	(2:00)	800	(13:20)
4	(0100)	150	(2:30)	1000	(16:40)
5	(0101)	180	(3:00)	1200	(20:00)
6	(0110)	210	(3:30)	1400	(23:20)
7	(0111)	240	(4:00)	1600	(26:40)
8	(1000)	270	(4:30)	1800	(30:00)
9	(1001)	300	(5:00)	2000	(33:20)
10	(1010)	330	(5:30)	2200	(36:40)
11	(1011)	360	(6:00)	2400	(40:00)
12	(1100)	390	(6 30)	2600	(43:20)
13	(1101)	420	(7 00)	2800	(46:40)
14	(1110)	450	(7 30)	3000	(50:00)
15	(1111)	480	(8 00)	3200	(53:20)

need to bend the connections to the pushbuttons at right angles to the body to make them fit. The location of the controls on the lid is only critical in as much as taking care not to foul components on the PCB. Figure 4 provides a scale template for the relative position of holes for the prototypes. Take a photocopy if you want to avoid damaging this magazine, but please check it matches with your PCB, etc, before using it! It should be possible to replace the "on" and "reset" pushbuttons with a subminiature toggle switch, DPDT, centre off, momentary action. I have not tested this idea but it would save space.

Pressing the START button PB2 will close the relay contacts, energising the load or contactor if used. The first LED will light (About the 11 o'clock position with the remote board upright). The LEDs will count anticlockwise, at the end of the count the unit and load will turn off.

Setting the delay depends on the clock frequency chosen at time of construction and the number set on DIL switch SW1. The table below gives the various combinations.
Pressing PBI at any time will turn the load and the unit off prematurely. Pressing PB3 resets the count for a fresh time delay without interrupting the supply to the appliance.

Note that if you turn the unit off with PBI and wish to turn it on again almost immediately, press PB3 (Reset) and then PB2 (Start) as C3 and C5 take 30 seconds or so to discharge.

My cat now sleeps soundly in the knowledge he will not wake to see the world revolving at an alarming rate on what appears to be a very warm day

PARTS LIST

Resistors

- RI 220K (A220K)
- R2,6,7,8,9, 10,11,12,13 IOOK (A10OK)
- R3 1K8 (A1K8)
- R4 47K (A47K)
- R5 10K (A1OK)
- R14 1K0 (A1KO)

Capacitors

- CI 1000u 35v Electrolytic (FFI8U)
- C2 IOn Disc Ceramic (WX77J)
- C3,4 IOu 50v Electrolytic (FFO4E)
- C5 220u 35v Electrolytic (JL22Y)

Semiconductors

- IC1 78L12ACZ Voltage Regulator (WQ77J)
- C2 4020 14 stage binary counte (QX11M)
- IC3 4081 Quad 2-Input AND-gat (QW48C)
- IC4 4516 Binary Presettable Counter (QW87U)
- C5 4017 Decoded Decade Counter (QX09K)
- TR1 BC109C NPN Bipolar Transistor (QB33L)
- TR2 BC179 PNP Bipolar Transistor (QB54L)

PARTS LIST

- D1,4,5 — 1N4001 Rectifier Diode (QL73Q)
- D2,3,6,7,8,9 — 1N4148 Signal Diode (QL80B)
- BR1 — WOO5 Bridge Rectifier (QL37S)
- LED1 - 9 — Red 5mm LED (WL27E/AQ12N)

Miscellaneous

- T1 — 6v-O-6v or 0-12v 100mA Sec (WBOOA) 0-240v Pri Mains Transformer
- RLA1 — 12v 200 ohm coil 240v 5A DPDT Relay (YX98G)
- PB1 — Push to break pushbutton (FH6OQ)
- PB2,3 — Push to make pushbutton (FH59P)
- BI — Alkaline "PP3" (ZB52G)
- SW1 — 4 way SPST DIL switch (JH081)
- CT1 — Hager E220 Contactor (Optional)
  16 pin DIL sockets x 3 (BL19V)
  14 pin DIL socket x 1 (BL18U)
- P4, P11 — 6way PCB Connectors as Maplin BH65V/YW12N/YW25C
- P5 — 3 way PCB Connector as Maplin BX97F/BX96E/YW25C
- P6,P7 — 3 way Mains Connectors as Maplin JY95D
- P8,P9 — 2 way Mains Connectors as Maplin JY93B
- P10 — 2 way PCB Connector as Maplin HB59P/RK65V/YW25C
- FI — Panel Mounted fuseholder (DA59P) & suitable fuse (up to 5A) - see text.
- Insulated Spacers, 20mm. (FS38R)
- 35mm "Top Hat" DIN rail (see text).
- MK 2757WHI single 13A socket or equivalent (note the unswitched type also suitable), MK2200 mounting frame.
- 6 pin DIN chassis socket (HH36P)
- 6 pin DIN plug. (HH29G)
- 6 Core cable. (XS54J)
- 3 Core Mains Flex (XR10L)
  13A Plug
- Cable Gland (see text)
- PP3 connector (HF28F)
- Battery Holder 9" x6 "x 3"
- adaptable box (see text) for main unit.
- Maplin case Box 321 (FK3IQ)
- Cable Ties, Nuts, Bolts, etc.

Basic for the pic microcontroller

PART 3

The developer of this unique project, Robin Abbott, looks at some other versions of the ETI PIC based controller module. These offer the user a range of additional options which make them ideal for specific applications

This month we will look at the versions of PIC Controller BASIC which operate on the 16C5x series of processors. In the original article, it was stated that there would be a version of PIC Controller BASIC which would operate on the 16C56. However, it has very little RAM and the extra program requirements of the paged memory system used on the 16C5x series meant that the version which was eventually produced was too limited in capability for serious use.

The 16C57 and 16C58 processors, however, have the advantage of 70 bytes of RAM each and 2K of EPROM. This means that versions of PIC Controller BASIC for these processors allow extensions to the BASIC language which are described in this article. The 16C57 is provided in a 28-pin package which supports three I/O ports and so, for the BASIC application (which uses 4 bits of port A), there are 16 I/O pins and one input for the real time counter. The 16C58 is provided in an 18-pin package, and uses the same circuit and board layout as that shown in last month's article for the 16C84 device.

The 16C57 and 16C58 processors are a better processor than the 16C84 for the BASIC project in every respect with the exception of interrupt support and upgrading. Although it is possible to upgrade the 16C84 device to the latest version of PIC Controller BASIC, it is only possible to do this with the '57 and '58 versions by using the more expensive erasable devices. However, One Time Programmable (OTP) versions of the '57 and '58 are available at a very reasonable cost.

Circuit description

Figure 1 shows the circuit diagram for the 16C57 version of PIC Controller BASIC. The essential circuit is identical to the 18-pin version shown in the October issue of ETI. The serial port is a low-cost interface which relies on the voltage on the incoming data line to provide the negative supply on the outgoing data line. The oscillator can be a crystal or ceramic resonator. I/O on this module type is provided on a 20-way IDC connector which allows connection to application circuits through 20-way cable. The voltage regulator is optional, the circuit will work up to 6V but, if greater voltages than this are to be used, then a regulator must be provided. For application circuits which will use less than 90mA then a 78L05 may be used; for greater current consumption, use a 78M05 (500mA) or 7805(1A) device.

IC2 is the EEPROM device; either 24LC16 or 24LC65 devices may be used. However, a different program is used in the PIC for each device.

The brown out protection circuit is based around TR1 which ensures that the PIC is reset if the power supply falls below 4V. Interestingly, Microchip has recognised that brown out protection should be provided on the chip and the latest devices (the 16C2X series) all have a brown out protection circuit and an enable bit in the configuration fuses.

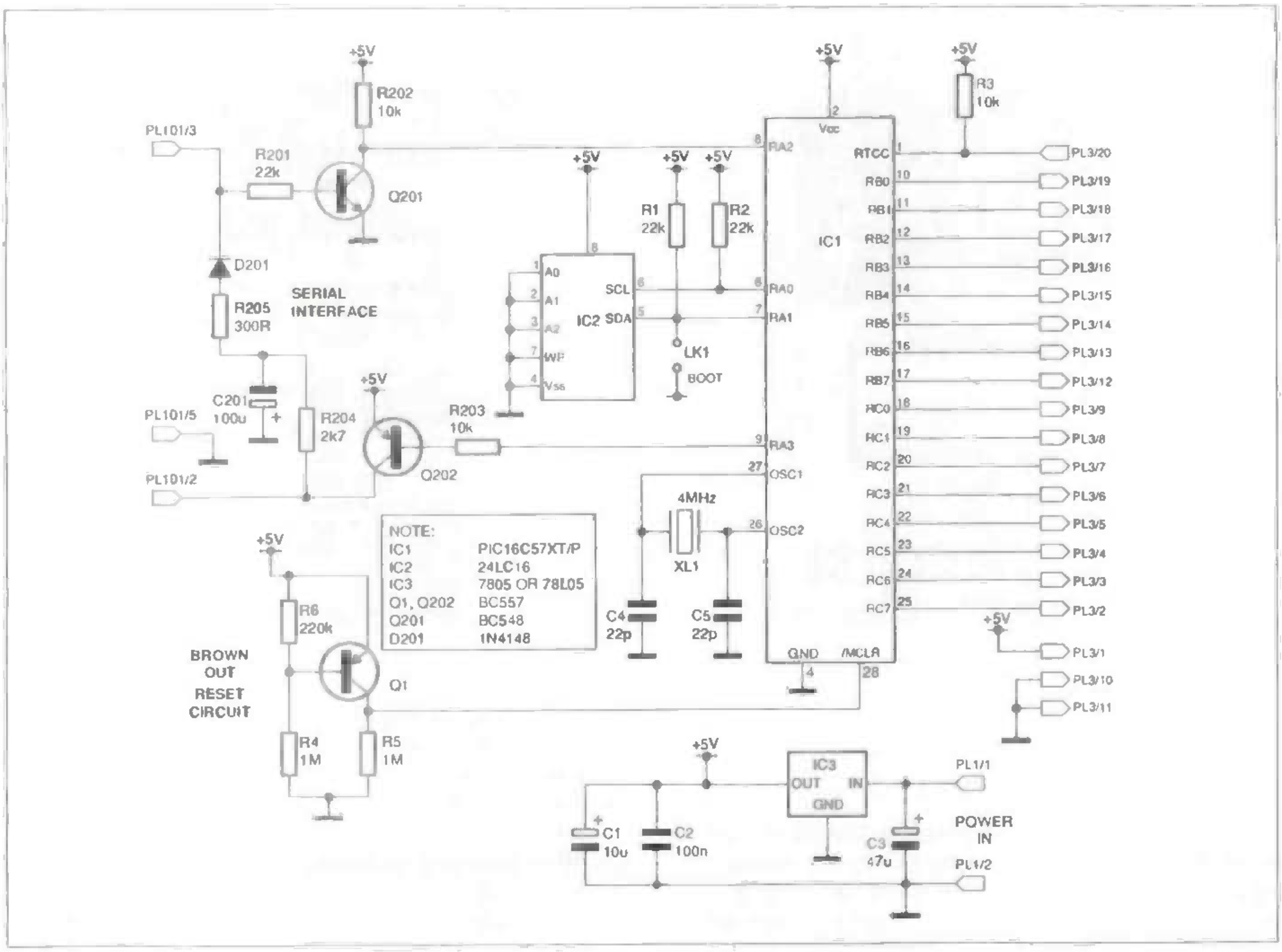
The 16C58 version uses the circuit shown in the October issue of ETI. However, the component references are identical to those shown in Fig. 1 and it is possible to build the circuit from Fig. 1. The I/O connector for 18 pin versions of BASIC is a 16-pin DIL IC socket.

Versions of the '57 and '58 devices are available for 4MHz, 10MHz and 20MHz clock frequencies. The clock frequency is hard programmed in to the code to save on program space.

Construction and testing

Construction is straightforward. Use sockets for IC1 and IC2. The circuit board overlay is shown in Fig. 2 for the 16C57 version and the overlay for the 16C58 is shown again in Fig. 3; this is the board which was given away with the October issue of ETI. The 16C57 version has three wire links. Use thin single core hook up wire as the links must not interfere with PL3. Insert wire links and IC sockets first, then resistors, capacitors, voltage regulator and transistors. Finally, insert PL1 and PL2.

Testing is very straightforward. Without IC1 or IC2 in circuit, connect the power supply and check that the socket for IC1



has +5 between pins 2 and 4. Power down, insert IC1 and IC2 and connect to the host PC. Start the PICBASDE program and check that the module is detected. There are a number of test programs provided with PICBASDE. Provided that they don't use interrupts, any of these may be downloaded to the module to test it. It is recommended that a program which uses no external devices is used.

The use of PICBASDE is fully explained in the November issue of ETI.

Extended BASIC

The BASIC language provided for the '57 and '58 is extended to level 1. This provides new program constructs and various commands to drive external hardware.

The new commands and facilities in level 1 PIC Controller BASIC are as follows:

- **LED driving. A new command provides for the M4540 device which allows 4 digit, 7 segment LED displays, or up to 36 external devices to be driven from 2 output pins on the BASIC module.**
- **LCD driving. New commands provide a simple 4 bit interface to those LCD modules (the majority) which use the Hitachi chip set.**
- **Infra red transmission and reception is supported to send 8 bit numbers between two PIC BASIC modules, which may be separated by up to 10m.**
- **A fast data protocol is provided to send information on a clocked data line between two PIC BASIC modules.**
- **The width command measures pulse width of either polarity on an input pin.**
- **The clocks command sends any number of clocks of either polarity on an output pin.**
- **The wait command pauses program execution for any time between 1mS and 30S.**
- **Shift left and shift right operators provide fast multiplication and division by 2.**

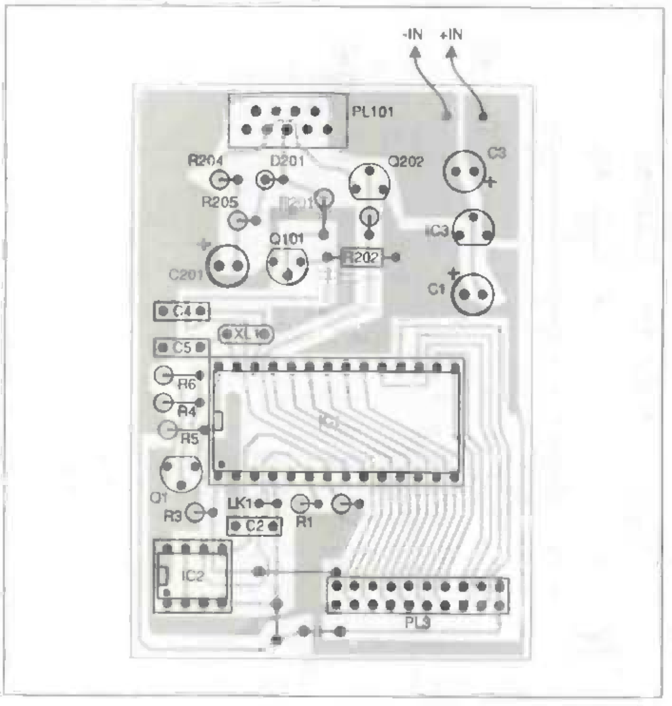
Some of these new commands and constructs are detailed in the rest of this article.

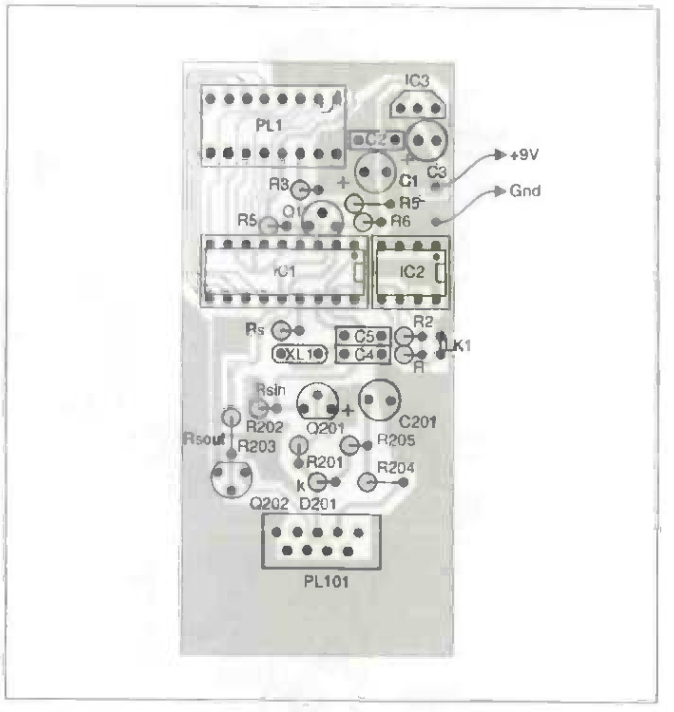
Parameter passing to functions and local variables

The extended RAM which is available in the '57 and '58 devices allows PIC Controller BASIC to make use of the stack to provide parameters in functions, recursive functions and local variables in functions.

Function parameters allow numbers to be passed to functions and subroutines. These are set up in the same way as normal functions and subroutines using the TYPESUB and TYPEFUNC keywords. For example, the following program calculates the Centigrade equivalent of Fahrenheit temperatures from 0 to 100 in 10 Fahrenheit steps and puts them in the array temps, which can be read in the debugging window on the host PC.

```
typefunc ftoc(temp)
dim temps[11],8
for i=0 to 100 step 10
temps[i/10]=ftoc(i)
```






```
next
monitor()
func ftoc(x)
return ((x-32)*5)/9
end
```

Local variables are variables which are declared in a function or subroutine. They may then only be used in that function. If the same variable is declared in the main program and in a function or subroutine, then the local variable takes precedence in the function or subroutine, but is invisible outside it. Local variables may only be of 8 or 16 bits in length and should be declared using the DIM statement. Local variables must be declared at the top of the function or subroutine.

For example, the following version of the function ftoc works exactly the same as that shown above, but uses a local variable. It is less efficient of RAM usage and is only shown here as an example. Local variables do not appear in the debugging window.

```
func ftoc(x)
dim i.8
i=((x-32)*5)/9
return i
end
```

The final advantage that local variables and parameter passing gives is that recursive functions may be used. To consider a typical use for recursive functions, consider the factorial function. The factorial of a number X is defined as X*(X-1)*(X-2)...(1). Thus, the factorial of 4 is 4*3*2*1 which is 24. The alternative definition of factorial of X is to say that factorial(1) is 1, and if x is greater than 1 then factorial(x) is x*(factorial(x-1)). This latter definition is used in the recursive function factorial shown below:

```
typefunc factorial(x)
; program here
func factorial(x)
if (x=1) then return 1
return factorial(x-1)
end
```

Recursive functions can often be a very neat method of calculating results, or performing complex operations. However, they consume stack memory very rapidly and a simple test program based on the factorial function shown only worked up to factorial(8) (which exceeds the range of 16 bit numbers), factorial(9) caused the stack to overwrite the system variables and BASIC crashed.

Device driving commands

Most of the commands in the following sections allow the user to define any pin on the I/O ports of the PIC to be used for peripheral device connections. These pins are defined using the port definition form. This is the form used for the serout, seroutstring and serin commands which were shown in the November issue of ETI. Consider the width command. The width command looks at the current state of an input pin, looks for a pulse of the opposite state and measures its width. Thus, if the pin is high, then the width command waits until the pin becomes low, then measures the time before it goes high again. The width command needs one parameter which is the pin on which a pulse is to be measured. The pin is defined as the address of the port+16*bit number. Thus, bit number 4 on port A is defined as ADDPORTA+16*4. The following example program shows how to measure the width of a pulse on port B, bit 5; the result can be read in the debugging window.

```
const portpin=ADDPORTB+16*5

dim x.16
x=width(portpin)
monitor()
```

The result returned depends on the processor frequency. For example, with a 4MHz clock, the result is in units of 10uS; with a 20MHz clock the result will be in units of 2uS. Thus, the above program will measure a 1KHz square wave as x=100 with a 4MHz clock, and x=500 with a 20MHz clock.

Next Month...

Next month we'll take a look at the 16C64 version of PIC BASIC, which offers futher extensions to the language.

Designing a Pic Micro controller based project

PART 6

Bart Trepak concludes his construction of a PIC based alarm clock

As discussed earlier in this series, five switches will be required to set our clock (plus the pressure mat) and these have been connected as a 6x1 matrix as shown in Fig 5. During the KEYBD routine, the digit drives are switched off and port line B6 is redefined as an input while the rest of port B remains programmed as outputs. Each output port is then switched high in turn using the BSF instruction and the line B6 read using the BTFSS instruction.

The PRESSURE MAT input is a bit of a problem because, unlike the other keys, it does not have a momentary action and could be on for long periods of time (if you are in bed) and especially during periods when the other keys may have to be read. You may, for example, want to set the alarm time when you are already in bed and the mat "switch" is closed and you will almost certainly want to operate the snooze button next morning when this is the case. During the time that the other keys were being scanned, the output B5 would be at 0 Volts which would have the effect of placing a 1k resistor in parallel with the 10k pull down resistor if the mat switch were closed. This would prevent the voltage at B6, resulting from a possible closure of another switch, from rising above half the supply rail which may not be enough to register as a switch closure. The solution to this is to programme the line B5 as an input (high impedance) during the time when the mat status is not required. This means that even if it is closed it will not affect the voltage at B6 and will not interfere with the operation of the rest of keyboard. Because the reverse would also be true, with operation of other switches preventing the mat status to be read, the lines B0-B4 will also be defined as inputs during the period when the mat switch is read which occurs only during the alarm routine.

The Key scanning flowchart is shown in Fig. 21a and like the CONVRT routine it returns with a number in the W register which depends on the key pressed. If no key is pressed, the routine returns with 00h in the W register. This is written as a subroutine called KEYBD in the final programme and is called from the main routine after the DISPLY routine. The value returned is further processed in the routine marked KEY

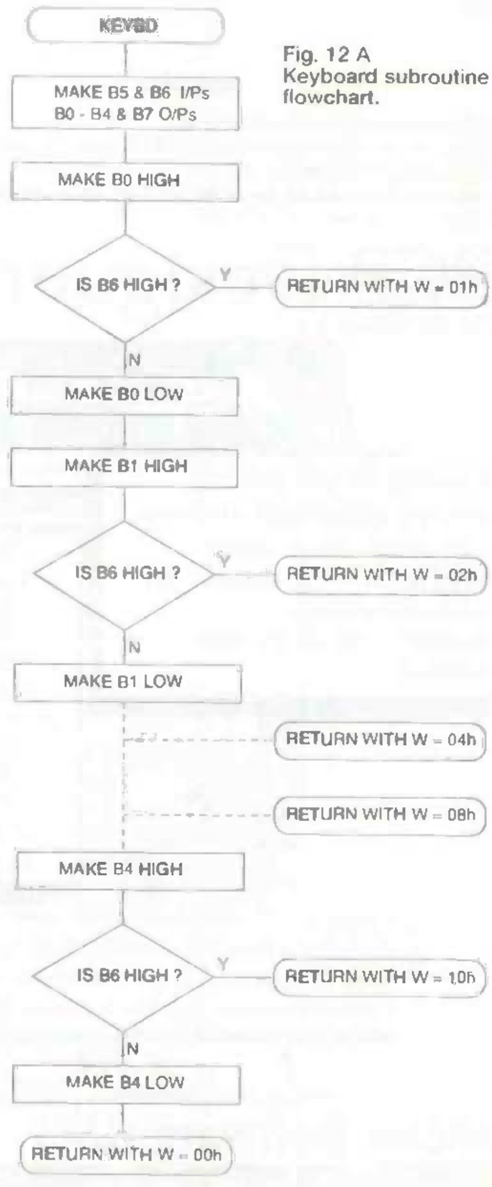


Fig. 12 A
Keyboard subroutine flowchart.

(FIG.21), where it is compared with the LKP register (Last Key Pressed register defined as 14h) and if it is different, the new value is stored in LKP and the programme goes back to the beginning to display digits and continue counting which takes 10mS and forms the keyboard debounce delay.

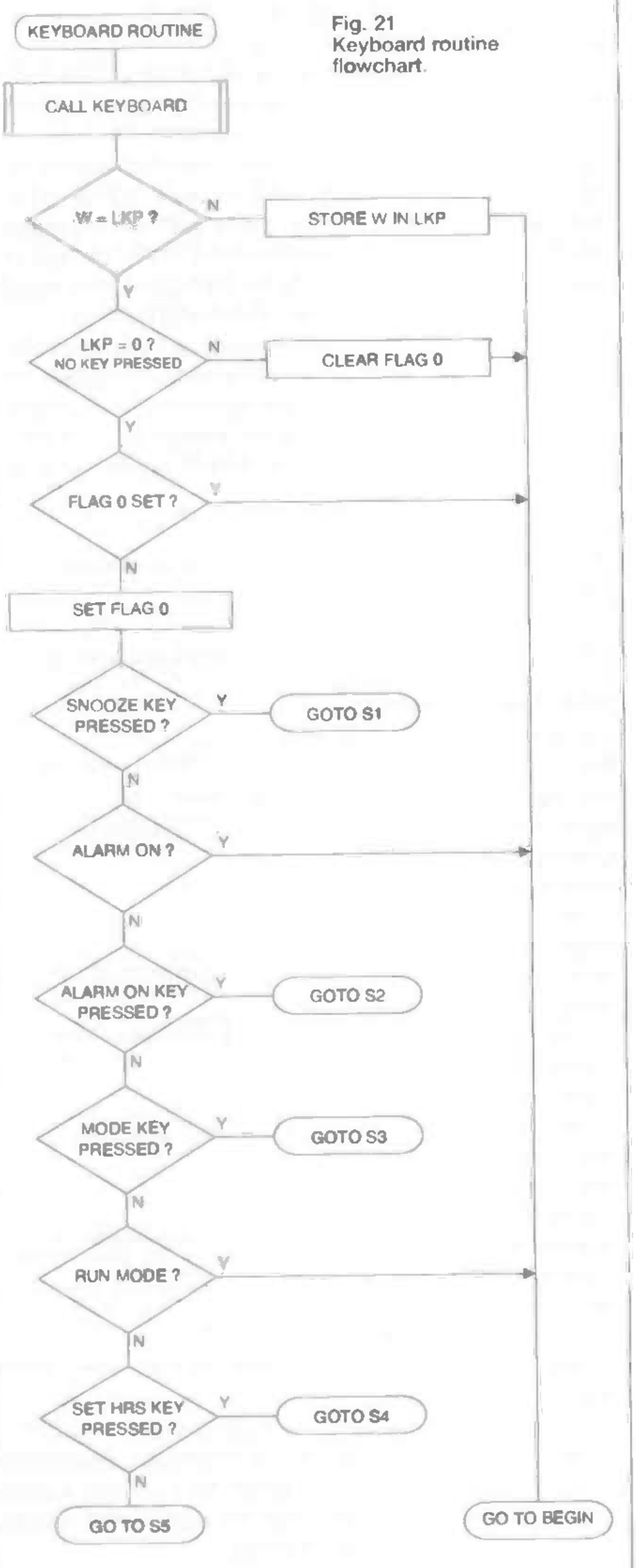
If the key currently pressed matches that already stored in the LKP register from the previous scan, bit 0 in a FLAG register (defined as 13h and shown in FIG. 21b) is tested and if it is clear, it is set to one and the function of the key is performed. The next time the subroutine is called, the chances are that the same key will still be pressed so that the LKP register will match the number returned by the KEYBD routine. This time however, bit 0 of the FLAG register will already be set so that the function of the key will be ignored. Only when a 00h is returned when the key is released will bit 0 be cleared enabling a new function (or the same one) to be performed when a key is pressed.

Each key will therefore operate only the first time that it is pressed so that to set 11:15 PM from a display of 12:00 AM, the mode button will have to be pressed until the SET TIME mode is reached (i.e. colon on but not flashing) and the SET HOURS button pressed and released 23 times and the SET MINUTES button 15 times. Although this may seem very time-consuming, it does not take that long and is perhaps not as annoying as the fast set button on some clocks which runs the clock at a faster rate. Here the required setting is invariably missed and the procedure of going through the whole 24 hour sequence has to be repeated. For those interested, the setting method could be converted to this by altering the value loaded into the HSREG and/or TBREG to make the clock count faster and the key processing routine changed to continuously increment the hours or minutes as long as the relevant key were held down. It would make an interesting exercise to gain experience in programming the PIC micro-controller.

The function of each key and the order in which they are scanned is determined by the programme and this could easily be changed to make the controls more (?) logical or easier to lay out on the front panel. Here the switches are numbered S1 to S5 reading from top to bottom of the printed circuit board and the functions assigned to them are SNOOZE, ALARM ON/OFF, MODE SELECT, SET HOURS and SET MINUTES respectively. Initially the programme can be developed with only one function implemented, say SET MINUTES to check that the KEYBD routine is working correctly before the logic for the other switches is worked out.

The switch functions are perhaps best understood with the aid of the flowcharts shown in Fig. 22. The corresponding code for this can again be found in the final programme listing under labels S1 to S5. The set hours and set minutes (S4 and S5) are not shown because they consist simply of calling the subroutines INCRH and INCR and since the appropriate register for the current mode will already have been loaded into the FSR, the correct register for that mode will be incremented. The MODE SELECT function (S3) is shown and is basically also an increment instruction operating on MDREG, but since there are only three modes this register must be reset to zero if a count of three is reached so that only modes 0, 1 and 2 (corresponding to RUN, SET ALARM TIME and SET TIME) are possible. This could easily be changed so that a fourth, fifth or greater mode were possible for setting alternate alarm times or switch off times if required. Note that it is most important that this register is cleared to zero during the initial power-up routine otherwise it could start with an initial value greater than three which would be most confusing - not only to the

Fig. 21
Keyboard routine flowchart.



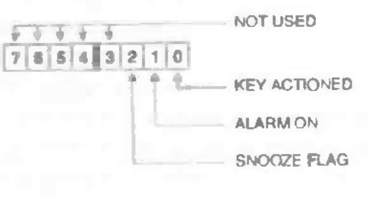


Fig. 21B
Flag register

programme but also to the programmer.

The ALARM ON/OFF switch (S2) should only be allowed to operate if the alarm is not already on to prevent the alarm being switched off by pressing this once it has sounded. The alarm output (PORT B7) cannot be used to check this because the alarm may not actually be sounding when the clock is in the alarm mode as it could have been cancelled temporarily by the snooze button or indeed by the occupant getting out of bed. Instead, bit 1 of the FLAG register is set when the alarm time is reached and this is tested instead. Only if this test is passed is the alarm LED (bit 2 in the INDFLG register) toggled. The logic for the SNOOZE switch (S1) is slightly more complicated because it is only allowed to operate once after the alarm has sounded. Another bit in the FLAG register (bit 2) is used to remember if the snooze switch has been pressed by setting it if it is. The effect of pressing the SNOOZE button is to increase the number stored in the TMTMR register by ten but to understand the logic behind this it is first necessary to consider the alarm sounding routine. The flowchart for this function is shown in Fig. 23.

Don't be alarmed

The software development for the clock is now nearing its end and it only remains to design the logic required to actually sound the alarm when required. This is done in the ALRM subroutine, but before we develop the flowchart, it would be best to recap on what is required.

The first step to take before deciding if the alarm is to be sounded is, of course, to see if the current time (as stored in the HRCTR and MINCTR) has reached that stored in the alarm time registers and, indeed, if the alarm has been set in the first place. This can be easily done using the XOR function as discussed before - not only on the hours and minutes counters but also on the INDFLG register which contains AM/PM and alarm ON/OFF information. Because the alarm is to be maintained, if necessary, for more than a minute, a successful initial comparison should be noted after which the registers need no longer be compared.

Since the alarm is to remain active for ten minutes, a separate counter (TMTMR or Ten Minute TiMeR designated 15h and loaded with .10 when the above registers match) is decremented at the same time as the MINCTR is incremented, and this is used to time the alarm interval. This has not been shown on the flowchart as it belongs more properly to the INCR (increment counters) subroutine. The code for this has been added to the beginning of the INCR subroutine shown in Fig. 24. Operating the SNOOZE switch postpones the alarm for a period of ten minutes by adding another ten to the above counter when this switch is pressed using the "addwf TMTMR" instruction. The alarm is then potentially activated only if the count remaining in this timer is less than ten minutes, but made inactive if it is greater than this which would be the case if the SNOOZE button had been pressed. Since only one operation of the SNOOZE button is allowed during each alarm period, more than ten cannot be added by repeatedly pressing this switch.

Assuming that the time remaining in the TMTMR register is less than ten minutes, the alarm would still only be required if the occupant were still in bed so the mat switch would need to be tested at this point. The alarm would only be cancelled when the count in the TMTMR reached zero which would take ten minutes so that before this happened, any return to bed would immediately restart the alarm. By this time, it is hoped, the owner would be well and truly awake.

Finally, because a pulsed alarm is more effective than a continuous tone at waking people from their slumbers, the output is switched on only if the colon is on resulting in the alarm being switched on and off every half a second.

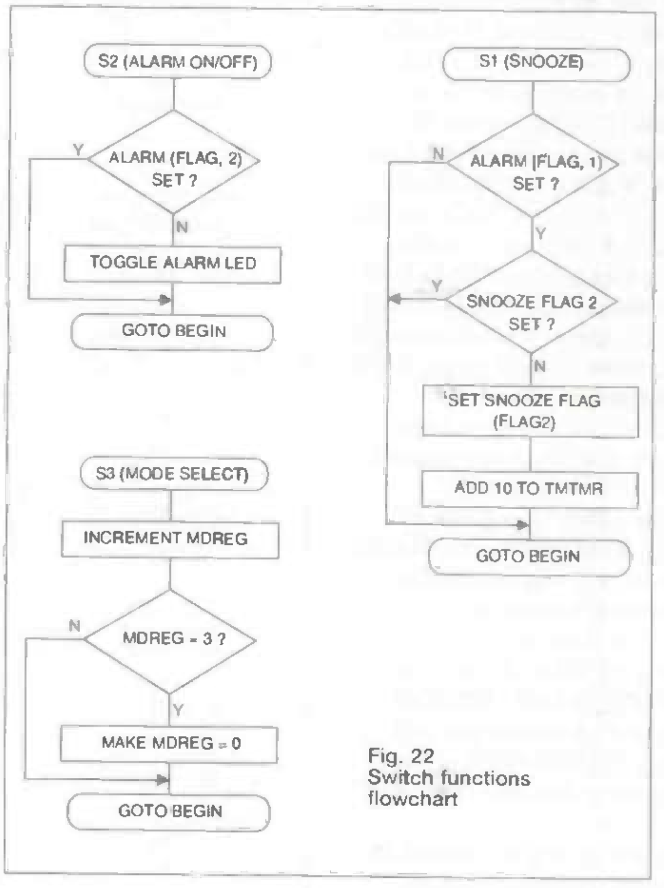


Fig. 22
Switch functions flowchart

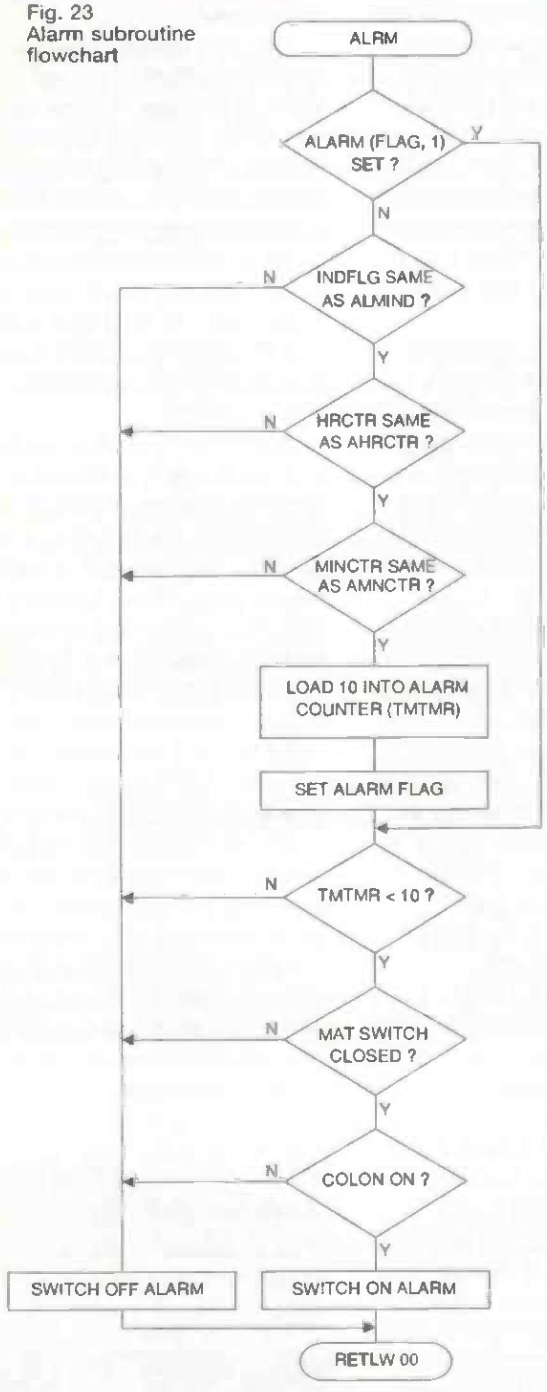
The flowchart for this is shown in Fig. 23 and it should now be quite easy to code using the mnemonics given in Fig. 3. The only new technique required is how to determine if the contents of the TMTMR register are less than ten. The simplest way to do this is to load ten into the W register and subtract it from TMTMR using the "subwf TMTMR,w" instruction, having first set the carry bit in the STATUS register. If TMTMR contains a value of ten or less, the carry bit in the STATUS register (bit 0) will be cleared indicating that a "borrow" has occurred, while, if the value is greater it will remain set. Although not used here, by loading W with the contents of another register, this technique could be used by extension to compare two registers to decide which of the two was greater or smaller or by testing the zero bit (bit 2) if they were equal. The SUBWF instruction could therefore also be used to test equality instead of the XOR instruction used earlier.

The listing for this part of the programme is shown at the label ALRM in Fig. 24 which is the complete listing for the alarm clock. Note the additions to the list of "equ" statements at the beginning of the programme and the changes in the INILTLSE routine which now contains the initial conditions required in all the relevant registers to ensure that at switch on, the initial time stored is 12:00 AM with the clock in the RUN mode and the alarm time set to 12 00 AM but disabled.

Because the ALRM routine drives port B7 which has to be on continuously while the alarm is to sound, the DISPLY routine which also shares the rest of the port B lines must be altered to make sure that B7 is not reset when the LED displays are switched on and off. In the original listing for this routine (Fig.

13) the value returned from the CONVRT routine was simply re-written to port B to switch the appropriate display segments on. Since bit 7 in the CONVRT table is always zero as it does not drive any segment, it would be reset as soon as the DISPLY routine was called. One way around this would be to have two look-up tables with one having bit 7 set and the other cleared. Then choose which table to use depending on whether the alarm was to sound or not. The solution adopted here is to "inclusive or" the data from the look-up table with port B using the IORWF PORTB, same instruction which loads the seven segment data into the port while leaving B7 unchanged, instead of the original MOVWF instruction. For this to work, however, the other bits in port B must first be reset; otherwise, data from the last digit displayed would be mixed with the new data. All outputs except B7 are therefore cleared using an ANDLW instruction before the digit is displayed which accounts for the slightly longer DISPLY routine in the final version of the programme compared with that originally shown.

Fig. 23
Alarm subroutine flowchart



Around and around

This ends our series as far as the "Digital Clock for the Unemployed" is concerned and it only remains to programme a chip and plug it into the socket on the board to complete it. The software has been fully described and many other techniques mentioned so it should be an easy matter to modify the design to, say, take week-ends and even public holidays into account or to allow two (or more?) snooze operations before the alarm sounds constantly. Many of the routines could be used as they are or slightly modified for other projects where, say, a keyboard and/or a display is required. In some cases, even the printed circuit board may remain the same!

Perhaps the only major instructions listed in Fig. 3 not used in this series are the "Rotate Left Through Carry" and "Rotate Right Through Carry" instructions (RLF f,d and RRF f,d). The operation of both of these is similar and quite simple to understand although their uses may not be so obvious. The RLF f,d instruction, for example, takes the value of the most significant bit in the register "f" and places it into the carry bit in the STATUS register while the value of the carry bit is pushed into the least significant position and all the other bits are also shifted one place to the left. This is shown in Fig. 25, along with the corresponding situation for the RRF f,d instruction, which depicts the contents of a register before and after these instructions have been executed. One application of these instructions is to shift information serially out of an I/O pin in, say, a remote control transmitter application. After every shift operation, the carry bit in the STATUS register (bit 0) could be tested and the relevant I/O port bit set or cleared using the "BSF f,b" or "BCF f,b" as required. A similar routine could then read an input pin and set or clear the carry bit and shift this into a register to reproduce the transmitted word at the receiver. A separate output on the transmitter could be used to synchronise the shift operation at the receiver to keep the two in step or the received signal sampled at precise time intervals provided that the clocks in the transmitter and receiver were stable enough for the application. This is not the only use of these instructions, however. Just as with normal decimal numbers, where shifting the position of the digits one place to the left is equivalent of multiplying the number by ten while shifting them one place to the right effectively divides it by ten, with binary numbers the effect is similar except that the value is not increased or decreased by a factor of ten but two. The RLF instruction can therefore be used as a convenient way to multiply a number stored in a register by two (provided that the carry bit is first cleared) while the RRF can be used to divide it by two. Care must be taken to ensure that the carry bit is taken into account if necessary. Successive shifts will multiply or divide the original number by 4 ,8 and so on provided an overflow (or underflow) does not occur.

PIC and mix

This series of articles has only scratched the surface of the possibilities opened up by designing with micro-controllers. The PIC16C5X series has many other features which have not been used in the clock project but which can be useful in other applications.

All the devices in the series have, for example, a Watch Dog Timer (WDT) which runs independently of the main clock and will reset the processor every 18mS or so. This time can be extended by assigning the prescaler to the WDT, although not if it is already being used by the RTCC register. In use, the CLRWDT (Clear Watch Dog Timer) instruction is inserted into the programme so that this instruction will normally be executed before the WDT times out, ensuring that the processor is not reset. If due to noise, or other malfunction, the contents of a memory location get corrupted or for some other reason the programme crashes, the WDT will time out because the CLRWDT instruction will no longer be executed regularly or at all and the processor will be reset allowing it to restart the programme correctly. By reading certain bits in the STATUS register, the programme can differentiate between a reset caused by the WDT and the reset which occurs when power is first applied. This means that overwriting any previously stored conditions by the normal initialisation routine can be avoided. This feature is useful in electrically noisy environments such as cars or applications where a programme malfunction could have bad or even dangerous consequences.

If this function is not used, the WDT must be disabled by suitably programming the Configuration EPROM. This is not part of the main EPROM used for programme storage and consists of four bits. Two are used to select the clock type (i.e. RC, crystal etc.) one disables the WDT when set to zero while the fourth bit, when set to zero, prevents the contents of the programme memory being read out in a meaningful way - thus preventing someone from copying your design. To help with identifying programmed and code protected chips, there is also another 16 bit EPROM which can be programmed with a user identification code.

Another useful feature is the ability to put the circuit to sleep by executing the SLEEP instruction. This switches off the clock and shuts down the circuit so that current consumption falls to only a few micro-amps making it very useful in battery powered applications and eliminating the need for an on/off switch. In this condition, the output pins remain in their previously set conditions as inputs or outputs driving high or low and the WDT (if it is enabled) keeps running. The circuit may be awakened by a WDT time out or a reset pulse to the MCLR pin. Again, bits in the STATUS register can be read to determine what caused the device to wake up and the programme executed accordingly. This feature can be used in remote control transmitters for example where the circuit needs to be switched on when a key is pressed and switch off automatically when the transmission is finished.

Perhaps the best thing about the PIC series is the fact that the EPROM versions are also available at greatly reduced prices in a plastic package without the window. This, of course, means that the device can only be programmed once (One Time Programmable or OTP) and cannot be erased so it is not suitable for developing new programmes but is ideal for use in a finished project enabling the EPROM part to be used again to develop a new application. The only limitation is that the oscillator type is not programmable in the OTP device so that the required type must be purchased but even this is about to change.

We should at least mention two other members of the PIC16CXX family which share all of the features of the PIC16C5X.These include virtually the same instruction set but also have more advanced features such as interrupts and a deeper stack enabling more subroutines to be nested i.e. called from within subroutines. They also have some hardware features which will make them useful in more advanced applications.

The first of these is the PIC16C71 which has a built in A/D converter and a four way input multiplexer. This could be used, for example, to measure and display temperature at four different locations. The obvious application which springs to mind is to measure and display the house temperature and use this to control the heating while the other channels could measure the freezer, greenhouse and hot water temperatures and sound an alarm if the temperature moves outside the preset levels.

The other device is the PIC16C84 which has an EEPROM programme memory instead of the EPROM of the 16C5X series. This enables the device to be reprogrammed electrically without first erasing it with UV light which can make the whole process of developing programmes a lot faster. As well as this, the PIC16C84 has a small EEPROM memory which can be written to during programme execution. This enables the device to retain data even when the circuit is switched off. This can be extremely useful in some applications (e.g. milometers, digital locks - or keeping a running total of grass cut to date in that all-singing, all-dancing lawnmower perhaps?) and removes the need for back-up batteries when non-volatile storage of data is required.

Both of these devices are available in 18 pin DIL packages and use the same mnemonics (and to a large extent the same architecture) as the PIC16C54 micro-controller described together with one or two new instructions to support the new functions. This makes it very easy to "upgrade" to these or convert programmes from one device to another. The PICSTART programmer and software can also be used to develop programmes and programme these devices, despite the fact that they have a 14-bit wide programme memory instead of the 12-bit one of the earlier device making the PICSTART-16B even better value for money. The down side is, of course, that they cost more but still not as much as an equivalent CMOS design would cost - even if you could build it.

The trouble with technology is that it always seems to create as many problems as it solves. With all these micro-controllers at my disposal, I find that far from not being able to get up in the morning, I now cannot get to sleep thinking about my next project! The Alarm Clock has fallen into disuse (by me, at any rate) and as for watching soap operas, I find myself still looking at a screen all day but the programmes on mine are rather different compared to those on the other screen in the corner of the lounge.

FIG 24 - COMPLETE PROGRAMME FOR ALARM CLOCK

```
;
;*************************************************
*********************************
;
MDREG equ 08h         ;    MoDe REGister -
RUN=0, SET ALARM=1, SET TIME=2
MINCTR equ 09h        ;    MINute DiSPlay
HRCTR equ 0Ah         ;    HouR DiSPlay
INDFLG equ 0Bh        ;    INDicator FLaG holds
status of AM/PM, COLON & ALARM
DYCTR1 equ 0Ch        ;    DelaY CounTeR 1
DYCTR2 equ 0Dh        ;    DelaY CounTeR 2
HSCTR equ 0Eh         ;    Half Second CounTeR
TBCTR equ 0Fh         ;    Time Base CounTeR -
counts 120 half seconds
AMNREG equ 10h        ;    Alarm MiNute REGister
AHRREG equ 11h        ;    Alarm HouR REGister
AINDFG equ 12h        ;    Alarm INDicator FlaG
```

```
 G equ 13h              ;    FLAG register 0=KEY
CTIONED
KP equ 14h                   ;       Last Key
Pressed register
TMTMR equu 15h          ;    Ten Minute TiMeR -
counts alarm and snooze time
;
    LIST P=16C54 ; f=inhx16
    INCLUDE "PIC.H"
;*************************************************
**********************************
    goto START
;*************************************************
**********************************
;
DISPLY                  movlw 00h
                        tris PORTA
;   make port A o/p
                        tris PORTB
;   make port B o/p
                        clrf PORTA
;   switch off digit drives
                        movlw 80h
;   ie 1000 0000
                        andwf PORTB,same
;   clear PORTB except B7
; *********LED DISPLAY SUBROUTINE************
;
                        swapf 0,w
;   load tens of mins into w
                        andlw 0Fh
;   mask MSDs by ANDing with 0000 1111
                        call CONVRT
;   no - decode segments
                        iorwf PORTB
;   switch on segment drive
                        bsf PORTA,0
;   switch on digit drive
                        call DLY
;   delay for
                        bcf PORTA,0
;   switch off digit drive
                        movlw 80h
;   ie 1000 0000
                        andwf PORTB,same
;   clear PORTB except B7
;
                        movf 0,w
;   load units of mins into w
                        andlw oFh
;   select units of mins for display
                        call CONVRT
;   decode segments
                        iorwf PORTB
;   switch on segment drive
                        bsf PORTA,1
;   switch on digit drive
                        call DLY
;   delay for
                        bcf PORTA,1
;   switch off digit drive
                        movlw 80h
;   ie 1000 0000
                        andwf PORTB,same
;   clear PORTB except B7
;
                        incf FSR,same
      ;                 increment FSR to point to
Hours
;
                        swapf 0,w
;   Swap counter pointed to by FSR(10's HRS)
                        andlw 0Fh
;   mask MSDs by ANDing with 0000 1111
                        btfss STATUS,2
;   is digit zero? ie STATUS,2 is set
                        call CONVRT
;   no - decode segments(skipped if digit=0)
;
                        incf FSR,same
      ;                 point to indicator flag
register
```

```
                        iorwf 0,w
;   add colon (to be modified later)
                        decf FSR,same
;   reset pointer
                        iorwf PORTB
;   switch on segment drive
                        bsf PORTA,3
;   switch on digit drive
                        call DLY
;   delay for
                        bcf PORTA,3
;   switch off digit drive
                        movlw 80h
;   ie 1000 0000
                        andwf PORTB,same
;   clear PORTB except B7
;
                        movf 0,w
;   load counter pointed to by FSR
                        andlw 0Fh
;   select units of hours for display
                        call CONVRT
;   decode segments
                        iorwf PORTB
;   switch on segment drive
                        bsf PORTA,2
;   switch on digit drive
                        call DLY
;   delay for
                        bcf PORTA,2
;   switch off digit drive
                        movlw 80h
;   ie 1000 0000
                        andwf PORTB,same
;   clear PORTB except B7
;
                        decf FSR,same
;   reset pointer
                        retlw 00
;   RETURN FROM SUBROUTINE
;*************************************************
**********************************
;
CONVRT                  addwf PC,same
;*****BCD-7SEG CONVERSION SUBROUTINE*******
                        retlw 3Fh
;   segment drives for 0
                        retlw 12h
;   segment drives for 1
                        retlw 4Fh
;   segment drives for 2
                        retlw 57h
;   segment drives for 3
                        retlw 72h
;   segment drives for 4
                        retlw 75h
;   segment drives for 5
                        retlw 7Dh
;   segment drives for 6
                        retlw 13h
;   segment drives for 7
                        retlw 7Fh
;   segment drives for 8
                        retlw 77h
;   segment drives for 9
;*************************************************
**********************************
;
DLY                     movlw .4
;************DELAY ROUTINE*****************
                        movwf DYCTR1            ;
load DYCTR1 with 4 decimal
D1                      movlw .100
                        movwf DYCTR2            ;
load DYCTR2 with 100 decimal
D2                      decfsz DYCTR2,same
;   decrement and skip if zero
                        goto D2
;   if not zero
                        decfsz DYCTR1
;   decrement DYCTR1 if DYCTR2 is zero
                        goto D1
;   reload DYCTR2 if DYCTR1 is not zero
```

```
                        retlw 00
;    RETURN FROM SUBROUTINE if DYCTR1 is zero
;*****************************************************
**********************************
;
INCR                    nop
;******INCREMENT COUNTERS SUBROUTINE******
                        movf TMTMR,same
                        btfsc STATUS,2
;    is TMTMR =0 ?
                        goto INCR1
;    TMTMR is zero - cancel alarm
                        decf TMTMR,same
;    not zero - decrement
                        goto INCRM
;
INCR1                       bcf FLAG,1
    ;                   clear Alarm time reached
flag
                        bcf FLAG,2
;    clear SNOOZE key pressed flag
;
INCRM                   incf 0,same
;    INCREMENT MINUTES - POINTED TO BY FSR
                        movf 0,w
                        andlw 0Fh
;    and with 0000 1111 to mask MS bits
                        xorlw 0Ah
;    compare with Ah (10 decimal)
                        btfss STATUS,2
                        retlw 00
;    not = 10
                        movlw 06h
;    equal to 10
                        addwf 0,same
;    add 6 to file pointed to by FSR
                        movf 0,w
;    place in W register
                        xorlw 60h
                        btfss STATUS,2
;    equals 60?
                        retlw 00
;    no
                        clrf 0
    ;                   set to zero
;
                        movf MDREG,same
                        btfss STATUS,2
;    RUN mode? bit will be set if it is
                        retlw 00
;    no - do not change hours
;
INCRH                   incf FSR,same
    ;                   change pointer to hour
register
                        incf 0,same
;    INCREMENT HOURS
                        movf 0,w
                        andlw 0Fh
;    mask MS bits
                        xorlw 0Ah
;    compare with Ah (10 decimal)
                        btfss STATUS,2
                        goto CHECK1
;    not = 10 - check if counter = 12
                        movlw 06h
;    equal to 10
                        addwf 0,same
;    add 6 to file pointed to by FSR
;
CHECK1                  movf 0,w
;    COUNTER EQUALS 12?
                        xorlw 12h
                        btfss STATUS,2
;    equals 12?
                        goto CHECK2
;    no - check if counter = 13
                        incf FSR,same
    ;                   change pointer to
indicator register
                        movlw 40h
;    ie 0100 0000
                        xorwf 0,same
;    toggle AM/PM flag
                        retlw 00
;
CHECK2                  movf 0,w
;    COUNTER EQUALS 13?
                        xorlw 13h
                        btfss STATUS,2
                        retlw 00
;    no
                        movlw 01h
;    yes
                        movlf 0
;    set hours register to 01
                        retlw 00
;
;*****************************************************
**********************************
;
KEYBD                   movlw 60h
;******KEY READIND ROUTINE*****************
                        tris PORTB
;    make B0-B4 & B7 o/ps and B5 & B6 inputs
                        movlw 80h
;    ie 1000 0000
                        andwf PORTB,same
;    clear bits 0-6 B7 does not change
;
                        bsf PORTB,0
;    set B0 high
                        nop
                        btfsc PORTB,6
;    B6 high?
                        retlw 01h
;    S1 pressed
                        bcf PORTB,0
;    no - clear B0
;
                        bsf PORTB,1
;    set B1 high
                        nop
                        btfsc PORTB,6
;    B6 high?
                        retlw 02h
;    S2 pressed
                        bcf PORTB,1
;    no - clear B1
;
                        bsf PORTB,2
;    set B2 high
                        nop
                        btfsc PORTB,6
;    B6 high?
                        retlw 04h
;    S3 pressed
                        bcf PORTB,2
;    no - clear B2
;
                        bsf PORTB,3
;    set B3 high
                        nop
                        btfsc PORTB,6
;    B6 high?
                        retlw 08h
;    S4 pressed
                        bcf PORTB,3
;    no - clear B3
;
                        bsf PORTB,4
;    set B4 high
                        nop
                        btfsc PORTB,6
;    B6 high?
                        retlw 10h
;    S5 pressed
                        bcf PORTB,4
;    no - clear B4
;
                        retlw 00
;    no keys pressed
;
;*****************************************************
**********************************
;
```

```
ALRM                    nop
;***********ALARM SUBROUTINE***************
                        btfsc FLAG,1
;    has alarm time been reached?
                        goto CHKTMR          ;
yes - check if TMTMR is zero
                        movf AINDFG,w
;    no
                        xorwf INDFLG,w
;    compare INDFLG with AINDFG
                        btfss STATUS,2
                        goto NOALRM          ;
not the same - switch off alarm
                        movf HRCTR,w
                        xorwf AHRREG,w
;    compare hours
                        btfss STATUS,2
                        goto NOALRM          ;
not the same - no alarm
                        movf MINCTR,w
;    same
                        xorwf AMNREG,w
;    compare minutes
                        btfss STATUS,2
                        goto NOALRM          ;
not the same - no alarm
                        movlw .10
;    same - alarm time reached
                        movwf TMTMR          ;
load Ten minute timer with 10
                        bsf FLAG,1
;    set ALARM TIME flag
;
CHKTMR                  bsf STATUS,0         ;
set carry bit
                        movlw .10
;    check if TMTMR is less then 10
                        subwf TMTMR,w
                        btfsc STATUS,0
;    is carry bit reset? ie. result negative
                        goto NOALRM          ;
no - time > 10 mins - SNOOZE
                        movlw 5Fh
;    yes - snooze is over - check mat
                        tris PORTB
;    make B5 and B7 o/p all others i/p
                        bsf PORTB,5
;    make B5 high
                        nop
                        btfss PORTB,6
;    test B6
                        goto NOALRM          ;
mat not closed - no alarm
                        btfss INDFLG,0
;    is colon on?
                        goto NOALRM          ;
no - makes alarm switch off for 0.5sec
                        bsf PORTB,7
;    switch on alarm
                        retlw 00
;
NOALRM                  bcf PORTB,7
;    switch off alarm (B7)
                        retlw 00
;
;******************************************************
*********************************
;
START                   nop
;
;*********INITIALISE ROUTINE*****************
INTLSE                  movlw 00h
;    ie 0000 0000
                        tris PORTA
;    make PORTA o/p
                        movwf PORTA          ;
make PORTA 0000
                        tris PORTB
;    mkae PORTB i/p exept B4
;
                        movlw 07h
;    ie 0000 0111
                        OPTION
;    int signal, L to H, presclr 256 to RTCC
                        movlw .224
;    move 244 decimal into
                        movwf RTCC
;    RTCC - gives 10mS with 3.2768Mhz xtal
;
                        movlw 12h
                        movwf HRCTR          ;
load HRCTR with 12
                        movwf AHRREG
                        movlw ooh
                        movwf MINCTR         ;
load MINCTR with 00
                        movwf AMNREG
                        movlw 04h
                        movwf AINDFG         ;
set AINDFG to AM, colon off and alarm on
                        clrf MDREG
;    set MDREG to 0 ie. run mode
                        movlw .50
                        movwf HSCTR          ;
load HSCTR with 50 dec to count halfsecs
                        movlw .120
;    load TBCTR with 2 (temporary) so that
                        movwf TBCTR          ;
clock runs faster (change to 120 later)
                        clrf INDFLG
;    INDFLG = am, colon and alarm off
                        clrf FLAG
                        clrf TMTMR
;
BEGIN                   movf RTCC,w
                        btfss STATUS,2
;    test if w (RTCC) = 0
                        goto BEGIN
;    w (RTCC) not zero
;
                        movlw .224
;    if RTCC=0 move
                        movwf RTCC
;    224 dec. into RTCC
;
MODE                    movf MDREG,w         ;
places MDREG into w
                        btfsc STATUS,2
;    test if MDREG=0
                        goto RUN
;    yes
                        xorlw 01h
;    no - XOR MDREG (w) with 01h
                        btfsc STATUS,2
;    test if MDREG=1 - Z bit will be set if
;    it is
                        goto SETARM
;    yes
;
SETTIM                  movlw 09h
;    no - set time routine
                        movwf FSR
;    set pointer to time registers
                        bsf INDFLG,0         ;
switch colon on
                        goto PROG
;
SETARM                  movlw 10h
;    set alarm routine
                        movwf FSR
;    set pointer to Alarm registers
                        goto PROG
;
RUN                     movlw 09h
;    RUN ROUTINE
                        movwf FSR
;    load address of MINCTR into FSR
;
                        decfsz HSCTR,same
                        goto RUNEND          ;
if HSCTR not zero go to RUNEND
                        movlw .50
                        movwf HSCTR          ;
if zero - reload with 50 dec
                        movlw 01h
```

```
                              xorwf INDFLG,same
;    toggle bit 0 (colon) of INDFLG
                              decfsz TBCTR,same
                              goto RUNEND           ;
if TBCTR is not zero
                              movlw .120
;    reload TBCTR with 2 (change to 120
                              movwf TBCTR           ;
later) if TBCTR=0
                              call INCR
RUNEND                        movlw 09h
                              movwf FSR
;    load address of MINCTR into FSR
;
                              call ALRM
PROG                          call DISPLY
;
                              call KEYBD
;    RETURNS WITH VALUE OF KEY IN W
                              xorwf LKP,same
;    compare returned value
                              btfss STATUS,2
;    with Last Key Pressed register
                              goto NTSAME           ;
not the same
                              movwf LKP
;    same - place W into LKP
;
                              movf LKP,same
;    check if LKP = 0 ie. no key  pressed
                              btfss STATUS,2
                              goto KEY
;    key pressed
                              bcf FLAG,0
;    no key pressed - clear key actioned flag
                              goto BEGIN
;
KEY                           btfsc FLAG,0
;    has key already been actioned?

                              goto BEGIN
;    flag,0 set - yes
                              bsf FLAG,0
;    no - set flag,0 and action
;
                              btfsc LKP,0
                              goto S1
;    S1 pressed
                              btfsc FLAG,1
;    is alarm on?
                              goto BEGIN
;    yes - no other keys valid
                              btfsc LKP,1
;    no - test other keys
                              goto S2
;    S2 pressed
                              btfsc LKP,2
                              goto S3
;    S3 pressed
;
                              movf MDREG,same
                              btfsc STATUS,2
;    MDREG=0? ie RUN mode
                              goto BEGIN
;    yes - do not set hours/mins
;
                              btfsc LKP,3
;    no
                              goto S4
;    S4 pressed
                              goto S5
;    S5 pressed
;
S1                            btfss FLAG,1
;    SNOOZE - is alarm on?
                              goto BEGIN
;    no - goto BEGIN
                              btfsc FLAG,2
;    yes - is snooze flag clear?
                              goto BEGIN
;    no - snooze already operated
                              bsf FLAG,2
;    yes - set snooze flag
                              movlw .10
                              addwf TMTMR           ;
add 10 to alarm timer
                              goto BEGIN
;
S2                            movlw 04h
;    ALARM ON/OFF
                              xorwf INDFLG,same
;    toggle alarm indicator
                              goto BEGIN
;
S3                            incf MDREG,same
;    MODE SELECT
                              movlw 03h
                              xorwf MDREG,w
                              btfsc STATUS,2
;    MDREG=3?
                              clrf MDREG
;    yes - clear MDREG
                              goto MODE
;
S4                            call INCRH
;    SET HOURS
                              goto BEGIN
;
S5                            call INCRM
;    SET MINS
                              goto BEGIN
;
NTSAME                        movwf LKP
;    store new value in LKP
                              goto BEGIN
;
;*************************************************
*************************************
;
                              ORG 1FFh
;
                              END
```

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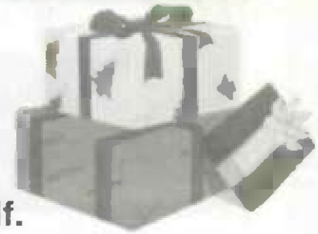

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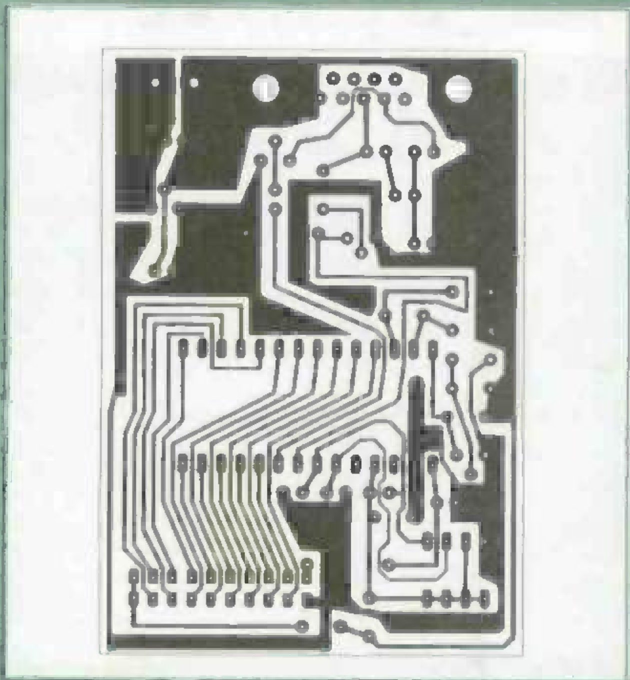

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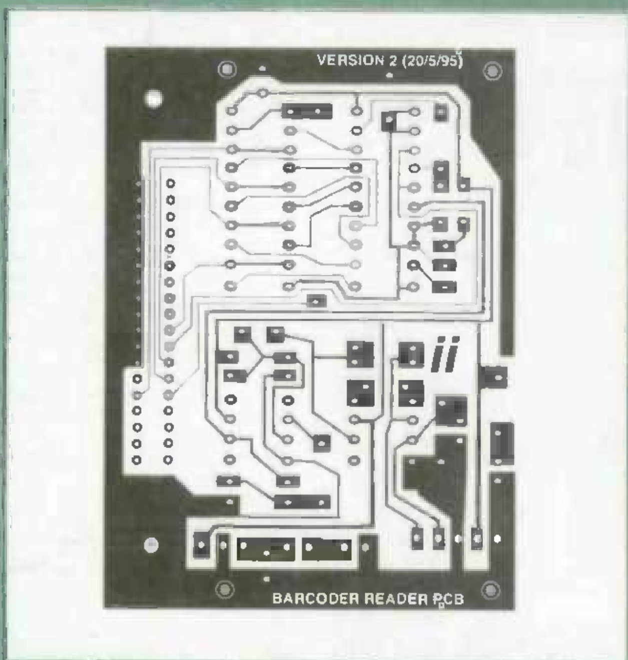

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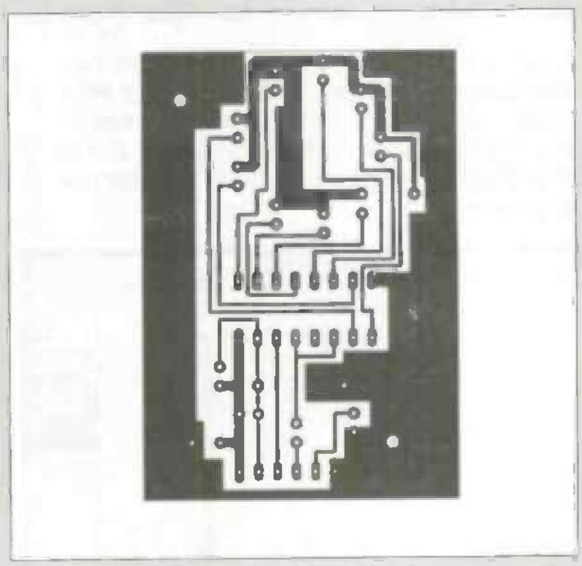

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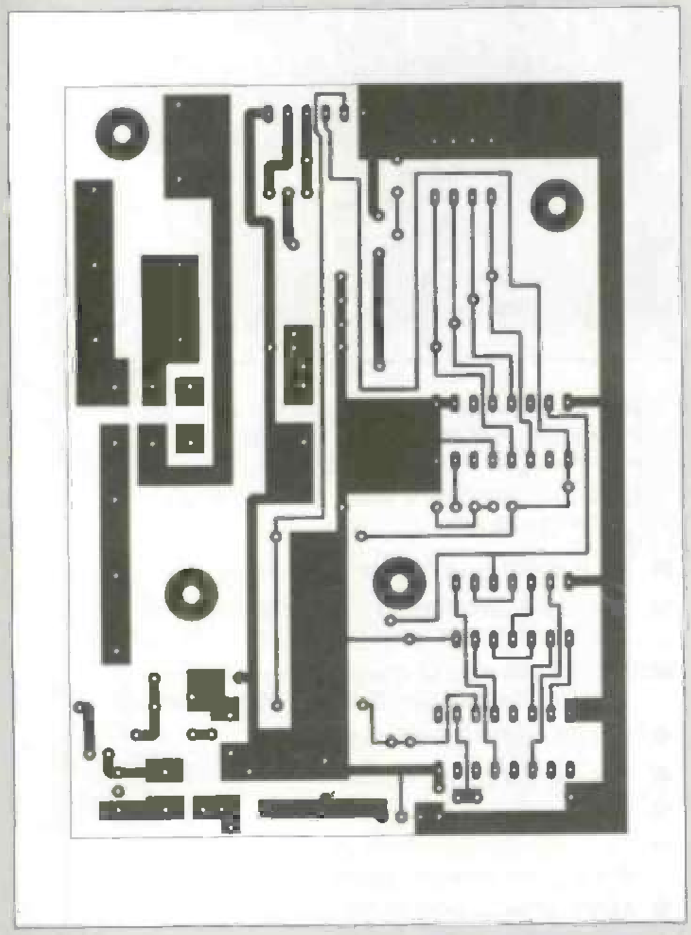

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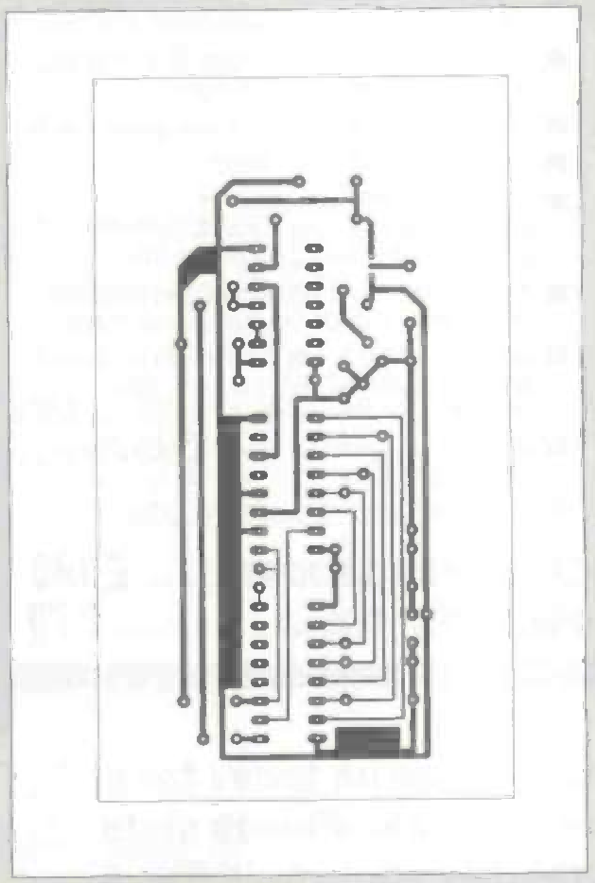

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APOLOGY by R Grodzik to NJD Limited

In the June edition of Electronics Today International" I contributed an article (beginning on page 46) entitled "4-channel touch-switch interface."

The source for the circuit described in this article was in fact a circuit which was developed and manufactured by NJD Limited of 10 Ascot Industrial Estate, Sandiacre, Nottingham, NG10 5JD, United Kingdom. (Manufacturers of professional Lighting and Lighting Control Equipment). NJD Limited manufacture and use such circuits in their products, notably the LOGIC T12, TS10R and LOGIC S12, all touch sensitive switch panels and the "SAVER" touch sensitive panel for the handicapped.

I would like to apologise to NJD Limited completely and unreservedly for any misleading impression which I may have given to the effect that the circuit was developed by me as indeed this was not the case and acknowledge the copyright held by NJD Limited on their designs of this and any of their other circuits.

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Round up

Nick Hampshire takes a look at the technology of tomorrow

Three-dimensional imaging systems have been a constant theme in science fiction films - images hovering in the air in front of the actors as if the subjects of the image were really there. As is very often the case, science fiction has a habit of becoming fact and, in this instance, for the last couple of months, shoppers in New York's Union Square have been astounded to see completely life-like images of products floating above the pavement in front of Bradlees, a well known department store.

The technology which produces these three-dimensional floating images is causing considerable excitement in the advertising and entertainment industries. It was invented by Dimensional Media Associates of the US and is now being further developed in conjunction with CRL of Hayes in Middlesex, the former research division of Thorn EMI.

Surprisingly, the technology is not based on holography but on a complex system of polarisers, lenses and filters which build up the image, focused in free space, from multiple image sources. The technique is capable of generating true three-dimensional volumetric displays that look almost solid.

The big advantage it has over holographic systems lies in the fact that for the first time it is possible to generate full motion, high resolution images which can not only be seen by viewers without the aid of special glasses but can also be generated virtually in real time.

It is understood that advertising companies are queuing up to buy systems as soon as they become commercially available. In the meantime the world's second demonstration system is being installed in London and should be projecting three-dimensional images outside the Knightsbridge store of Emporio Armani in time for Christmas.

There has been quite a lot of work done on 3-D imaging systems, primarily using holography or flexing/rotating mirrors. Much of this work has been funded by the US Dept of Defence whose main interest it seems is the construction of battlefield display systems which will show the exact location of aircraft, both friend and foe, within the battle zone. However, virtual reality systems seem to have put some of this work onto the back burner.

The development of 3-D imaging systems has also attracted the interest of civilian air traffic controllers for whom it would offer an excellent way of looking at, and control of, aircraft movements. But judging by recent announcements from America's Federal Aviation Authority, the whole concept of air traffic control is about to change, thanks to another bit of military technology - the satellite-based global positioning system (GPS).

It is being proposed that all aircraft are fitted with GPS systems which can accurately determine the aircraft's position and height to within a few metres. This data would then be relayed by satellite to a system of ground-based computers that would maintain a safety zone around each aircraft and automatically order a shift in course if the safety zones of two aircraft overlapped.

This essentially means the end of the human air traffic controller, but because there is no longer any need to stick to predefined air corridors it should be possible to increase considerably the number of aircraft in the air at any one time and theoretically improve punctuality with flights being up to 20% shorter.

In Britain, the CAA are also examining this so-called 'free flight' technology but, understandably, severe reservations are being expressed by both existing air traffic controllers and by many pilots. The pilots are particularly concerned about how failsafe the system actually is, a legitimate concern since there will be no human backup.

Next Month...

In the January 1996 issue of Electronics Today International we will be continuing our premier autumn project, the ETI Basic programmable micro controller.

Dr Pei An shows how to build a heartbeat monitor and, from Terry Balbirnie, there is an electronic guard dog project which will bark at any unwelcome visitors. Meanwhile, if you blow a fuse and are plunged into the dark Bob Noye's torch pad will allow you to find the torch that will help you mend the fuse. There is a 16-channel MIDI-controlled audio mixer project from Tom Scarff and Bart Trepak concludes his practical look at designing a project around the PIC micro controller.

The main feature article will be looking at the Ulysses solar mission and we will also be reviewing some more PC software of interest to readers.

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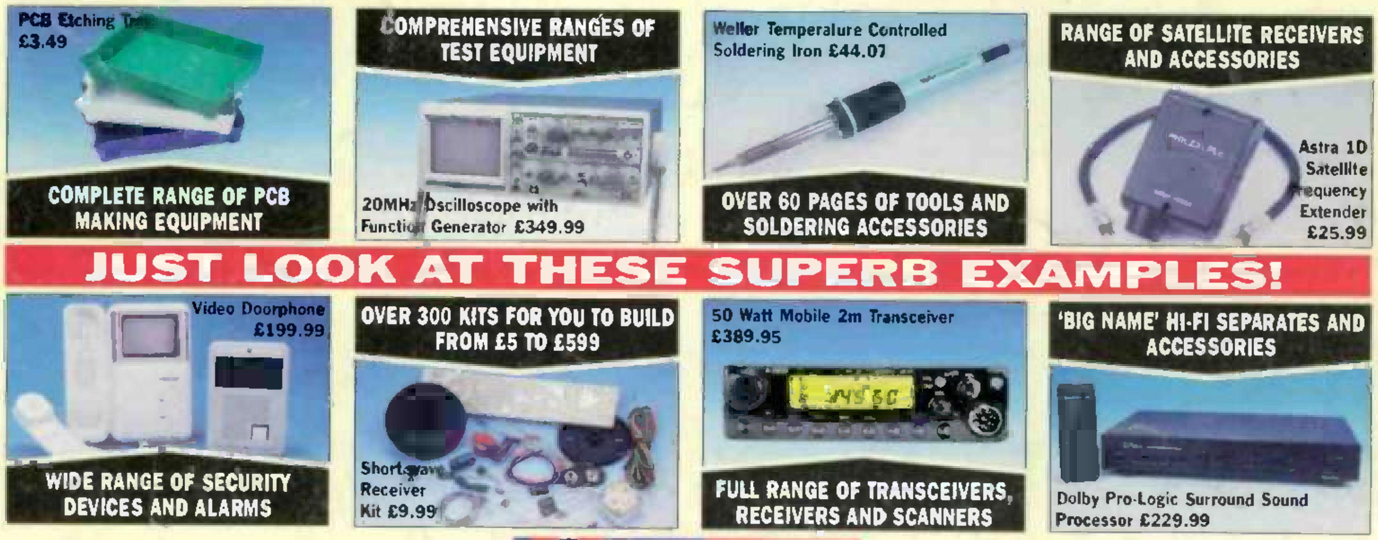

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