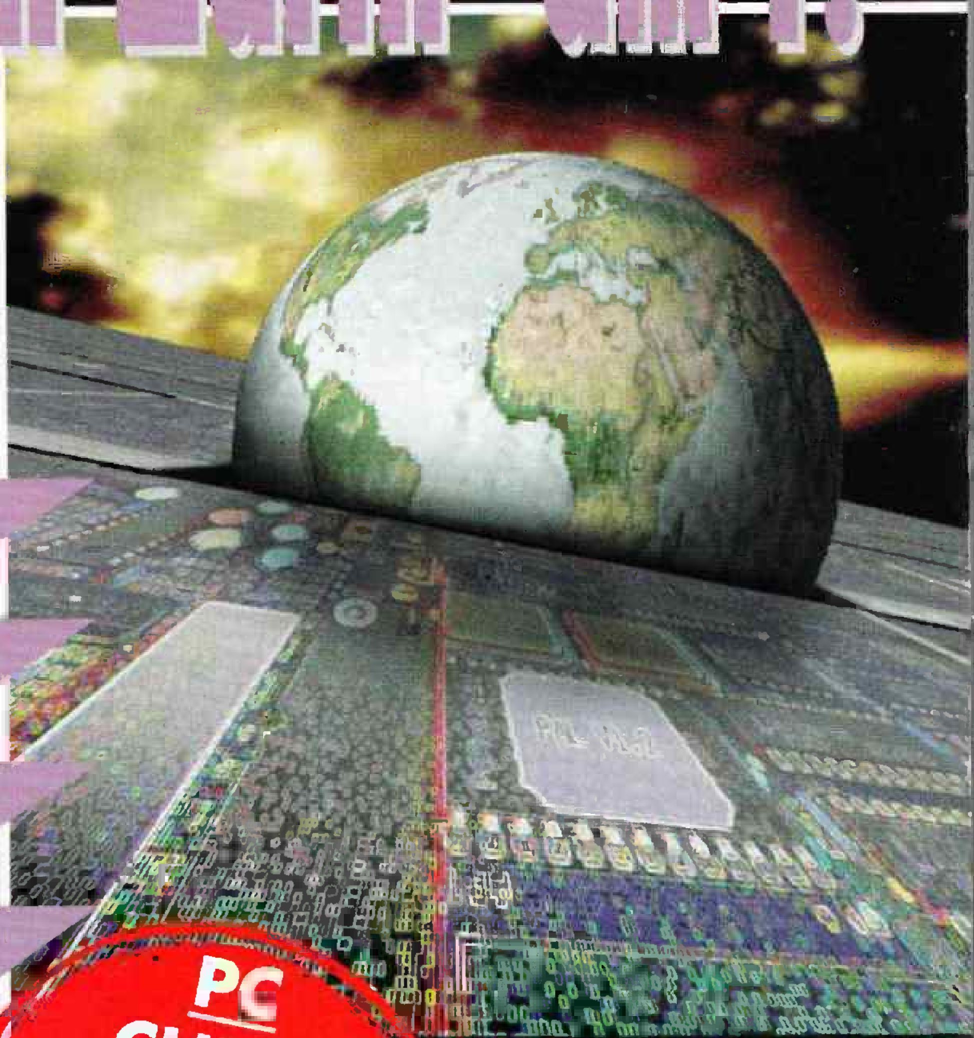
ETI
ELECTRONICS TODAY INTERNATIONAL

TOMORROW'S TECHNOLOGY TODAY

6 SUPER PROJECTS FOR YOU TO BUILD

Where on Earth am I?

A LOOK AT HOW GLOBAL POSITIONING SYSTEMS CAN PLACE YOU WITHIN METRES



Microprocessor Motor Control

Build a car lights-on reminder

Turbo speed Indicator for PC

Make a video light meter

Measure minute changes in the earth's magnetic field

PC CLINIC
PROCESSORS
CO-PROCESSORS
AND CACHE
MEMORY

August 1994 £2.15

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9 770142 722054

ARGUS SPECIALIST PUBLICATIONS asp

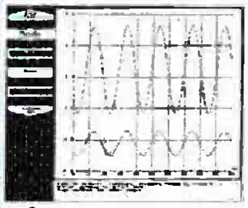
Low cost data acquisition for IBM PCs & compatibles

A unique range of easy to use data acquisition products designed for use with IBM compatible computers. Combined with the software they allow your PC to be used as a host of useful test and measurement instruments, or as an advanced data logger.

Installed in seconds they simply plug into the parallel port (except the ADC-16 which connects to the serial port). They are self-contained, require no power supply and take up no expansion slots.

Each device comes with a comprehensive manual. C, Pascal and Basic drivers are included for users who wish to write their own software. Software supplied on 3.5″ disk.

PicoScope

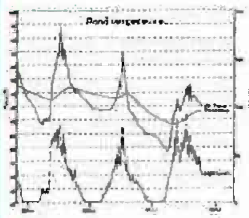


Scope, voltmeter, spectrum analyser

"Virtual instrument" software package. Storage oscilloscope with trigger, timebase, rulers and offset functions. Realtime spectrum analysis with min/max frequency and signal averaging. Multiple meters on screen (digital and bargraph).

Printer and file handling support

PicoLog



Collect, store, display and print data from 1 sample per ms to 1 per day. Record average, min/max values or scaled values (linear, equation, table look up). Report types: monitor (with min/max alarms), y-t graphs, x-y graphs, tabulation.

Advanced data logging software package

NEW *ADC 100* Virtual Instrument

Dual Channel 12-bit resolution

The ADC 100 offers both a high sampling rate (100kHz) and a high resolution. It is ideal as a general purpose test instrument either in the lab or in the field. Flexible input ranges (±200mV to ±20V) allows the unit to connect directly to low output sensors such as microphones or to high level signals (±200V with a x10 scope probe).

ADC 100 **with PicoScope £199**
PicoScope & PicoLog £209

NEW from PICO

- Digital Storage Scope
- Spectrum Analyser
- Voltmeter
- Frequency Meter
- Chart Recorder
- Data Logger

ADC 10

1 Channel 8-bit

- Lowest cost
- Up to 22kHz sampling
- 0-5V input range

The ADC 10 gives your computer a single channel of analogue input. Simply plug into the parallel port and your ready to go.

ADC 10 **with PicoScope £49**
PicoScope and PicoLog £59

ADC 11

11 Channel 10-bit

- Digital output
- Up to 18kHz sampling
- 0-2·5V input range

The ADC 11 provides 11 channels of analogue input in a case slightly larger than a matchbox. It is ideal for portable data logging using a "notebook" computer.

ADC 11 **with PicoScope £85**
PicoScope and PicoLog £95

ADC 12

1 Channel 12-bit

- High resolution
- Up to 17kHz sampling
- 0-5V input range

The ADC 12 is similar to the ADC 10 but offers an improved 12-bit (1 part in 4096) resolution compared to the ADC 10's 8-bit (1 part in 256).

ADC 12 **with PicoScope £85**
PicoScope and PicoLog £95

ADC 16

8 Channel 16-bit + sign

- Highest resolution
- 220Hz sampling
- 2Hz sampling – 16-bit

The ADC 16 has the highest resolution of the range, it is capable of detecting signal changes as small as 40μV. Pairs of input channels can be used differentially to reject noise. Connects to serial port.

ADC 16 **with PicoLog £115**

PicoLog for ADC 10/11/12 £25. Oscilloscope Probes (x1, x10) £10. Carriage UK free. Overseas £6

PICO TECHNOLOGY

VISA

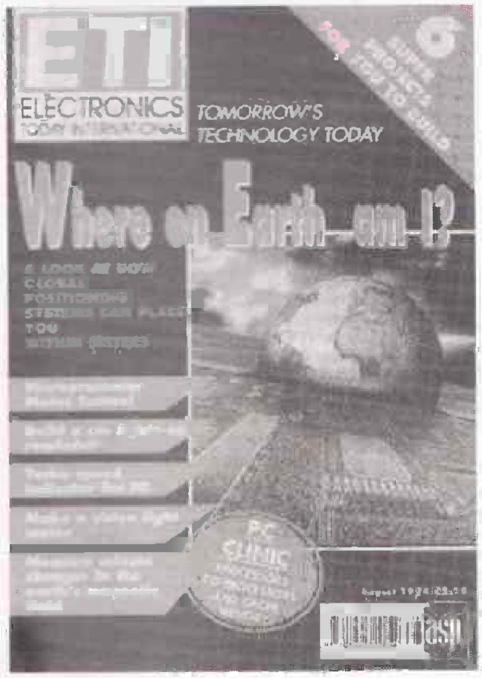
Pico Technology Ltd., Broadway House, 149-151 St Neots Road, Hardwick, Cambridge. CB3 7QJ.

TEL: 0954-211716 FAX: 0954-211880

Access

Phone or FAX for sales, ordering information, data sheets, technical support. All prices exclusive of VAT.

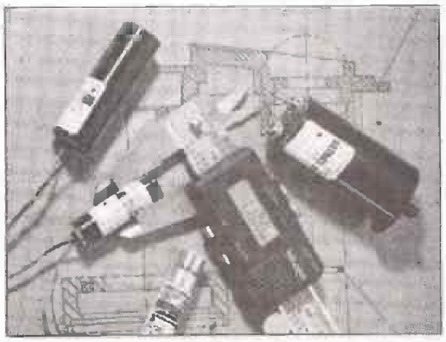
Contents



Volume 23 No.7

Features & Projects

Regulars



Competition

CVC Chelmer Valve Company

for audio valves

Audio valves with famous brand names of yesteryear such as MULLARD, MOV, GEC,RCA etc, are in very limited supply and their scarcity also makes them very expensive.

We at Chelmer Valve Company however provide high quality alternatives to these old makes. We have over 30 years experience in the supply of electronic valves of all types and during this time have established close ties with factories and sources worldwide.

For high fidelity use we further process valves from these souces using our specially developed facilities. After rigorous testing - including noise, hum, microphony, post burn-in selection and matching as needed - we offer this product as CVC PREMIUM valves.

A selection of the more popular types are listed below.

Price list & order form for CVC PREMIUM Audio Valves

	UNIT PRICE	QTY.	TOTAL PRICE
PRE-AMP VALVES			
ECC81/12AT7	5.00		
ECC82/12AU7	4.00		
ECC83/12AX7	5.00		
ECC85	4.00		
ECC88	5.00		
EF86	4.00		
E81CC(GOLD PIN)	6.00		
E82CC " "	6.00		
E83CC " "	6.00		
E88CC " "	7.00		
E80F	9.00		
E83F	5.50		
6SL7GT	4.00		
6SN7GT	4.20		
6922	5.00		
POWER VALVES			
2A3 (4 PIN)	14.00		
2A3 (OCTAL)	14.00		
211	22.00		
300B	50.50		
811A	9.50		
845	29.90		
EL34/6CA7	7.50		
EL84/6BQ5	4.00		
EL84/7189A	5.10		
KT66	9.20		
KT77	12.00		
KT88	12.50		
KT88 (GOLD Q)	18.50		
6L6GC	6.50		
6L6WGC/5881	8.00		
6V6GT	5.00		
6146B	10.20		
6336A	40.00		
6550A	11.00		
6550A-S	13.50		
7581A	11.00		
TOTAL CARRIED FORWARD			

	UNIT PRICE	QTY.	TOTAL PRICE
CARRIED FORWARD			
RECTIFIERS			
GZ32	4.50		
GZ34/5AR4	5.00		
5U4G	5.00		
5Y3GT	3.20		
5Z4GT	3.50		
SOCKETS			
B9A (PCB)	1.60		
B9A (CHASSIS)	1.60		
OCTAL (CHASSIS)	1.75		
4 PIN (UX4)	3.00		
4 PIN (FOR 211 + 845)	11.00		
MATCHING CHARGES*			
POST & PACKING (UK)			3.00
TOTAL EXC. VAT			
VAT @17 1/2% (UK & EEC)			
TOTAL TO PAY			£

***MATCHING, if required; state valve types & if PAIRS, QUADS or QCTETS - Allow £1.00 per valve for this service.**

Make CHEQUES payable to 'CHELMER VALVE COMPANY or pay by ACCESS/MASTER CARD/VISA, give details:

Signature .... Expiry ....

Name ....

Address ....

....

....

.... Post Code ....

Valve amplifiers sound better still with CVC PREMIUM valves!

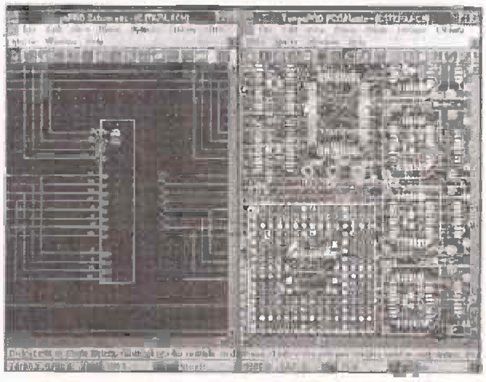
130 New London Road, Chelmsford, Essex CM2 0RG, England. Telephone 0245 355296/265865 or FAX. 0245 490064

ETI News...

PCB software for Windows

Pentica Systems of Wokingham has launched a new entry level version of its powerful Tango circuit design and board layout software, which runs under Windows and offers users work-station class performance at one fifth of the cost. TangoPRO Schematics Lite and TangoPRO PCB Lite are both sub-sets of the higher end TangoPRO software, with the benefit of the Windows environment. Their capacity and features are suitable for 80% of PCB designs being produced today.

TangoPRO Schematic Lite offers powerful placement and editing tools, keyboard short-cuts and instantaneous netlist generation. There are over 20,000 unique library components and new components can be created on the fly. Advanced features include intelligent wires and busses and support for user defined attributes. Junctions and bus entries are placed automatically. Capacity is up to 200 components, 500 nets and three sheets per design.

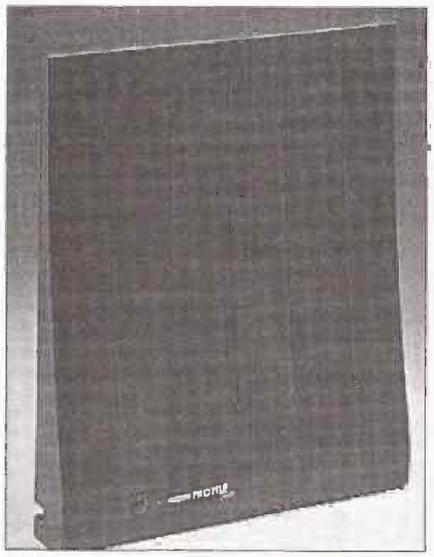


The PCB design program includes a Cut/Copy/Paste capability for moving selected items to and from the Windows Clipboard, design error indicators with on-screen highlighting, enhanced report formats and improved attribute editing, with the ability to change reference designators on previously placed components. The 32 bit database gives imperial and metric support down to a tenth mil, or 10 microns. Capacity is for 200 components, 500 nets, and six layer designs.

TangoPRO Lite Schematics costs £175 and the PCB design program £685. For further details on these two products contact Pentica Systems on 0734 792101.

70W Titanium Composite Tweeter

The latest product to be added to the fully comprehensive range of speakers and sounders from Maplin Electronics is the 70W Titanium Composite Tweeter. This is a dome tweeter, where the diaphragm is made from pure titanium which is ion deposited onto an advanced, glass-fibre reinforced, soft polymer 1in diaphragm. The composite that results offers increased stiffness with high internal damping, combining the advantages of pure metal domes while retaining the low distortion of soft dome, leading to detailed sound reproduction for the best musical quality. Efficiency is up to 93dB and the voice coil is ferrofluid cooled. The Faceplate is of a fibre reinforced polymer.



This tweeter is available from all branches of Maplin Electronics and costs £13.95. For more details ring 0702 552911.

Ultra bright laser diode modules

Imatronic, the leading semiconductor laser diode module manufacturer, has released a new addition to its world beating range of OEM laser diode modules - a 633nm wavelength option. The new wavelength optios are available in the popular LDM115 (11mm diameter) and the LDM145 (16mm diameter) package styles. The 633nm wavelength offers 9 times improvement in visibility over the 670nm versions available to date. This improvement in visibility makes both indoor and outdoor operations such as alignment, positioning and levelling far simpler and effective. Particular applications include machine tool alignment, target sighting, patient positioning, robotic control and bar code systems. These highly reliable modules have been specifically designed to make the user's life easy. They feature simple DC operation (4-6V DC) and low current consumption of around 80mA. The focusing optics can be adjusted by the user with a simple tool provided with each module, so that the focus of the laser can be optimised for his own application. The integrated output power stabilisation circuitry regulates the laser output to be always

PC based PLD trainer

Programmable Logic Devices (PLDs) are now very widely used and there is a considerable need for systems which can be used to train students and engineers in their use. To cater for this need, Southampton based Flight Electronics International has launched a menu driven PC based PLD training system, the PAL Trainer. It is aimed at universities and colleges, although engineers working on their own could also use it to learn quickly about PALs and PALASMs, eventually using it as a laboratory tool for PAL programming.

Flight Electronics claims that it is the only completely self contained system available which successfully introduces students to the world of PLDs, without the need to source the hardware, software and documentation separately. This not only saves time, resources and money, but also ensures that lecturers are provided with an integrated teaching tool that gives students more than just a cursory glimpse of the real world of industry.

The PAL Trainer will run on IBM XT, AT, or compatible PCs and consists of a complete training course ranging from initial logic design to PC simulation, device programming and testing, there are 18 ready to run examples. Programming of actual devices is done with the aid of a GAL programmer and test unit which is connected to the PC via an interface card and cable. The programmer is controlled by software running on the PC. Programming is performed with the aid of the widely used industry standard PALASM V4 programming language.

The programmer/test unit has one ZIF 24-way textool for programming and three ZIF 24-way textools for testing, there is a matrix display, four 7 segment displays, a LED array, ten debounced switches and a variable frequency counter. There is a separate demonstration area for use with the worked examples and jumper wires allow the pins of the PLD to be quickly and simply connected to other areas of the main board.

The full training system costs £695 and for further details contact Flight Electronics International Ltd, on 0703 227721.

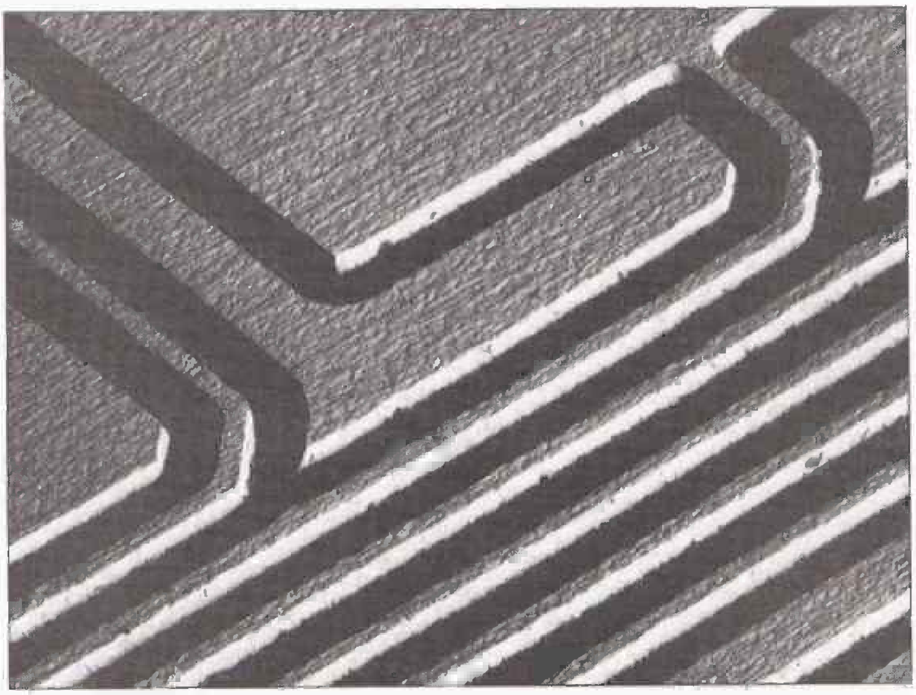
Cutting PCBs by laser

The Berkshire based company Tracks CAD Systems has launched a multifunction laser prototyping machine which is aimed at anyone who involved in the development or production of high density Printed Circuit boards, in particular those used with surface mounted devices. Modern PCBs call for closely spaced pins and conductor or isolation paths, three or more times finer than those that have been traditionally produced using chemical etching or mechanical cutting. With its laser system, Tracks has been able to easily cut seven conductor paths, separated by 40µm isolation channels between two IC pads, the laser having a cutting resolution of 1µm and an accuracy of 2µm.

This laser system will cut standard FR4 PCB materials or copper coated ceramic material with equal facility and all track edges will be clean and square to a degree impossible to achieve in any other way. The laser will not wear, so maintenance is simple and repeatable quality assured. In addition, the system does away with the need to treat large quantities of highly polluting aqueous chemical solutions.

The system can be installed in any normal laboratory or production area and, apart from power, compressed air and water has no special requirements. A floating focus system is used on the laser, to eliminate risk of optical hazard. The system can be directly driven from a PC CAD system for flexible prototyping. With more powerful laser cutters, it can be used to cut metal stencils, cut and score ceramics, make board corrections and label products.

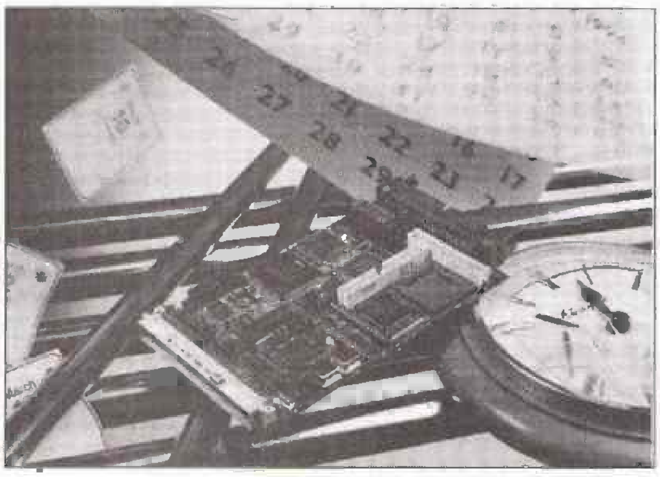
For more information, contact Tracks CAD Systems on 0344 55046



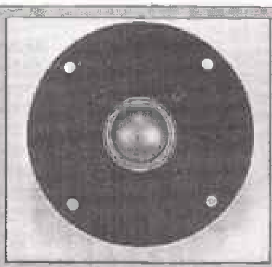
386 system on an STEbus board.

Arcom Control Systems has developed a powerful new 386SX single board computer for embedded control applications, which fits on a single standard STEbus board. Compatible with PC based development and debug tools and offering a DOS like, but royalty free, stand alone operating environment, it delivers far superior real time performance to conventional embedded PCs. Called the SCIM386T, the board provides a complete hardware solution for many embedded tasks, but is also highly configurable, offering a choice of three expansion routes - STEbus, SCIM mezzanine bus and signal conditioning system.

The board is available with 25 or 16MHz versions of the 386SX CPU. Eight surface mount memory sites allow up to 4MB of dynamic RAM to be fitted. This can be extended to 16MB, using the SCIM mezzanine bus expansion facility. Further hardware includes a 32 pin EPROM socket for the stand alone operating environment and application firmware, keyboard interface, real time clock, a parallel port and two serial ports.



For more information, contact Arcom Control Systems Ltd of Cambridge on 0223 411200.



Profile Plus Indoor FM Aerial.

New from Maplin Electronics is the profile Plus Indoor FM Aerial. This unit is a unique innovative design of an indoor aerial that would pass any critical eye test for modern styling. This bi-directional aerial is suitable for all FM applications in the frequency range 88 to 108MHz. It includes an integrated low noise signal amplifier/booster, for weak signal areas.

The aerial measures 320 x 220 x 50mm and is coloured slate grey. It requires two AA batteries and is supplied with a flylead 2m long. It costs £19.95 and is available from all branches of Maplin Electronics or via mail order. For further details ring 0702 552911.

Negative differential resistance

Negative differential resistance (NDR), a novel transistor effect that occurs in compound semiconductors, is being exploited by advanced device researchers in a bid to build a new, highly compact, digital logic family. NDR logic cuts through much of the complexity of traditional gate design, by exploiting the folded current-voltage (I-V) curves of advanced super lattice transistors. While standard transistors have only one operating point, a variety of experimental devices built with super lattice junctions can have two or more stable points, which are used to implement several logic functions with the same circuit.

While the new approach to digital logic offers the usual advantage of speed that comes with hetero-junction transistors, it more importantly could form the basis for a new kind of Ultra Large Scale Integration (ULSI) technology. In the past, gallium arsenide technology was used for its speed advantage, but that proved to be a critical factor only in niche areas, such as microwave technology. The new generation of NDR logic designs indicates a new direction for compound semiconductors, augmenting the speed advantage with large gains in functional density.

As the voltage across the junction increases, the resulting current begins to increase in a manner similar to a conventional p-n diode. However, at a critical point, the resonant tunnelling effect kicks in and the current begins to decrease as the voltage increases. The negative slope of the I-V curve in this region represents the unique negative differential resistance of these diodes, the basic effect that is now being tried in novel logic families.

At Texas Instruments Central Research Labs. (Dallas), TI researchers were the first to build a three-terminal resonant tunnelling device that directly modulated the potential inside the super lattice junction. Previous devices had simply been monolithic realisations of the RT diode HBT pair.

The University of Michigan group is attempting to push the technology to the next stage by developing a comprehensive set of design principles and simulation tools. Rather than focusing on specific devices, the group is learning general rules for controlling the NDR effect in logic design. A device simulator that solves the quantum mechanical equations that govern resonant tunnelling effects has allowed the researchers to explore design aspects of the NDR devices. The group has also built a circuit simulator that takes either data generated by the device simulator or actual experimental data to simulate NDR logic designs.

In addition, different digital logic styles, making use of the more complex behaviour of NDR transistors, have been developed. In conventional circuit design, logic 0 and 1 values are represented by 0 and +5V levels. The I-V characteristics of the NDR devices allows for multiple logic values via multiple stable operating points. The University of Michigan group is using a logic representation that exploits two stable points in the I-V characteristic to represent Boolean logic, with two positive voltage levels

Big successes for ARM RISC

The UK RISC processor company Advanced RISC Machines Ltd seems to be on to a winner. This company, jointly owned by Acorn Computers, Apple and VLSI, has just announced two significant developments. Firstly it has signed an agreement which will allow Korean electronics and semiconductor giant Samsung to embed ARM6, ARM7, and ARM610 RISC technology into products jointly developed by Samsung and ARM for the emerging markets, where computing, communications, and consumer electronics converge. These will include wireless personal digital assistants, cellular fax/phones and interactive TV, plus more traditional products such as hard disk drives, laser printers and multimedia processors.

The second development is the announcement by IBM that the ARM RISC technology is to form the heart of its new Serial Storage Architecture (SSA) interface. This technology, developed at IBM's UK research facility in Havant, is seen as a key component in linking the computers of the future and will replace existing serial and SCSI interfaces. It is an extremely powerful interfacing system capable of full duplex operation at a minimum 20MB/s in each direction, with sophisticated error detection, isolation and recovery features. SSA is destined to be a standard for communications with peripherals such as disk drives.

Low cost microcontroller development kit

Mitsubishi has introduced a new low cost Designer's Kit which will enable users to cost effectively develop 16 bit microcontroller applications. The easy to use kit comes as a complete system and is simply installed on a PC with a text editor. At the heart of the kit is a DB16 designer board which incorporates an M37702S1ASP chip that is representative of the Mitsubishi 16 bit range and boasts the widest range of features available in single chip microcontrollers.

The on-board device operates in microprocessor mode and together with an M5M82C55 I/O expanded mapped in page zero, preserves the I/O operations by replacing the ports used as data and address buses. Ample space is provided for user software by 64KB each of battery backed RAM and EPROM. A decoder chip select is also included. Other on-board features include 52 I/O lines, together with eight 8 bit analogue to digital inputs. There are two serial ports with RS232 drivers, eight 16 bit multifunction timers and a watchdog timer, three external and 16 internal interrupts.

The software provided with the kit is a relocatable assembler which allows software to be written in pure Assembly language with user defined macro functions. Example programs in source code format can be used as templates, including those of the on board Debug monitor. This monitor includes facilities to examine and set processor registers and memory contents, upload programs from host to RAM, go to program from an address, set break point in RAM, fill memory and read analogue port. Drivers are also provided for serial and analogue to digital ports.

The designers kit operates from 5V supplies and comes complete with serial cable and 9 to 25 way adaptor, comprehensive documentation, software and the development board. The kit costs £299 and for details of suppliers contact Mitsubishi in Hatfield, Herts., on 0707 276100.

Event Diary.

27-29 June	5th Satellite Systems for Mobile Communications & Navigation Conference, Institute of Electrical Engineers. London. Tel: 071 240 1871
4-7 July	HF Radio Systems and Techniques Conference, Institute of Electrical Engineers, University of York. Tel: 071 240 1871
5 July	Talk on propagation. Sudbury and District Radio Amateurs. Tel: 0787 313212.
14 July	Special Event Station in Woodhall School, Sudbury and District Radio Amateurs. Tel: 0787 313212
16 July	Annual Outing. Crystal Palace and District Radio Club, All Saints Parish Church Rooms, Beulah Hill. Tel: 081 699 5732.
19-21 July	6th Electronic Engineering in Oceanography Conference, Institute of Electrical Engineers. Churchill College Cambridge. Tel: 071 240 1871
20-24 July	Electrotech 94. National Exhibition Centre, Birmingham. Tel: 071 240 1871.
13 Nov.	Midland Amateur Radio Society rally at Stockland Green Leisure Centre, Slade Road, Erdington, Birmingham. Doors open at 10am, admission £1. For further details ring 021 422 9787 or 021 443 1189 (evenings only).

If you are organising an event which you would like to have included in this section, please send full details to ETI, Argus House, Boundary Way, Hemel Hempstead, Herts. HP2 7ST, clearly marking your envelope Event Diary.

SEALED LEAD ACID Battery, 6v 80/100 AH made for BT, ex equipment but ok £45 each ref APR47. Ideal electric vehicle etc.
ASTEC SWITCHED MODE PSU Gives +5 @ 3.75A, +12@1.5A, -12@.4A. 230/110, cased, BM41012. £9.99 ref APR10P3.
TORRODIAL TX 30-0-30 480VA, Perfect for Mosfet amplifiers etc. 120mm dia 55mm thick. £18.99 ref APR19.
MOD WIRE Perfect for repairing PCB's, wire wrap etc. Thin insulated wire on 500m reels. Our price just £9.99 ref APR10P8.
12v MOVING LIGHT Controller. Made by Hella, 6 channels rated at 90watts each. Speed control, cased. £34.99 ref APR35.
ELACTRON FLASH TUBE As used in police car flashing lights etc, full spec supplied, 60-100 flashes a min. £9.99 ref APR10P5.
24v 96WATT Cased power supply. New. £13.99 ref APR14.
STETHOSCOPE Fully functioning stethoscope, ideal for listening to hearts, pipes, motors etc. £6 ref MAR6P6.
OUTDOOR SOLAR PATH LIGHT Captures sunlight during the day and automatically switches on a built in lamp at dusk. Complete with sealed lead acid battery etc.£19.99 ref MAR20P1.
ALARM VERSION Of above unit comes with built in alarm and pir to deter intruders. £24.99 ref MAR25P4.
CLOCKMAKER KIT Hours of fun making your own clock, complete instructions and everything you need £7.99 ref MAR8P2.
CARETAKER VOLUMETRIC Alarm, will cover the whole of the ground floor against forcred entry. Includes mains power supply and integral battery backup. Powerful internal sounder, will take external bell if req'd. Retail £150+, ours? £49.99 ref MAR50P1.
TELEPHONE CABLE White 6 core 100m reel complete with a pack of 100 clips. Ideal 'phone extns etc. £7.99 ref MAR8P3.
VIEWDATA RETURNS £6 made by Tandata, includes 1200.75 modem, k/bd, RGB and comp o/p, printer port. No PSU £6 MAG6P7.
IBM PC CASE AND PSU Ideal base for building your own PC. Ex equipment but OK. £14.00 each **REF: MAG14P2**
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
SOLID STATE RELAYS Will switch 25A mains. Input 3.5-26v DC 57x43x21mm with terminal screws £3.99 REF MAG4P10
300DPI A4 DTP MONITOR Brand new, TTL/ECL inputs, 15" landscape, 1200x1664 pixel complete with circuit diag to help you interface with your projects. JUST £24.99 REF MAG25P1
ULTRAMINI BUG MIC 6mmx3.5mm made by AKG,.5-12v electret condenser. Cost£12 ea, Our? four for£9.99 REF MAG10P2
RGB/CGA/EGA/TTL COLOUR MONITORS 12" in good condition. Back anodised metal case. £99 each REF MAG99P1
GX4000 GAMES MACHINES returns so ok for spares or repair £9 each (no games). REF MAG9P1
C64 COMPUTERS Returns, so ok for spares etc £9 ref MAG9P2
FUSELAGE LIGHTS 3 foot by 4" panel 1/8" thick with 3 panels that glow green when a voltage is applied. Good for night lights,front panels, signs,disco etc. 50-100v per strip. £25 ref MAG25P2
ANSWER PHONES Returns with 2 faults, we give you the bits for 1 fault, you have to find the other yourself. BT Response 200's £18 ea REF MAG18P1. PSU £5 ref MAG5P12.
SWITCHED MODE PSU ex equip, 60w +5v @5A, -5v@.5A, +12v@2A,-12v@.5A. 120/220v cased 245x88x55mm IEC input socket £6.99 REF MAG7P1
PLUG IN PSU 9V 200mA DC £2.99 each REF MAG3P9
PLUG IN ACORN PSU 19v AC 14w , £2.99 REF MAG3P10
POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9
ACORN ARCHIMEDES PSU +5v @ 4.4A. on/off sw uncased, selectable mains input, 145x100x45mm £7 REF MAG7P2
GEIGER COUNTER KIT Low cost professional twin tube, complete with PCB and components. £29 REF MAG29P1
SINCLAIR C5 13" wheels complete with tube, tyre and cycle style bearing £6 ea REF MAG6P10
AA NICAD PACK encapsulated pack of 8 AA nicad batteries (tagged) ex equip, 55x32x32mm. £3 a pack. REF MAG3P11
13.8V 1.9A psu cased with leads. Just £9.99 REF MAG10P3
360K 5.25 brand new half height floppy drives IBM compatible industry standard. Just £6.99 REF MAG7P3
PPC MODEM CARDS. These are high spec plug in cards made for the Amstrad laptop computers. 2400 baud dial up unit complete with leads. Clearance price is £5 **REF: MAG5P1**
INFRA RED REMOTE CONTROLLERS Originally made for hi spec satellite equipment but perfect for all sorts of remote control projects. Our clearance price is just £2 **REF: MAG2**
TOWERS INTERNATIONAL TRANSISTOR GUIDE. A very useful book for finding equivalent transistors, leadouts, specs etc. £20 **REF: MAG20P1**
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ALL PRICES ARE SUBJECT TO 99p POST AND VAT. Some of our products may be unlicensable for use in the UK (particularly the FM transmitters.)

TOMORROW'S TECHNOLOGY

Where on Earth am I?

A network of US military satellites can now be used to pin point your position in three dimensions, to within just a few metres anywhere on the surface of our planet. We look at how this system works and how it is being used as the basis for a range of new devices that could affect all our lives.

During the Gulf War, the US military and their allies made unprecedented use of high technology to give them a strategic advantage over their Iraqi opponents. This allowed them to attack key targets with enormous precision and minimum risk to their own forces. Remember the news shots of cruise missiles flying low along a main street in Baghdad? Missiles capable of locating and destroying a specific building or installation and so accurate that they could fly into an air conditioning duct on a concrete bunker. There were also SAS teams who were capable of moving across the desert at high speed, under cover of dark, to accurately locate and destroy Iraqi supply columns and SCUD missile launchers.

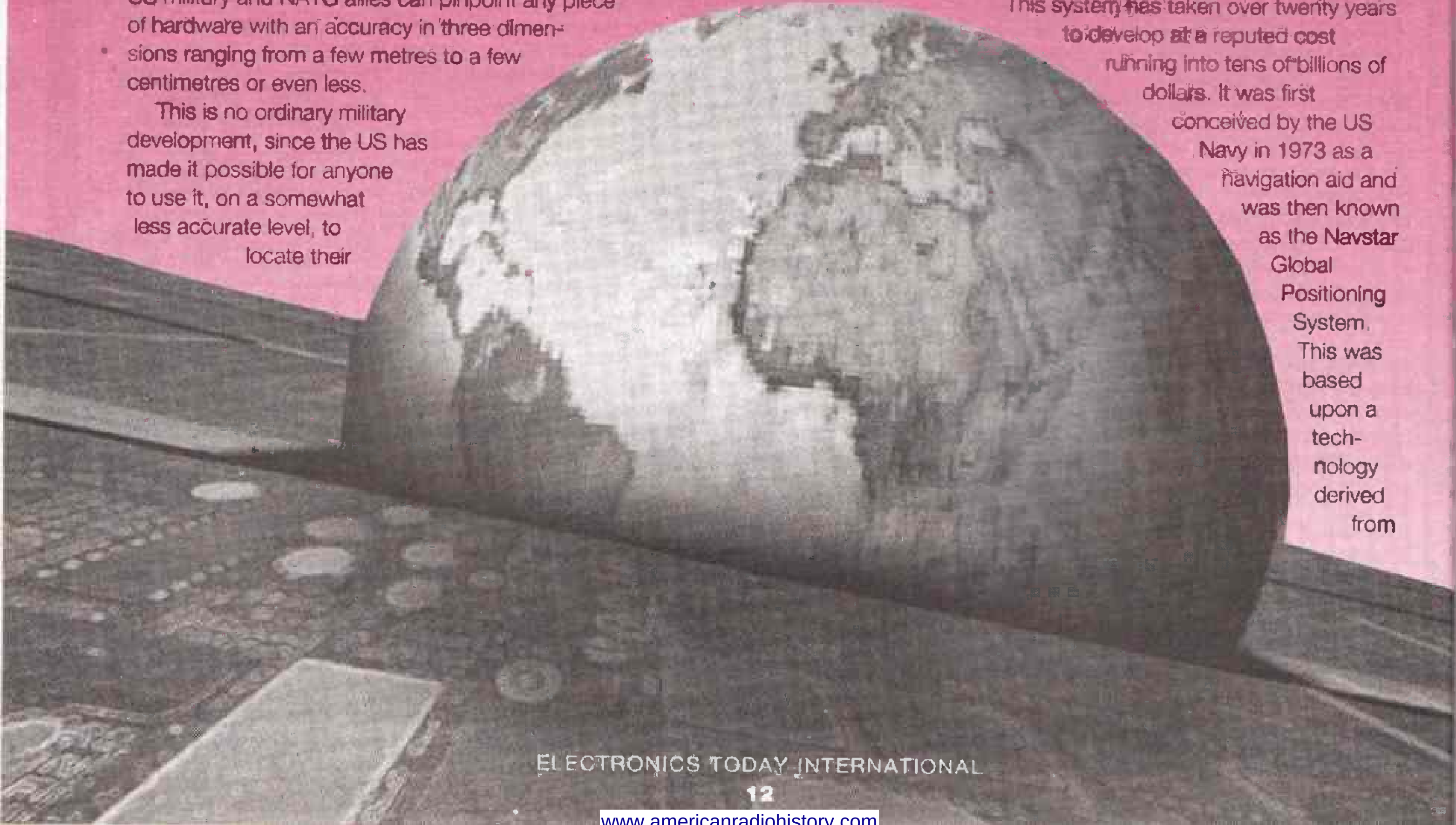
The technology which allowed the allied forces to precisely target missiles, aircraft and troops gave them an enormous edge. It was based on a highly sophisticated network of satellites, orbiting the Earth at a height of 20,200 kilometres, known as GPS, or Global Positioning System. With this system, the US military and NATO allies can pinpoint any piece of hardware with an accuracy in three dimensions ranging from a few metres to a few centimetres or even less.

This is no ordinary military development, since the US has made it possible for anyone to use it, on a somewhat less accurate level, to locate their geographical position or that of some piece of mobile equipment. All over the world, merchant ships, yachtsmen, commercial and private aircraft are now using GPS systems to track their current position. Transport companies are using it to locate their vehicles, emergency services are using it to identify the nearest team to a particular incident, even taxi companies are using it to locate the nearest cab to a customer.

Very soon GPS systems will influence the lives of all of us. The big car companies, for example, are developing techniques which will allow drivers to know exactly where they are on an electronic atlas. Air traffic control systems are being developed which will utilise GPS to allow increasing numbers of aircraft to fly on busy routes. GPS systems are so accurate that they are even being used to measure and survey new buildings, roads and bridges, to remotely check for dangerous distortions in dams and earth movement in earthquake zones.

The development of GPS

This system has taken over twenty years to develop at a reputed cost running into tens of billions of dollars. It was first conceived by the US Navy in 1973 as a navigation aid and was then known as the Navstar Global Positioning System. This was based upon a technology derived from



earlier, land based, radio beam navigation systems, such as the well known Loran in America and the Decca in Europe. These had been developed during and after World War II for maritime navigation purposes.

The designated function of Navstar GPS was, like Loran and Decca, to provide an accurate all weather naval navigation system. However, this function was broadened as a result of its being merged with the US Air Force 612B programme, to provide highly accurate three dimensional positioning which could be used not just by naval vessels, but also by aircraft and for the new generation of smart missiles.

The GPS concept was the subject of an enormous amount of very careful design work, both from the practical aspect and from the strategic aspect. The system had to be capable of very high accuracy, but also had to be proof against jamming by an enemy. The result of this design work was the launch of a test satellite in June 1977.

The first test system was sufficiently successful to persuade the Pentagon to go ahead with launching a network of GPS satellites. The first of these were launched from the USAF's rocket launch facility at Vandenburg Air Force Base in California, in 1978 and a limited two dimensional positioning system was first possible in October of that year. Three dimensional positioning was demonstrated two months later.

This early system relied on just a small number of satellites and thus provided only a few hours of operation each day. To give a 24 hour global, high accuracy, three dimensional positioning capability required the launch of a lot more satellites, so that at any time at least one and preferably more satellites were above the horizon at any position on Earth. These have been launched over the years, using the space shuttle or Delta rockets.

At the moment, the GPS satellites system can provide full two dimensional high accuracy positioning, 24 hours a day, anywhere on the surface of the Earth, but it is still only capable of providing about 22 hours per day worth of full, high accuracy, three dimensional positioning, depending of course on latitude and altitude. The network is expected to be completed and fully operational with 24 hour three dimensional positioning capability by mid 1995.

The only real problem which remains is the fact that GPS signals will not penetrate buildings or rock and consequently a GPS receiver can be effectively shielded from the satellites, thus reducing its ability to give an accurate position. This can lead to problems with accurate positioning in built up or mountainous areas. Another source of problems is ionospheric distortion, a signal distortion which can easily account for a positional error of 20 or 30 metres.

The signal shielding problem can, to a degree, be overcome by use of advanced software techniques in the receiver, coupled with an increased number of GPS satellites. The ionospheric distortion problem, on the other hand, is overcome by having the satellite produce two signals at different frequencies. Since the degree of distortion varies with signal frequency, it is thus possible to compare the two signals and compensate for the ionospheric distortion. Again, this is a problem which requires advanced software in the receiver for a satisfactory solution.

The military and civilian modes

The fascinating thing about the US military GPS system is that it is probably the only military system which civilians are allowed to use. Indeed, the US government has guaranteed free access for civilian users until at least the year 2005 and probably longer. However, they are not giving civilian users unlimited access, otherwise they would be handing over the technology to any potential enemy.

The result is that, although a GPS system in stand alone mode has a positional accuracy of about 20 metres, this is degraded to 100 metres in civilian systems. Civilian systems can, however, be used to

How GPS works

The GPS system consists of a network of satellites orbiting Earth at an altitude of 20,200 kilometres twice per siderial day (a siderial day is 23 hours and 56 minutes long). This means that they cover the same track each day, but four minutes earlier. There are six orbiting planes of three satellites at 55 degrees inclination to the horizon.

Each of the eighteen satellites in current operation transmits continuously on the same frequency, the carrier frequency being 1575MHz. The actual signal is transmitted using spread spectrum modulation, which means that the carrier wave is phase inverted by a pseudo-random code running, at 1.023MHz. In order to recover the signal, it is multiplied by a replica of the code used in the satellite. There are two versions of this code the normal civilian version and the secret, highly accurate, military P-code.

Each satellite has its own code which identifies the satellite, its current position and the current time. The code containing this information is 1023 bits long and repeated once every millisecond. Timing has to be very accurate and on each satellite is derived from an atomic clock.

Using this system, the receiver finds the position using two techniques. Firstly, it measures the Doppler shift of the signal that results from the satellite's motion relative to Earth. Secondly, it measures the signal propagation delay between several satellites. The data from these two techniques is combined by the controlling computer with data on the satellite orbits and the exact position of the satellites in those orbits, to generate the receiver's exact position.

Accurate position calculation requires that a lot of factors are taken into account. Thus, corrections need to be made for ionospheric distortions and even the effect of relativity (due to an increase in frequency from the signal interacting with the gravity gradient) has to be taken into account and corrections made to the calculations. GPS systems rely upon an enormous amount of highly sophisticated computation to produce their results, hence their need for powerful processor chips.

achieve much higher accuracy when used in other modes. Thus, a five metre accuracy is possible when used in differential mode with corrections from a reference receiver at a known location. Even greater accuracy, down to a few millimetres, is possible when the system is used with carrier phase tracking.

The primary military and civilian use for GPS systems is in the form of real time, stand alone systems, rather than those involving linkage with other receivers and a considerable amount of post processing. For this reason, it is the stand alone mode which is degraded in the civilian versions.

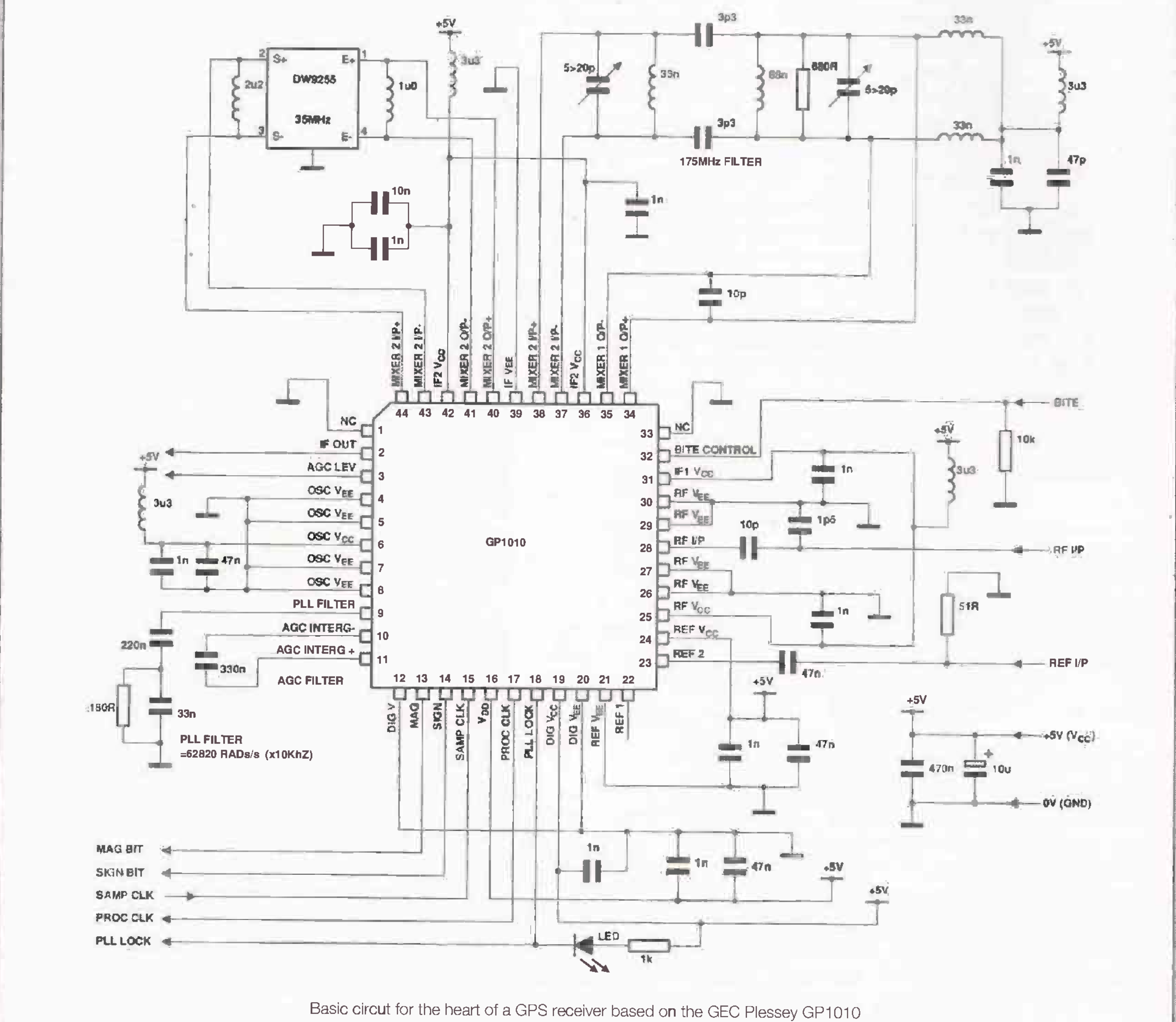
This degradation, known as 'Selective Availability' is achieved by use of a secondary code, the P or 'precise' code, that is transmitted by the satellite along with the conventional positional and time data. This P-code contains the information which allows far greater positional accuracy to be obtained. This P-code can be changed at regular intervals to prevent enemy access and has also been designed so that an enemy can not generate spurious GPS signals and thus deceive the receiver into giving a false location.

Of course, as one would expect, the Russians have an equivalent GPS system known as GLONASS. To date, this Russian system has not been used commercially, but moves are underway to incorporate it into the GPS network with the development of combined GPS/GLONASS receivers. Such combined receivers will have the benefit of a far larger number of satellites and thus be less prone to error.

The commercial application of GPS

A practical GPS system consists of two components, the radio receiver/antenna system and the signal analysis computer. Thanks to the military origin of the system, the radio receiver/antenna system is already available as highly integrated units, indeed GEC Plessey Semiconductors has produced a single chip which contains most of the receiver electronics. Similarly, the analysis computer can be one of the high power microprocessor chips that are now widely available and here the Transputer seems to be a common choice. All this means that the actual hardware for a basic commercial GPS system can now be obtained for just a couple of hundred pounds.

The relative low cost of commercial GPS systems has meant that over the last few years there has been an enormous boom in the sales of sets. As one would expect with a system that was initially conceived as a maritime navigation aid, the first big market to appear for commercial GPS was among professional



Basic circut for the heart of a GPS receiver based on the GEC Plessey GP1010 and amateur boat owners. Boat owners were also the first to benefit from 24 hour GPS coverage, because the wide, uninterrupted horizon at sea allowed position fixing with a network of fewer satellites, while sailors did not need the more complex three dimensional positioning capability of the full GPS system.

There was initially considerable competition from the existing Loran and Decca navigation systems, but as the price of GPS has come down, it has become more popular, particularly in the professional market and with the serious yachtsman. Indeed, one only has to pick up a copy of any on of the yachting magazines to find dozens of adverts for GPS equipment, at prices ranging from three or four hundred to several thousand pounds.

This increasing popularity is due to a combination of factors. Firstly, the decreasing cost and secondly, the integration of GPS systems with electronic charts and course plotting software that will run on personal computers. Amongst certain professional users the very high accuracy of differential and carrier phase tracking GPS systems has been employed with considerable success. For example, oil rigs are now routinely positioned in oil fields such as the North Sea with enormous accuracy, thanks to GPS, in fact so accurately that a production platform can be exactly positioned above the well head left by a drilling rig.

Ferry companies are amongst the other users of GPS systems that require high accuracy. In many busy and confined navigation channels, such as the Channel and large navigable rivers like the Mississippi or the Rhine, GPS systems can be used to accurately keep a vessel in navigable channels and also in the correct channel to avoid collisions with vessels going in the opposite direction.

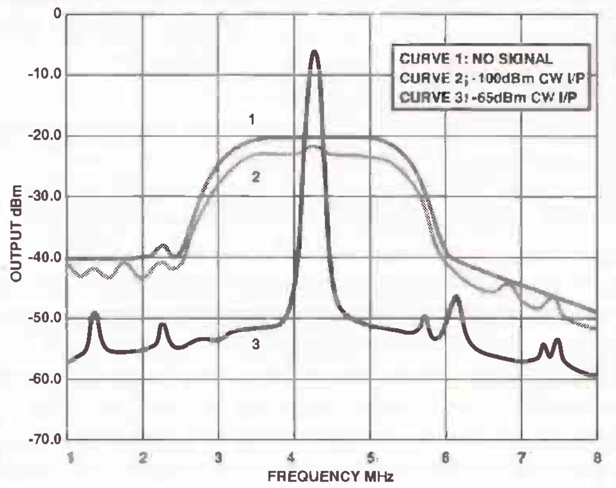
The maritime emergency services have also started to make considerable use of GPS. Here, the International Maritime Organisation was one of the first to realise that search and rescue operations could be made much more effective if a GPS system was used to give an accurate position of a vessel in distress. It is now an IMO requirement that all commercial vessels carry a GPS receiver, which means that search and rescue craft can be sent directly to a site and locate it using their own GPS receivers.

Private and commercial pilots were also quick to realise the potential of GPS as an additional aid to navigation. For years they had been relying upon a network of VHF radio beacons to provide accurate fixes, while commercial jets also had an Inertial Navigation System, or INS, for navigation across oceans. Pilots used a combination of these two position location systems, with radar, altimeters and of course voice links with air traffic control, to provide accurate navigation.

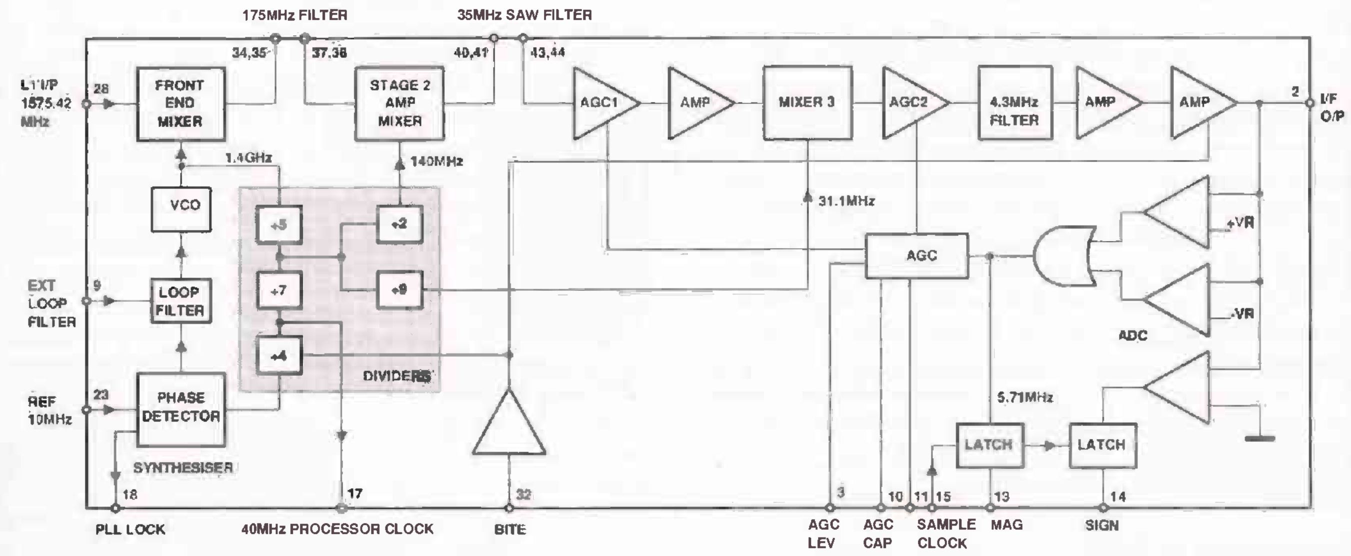
GPS on a chip

For anyone interested in experimenting with GPS systems, GEC Plessey Semiconductors has made life a lot easier with the development of a single IC, including all the active circuitry needed to convert global positioning information in rf spread spectrum form to a 4.309MHz if form, that can be used for subsequent processing. The diagrams in this box show how this chip, the GP1010, functions, as well as a basic applications circuit.

For more information on the GP1010 contact GEC Plessey Semiconductors, in Swindon on 0793 518000.



IF output spectra for a GP1010 based GPS receiver



Block diagram of a GP1010 GPS chip

The problem with the network of beacons is that it automatically creates a system of lanes in the sky, along which aircraft travel from one beacon to another. The result is a localised build up of aircraft in a particular part of the sky, thereby putting limits on the number of aircraft which can safely fly a particular route. The other limitation is that many leisure flyers, such as microlights, small aircraft and balloons may be unable to properly utilise the beacon system.

This is less of a problem over oceans, where there is no beacon network and pilots have to rely upon their INS. But INS systems are notoriously inaccurate and can quite often register a drift of one degree per flying hour, a drift which can result in a serious positional error after a long ocean flight.

The use of GPS systems solves all these problems. They can give accurate positional fixes to within 100 metres on the horizontal and 150 metres in the vertical, which means that there need be no positional drift over oceans, deserts, etc., and where air traffic is heavy, many more lanes can be created and the separation between aircraft reduced. Furthermore, because GPS systems are cheap and lightweight, they can be installed in any type of aircraft, even microlights.

Perhaps the most spectacular use of GPS systems in terms of accuracy is in ground based surveying with the aid of carrier phase tracking. Besides being used in building and civil engineering construction surveying, it can be used to create extremely accurate maps. Maps that are being combined with satellite images to provide information on a wide range of geological, economic and environmental subjects. They can, for example, be used to accurately measure movements in the tectonic plates of the Earth, or in a major fault line and thus help predict earthquakes.

Stand alone GPS systems are also being used by freight companies to accurately locate the position of heavy goods vehicles, trains or even individual freight containers. These systems involve linking the GPS to either existing voice VHF networks for automatically relaying vehicle position within a local area, or via the Inmarsat satellite system for global position location. This not only enables the operator to accurately locate the vehicles in a fleet, thereby optimising their use, but it also allows them to track any stolen vehicles. This is a particularly important feature of the system when one considers that goods vehicles and their freight loads worth over £500 million are stolen every year and most of them are never located.

Automatic location of mobile units with the aid of GPS systems is also proving useful to the various emergency services, since it allows police, ambulance and fire services to locate the nearest appliance to an incident and thus reduce the time taken to reach it. A similar system is also being deployed by the London cab company, Computacabs, to enable them to get a cab to a customer as quickly as possible and also via VHF links to warn drivers of problems on the roads, check customer credit cards and advise on optimum routes. Other potential users of such systems include bus companies and service/maintenance vehicles for power and telecommunication companies.

Surprisingly enough, GPS systems are also being used in applications which do not involve position location. In fact, GPS systems can also be used as very accurate time and frequency sources (the satellites all contain highly accurate atomic clocks) and moreover, as a time source which is globally synchronised. The BBC time signal is no longer derived from a time source in Greenwich, but from a GPS receiver.

The future of GPS

As we have seen, GPS systems are already being employed in a wide range of non military applications. However, the development of GPS applications is still in the early stages and we have yet to see some of the most exciting of these developments, which look likely to have an impact on the lives of nearly all of us.

The application which will undoubtedly have the widest impact is the development of GPS systems for cars. All round the world, the major motor manufacturers are working on such systems. These products range in sophistication from a simple emergency beacon to full scale navigation systems, complete with electronic map displays. Prototype in car navigation systems are already undergoing tests in Japan, the US, the UK and Germany.

Probably the most sophisticated of these projects is being developed by a consortium of Japanese car companies. It involves storing a high precision 50,000:1 vector map database in the car as part of the GPS system, which is displayed on a PC quality flat screen display. This database is linked to a sensor system, allowing the car to be precisely positioned on the map with the aid of dead reckoning and map constraints, all based upon a GPS reference. This gives the navigation system far greater accuracy than is possible with the GPS system alone.

Because the navigation system must not distract the driver, the Japanese system will only function when the car is stationary or moving at under ten miles per hour. At higher speeds, it will simply display trunk roads without any finer detail. The problem of driver distraction has led some European developers to propose a purely voice command system (I can see this driving people mad very quickly!, Ed.).

Car navigation systems based on GPS could be on the market today and, indeed some simpler systems are, but their further development is constrained by one major factor - the lack of high precision electronic map data for many areas of potential use. It is the availability of such maps that has allowed the Japanese to gain an early lead in this market.

Car navigation systems may well prove to be the big commercial market for GPS systems but the future for this technology is no less exciting in other areas. For example, in maritime applications, experimental GPS receivers are now being linked with communications systems that utilise the low flying COSPAS SARSAT satellites to continuously report on a vessel's position. In future they will probably be linked to geostationary satellites as part of a system which will allow accurate control of shipping movements.

Moves are also afoot to use GPS systems to replace some elements of air traffic control and permit planes to fly much closer to each other. Again, this will rely upon GPS systems on the plane continuously reporting exact positions to air traffic control, via a geostationary satellite. Problems associated with a failure of the actual GPS system have now been overcome and the safety aspect of relying on GPS has been satisfactorily resolved.

Another aeronautical application for GPS is for precision approach and landing systems. This is a particularly important development, since it will considerably improve safety at countless airports, particularly in the third world, where no MLS system is installed.

This article has, I hope, shown that satellite base global positioning systems are likely to have a considerable impact over the coming decade in a wide range of different non military applications. GPS should improve efficiency and safety in a great many transport operations, and allow scientists and engineers to measure minute movements in the environment, providing vital clues to climatic changes or impending earthquakes.

This is one piece of military expenditure for which we should all be thankful!

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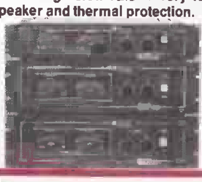

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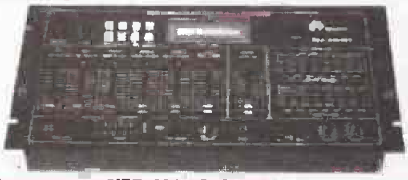

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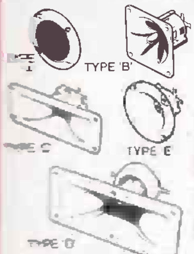

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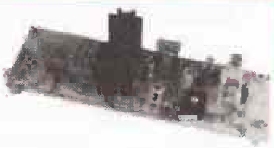

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Computer controlled stepper motors

This month, Jim Spence looks at an application for the ETI Forth Experimenters Computer - using it to accurately control the rotation of a stepper motor.

Have you ever experimented with a stepper motor? Did it work? Were you pleased with the results? This is a practical article, the intention of which is to tell you how to use stepper motors and make them work for you in your application. Described is an unusual way of driving the ordinary stepper motor and obtaining a much improved performance. Stepper motors seem to be used everywhere - in printers, disk drives, robots, fruit machines, in fact anywhere where mechanical positioning is important.

This is good news for the average electronics enthusiast, if there is such a thing. Why is it good news? Well, you can pick up at a car boot sale, or better still at a Radio Rally, 'junk' disk drives and printers for next to nothing. The old daisy wheel printers (if you can lift

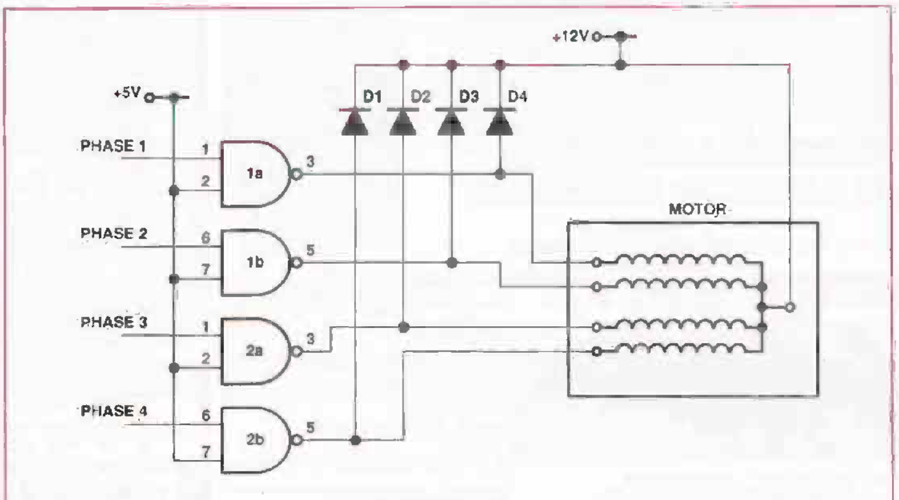


Figure 2: 2 x 75463 ICs as drivers

one) have about 5 stepper motors in and these would have cost a fortune to buy new.

Types of stepper motor

The two most common types of stepper motor are unipolar and bipolar. The type you are most likely to encounter is the unipolar, which is shown in Figure 1. They come in two types, 5 wire and 6 wire. Bipolar motors only have two windings and therefore 4 wires (Figure 1d), while modern motors have 8 wires and can be wired either as unipolar or bipolar (Figure 1c).

Before you can use one of these motors you must establish two things. Firstly the common connection, as in the case of Figure 1a and 1b, and secondly the sequence of the phases. The colours of the wires are of no help, as every manufacturer appears to have their own scheme.

The first step can be achieved with a meter. Usually, the motor windings will be between about 6 and 150 ohms. Obviously, the resistance between two windings will be twice that of the resistance between the common connection and a winding.

Having established the phases, you must determine which phase steps the motor to which position. Do this by wrapping a piece of stiff wire round the shaft of the motor, to act as a kind of clock hand or pointer. Connect each phase in turn to a power source and mark the top of the motor. You will easily establish the sequence of phases this way.

Typical Motor Characteristics

Basically, a stepper motor is a motor capable of revolving in fairly accurate discrete steps, a kind of digital motor if you like. Stepper motors have definite characteristics, they are good for some things but not for others. To begin with, they are not very fast in terms of RPM. An average stepper motor will go up to about 1000 steps per second if driven correctly and this translates to 150 RPM for a 1.8 degree per step motor, driven in half step mode. Now for a ballerina that's fast, but for a motor it isn't and it certainly wouldn't be suitable for use on the end of a garden strimmer! Having said that, modern motors are capable of quite reasonable speeds, as high as 10,000 steps per second without appreciable loss of torque.

Stepper motors also need special arrangements to make them work. You can't simply connect them up to a battery and watch them go round. As you will see later, the arrangements for driving this type of motor can make all the difference.

So what's the good news? Well, in spite of the special arrangements needed for driving, for positioning type applications they make life very simple because there is no need to have a constant feedback (as in closed loop). They can also be very accurate. For example, you can do things like move in extremely small increments. All of these options are simply not possible or practical with an ordinary motor.

With these properties, the motor lends itself to 'positioning' applications such as plotters and CNC (computer numerically controlled) machines, the main advantage being that there is no feedback required as to the position of the machine. This is known as an open loop system. For example, all you would need to do is to tell the motor to advance a certain number of steps and this would cause an exact and repeatable location to be realised.

In practice there is always some kind of feedback, even in an open loop system. Take a pen plotter. At switch on, how would the controller know where the pen was if there wasn't a 'home' position? There could also be an intermediate monitoring position so that whilst plotting, if this position was crossed. The controller could work out if it should have been there or not, issuing an error if an anomaly occurred.

The point is that in a system like this, the monitoring is minimal. In contrast, a closed loop system requires a constant update of the position. A closed loop system is 'safer' in the sense that if external forces interfere with the motor, e.g. you stick your hand in the machine, the effects are known immediately and corrective action can be taken, whatever that may be. An open loop system would not know if anything had gone wrong until the monitoring position, if any, which may be too late.

Fundamentals of stepper motor control

Although this text is of a practical nature, there are a few fundamental things about stepper motors which must be covered in order to make sense of the rest of the text and to enable you to put your 'junk' motor to good use.

Steps

Most stepper motors, you are likely to encounter, will step either 7.5° or 1.8° per step. This will give 48 and 200 steps per revolution respectively. Ninety degrees per step is also common but these are usually geared down. Obviously, the smaller the step, the better the resolution that can be obtained for a given gear ratio.

Pull-in and Pull-out Rate

The pull in rate is the maximum switching rate at which a loaded motor will start without losing steps. The pull-out rate is the maximum switching rate a loaded motor can go at. The pull-in rate is always lower than the pull-out rate and from this statement it can be seen that, if you want to drive a motor at its full speed, the pull-out rate, then you must progress to this, stepping slowly at first and increasing gradually to the pull-out rate. This is called ramping.

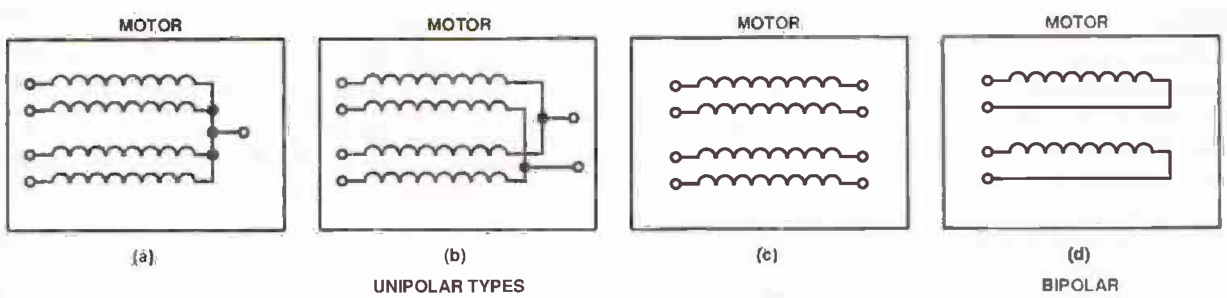


Figure 1: Motor winding types

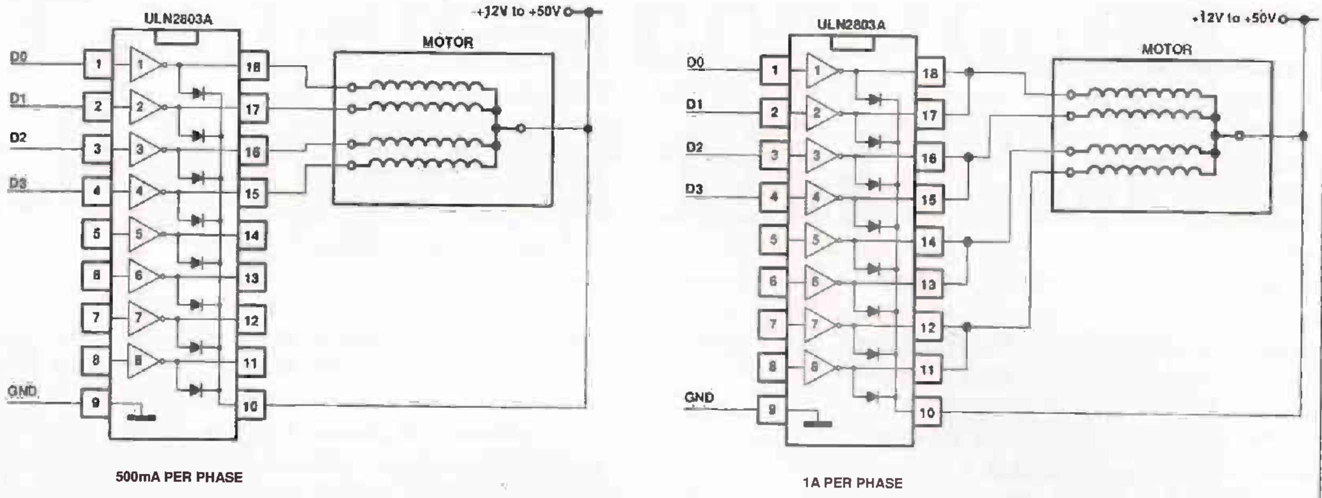


Figure 3: Using an ULN2803 as a driver

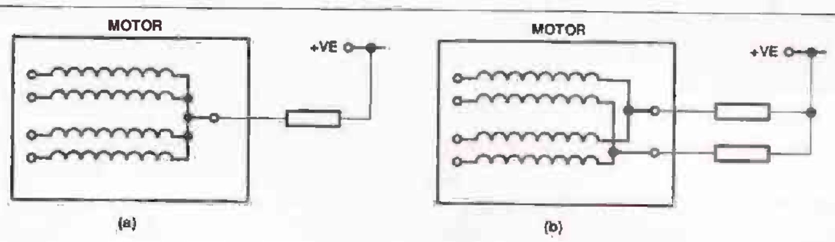


Figure 4: Forcing resistors improve motor performance

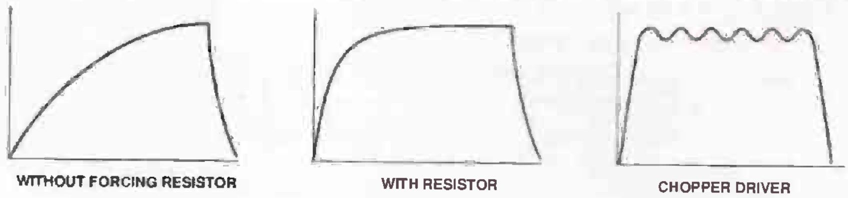


Figure 5: 3 types of drive arrangement

Resonance

Certain operating frequencies cause the motor to resonate. You can actually hear this and it may cause the motor to lose steps. These frequencies should be avoided.

General

There are, of course, many other parameters but for practical purposes the above will suffice. It is also important to realise that the motor will behave very differently when installed in a machine than it does when it is driving nothing.

Motor drivers

How you drive a stepper motor can make all the difference. You may be able to stop a motor with your thumb and finger when it is driven by one method, but take the same motor and drive it differently and it will be unstoppable and probably consume less average current.

Unipolar

As mentioned earlier, there are two broad types of motor - unipolar and bipolar. This, however, refers as much to the way motors are driven as to the way the motors are constructed. Some motors are designed to be driven either way. For example Figure 1c. The term unipolar, meaning

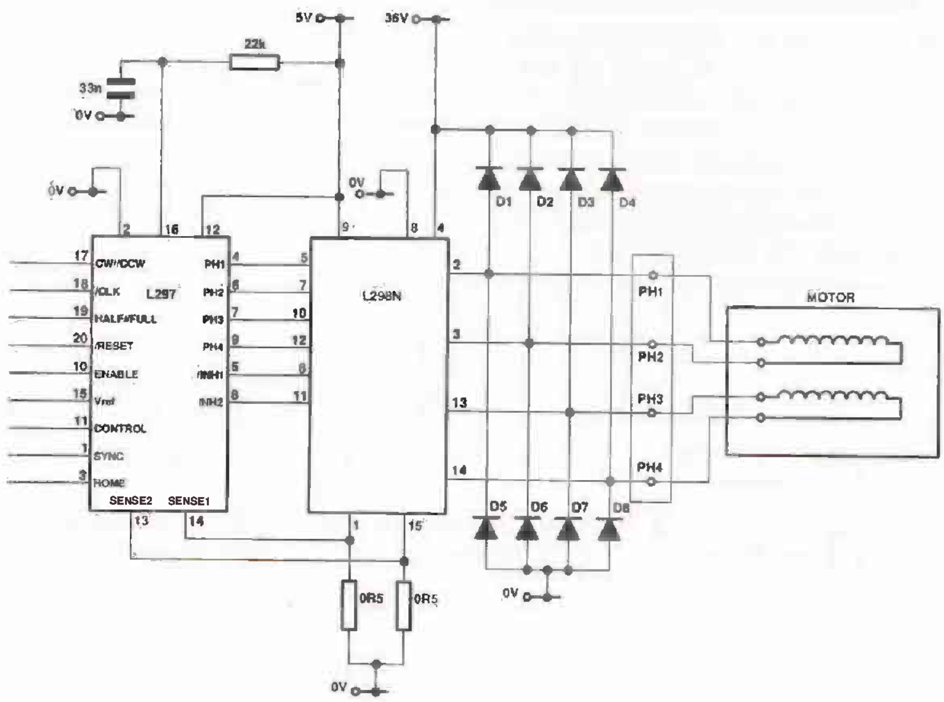


Figure 6: Driver circuit 1

one direction through the windings.

The old full height 5 1/4in disk drives have a small 12V stepper motor to position the heads. This is driven very simply by two 75463 driver chips (see Figure 2). This is a very simple circuit indeed and I am sure that no attempt is made to get the maximum performance from the motor. However, for this application it obviously fits the bill.

A more practical and modern circuit for driving a stepper motor this way is to use an octal driver chip, ULN2803. This incredible device has eight Darlington driver outputs capable of sinking 500mA each, at up to 50V. The outputs may also be paralleled to give greater output current and all this for less than £1 (see Figure 3). Be warned here however, the device is an 18 pin DIL with no heat sink, so don't put your finger on the top to see if it's getting warm. I still have a blister!

More performance

The main problem with the circuits shown so far is in obtaining the full pull-out rate (maximum speed). If the motor is fed with its rated current at a low 12V voltage, it may take, say 10 ms, for the winding to become fully energised. This will be the determining factor for the maximum speed. In order to get more performance, the motor can be driven with a higher voltage but through a resistor to limit the current. The effect of this is to reduce the time taken for the winding to reach its maximum energy and thus increase the maximum speed. It is common practice to use a resistor, which is generally called a Forcing resistor. Using a resistor also gives improved torque and as a rule the higher the value the resistor, the better the improvement, providing the current is maintained.

The jargon used is L/nR, where nR is the sum of the external resistance plus the winding resistance R. The idea is to maintain the rated current but with a higher voltage. For example a 20 Ohm 10V motor (0.5A per phase) driven in L/4R mode would have a 60 Ohm series resistor (60+20=80=four times phase resistance) and be driven with a 40V supply, thus maintaining the 0.5A. See Figure 4.

It is normal practice for manufacturers to quote torque in the performance figures using a particular L/nR value.

The forcing resistor needs to be fairly hefty and the above example would require a 20W resistor which would get quite hot, therefore probably requiring a heat sink. This is the main problem with the forcing resistor arrangement, it is very inefficient. The alternative is to dispense with the resistor but still use a high voltage and monitor the current in the phase winding. Just as the current begins to exceed the rated value, switch off the supply. As the current falls switch the supply back on again, so on and so forth at high speed. This is called chopping, see Figure 5. This is the best arrangement of all and because of the near ideal waveform, gives very much improved performance. For unipolar types of drive, it is usually adequate to use either direct or L/nR types of driving arrangement.

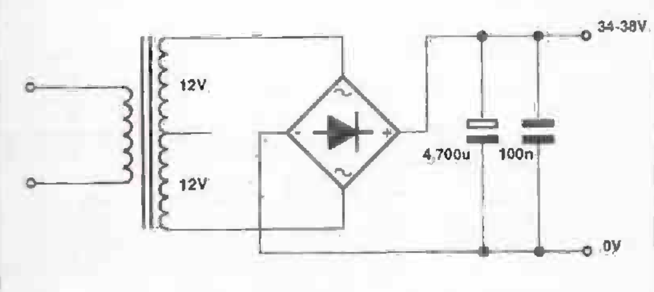


Figure 8: Power supply circuit

Bipolar

This method of driving stepper motors gives quite a remarkable improvement in performance over unipolar. The phases need to be driven in opposite directions and so the driver circuit needs to be able to source current as well as sink it. In the unipolar arrangement, the unwanted phase is simply switched off. In the bipolar arrangement the phase is either connected to ground or +ve. The main disadvantage, in the past, has been the difficulty, and complexity of the driving circuits, but there are now ICs available which take care of all the driving complexities.

Chop It

The maximum performance which can be obtained from a stepper motor will be achieved with a bipolar circuit and some

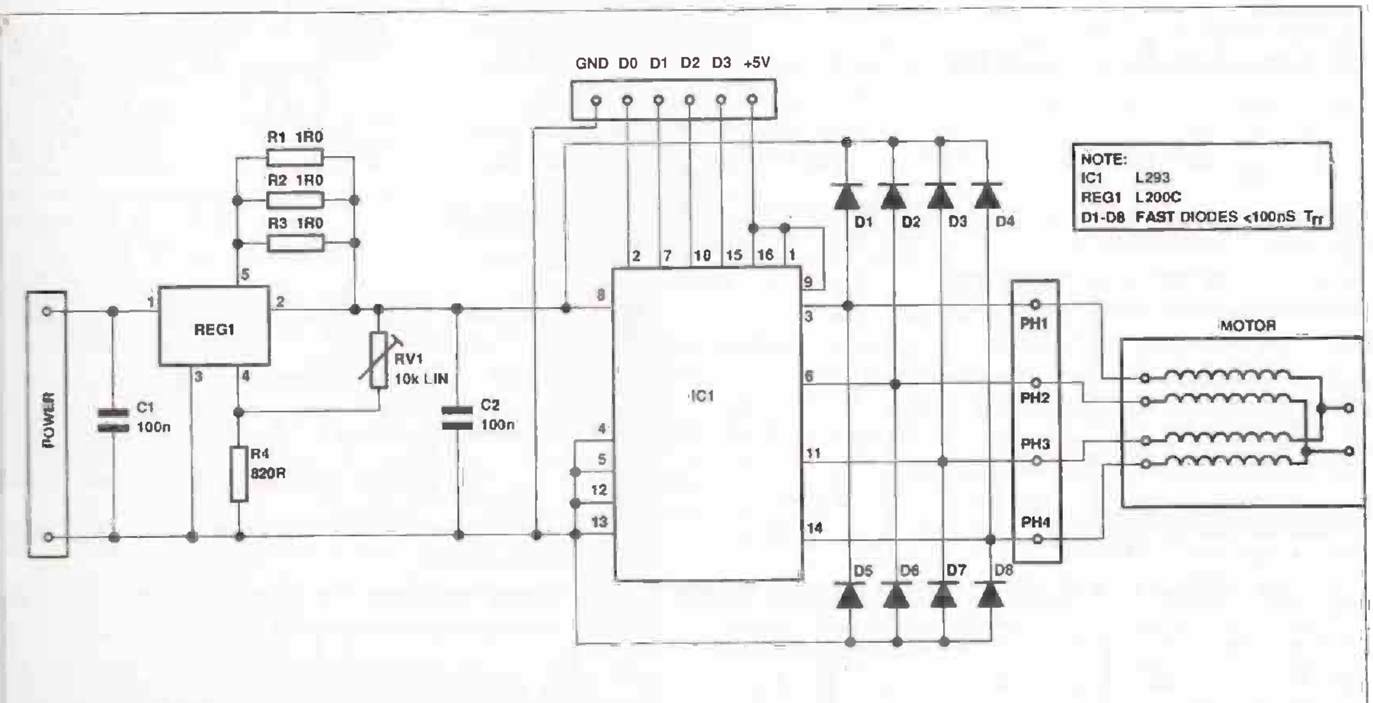


Figure 7: Driver circuit 2

form of chopping mechanism driving a motor designed for bipolar operation. This can be achieved fairly simply using just 2 IC's, Figure 6. The first IC (L297), is the controller IC and the second (L298N) is the driver IC. This is very similar to the L293, except the package enables it to handle greater currents. The two sense lines monitor the voltage across the motor windings and cut off the current at a predetermined value. This value is set by the input Vref. It is beyond the scope of this article to go into the details of this circuit, as the circuit proposed in Figure 7 performs almost as well. For a lower cost system, the added expense of the chopper circuit will make no practical difference.

The Circuit

The philosophy behind the circuit in Figure 7 was to construct a general purpose high performance stepper motor driver, capable of working with as many different types of motor as possible. The circuit is configured to drive a bipolar motor, but as you can see, a unipolar motor is shown connected. We can get away with this by leaving the common connections unconnected. The circuit will even work with a 5 wire type although some losses can be expected and the 5 wire motor may not reach its maximum performance. It will, however, perform far better with this circuit than it will with the unipolar circuit.

IC1 is a general purpose motor controller capable of supplying 1A per channel, which is more than adequate for a lot of motors. The board has an on board variable voltage regulator which will need a heat sink. This is so that the current can be adjusted to suit the particular motor. Also, there is a Link on the board which is for an ammeter. Four output lines from the computer are needed as well as +5V and ground. This is provided by the 6 way connector. Only 4 wires are needed for the motor (see How It Works) and two pins are provided for the power input.

In practice, the circuit will supply about 1A for short periods without getting too hot. 300 to 500mA is a realistic figure for continuous operation and you will be surprised how powerful some motors can be at this current.

Power Supply

Modern stepper motors have winding resistances as low as 1 to 2 ohms. A low voltage supply can therefore provide adequate currents. Older, cheaper motors however, have winding resistance's of 50 ohms and up. Connecting unipolar motors to run in bipolar mode effectively doubles the resistance. The practicality of the above means that to drive motors with a high resistance, a high voltage supply is needed. The circuit shown in Figure 8 will provide about 35V, which is the maximum rating of IC1.

How It Works

REG1 is a virtually indestructible variable voltage regulator. Resistors R1 to R3 limit the current to about 1.5A and VR1 controls the voltage output, which will swing between 3 and 36V. C1 and C2 help to reduce the noise caused by switching the motor windings. IC1 is an L293 which is intended as a general purpose motor driver, not just stepper motors. Diodes D1 to D8 prevent the normal voltage spikes exceeding the 0V and 36V rails, usually associated with inductive loads. There exists a variation of the IC, L293D, which has the diodes already built in. If you are using this chip, then the diodes are unnecessary.

As mentioned earlier, only 4 wires are required. The common connections are simply not used (see Figure 7) Figure 7 shows a 6 wire unipolar motor connected to IC1, ready to be driven in bipolar mode. Because current flows through two phases, for example from phase 1 to phase 3, rather than from phase 1 to common, twice as much torque is available. If phase 1 and phase 3 are opposite each other, physically on opposite sides of the motor, one will be pushing and the other will be pulling so to speak. This gives double the torque that can be obtained from a unipolar system. A five wire motor also works driven by this method. Although current is flowing through the other two, unused phases, it has the same magnitude and direction. They therefore cancel each other out and do not mechanically affect the operation of the motor. This is not ideal, but it does give good results. A bipolar motor only has four wires and this circuit is ideal for driving one of these.

Construction and Testing

Use of the PCB is highly recommended, unless very low currents are to be used. You will notice that the PCB has large areas of copper connected to the ground pins and this is to help dissipate the heat from the IC. The chip is physically bonded to the ground pins for this purpose.

It goes without saying that for once an IC socket should not be used. Solder in all the components except the IC, taking particular care over the orientation of the diodes.

Connect up a power supply and check that the regulator IC is working and varies the voltage as you turn VR1. If everything is functioning correctly, solder in the IC. Make absolutely certain you get it the right way round.

After completing the board, connect a motor to the 4 way connector, a suitable power supply to the two pins, +5V and ground, to the six way connector and an Ammeter across the pins marked Link. With nothing connected to D0-D3, there should be no current flowing. Connect D0 to the +5V pin and adjust VR1 to give about 150mA. The motor should jerk at this point, indicating current flowing through it. The actual current depends very much on the type of motor you have connected. 150mA is a fairly safe starting point.

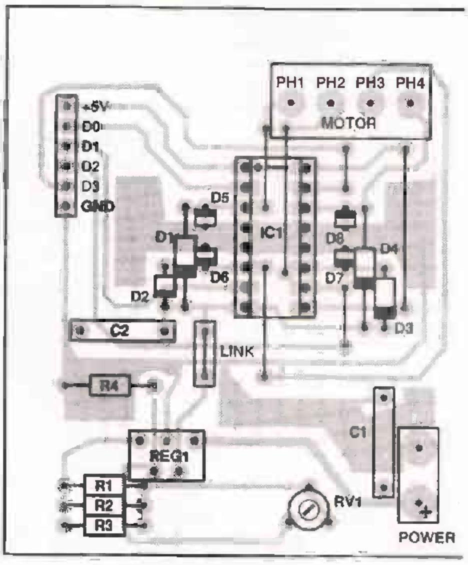


Figure 9: PCB component overlay

PARTS LIST

IC1	L293 or L293D
REG1	L200CV
R1, 2, 3	1R 0.25W
R4	820R 0.25W
VR1	10K lin pre-set
C1, 2	0.1µF
D1-D8	BYW98-100 *

4 x PCB pins, 1 x 6 way PCB connector, 2 x PCB 2 way terminals

* Diodes must have a Trr of less than 200ns, not needed if type L293 is used.

Next month ...
we will look at the software for driving the stepper motor circuit described in this month's article.

Turbo speed indicator

In this month's PC project, John Lanigan shows how to build a simple little display which will indicate how fast your PC is running.

The old IBM XT spends more time in bits on my desk than in one piece running software. It's the one that gets all the tinkering, adding this, tweaking that. It started out as a Portable with twin floppy drives and a built-in mono monitor. Now it is in a new case with uprated power supply, 3-1/2in and 5-1/4in floppies, hard disk,

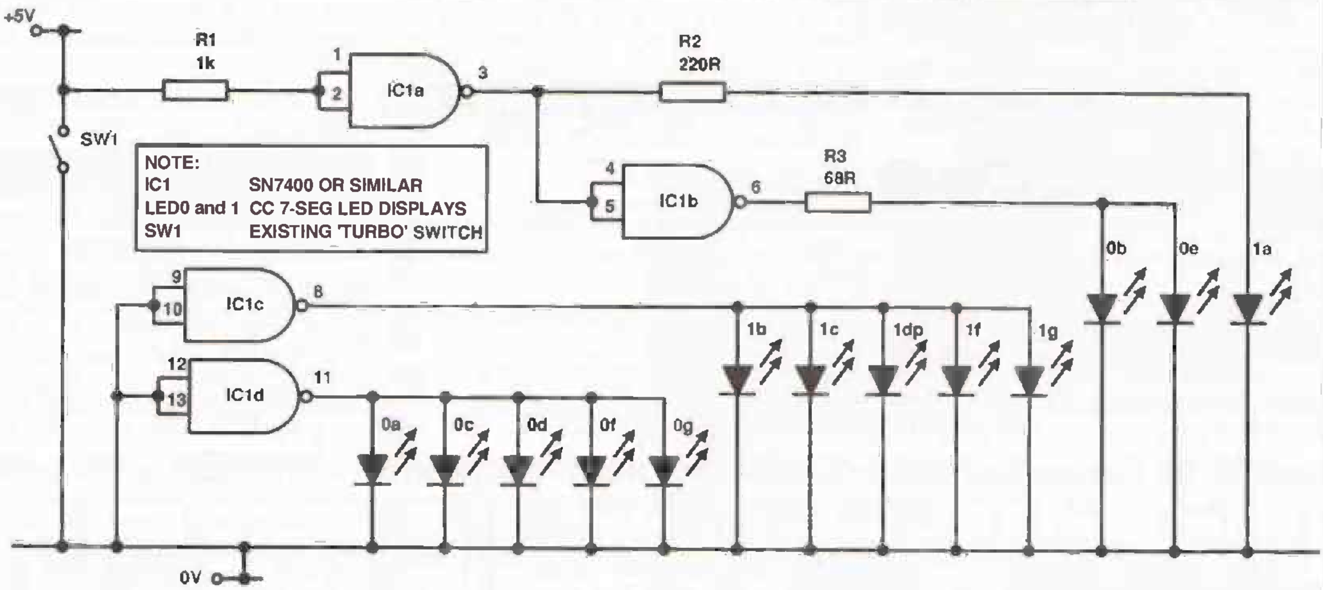


Fig. 1. Turbo indicator circuit

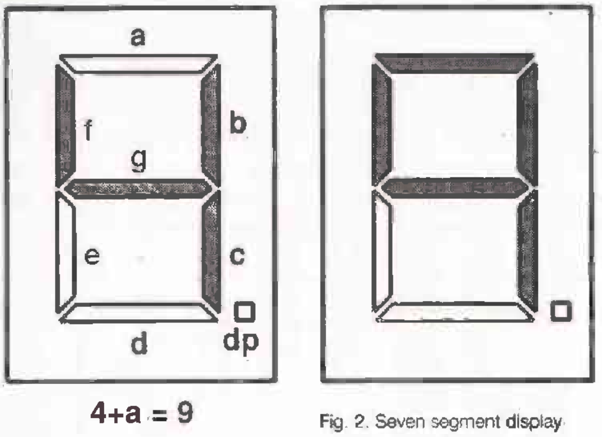


Fig. 2. Seven segment display

colour display and turbo motherboard. It was while I was putting in the turbo board that I thought about digital speed indicators, like those on some of the flashier AT clones. It is not necessary to build a counter and decoder-driver circuit to display the two speeds at which turbo boards normally run. All we need is a switching element (a turbo switch for example) and a little hard-wired logic.

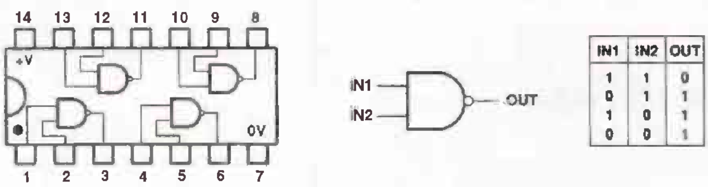


Fig. 3. 7400 Pin out and logic table

The 7-segment display provides a crude but universally recognisable rendering of the digits 0 to 9 by illuminating 2 or more bars of its 7 bar array. For any given 2 digits, several of the illuminated bars will be the same. For example, 0 and 8, where the only difference is the centre bar. The board I used for the XT had a base speed of 4.77 and in turbo mode 9.54 MHz. To show 4.8, and in turbo mode 9.5, 10 of the segments involved remain unchanged, including the decimal point of course. A 4 becomes a 9 by adding one more segment and an 8 is made into 5 by removing 2 segments (see Figure 2). If we can hold the unchanging segments on and switch only those that change, we can produce a display of the CPU speed with a simple logic circuit.

How It Works

In the diagram (Figure 1), with SW1 open, the 2 inputs of IC1a are held high, giving a low output. This keeps LED1a turned off and at the same time holds the inputs to IC1b low. A low on both inputs switches IC1b output to high, so lighting the segments LED0b and 0e. A truth table is given in Figure 3 and the display segments are identified in Figure 2.

IC1c and IC1d have permanent high outputs, because their inputs connect to the 0V line. These outputs drive the segments LED0a, c, d, f, g and LED1b, c, d, p, f, g. They are the permanent segments.

Closing SW1 pulls IC1a inputs low and consequently the output goes high, lighting segment LED1a. The same 'high' connects to the inputs of IC1b causing its output to go low and turn off the segments LED0b and 0e.

The 2 resistors, R2 and R3, in the lines to the switched segments adjust their brightness to match that of the permanent segments. This is necessary because 5 of the permanent segments are driven by each of the remaining 2 gates. If the current to the switched segments was not limited they would be noticeably brighter than the rest.

Assembly and Testing

Before starting this project you should determine the switching levels on your turbo switch, SW1. Almost certainly, it will be switching between 0 and 5V, but it is always more comfortable to be sure. You need to find the 'high' side of the switch for connecting up anyway. You can check this with a 20k-ohm/V meter set to the 10V range. You should connect the common lead to a known ground such as the chassis metalwork. If you have more than 5V, (up to 15V), on your turbo switch, you must use a potential divider network to reduce it to 5V. Use high value resistors to minimise the current drawn down the network.

Assembly should not present any problems with only a few components. Start with the low profile parts, the resistors, then the IC followed by the 7-segment displays. While soldering, do not concentrate on one device at a time. Move from one to another as this will avoid over-heating and possible damage. This is particularly important if you have difficulty with one joint. Do not keep trying to complete it in one go, move to another component so that the first can cool.

When all the parts and the leads are in place, connect to a DC supply set at less than 5V. I usually use 3.5 or 4V, in case I have forgotten a current limiting resistor that should be protecting something either expensive or impossible to replace on a Sunday afternoon! Now connect the lead that goes to the turbo switch, SW1, to a 10k resistor and then to the supply. If you get the expected response - a dim 4.8 on the displays - you can take the supply up to 5V. Grounding the lead to SW1 should change the display to 9.5.

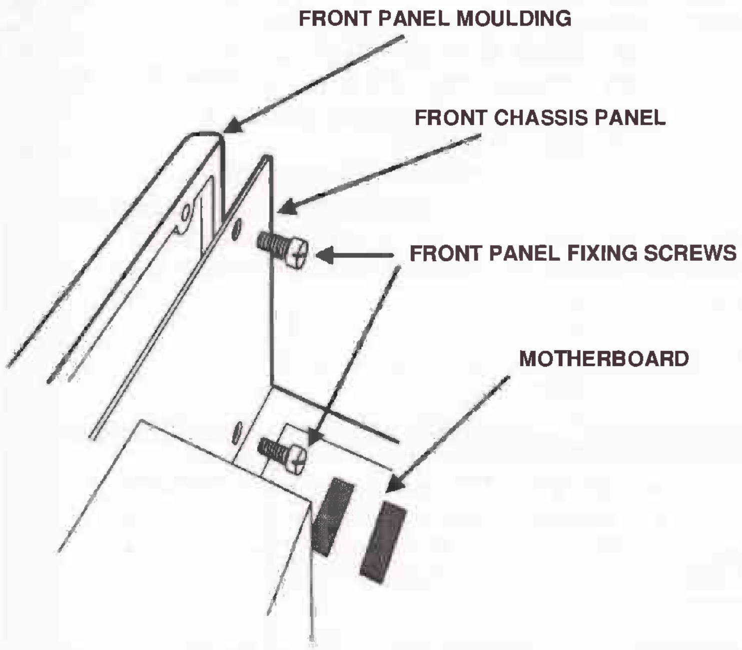


Fig. 4. Mounting inside A Pc

LED Shot?

If the circuit does not perform as expected, trace the connections on the board and compare to the diagram. If you don't have a display at all, even when you turn up to 5V, then switch off and start checking the power supply connections. Meaningless shapes or unexpected numbers on the display mean that the connections to the segment pins are incorrect. If you are using a socket for the IC and/or displays, then look carefully to ensure there are no bent pins. Of course, you didn't insert ICs the wrong way around did you? (Yes so did I.)

Those of you in-the-know will have realised that NAND gates are not essential for this project. It will work perfectly well with inverters, like SN7414, as that is exactly how a NAND gate behaves when both inputs are connected together. The 7400 however, has just the right number of gates and it was on the top of the 'bits box' when I started work on the prototype.

Some applications may need to show different figures from those given, but the How It Works section should allow the confident beginner to alter the circuit to display any value from 0.0 to 99.

Micro Surgery

It is not possible to describe fitting the board into all of the possible case types. They are, however, largely similar and the metalwork should not be too difficult.

Most cases have a lift and slide-off top, secured with a number of screws around the base of the unit. Under this is a chassis of sheet steel to which most of the sub-assemblies fix. The front panel moulding is held by screws to the front of the chassis from inside (see Figure 4), so some of the peripheral devices and driver cards may have to be removed first. There is usually a void between the front panel and the metalwork to which it mounts. This is where we will be fitting the new circuit board. You need to find a place for the circuit board that puts the 7 segment displays near to the front panel moulding. It may be necessary to mount the board on stand-offs or spacers, depending on the distance from the moulding to the chassis. The prototype was mounted on a sub-chassis that eventually made it easier to fit. If possible, pick a space where there is some room for a little adjustment. This will allow you to align the board/assembly when all the surgery has been completed.

When you are satisfied with the position of the board, fit it temporarily and measure from a fixed point on the metalwork, such as one of the holes for the front panel moulding fixing screws, to the LED display. Take care, as this dimension locates the cut-out in the front panel. Mark out the hole on the front of the panel and cut it out.

This is best done by drilling in the corners and cutting between them, then filing or scraping to your marked lines. Better still, if you know a toolmaker or machinist, ask them to do it for you, because the results of any poor craftsmanship will be visible on the front panel!

To finish off the front panel, cut a piece of tinted Perspex and either glue or heat-stake (melt the panel and the Perspex together with a soldering iron) it in place, over the hole. If you have been unlucky cutting the hole and have made less than a perfect job, it may be useful to fix the window on the outside. In this case, you will have to glue it of course. A useful 'dodge' is to use a bezel to cover the hole, so it is not so important to cut a good hole. With the front panel back on, you will need to adjust the position of the circuit board to align it with the window.

There are 3 connections to make - to SW1, the 5V and 0V lines. The supply is fairly easy just connect to the nearest disk drive power supply but make sure you don't pick the 12V line! I use a lot of 5A screw or block connectors for this sort of thing. For the switch, it is probably easiest to solder directly to the switch terminal. If you have one of the older PCs whose hard disk drives do not self park on power off, park your disk heads before dismantling or moving the case. This precaution will save you from considerable anguish later. Do not use the switch lead for your 5V supply. It may work, but more likely you will be trying to draw more current than was expected of the switch.

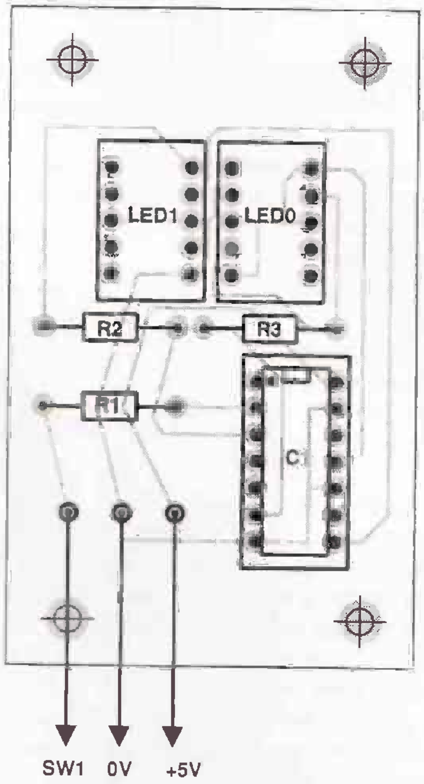


Fig. 5 PCB Component overlay

PARTS LIST

None of the components are difficult to obtain. Only the 7-segment displays are important in that they are low current, high brightness types.

Resistors

R1 1k
R2 220R
R3 68R
(all 1/8 W 5% carbon film)

Semiconductors

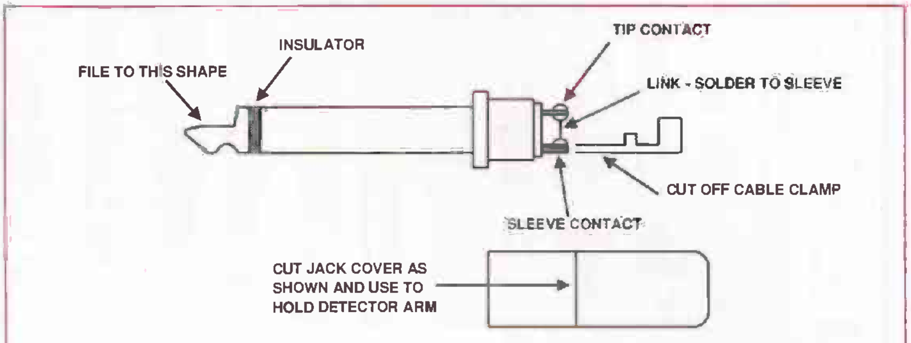
C1 SN7400 4 2-input NAND gate
LED0 and 1 low current, high brightness, common cathode 7-segment LED display (MAPLIN QY54J)

Miscellaneous

PCB or suitable Veroboard
Machine screws, nuts, washers and spacers
Connecting wire

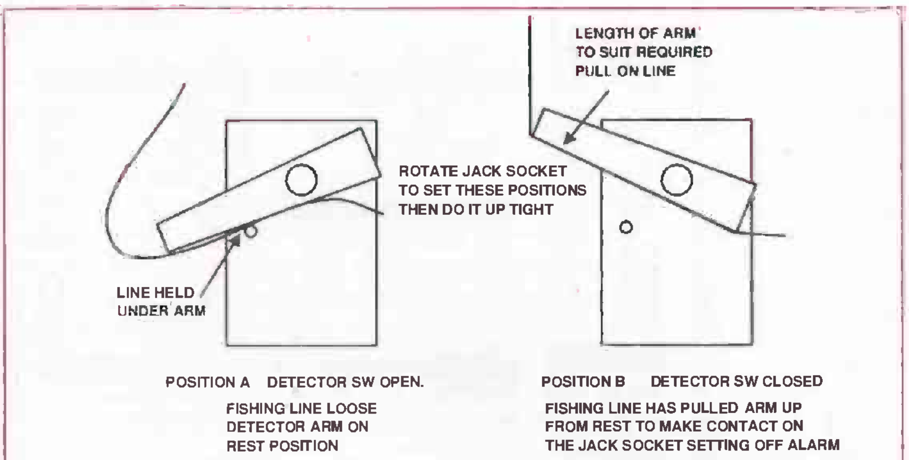
BITE ALARM

builds three different bite detectors for anglers, designed for varying stages of the National Curriculum.



Jack plug modification

This project has been designed to be compatible with the new National Curriculum ideals, where students of varying ability face the same problems but choose different levels of technology to overcome them.



Detector mechanics

The object in this case is to indicate audibly, via a beeper and visually through an LED, when a 'bite' is detected while fishing. This can be extremely useful, either when using two rods as a monitor for the second, or for night fishing.

There are three versions of this alarm to allow for the varying abilities of students, but all three use the same detector, box, LED and beeper, although the electronics varies from a couple of components to a dozen or more. Here are the three models, together with their appropriate levels within the National Curriculum and as assessed by the CDT Head of Department at Denefield School, Reading.

Model 1000 - very basic, no active electronics, suitable for pupils working at level 3, minimum.
Model 2000 - simple two stage circuit using a thyristor and a 555 IC, suitable for pupils working at Level 6 or at a range of levels from 4-7, provided they use the circuits and data supplied for justifying their solutions.
Model 3000 - a digital approach using 3 CMOS ICs. The complexity of this circuit is such that pupils using it could, if it is used as a basis for their own development of a bite alarm, achieve the highest levels. With the right description and folder work, this model is suitable for pupils working at Level 7 or higher.

General Background

There are a lot of good quality bite alarms on the market, but their prices seem well out of the reach of many enthusiasts. Several of those looked at seem to draw a fair amount of current when switched on but not indicating, which means battery replacement would be a frequent occurrence and with a good quality PP3 costing £2 a go, also expensive. So here are my cheaper, low current versions.

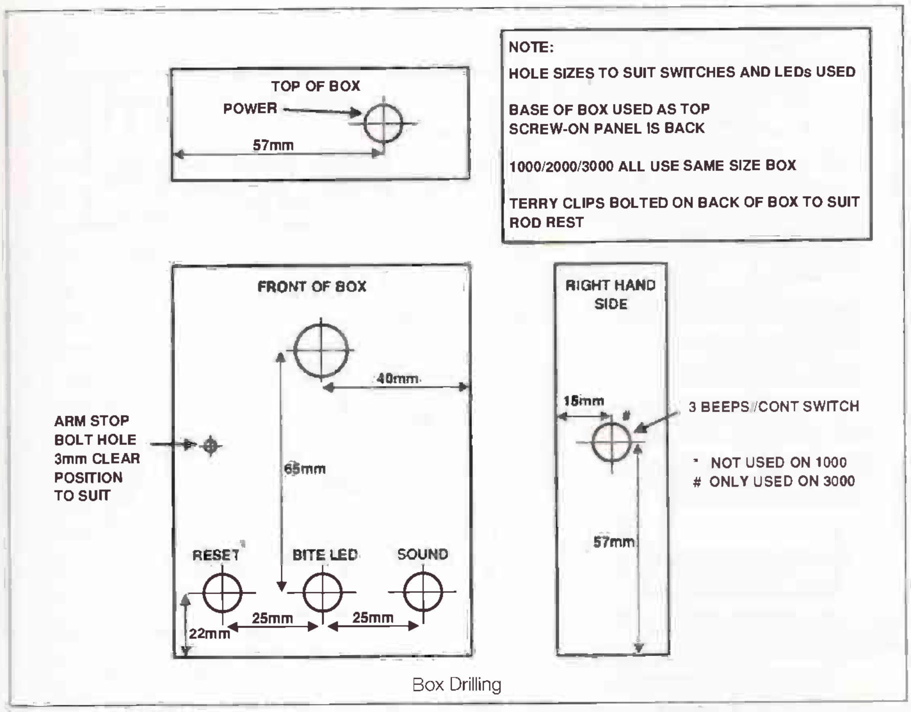
The single most important part of the Bite Alarm is the detector. Somehow, this must detect the increased tension caused by a fish pulling on the line but be able to ignore the constant tension due to current or wind. Many of the ready made units use a disc, which the line rotates when pulled tight and an opto detector is used to monitor dark and transparent sections of this disc. The manufacture of this rotating disc module in production terms and quantities is relatively easy, but trying to make a one off with tools readily available to the amateur is quite a different matter. The most difficult problem is making a spindle to run freely, but strong enough to take the punishment handed out during a day's fishing in all weathers and to survive the average fishing box. Several attempts were made, but all ended up using tools or materials not always available to the amateur. Another approach was required and this was to use a standard 1/4in mono jack plug socket. This, with slight modification, was found to be ideal - cheap, strong and effective.

The spring contact of the socket on the sleeve terminal is bent slightly backwards, to reduce the pressure it exerts on the jack plug. The tip contact on the plug is filed to produce a flat (as per diagram), so that when it is plugged into position A, no contact is made with the socket tip contact, but when the plug is rotated to position B, contact is made. By loosening the shaft contact, by bending it back slightly, we have reduced the current handling capacity of the jack plug/jack socket, but this is unimportant as we are only going to pass a few milliamps through it.

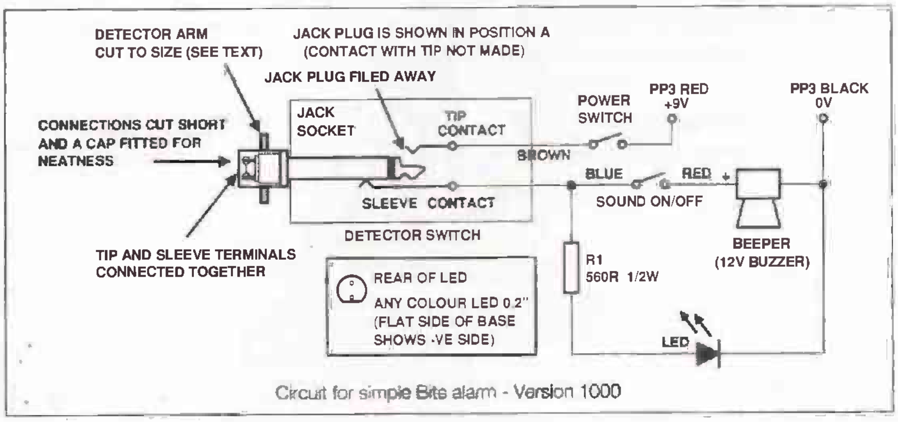
All three versions of the Bite Alarm use this type of detector switch. By filing different amounts off the tip contact on the jack plug, the distance between the position A and B can be varied to suit. Care must be taken not to file away too much or the tip connection is broken as this goes up the centre of the jack plug. To reduce the force required to turn the jack plug in the socket, a simple lever is used. The length of this lever can vary to suit, but remember the longer the lever, the less force is required to turn the jack plug, but the further the lever must be moved. For practical purposes, several levers can be made to suit conditions, short for fast moving water and longer for water that is still or slow flowing.

The jack plug top is also modified. The two connectors are cut off as near to the base as possible to allow them to be soldered together. The screw thread has two flats filed in it in order to stop the lever turning without turning the jack plug.

A short length of the screw cap is cut off to cover these shorted connections and to hold the lever arm in place. If only one arm is going to be used on each jack plug, it is advised that it is glued to the jack plug to give added support. Remember several lever arm jack plug assemblies can be made. The top of the short length of screw cap can be filled with glue gun glue and a small screw cap insert can be fitted to give it a professional look. These come in different colours and can be used to instantly recognise which one is most suitable for the conditions, e.g. blue for slow water and red for fast water, etc.



Box Drilling

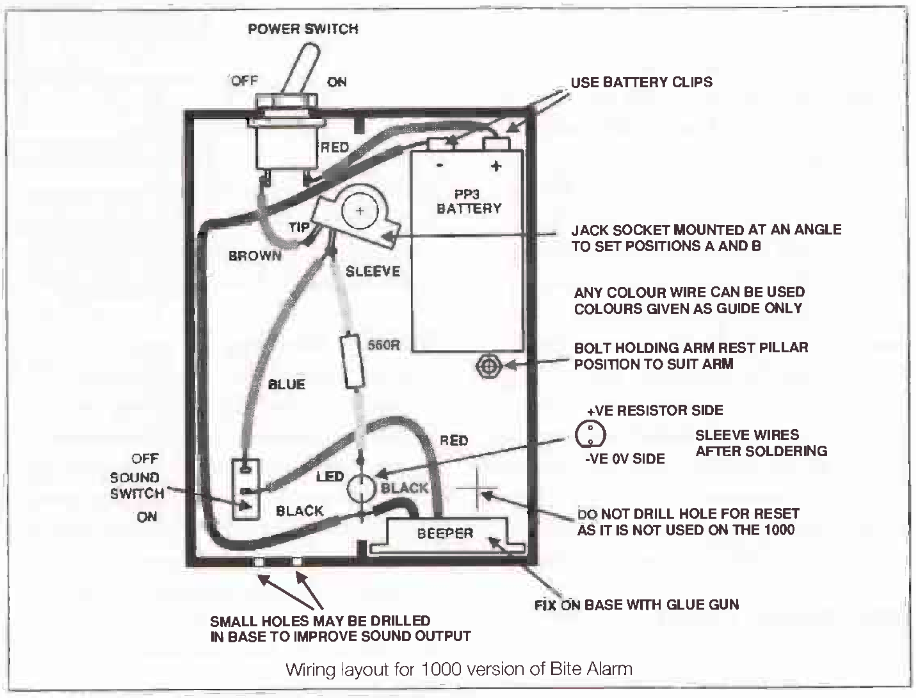


Circuit for simple Bite alarm - Version 1000

The position of the jack plug on the lever arm is also important as the metal to the right of the jack plug acts as a counterbalance weight, making this heavier and effectively decreasing the force required to turn the lever. Too heavy and it keeps the lever in position B, too light and it only detects Great Whites - quite rare here on the Thames.

The fishing line is passed under the detector lever arm in position A so that when the line is pulled taught by a fish, the lever moves to position B. In order for this to happen easily, the bite alarm is clipped on to the rod rest by a couple of small terry clips. The top of the rod rest has a short bar mounted on it, which has two uses. Firstly, it stops the Bite Alarm from rotating on the rod rest and secondly, it holds the rod in the correct position above the detector arm, to the left of the Bite Alarm. All three versions of the alarm use this type of detector switch, as well as using the same type of box. The switches are all mounted in the same position where applicable - this is to allow an upgrade at a later date if skill and confidence increase during the life of the alarm.

All three versions have a LED as well as switchable sound which indicates a 'bite'. The sound can be switched off if it is thought that it might disturb the fish or other people nearby. All versions have been extensively tested and their varying



Wiring layout for 1000 version of Bite Alarm complexity only determines the way a bite is indicated. It doesn't affect the sensitivity of detection, which remains the same in all three. Each version is equally useful, something not usually found in graded ability projects.

Bite Alarm 1000

This is the simplest version, but is still a very rewarding project which effectively has no active electronics.

How It Works

When the Power switch is On, the +9V from the PP3 battery goes to the jack socket tip terminal. If the jack plug on the detector lever is in position A, i.e. fishing line loose, the circuit is effectively broken as no contact is made to the tip of the jack plug. However when the jack plug is rotated to position B by the action of the line being pulled taught by a fish, the tip contact of the jack plug make contact with the tip contact of the jack socket and a circuit is made. The jack plug must have its two terminals connected together as shown in the diagram. The +9V now flows into R1, the current limit resistor and into the positive side of the LED. The negative side of the LED (the lead nearest the flat on the side of the LED) completes the circuit to battery 0V.

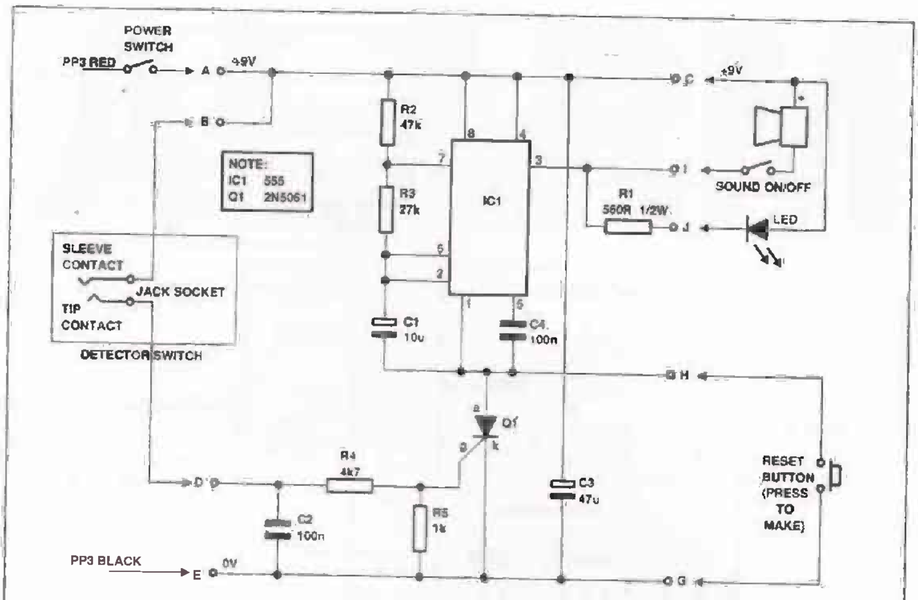
If the Sound switch is On, 9V is also passed to the positive side of the beeper, the red lead. The black lead goes to battery 0V. A low current, low price buzzer rated at 12V is used in my projects although any small low current piezo sound (active type with oscillator built in) will do.

Although in this version there is plenty of room, it is recommended that the alarm is built to the drawing and the controls fitted roughly where indicated - this then allows the project to be upgraded if required later, as the other projects use the same box, etc.

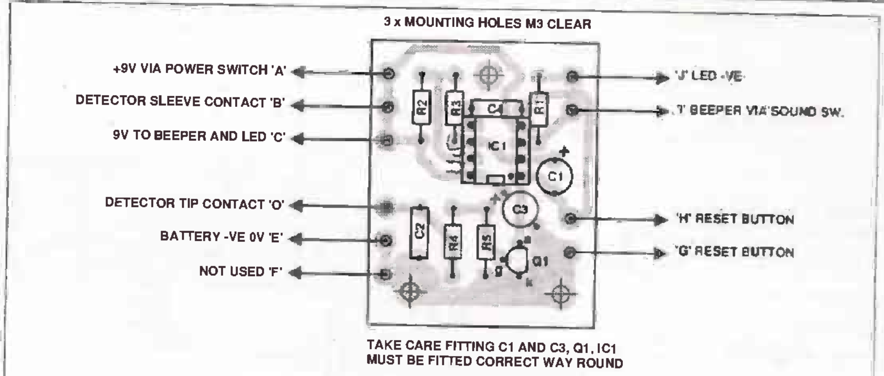
Although this is the simplest of the three alarms it does have the advantage that when the detector lever is in position A, not indicating a bite, no current flows at all, so increasing the life of the battery. Current is only drawn while indicating.

Bite Alarm 2000

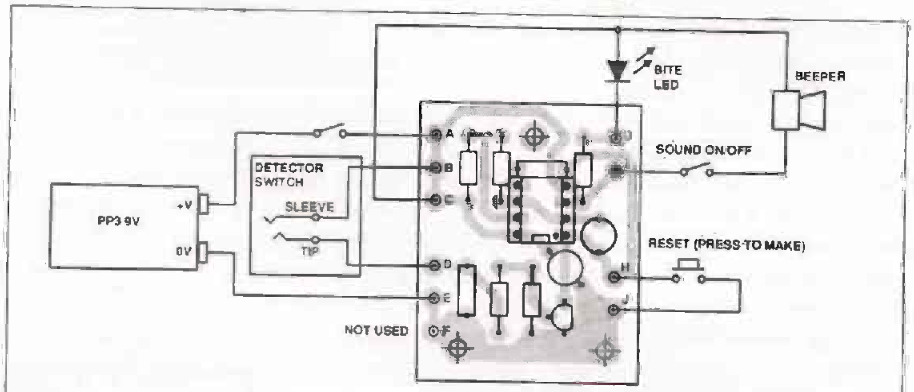
This circuit can be broken down into two distinct parts, both of which use components commonly found in school projects - the latch, built around a thyristor and the oscillator, built around the 555 timer.



Circut diagram for version 2000 of Bite alarm



Component overlay for version 2000 of Bite alarm



Wring diagram for version 2000 of Bite alarm

How It Works

The latch part of the circuit uses the property of a thyristor that once it is turned on it stays on, even if the input signal is removed. It will stay on until the current passing through it is taken away. The input signal comes from the detector switch which, when in position A, receives nothing as the switch is effectively open. When rotated to position B by a fish on the line, the detector contacts close, switching 9V to R4. R4 and R5 produce a voltage divider and current limiter, essential to the safe operation of the thyristor.

Thyristors vary considerably in their sensitivity and if a different one is used, it must have a similar specification. C2 is used to try to remove any RF (radio frequency) signals that may be present, shorting them down to 0V. If present in any quantity they could cause the thyristor to turn on, giving a false indication.

When the detector lever is in position B and the alarm power is switched On, the thyristor turns on, effectively going from open circuit to short circuit. This turning on to a short circuit condition will remain, even if the detector lever drops back from position B, removing the gate signal from the thyristor. From now on, the thyristor applies 9V to the 555.

In the oscillator, the 555 is connected

as a standard, slow running oscillator. C1 may be altered to suit anything from 2.2µF 16V to 22µF 16V. The speed of oscillation will change accordingly - the larger the capacitor the slower the oscillation. A LED with its current limit resistor R1 is connected to the output of the oscillator pin 3 and will then flash, indicating a bite. If the sound is switched On, the beeper will pulse. This pulsing is more distinctive than it being on continuously, as in the 1000 model. To stop the alarm the detector arm must be returned to position A and the reset button pressed.

The reset button bypasses the thyristor, so the current flows through the reset switch and not through the thyristor. Electricity always takes the path of least resistance, so reducing the current through the thyristor turns the alarm off. Usually, the current through the thyristor is reduced to zero by breaking the circuit, using normally closed contacts on a press switch. The thyristor is turned off by pressing the switch and opening the normally closed contacts, thus breaking the circuit. In our case, bypassing the thyristor has the added advantage that it can be used as a 'test' button. When the alarm is in the fishing box without the detector lever and jack plug plugged in, simply switching the alarm On and pressing the reset button should start the oscillator. This is because the reset switch bypasses the thyristor and applies power directly to the 555, but only while the reset button is being pressed. The beeper should sound if switched on and the LED should flash. The brilliance of the LED and volume of the beeper should show if the battery is OK. Some batteries deteriorate quite quickly even though they are not being used, so it is a good idea to check it before going fishing. It is easy to see the advantage of using this method of resetting over the method normally used.

It is recommended that the layout is followed to allow for a later upgrade to the 3000 if so required.

There are more wires connecting up this alarm PCB than in the 1000, but if different coloured wires are used, there should be no difficulty. They should be connected one at a time, checking with the circuit. Small holes are drilled under the alarm to allow the sound out, as in the 1000 unit.

A good quality PP3 battery, i.e. an alkaline type is recommended, more expensive but they don't have to be changed so often. Although unplugging the detector arm should reduce the residual current flow to zero, it is recommended that the alarm be switched off when stored and, at the end of the season, the battery should be removed to prevent it from leaking. Despite what the manufacturers say, batteries still leak when left in damp conditions.

Bite Alarm 3000

This is the most sophisticated of the three alarms and hence the most complicated. It gives the option of only having 3 beeps to indicate a bite, or will indicate continuously at the flick of a switch. The other advantage is that it may be reset either automatically after 3 beeps or manually, even though the lever is in position B.

This alarm works by using 3 digital CMOS ICs and processing the signal received via a series of logic functions, these include D type RS stat, NAND Schmitt gates (must be Schmitt type for the oscillator to work) and a walking 1 counter.

How It Works

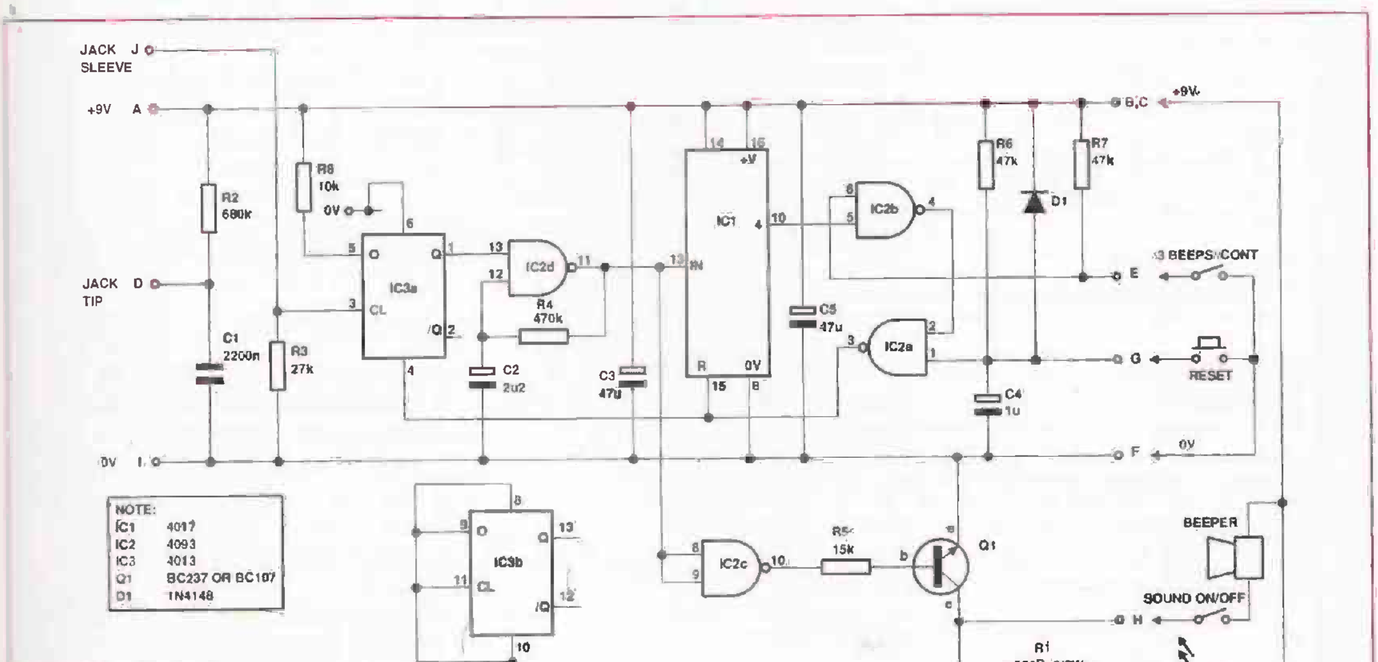
This alarm, with all these extra features, still uses the same detector switch as the other versions, but the inclusion of R2, R3 and C1 makes its operation slightly different, by allowing the alarm to be reset in the active B position.

When the lever is in position A, i.e. the detector switch is open circuit, C1 charges up via R2. This is passed to the detector switch and is at 9V when charged. When the lever is in position B, this 9V in C1 is applied to the clock input of IC1a, the D type stat, via the detector switch. This is normally held down by R3. The charge held by C1 allows the clock input to receive a logic 1 before the action of R3 discharges C1 back to a low, via the potential divider action R2, R3 680K to 27K - 25:1.

This somewhat complex action is required to allow the reset of the stat to operate and not be retriggered by the lever moving from B to A or even staying in position B.

Once the clock input has received a low to high transition and assuming the stat is not being reset, a 1 will appear on the Q output pin 1 of IC1a. This 1, or 9V, will stay on the Q output until reset by a reset signal on pin 4. The Q output is used to enable an oscillator which supplies the pulses for the LED and beeper.

The oscillator is built around IC2d and is fed to the input of the counter IC3, as well as being inverted by IC2c and used



Circuit diagram for version 3000 of Bite alarm to drive the output transistor Q1 to power the LED and beeper. A transistor is required to amplify the current output of the CMOS IC which can only supply 1mA or so directly.

The counter IC3 is a walking 1 type, which means that when the first pulse is received, assuming the counter has previously been reset, the output corresponding to count 1, pin 2 goes high, all the other remain low. On receiving the second pulse from the oscillator, the count 1 output goes low and the count 2 output pin 4 goes high. On receiving the third pulse from the oscillator pin 7, count 3 output goes high and pin 4 goes low. The pulses, as well as going to the counter, go to the LED and beeper, if switched on. So far, 3 flashes on the LED along with 3 beeps will have passed. The fourth pulse will cause pin 10 of IC3 to go high and pin 7 to go low. Assuming the 3 beeps option has been selected, pin 6 of IC2 will be high, pulled up by R7. Now the 4 output on the counter pin 10 makes pin 5 on IC1b high. Two highs in on a 2 input NAND makes the output go low, so IC2 pin 4 goes from a high to a low - this is fed to IC2 pin 2, the input, to another NAND gate. Any low into a NAND causes its output to go high, regardless of the other inputs. This high on the output of IC2a pin 3 resets the counter as well as the D type, returning the bite indicator to its start position, regardless of the position of the detector lever. All this from the generation of the fourth pulse happens so quickly that the beep is never heard, so it is cancelled before it has had time to sound or even illuminate the LED.

If the 3 beeps function is not selected, IC2 pin 6 remains low (switched to 0V by the selector switch), ensuring a high on the output pin 4 no matter what is on pin 5 due to the counter, so the oscillator will run on until reset by pressing the reset button. This puts a low on IC2 pin 1 causing pin 3 to go high, resetting the counter and D type.

D1, R6 and C4 form a switch on reset so that when the alarm is first powered up from the power switch, C4 from being fully discharged by D1, charges up via R6. So to start with, IC2 pin 1 is low until C4 charges up to above 60% of rail, or about 6V. During this charging up time, pin 3 is high, resetting IC1a, the D type and IC3 the counter, but as soon as pin 1 reaches 60% of rail it is seen as a 1 and IC2 pin 3 goes low, cancelling the reset.

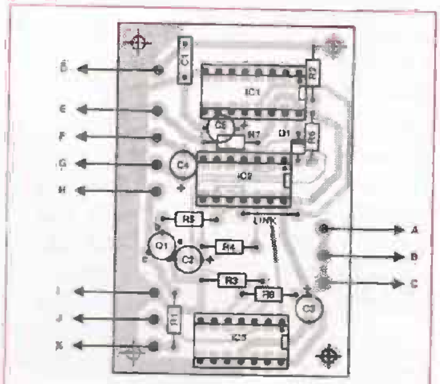
If all this seems a bit complicated, it is advised that the truth tables are consulted on the NAND operation. Although IC2 is a NAND Schmitt, its truth table is identical to a normal NAND, like the 4011. The difference is only in the hysteresis allowing it to be used as an oscillator, unlike a normal NAND gate.

IC1b is not used in the circuit but, as is required by all CMOS ICs, all unused inputs are either tied up or down, i.e. connected to rail or 0V and, not left unconnected to float.

It will be noted that the first beep is longer than the others - this is due to the fact that C2, the timing capacitor for the oscillator, charges up to rail volts, i.e. 9V, when the oscillator is off, so C2 must discharge from 100% to 40% of rail, taking longer than continuous oscillation where it only charges from 40-60% and back to 40%.

Although three possible options are given in this article, there are several other approaches to overcome the Bite Alarm problem. Even following one of the suggested circuits, there is still a lot of experimenting to be done with the lever length and shape, where to mount the jack plug, even the possible use of a counterbalance weight and so on.

I have experimented with making a very small alarm, actually mounted on the rod. Although it adds weight to the rod it still works, even if it does get in the way a little.



Component overlay for version 3000 of Bite alarm

Good luck with the project and good luck with the fishing too!

PARTS LIST

Model 1000

- R1 560
- LED1 Red or green, 0.2in round LED
- 12V buzzer
- 1 Jack socket (mono)
- 1 Jack plug (mono)
- 1 box
- 1 On/Off switch, 1 pole On/Off
- 1 On/Off sound switch, 1 pole On/Off
- 2 small Terry clips to suit
- 1 battery connector
- 1 battery, PP3

Model 2000

Resistors

- R1 560
- R2 47K
- R3 27K
- R4 4K7
- R5 1K

Capacitors

- C1 10μF 16 V Rad Elect
- C2 0.1μF 25V Ceramic
- C3 47μF 16V Rad Elect

Miscellaneous

- IC1 NE 555 timer
- 1 8 pin IC socket
- T1 thyristor 2N5061 or similar
- LED1 red or green 0.2in round
- 1 Jack socket (mono)
- 1 Jack plug (mono)
- 1 buzzer
- 1 On/Off switch, 1 pole On/Off
- 1 On/Off sound switch, 1 pole On/Off
- 1 press to make switch
- 1 box
- 1 battery connector
- 1 battery, PP3
- Vero pins 0.1in to suit

Model 3000

Resistors

- R1 560
- R2 680K
- R3 27K
- R4 470K
- R5 15K
- R6 47K
- R7 47K

Capacitors

- C1 0.22μF
- C2 2 μ2 TANT 16V
- C3 47μF 16V Radial
- C4 1μF 16V Radial
- C5 47μF 16V Radial

ICs

- IC1 4017 CMOS
- IC2 4093 CMOS
- IC3 4013 CMOS

Miscellaneous

- IC holders, 2 off 14 pin, 1 off 16 pin
- Q1 BC107
- D1 IN4148
- 1 On/Off switch, 1 pole On/Off
- 1 On/Off sound switch, 1 pole On/Off
- 3 beeps switch, 1 pole On/Off
- 1 press to make switch
- 1 box
- 1 Jack socket (mono)
- 1 Jack plug (mono)
- 1 buzzer
- 1 battery connector
- 1 battery connector
- 1 battery, PP3
- Vero pins 0.1in to suit

PC Clinic

This month in PC Clinic, we examine the heart of every PC - the CPU. We look at how it can be made to work faster with the aid of coprocessors, clock doublers and cache memory. We will also be looking at the BIOS software and its Power On Self Test routines, which enable us to track down system faults.

At the very heart of every personal computer, no matter what its make or design, there is a processor chip of some sort. In the IBM PC and all compatibles, this processor chip will belong to the Intel x86 family of processors, the familiar 8086, 80286, 80386, 80486 and most recently the Pentium. These processor chips were all originally designed and manufactured by the US semiconductor giant Intel, although the processor in your PC will not necessarily be manufactured by Intel, but maybe by one of the half dozen or so, mostly US based, manufacturers of 'clone' processors. These 'clone' processor chips will all run the same software as those from Intel, but often have slightly different performance ratings.

The function of the processor chip, or Central Processing Unit - CPU for short - is to execute the sequence of instructions which make up the program code. This code and its associated data is stored in memory and accessed by the CPU under control of the clock timing signals. In general, the faster the clock can be made to run, the more instructions can be executed in a given period and therefore the more powerful the processor is in computational terms.

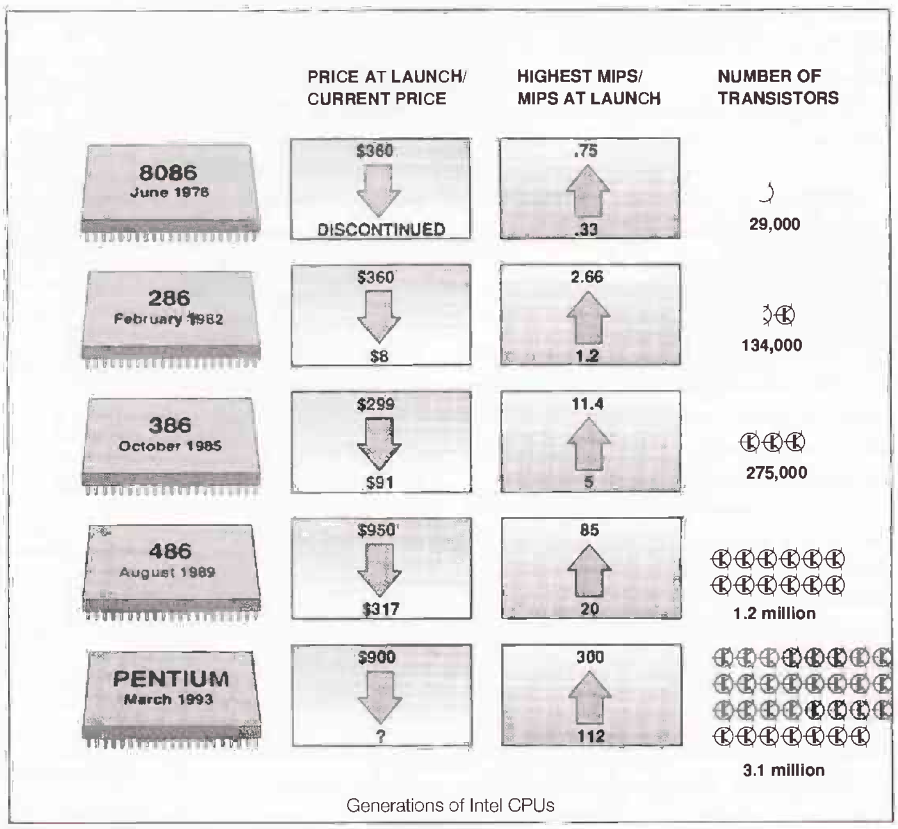
Program instructions and data are all stored in memory and processed within the CPU in binary form and are organised in units of eight bits, or one Byte. Since most instructions and data occupy more than one byte, a processor can be speeded up by handling two or more bytes in parallel. Thus, a 16 bit processor is approximately twice as fast as an 8 bit processor and likewise a 32 bit CPU is four times faster, assuming of course that they are all running at the same clock rate.

The processing power of a personal computer is thus dependent upon a combination of clock speed and the number of bits it can access from memory and process during any one clock cycle. This processing power is most commonly rated in terms of Millions of Instructions Per Second, or MIPS. The very first processor in this range, the Intel 8086, was launched in June 1978 and had a power rating of just .33 MIPS. Five generations of processor later and the Pentium, launched in March 93, had a rating of 112 MIPS. This is about 300 times the processing power of the CPU found in the very first IBM PCs.

Historically, Intel has launched a new generation of processor chip every 44 months, but under competitive pressure from manufacturers of new very powerful RISC based processors, this development rate has been accelerated. Peak power from the Pentium will be more than doubled later this year with a 150MHz version and the next generation, code named the P6, is already undergoing testing prior to launch next year, only 30 plus months after the Pentium. The P6 looks set to at least double the power output of the best Pentium.

So why do we need more power? The answer is simply that new software applications, particularly those which are highly graphics oriented, need more and more power. Try running Windows or a CAD/DTP package on an old 8MHz 286 and then compare it with the same software running on a 66MHz 486. On a slow machine, such software is virtually unusable, it cannot perform all the calculations and update the screen sufficiently quickly to prevent the display hardware having to wait for the processor.

This means that if you want to have a more powerful computer, but do not want to buy an entirely new system, then you will need to look at upgrading the processor. On the following pages we will show some of the ways in which this



Generations of Intel CPUs

Coprocessors

A coprocessor is essentially a piece of hardware, we could call it an assistant processor, which is designed to perform high speed operations which would otherwise have to be executed using much slower software routines, monopolising the main processor. It is called a coprocessor because its hardware is very closely integrated with that of the main processor so that in essence it extends the processor's instruction set with a number of new special purpose instructions, that can replace frequently used software routines.

Thus, a coprocessor might perform a specific function in two or three instruction cycles which would otherwise need a code sequence lasting fifty instructions. In specific applications, a coprocessor can give enormous improvements in processing speed.

Most people, when they talk about coprocessors, think about maths coprocessors, a coprocessor designed to perform a range of complex arithmetic operations which are not normally included in a processor's instruction set, such as calculations involving sine and cosine. However, coprocessors can also be used for other operations.

Some networking and communications systems use special coprocessors to relieve the main processor of the overheads inherent in communications and error checking. Similarly, advanced multimedia systems that are designed to handle video images use special image compression and decompression coprocessors. Indeed, literally hundreds of different types of coprocessor have been designed for the 80x86 CPU family alone.

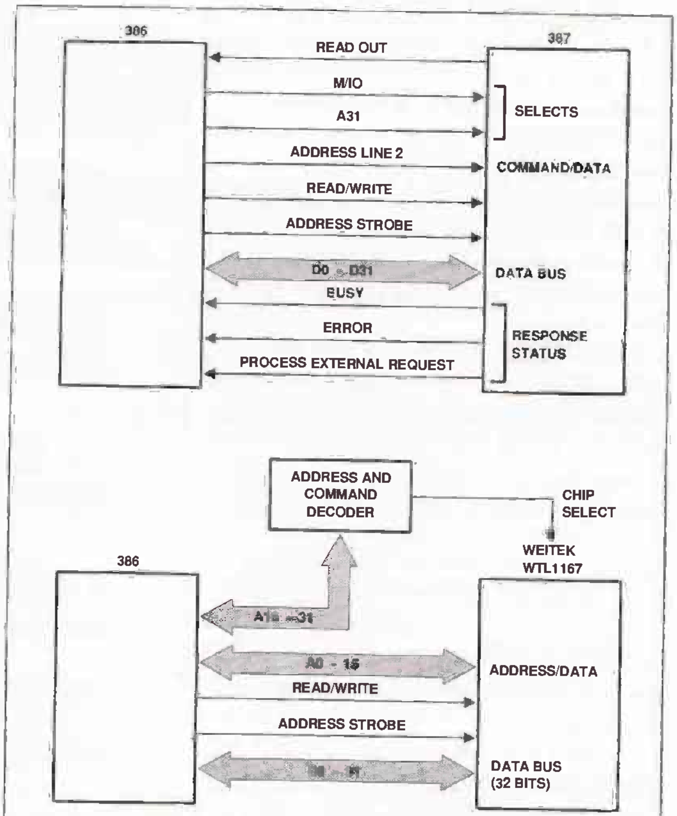
The most commonly encountered coprocessor is the maths coprocessor and there are two principle types - the Intel 80x87 range and the Weitek range. The Weitek maths coprocessors offer a better performance than a typical Intel version, but programs will have to be specially written to take advantage of it. Although the 486DX has a math coprocessor on the CPU chip, some systems also have provision for installation of a Weitek 4167.

As one can see from the two diagrams accompanying this section, the 386/387 interface is relatively simple, with the 387 being mapped into the high I/O address space of the 386 (A31 high and M/IO low). Address line 2 distinguishes command transfers from data transfers. Far more efficient is the much more closely coupled Weitek extended maths coprocessor interface, since it makes full use of both the address and data bus, thereby allowing commands and data to be transferred simultaneously. This interface means that the coprocessor runs about three times faster than the conventional 387 interface and it is thus worth checking to see if your motherboard supports it.

The most common choice of maths coprocessor is the Intel family and adding one to a 286/386 system is relatively easy, since nearly all motherboards designed for these processors have a dedicated coprocessor socket. When choosing a coprocessor, it is important that it matches the system into which it will be installed. Thus, if it is going into a 20MHz 386 system then the coprocessor will have to be a 20MHz 387, a 25MHz 386 will require a 25MHz 387 and so on.

When installing a coprocessor chip, always make sure that the power is disconnected before installing and that any static is fully discharged. Before attempting to insert it in the socket, first check that no pins are bent or damaged. If they are bent, gently straighten them with pointed nose pliers. Then make sure that the board under the socket is well supported as it is easy to crack a track by being over enthusiastic when pushing a chip into a socket. Finally check that the orientation of the chip is correct by matching the dot on the top of the chip to the dot or notch on the socket or the motherboard.

Having carefully done all these things, press the chip firmly in place. On some motherboards, it will be necessary to set a jumper or DIP switch to inform the system that a coprocessor is installed. You will have to check your motherboard documentation for details on which jumper or switch needs to be set. When this has been done, check it by switching the PC on and checking for any error messages. If your coprocessor chip comes with a diagnostic program then run this, otherwise enter the system's CMOS set-up program and check that it indicates that a maths chip is installed. If it does not, then switch off and carefully recheck that the chip is installed properly.



Coprocessor interfacing

REPLACING AND UPGR

In theory, we can improve the performance of a system by changing the CPU. A faster processor with a wider data width will give us more processing power, so if we swap a 286 for a 386 we should get about five times the processing power. Similarly, by changing from a 286 or earlier processor to a 386 or later, we can overcome the memory limitations that were inherent in these earlier systems.

But, unfortunately, changing processors is not that easy and in all but the most recent systems it is certainly not a case of simply removing one chip and plugging in another. The problem is that there are too many sub-systems and interrelated components for us to simply be able to change the current processor for a more powerful one.

We therefore have to think about the complete system, about the fact that the clock circuitry will be the wrong frequency and about the fact that the address, data, and control lines of the new processor could be entirely different. Not forgetting the simple fact that the processor chip could be a different size and have a lot more pins.

What this means is that simply changing the processor chip more often than not also involves changing the whole motherboard. However, we can improve the processing power of a system in certain applications with the aid of a maths coprocessor. The type of applications where this will be of value are those which involve a lot of mathematical calculations, rather than simply moving and manipulating data bytes - in other words applications such as image transforms in 3-D CAD packages, or system simulations.

Thus if you are running this type of mathematically intensive application on a 286 or 386 based PC, then a coprocessor of some sort will give quite a considerable boost in performance since it will allow calculations to be performed using hardware rather than software. The result is a reduction in the number of processor cycles needed to perform a specific calculation and thus an overall improvement in the speed at which the application works.

With the 486 and Pentium processors, the situation is slightly different since both chips were designed to include a maths coprocessor integrated on the same slice of silicon as the processor.

However, when the 486 was first launched there were apparently some problems associated

DING THE CPU IN A PC

with the coprocessor and rather than withdrawing the chip, it was decided simply to disable the coprocessor and relabel the device the 80486SX, as opposed to the 80486DX which has the coprocessor.

Apart from the presence or absence of the coprocessor, these two 486 chips are identical, so adding a maths coprocessor to a 486SX based system is simply a matter of removing the SX chip and replacing it in the same socket with a DX chip of the same speed.

At this stage in the development of the 80x86 family of processors, Intel introduced a new innovation which allows the user to increase the power of a system by simply replacing the processor chip. This technique is known as clock doubling (now we also have clock tripling and clock quadrupling) and overcomes a lot of the earlier problems associated with the close relationship between the processor and allied systems.

The clock doubling technique is an ingenious one, since it allows the processor to run at twice the speed (a clock tripler runs at three times the speed, and so on) that would otherwise be permissible. This means that, for example, a processor could run at 66MHz on a motherboard which is only rated for 33MHz. In this way, a processor chip is upgradable without having to upgrade the whole motherboard and, equally important, all the problems associated with designing and building very high speed motherboards are overcome. Board designers can thus optimise their design to give the best speed at the lowest cost.

System manufacturers have also discovered that this gives them a great flexibility, a single motherboard design can be used in a range of different models simply by changing processor and peripherals. This of course reduces the need for expensive stock holding, allows them to respond quickly to the development of new processors and new system requirements. It also acts as a good sales incentive to be able to say to customers that a system is relatively future proof and can easily be upgraded, a factor which has encouraged a great many manufacturers to use Zero Insertion Force - ZIF - sockets for processor chips, thereby making removal and replacement very easy.

Using a DX chip

As can be seen from the chart on page 35, the 80x86 family of processor chips has become bigger, more powerful and much faster. This posed an enormous problem for system designers, the processor was getting too fast for the system. Memory access times were becoming too fast for the type of memory chips which could economically be used on a PC, high clock speeds were starting to give rise to board design problems due to such factors as signal propagation delays.

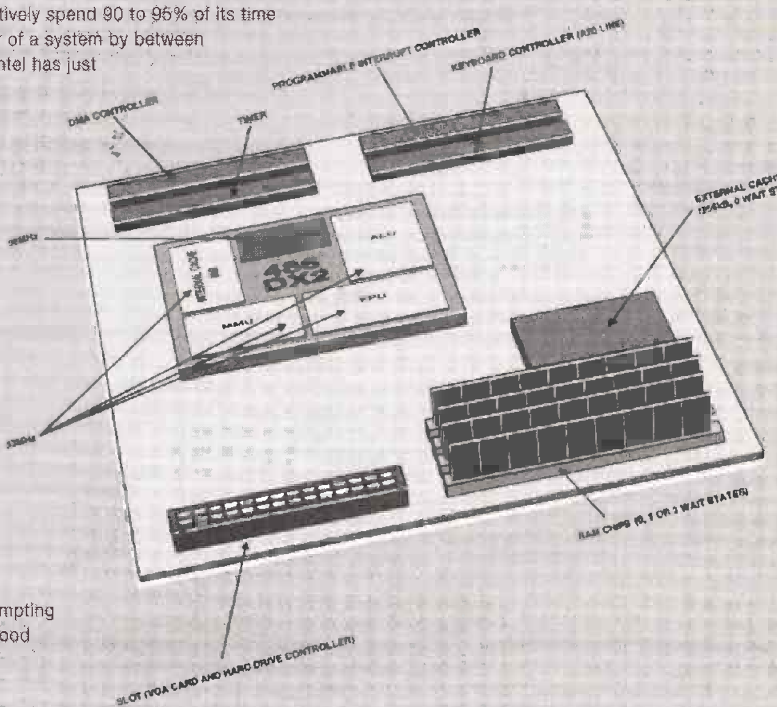
These factors all meant that, although it was feasible to build much faster system boards, it was uneconomic to push motherboard clock speeds much beyond the 30MHz area. Neither was it practical to do so, since the number of wait states entailed in accessing standard memory chips would effectively slow the system back down to that sort of level.

Processor manufacturers were nevertheless capable of making their processor chips run at substantially higher speeds. Furthermore, users and software producers had an insatiable demand for more power. There are of course only two ways in which processing power can be increased for a given type of processor. One way is to increase clock speed and the other is to increase the data bus width, but data bus width increase also adds a substantial overhead to system board production costs and would entail the use of an entirely new expansion bus interface.

The solution to these problems involved carefully examining the system and looking at which parts of the circuit needed to operate at high speed and which could continue to operate at lower speed. The high speed components would then be integrated onto the same slice of silicon as the CPU, thereby allowing the processor to work at maximum speed.

The result was the DX2, or clock doubling chip, which is in every way compatible with a DX chip but runs twice as fast internally. The bus interface unit on a DX2 chip allows the processor to work with the lower speed external circuitry with a 2:1 speed reduction, so that in such situations, the DX2 functions exactly like a DX. However, the area of memory currently being accessed is mapped onto an 8K block of memory within the DX2 chip, the processor cache, so that whenever the processor needs to access this memory, use its internal registers or perform a floating point operation, it can do so at twice the external clock speed.

In practice this clock doubling technique means that a processor can effectively spend 90 to 95% of its time operating at the higher speed, thus effectively increasing the processing power of a system by between 70 and 80%. Indeed ,this is a technique which can be extended even further. Intel has just launched its clock tripling series of DX4 processors (not as one would logically expect, quadrupling!) offering internal clock speeds of up to 100MHz.



In theory therefore, one can simply double the processing power of, say, a 25MHz 486DX by replacing the DX chip with a 50MHz DX2 chip. On some motherboards this simply involves replacing the DX chip with a corresponding DX2. Many newer designs of motherboard have ZIF sockets for the processor chip, thus making removal and replacement very easy.

Not all motherboards are the same and on older boards there is an additional socket for what is called an OverDrive chip, the function of which corresponds to that of a DX2 and not, as some vendors would have one believe, a coprocessor. Another type of overdrive socket found on more recent 486 system boards is the P24T socket, which allows the system to be upgraded to a Pentium. Doing so will simply involve putting the P24T chip into the 238 pin socket provided for it on the motherboard, which will then preempt the existing 486 processor.

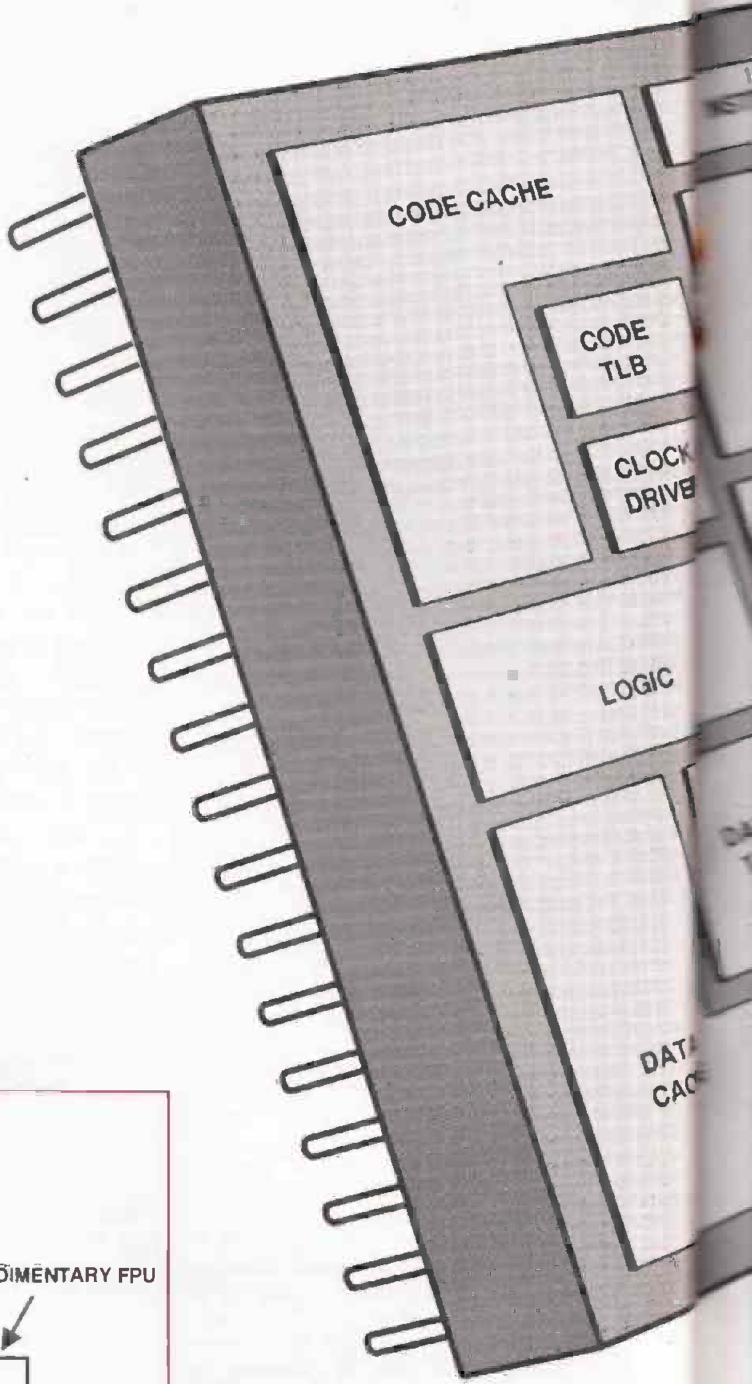
In the case of an original 486SX with a maths coprocessor socket, it is possible in some cases to upgrade the system to run a DX2 chip. Thus, a 20MHz 486SX could be replaced by a 40MHz DX2. This will entail carefully prising out the old CPU chip and replacing it with the new one, but before attempting to do this and certainly before buying the replacement processor chip, it is a good idea to check with the manufacturer that such an upgrade is feasible.

In practice, upgrading from a DX to a DX2 is not quite that simple. One major problem is that an increase in processor speed also means an increase in power consumption and thus in heat output. A DX2 chip consumes about 40% more power than the equivalent DX and outputs a correspondingly increased amount of heat. This means, that if you upgrade from a DX to a DX2 you will need to take special measures to dissipate the additional heat.

A miniature fan which is mounted directly on top of the processor chip is one solution to this problem and such fans can be readily obtained from the many vendors of PC upgrade equipment. Since overheating, where the chip temperature exceeds 185F, can easily damage the processor chip (and bear in mind that this is probably the most expensive component in the system and a new one can cost you several hundred pounds) it is also a good idea to use an audible monitor to indicate when the system is overheating - we will show how to build such a monitor in next month's ETI.

Inside an Intel CPU

The Pentium is the most powerful member of the Intel 80x86 family of processor chips. By every standard it is a truly massive chip, the packaging is a pin gate array (PGA) and measures 2.13in square with 273 pins. Inside the packaging is a 0.8 micron fabrication technology BiCMOS chip with 3.1 million transistors etched on it and at 66MHz it draws over 13W of power. All of which allows it to deliver 112 MIPS of processing power. On these two pages we take a look at what is inside a Pentium chip and compare it with a typical 486DX.



Instruction decode

At the heart of every processor is an area of circuitry which converts the instruction code into a sequence of operations which are performed by the other parts of the CPU. The circuitry which performs this function works at two levels. Simple instructions, such as moving a byte of data between registers, are initiated directly by the circuitry, but more complex instructions require a more sophisticated approach: In essence these instructions are executed by small programs stored within the microcode ROM, which is part of the decode circuitry. They are stored as sequences of simple instructions. It should be noted that nearly all simple instructions are executed in one clock cycle, whereas complex instructions usually take two or more.

Code cache

To overcome the need to use wait states when accessing relatively slow RAM, the Pentium has a high speed 8KB instructions cache.

Code TLB

Translation lookaside buffers for the code cache.

Clock driver

This circuitry provides the complex synchronisation pulses, all derived from the main system clock, which are necessary to ensure that the processor works properly.

Bus interface logic

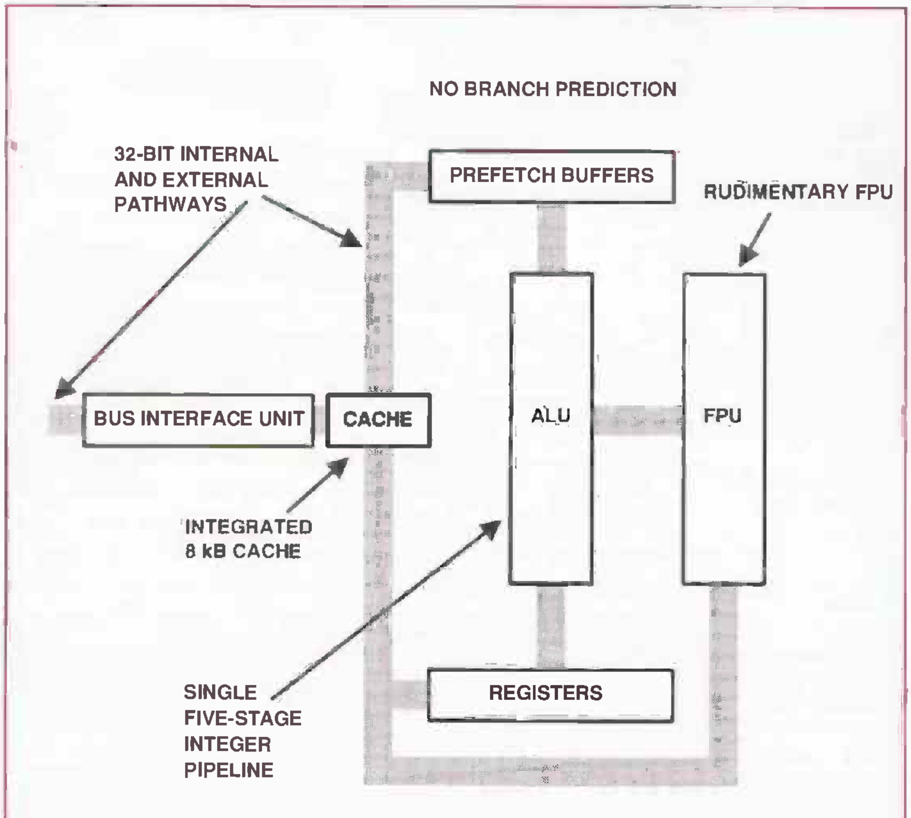
This interface logic connects the address, data and control buses of the main system to those within the CPU.

Data TLB

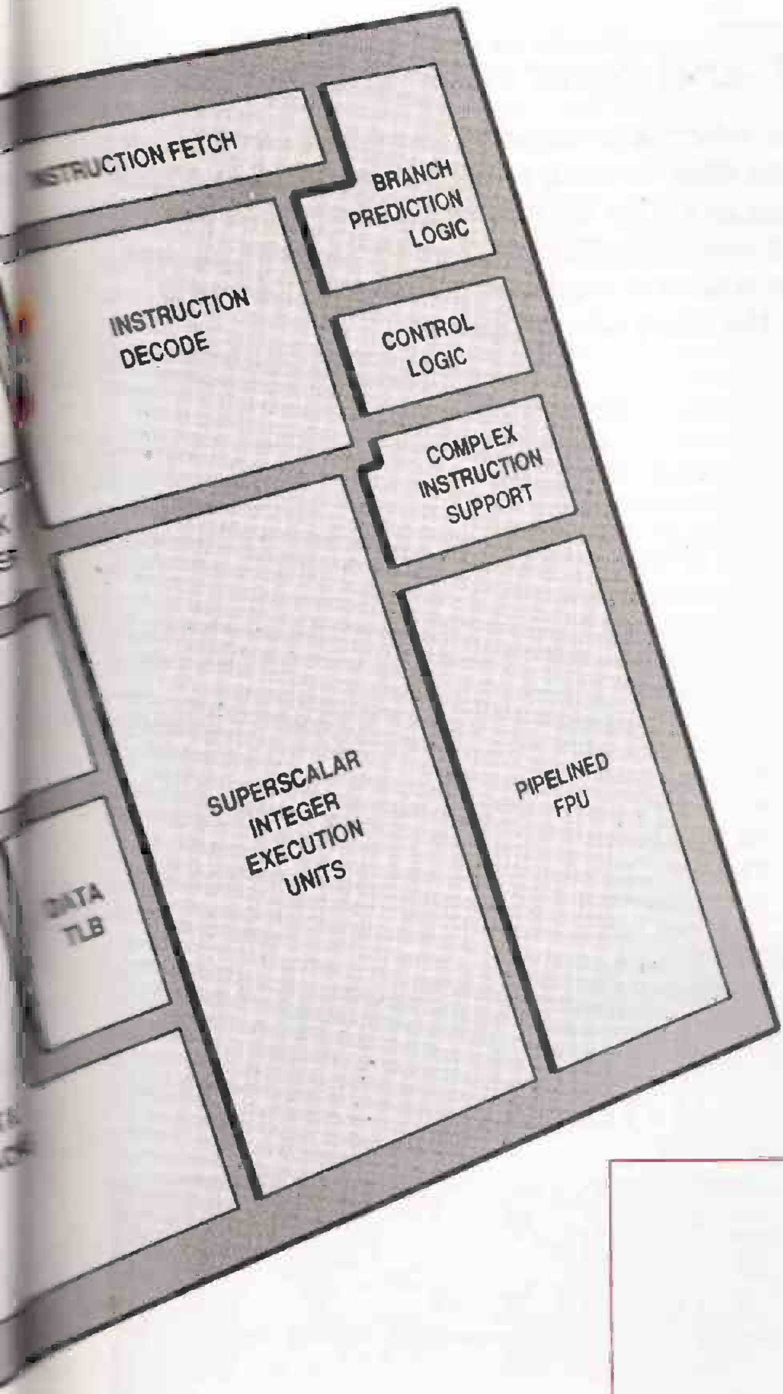
Translation lookaside buffers for the data cache.

Data cache

To overcome the need to use wait states when accessing relatively slow RAM, the Pentium has a high speed 8KB data cache.



Block diagram of a 486



Instruction fetch

There are two 32 byte instruction prefetch buffers, which process instruction addresses sequentially until it reaches a branch instruction. It then calls upon the branch target buffer to find the new instruction address.

Branch target buffer

The BTB contains information about previous branches and predicts whether the prefetched branch instruction will result in a branch or not. If not, then the prefetch will continue sequentially, otherwise the second prefetch buffer will begin to prefetch instructions based upon the BTB predictions. If the BTB prediction is wrong, then the pipeline is flushed and the correct instruction fetched, thereby causing a 3 clock cycle delay.

Control logic

The control logic circuitry handles the processor control bus and things such as interrupts, I/O requests, etc.

Complex instruction support

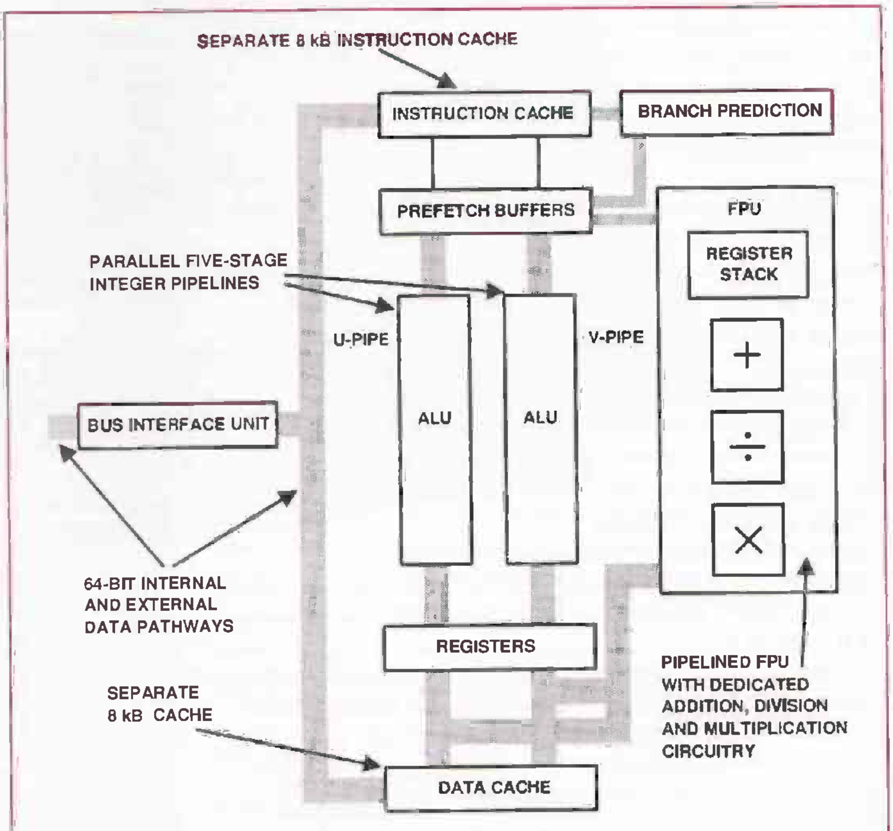
This is the part of the instruction decode circuitry which handles complex instructions that rely upon the ROM microcode. This circuity can be regarded as a processor in its right, but one which is embedded within the much larger processor.

Pipelined FPU

This is a pipelined floating point arithmetic unit with dedicated addition, multiplication and division circuitry. The use of dedicated circuitry means that no matter what the precision of the calculation, addition and multiplication is performed in just 3 clock cycles. Division will produce 2 bits of quotient per clock cycle. However, because of the pipelined architecture, it can actually achieve one addition or multiplication per cycle after the initial two cycle latency to fill the pipe is complete.

Superscalar integer execution units

In the Pentium, there are two parallel five stage integer pipelined arithmetic logic units. The fact that there are two integer ALUs means that the processor can fetch and decode two integer instructions at a time and, if possible, execute them in parallel. This means that when processing simple instructions, the processor's power can be considerably increased thanks to this parallelism



Block diagram of a pentium

BIOS – what is it and how can it be used?

When any processor is first powered up, or when it is reset by the reset circuitry, it is incapable of using programs straight from disk. In fact, it will know nothing about the system of which it is a part. It will not even be able to input data from the keyboard or output data to the screen. The only information that the processor has coded into it is a single memory address where it expects to find the start of a program, or a pointer to the start of a program.

Because the processor cannot yet load data from disk, this power up/reset system initialisation program has to be stored in non-volatile memory. Because it performs the task of actually defining the system and because it is permanently stored in ROM, it constitutes what is often referred to as firmware.

The PC is no different to any other computer system in this respect and this initial program is known as the system BIOS. If you look carefully at the motherboard you should be able to locate the one or two ROM chips in which it is stored (they often have a printed label stuck on top of the chip which identifies the source of the BIOS).

The name BIOS stands for Basic Input/Output System. Initially, the BIOS was developed by IBM, but comparable versions of BIOS are now produced by a number of other manufacturers, foremost of which are AMI and Phoenix. The different types of BIOS are all more or less identical, although the system has changed slightly over the years and old versions of BIOS may not work properly with some modern software.

The first function of the BIOS program is to test the system, to check that all its various components are working properly. This is the so called Power On Self Test, or POST, feature. If any failures are found, then they are reported as coded signals output on a special POST output port (this can only be accessed if you have the appropriate hardware). Errors are also signalled as coded beeps from the system's internal speaker.

Having checked that the system is running properly, the BIOS software then sets up a basic input/output system which allows user programs to have easy access to all the system components, by simply communicating with the BIOS I/O routines. This gives all PCs a universal software interface, irrespective of the actual system design and thus allows software to be easily moved from one PC to another without any compatibility problems. It also makes it far easier for the programmer, since he does not have to write specialist routines to directly communicate with disk drives, video cards, etc.

The final function of the BIOS program is to act as a bootstrap loader for the main operating system. In most PCs, this would be MS-DOS, but it could equally well be DR-DOS, one of the many different flavours of UNIX, or OS/2. The bootstrap loader searches for the operating system on disk, loads it and then transfers control to it.

One thing to remember is that BIOS routines can be extended and regularly are. The video display card will probably have a ROM containing a set of routines which extend the function of standard BIOS so that it can handle the hardware of the particular video display. Similarly, a hard disk controller may have a BIOS extension on the card. These applications card extensions of BIOS allow the operating system and hence application programs to utilise these devices, despite the fact that they are all probably very different from each other.

As has already been mentioned, older versions of BIOS can cause problems. A fairly general problem is that they can restrict the type of hard disk that can be used. Other problems are more applications oriented, but on some older 286 ATs the BIOS may cause problems when attempting to run advanced operating systems, in particular Windows 3.x. This is because the BIOS handles switching between real and protected mode operation and these early BIOSs were written before specifications on this operation were standardised.

Replacing the BIOS chip with a more modern version will unfortunately not do the trick and allow one to run this type of software - you will also need to replace the keyboard controller chip, since it seems that this chip is also involved in switching modes. Unfortunately finding any details of how the BIOS actually works is extremely difficult, a task made even harder for anyone living outside the US since all the BIOS producers are American.

However, unless you are involved in designing PC systems at firmware level, it is not really necessary to know about the inner workings of BIOS. What is important, however, is the fact that BIOS is the lowest level at which the system will operate. A system will run BIOS even without any functioning keyboard, display, or disk drives. This means that we can use BIOS to help us when attempting to repair a faulty system.

We can thus remove all the adapter cards and monitor the POST codes to prove that the motherboard is functioning properly, thereby proving that the fault lies in one of the adapter cards. If the motherboard is faulty we can use the POST codes to tell us where the fault lies. A knowledge of BIOS can also be of considerable use when developing hardware and software which interfaces directly to the PC - it is the most fundamental level at which the system operates.

POST Error Beeps

Problem area	Sound sequence
Power supply or system board	Repeating short or continuous beeps
System board, display board, or PSU	One long and one short beep
System board or power supply	One long and two short beeps
System board or power supply	One short beep and blank display
Disk drive, disk controller, or cable	One short beep and prompt for disk

Some of the more common POST Error Codes

Problem area	Error code number
System board	100-199
Battery error	161
Configuration error	162
Time and date error	163
System options not set	165
Memory error	200-299
Keyboard	301, 303, 305
Keyboard fuse	305
Parallel port	401
Floppy disk drive	600-699 (except 602)
Reference disk	602
Math coprocessor	701
Serial port	1100-1299
Hard disk drive	1700-1799
System board video	2400-2499
Pointing device	8600
Hard disk drive	10400-10499

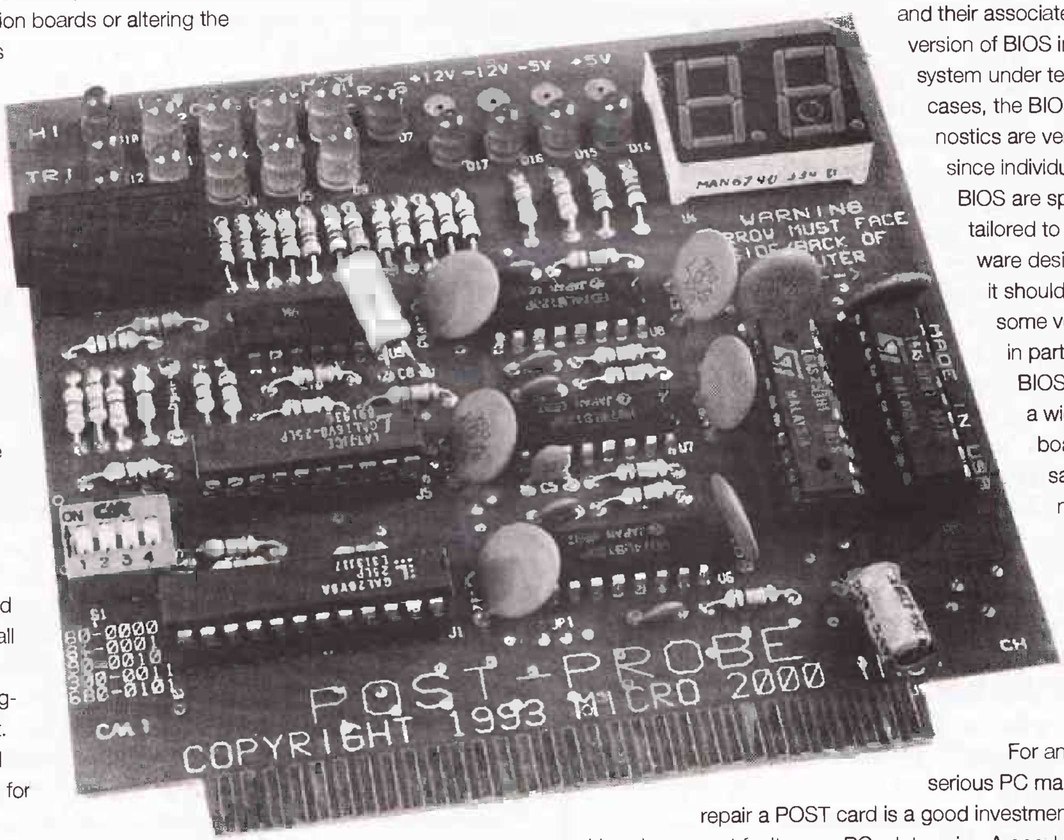
Using a POST probe card to check processor status

When you boot up your PC, one of the first functions of the BIOS routines is to perform a range of Power On Self Test, or POST, routines. These POST routines will check every part of the PC, the memory, the communications ports, the keyboard, video display and the disk drives. Unless your machine is faulty you will in most cases not be aware that the tests are taking place. Remember the way that your keyboard lights flash and the double beep before the hard disk is accessed and DOS loaded? These are the POST routines at work. However, if your machine is faulty, POST error codes could provide you with a valuable and accurate guide as to what is wrong.

There are three different ways in which the BIOS POST routines will tell us what is wrong with the system. The first is that it will generate a sequence of beeps on the internal speaker, with the beep sequence roughly indicating the fault area. The second way relies on the video display functioning, and POST generates one or more error messages which indicate where faults have been located.

The third way is probably the most powerful, since it can be used to diagnose faults in a motherboard without functioning video display or keyboard. Here, the error codes are output through an I/O port (on most EISA and ISA systems this is port 80) and can be displayed using a special plug in adapter card, commonly referred to as a POST card. The error codes displayed on the POST card's two digit hexadecimal display can be used to accurately pinpoint a fault to a specific area of the motherboard, or even a specific component.

At some stage in their lifetime, most PCs will generate some sort of POST code error. This is particularly likely to happen when adding or removing expansion boards or altering the configuration. It is also likely to happen when the internal battery fails and needs replacing. The fact that these can all cause POST errors means that whenever a POST error is encountered, the first step is to check that the batteries are OK, that all adapter cards are inserted properly, as are all cables and that the system configuration is correct. Only then should one start looking for faults.



The first step in any fault locating procedure using a POST card is to check the power supply to the system board (with the Micro 2000 POST card this is easy since the card has a built in logic probe and voltage test circuitry). Next, try removing and reinserting adapter cards in order to ensure that they are not the cause of the problem (not forgetting to switch off the power every time you remove or reinsert a card).

If you still have no luck, then power down the system, remove all the adapter cards one by one, except the POST card, reapplying power between each card removal. If the symptoms stay the same then the motherboard is probably failing. It is here that the POST card really comes into its own, since without it, problems can be very hard to track down. Shorts are a major source of problems and using the area indicated by the POST error code can be further traced with the aid of the logic probe.

First check the supply voltage and ground leads to the suspect chip. If a voltage is missing, then trace the line to its source. Shorts may be produced by defective resistors, ICs, or decoupling capacitors. In fact, such capacitors should always be checked, since this can be the cause of the failure.

With a POST card, it is a lot easier to track down and repair faults on a PC system board and it is surprising how often a fault is caused by the failure of a very cheap and easily replaced component. If you know what you are looking for, there is often every chance that a faulty board can be successfully repaired - forget those people who say that it is not worth doing and far better to just chuck the board away and replace it with a new one.

Note that this table can only be approximate, since the exact error codes used are different for each type of BIOS and for each type of hardware platform. Thus POST code 04 in Phonex BIOS signifies an error with the 8253/4 programmable interval timer chip, on the C&T BIOS that the 8237 DMA controller has failed and on AMI BIOS that there is a fault either with the 8259 programmable interrupt controller or with the CMOS RAM.

In order to get detailed information from the POST codes, it is essential to have a list of the codes and their associated errors for the version of BIOS installed in the system under test. In most cases, the BIOS POST diagnostics are very accurate, since individual versions of BIOS are specifically tailored to individual hardware designs. However, it should be noted that some versions of BIOS, in particular AMI BIOS, are written for a wide variety of boards with the same chipset, meaning that although generally correct, some codes may point to the wrong error.

For anyone involved in serious PC maintenance and repair a POST card is a good investment since it makes tracking down most faults on a PC a lot easier. A good example of such a card is the Micro 2000 POST Probe card and its associated diagnostic software, with which one can track down faults at all levels of functionality, even faults on boards unable to produce POST codes.

For more details on the POST Probe card contact Micro 2000 in Letchworth, on 0462 483483.

Watch out in future issues of ETI for our special build it yourself POST card project!

Cache Memory

Over the last few years, we have seen processor clock rates go up from 12MHz on a 286 AT to 66MHz on a Pentium or 486DX2 system. At the same time we have seen the amount of RAM in a system go up from 640K to 4, 8, or even 16+ MB, and the amount of hard disk storage go up from 20MB to 200MB or more. By any standard, a modern PC is thus an extremely powerful computer.

However, despite the powerful processor, lots of memory and a big disk we can no longer say that the performance of one make of PC is much like another, simply because it has the same processor, runs at the same speed and has the same general architecture. You only have to look at the benchmarks published by some of the PC magazines to realise this.

The truth is that, as well as bringing enormous processing power, high speed systems have also brought with them a lot of problems for the computer system designer. Problems which, in the way that they are solved, or are not solved, can make enormous differences to the performance of seemingly similar systems.

The problem with bottlenecks

The main reason for these design problems lies in the bottlenecks which can occur in the flow of data and instructions between the processor and the various types of memory used in the system. Bottlenecks can seriously reduce the actual processing power of the system, compared with its theoretical potential power and are moreover exacerbated by processor intensive applications such as Windows, CAD and DTP systems.

The reason that these bottlenecks exist is fairly simple. They are due to the fact that parts of the system are working much faster than data can be accessed from, or stored to, other part of the system. Thus, the access time of a standard RAM memory chip is longer than the fetch cycle of a 66MHz 486, the result being that the processor has to wait maybe two or three clock cycles for memory to be accessed. If we take statistical standard usage of a system with standard reasonably fast RAM, then the effective speed of a 66MHz system is reduced to an equivalent of one running at less than 55MHz, simply because the processor has to wait for memory.

The result of having a processor that is too fast for the available memory is quite a serious reduction in power. Computer system designers try to overcome these slow access speed related bottlenecks by using a special type of memory known as cache memory.

Cache memory is simply a block of memory which works at a higher speed than the ordinary RAM memory. By transferring the block of data and/or instructions currently being used into this cache memory, it is possible to eliminate a high percentage of the delays that would otherwise occur. This makes it possible for the system designer to more closely approach the theoretical maximum power of a given processor.

Memory hierarchy

In order to understand how cache memory works, we need to look at how a computer uses different types of memory. We can divide the memory resources of a computer into a hierarchy and on most systems there are two levels - short term, fast access RAM memory and long term, slow access, disk memory.

No programmer would attempt to write a program which ran directly from disk memory, in theory it could be done, but it would be terribly slow. Instead, the program stored on disk is transferred to RAM memory and run from there. The same applies to data - rather than slow down the system by accessing the disk directly for each byte of data, a whole block of data is transferred to RAM memory and accessed there.

The function of a CPU cache is to add another one or two levels to that hierarchy, which lie above RAM memory. At the highest level is the primary, or on chip, cache. The 486 has an 8KB cache on the processor chip and the Pentium has two 8KB caches. The level below this and immediately above RAM memory is the external or secondary CPU cache, which consists of between 64K and 1MB of very fast static RAM.

If we think of RAM memory as being short term memory, then the primary and secondary CPU caches are a type of selective memory in which are stored the most commonly requested pieces of program code and data. Thus, when the processor accesses instructions or data from main memory, a copy is simultaneously transferred to cache memory and all future accesses to that information will be to cache memory rather than main memory. This means that only the first access will be slowed down, all subsequent accesses will be at top speed. So, the more primary cache memory that is built into the actual processor chip, the better the overall improvement in performance. There are, however, limits to the amount that can be put on a processor chip, and anyway it is pre-set by the chip manufacturer, hence the need for external cache memory. Once again, a simple statement such as 'the system has 256K of cache' is insufficient to indicate performance quality, although of course, broadly speaking, the larger the cache the better the performance improvement.

Cache operation

The type of cache design used is very important, since there can be very significant differences in performance between different designs, especially when the cache is fairly small. There are three commonly used secondary CPU cache designs, fully associative cache, direct mapped cache and set associative cache. Of these, the fully associative cache is too slow for today's processors.

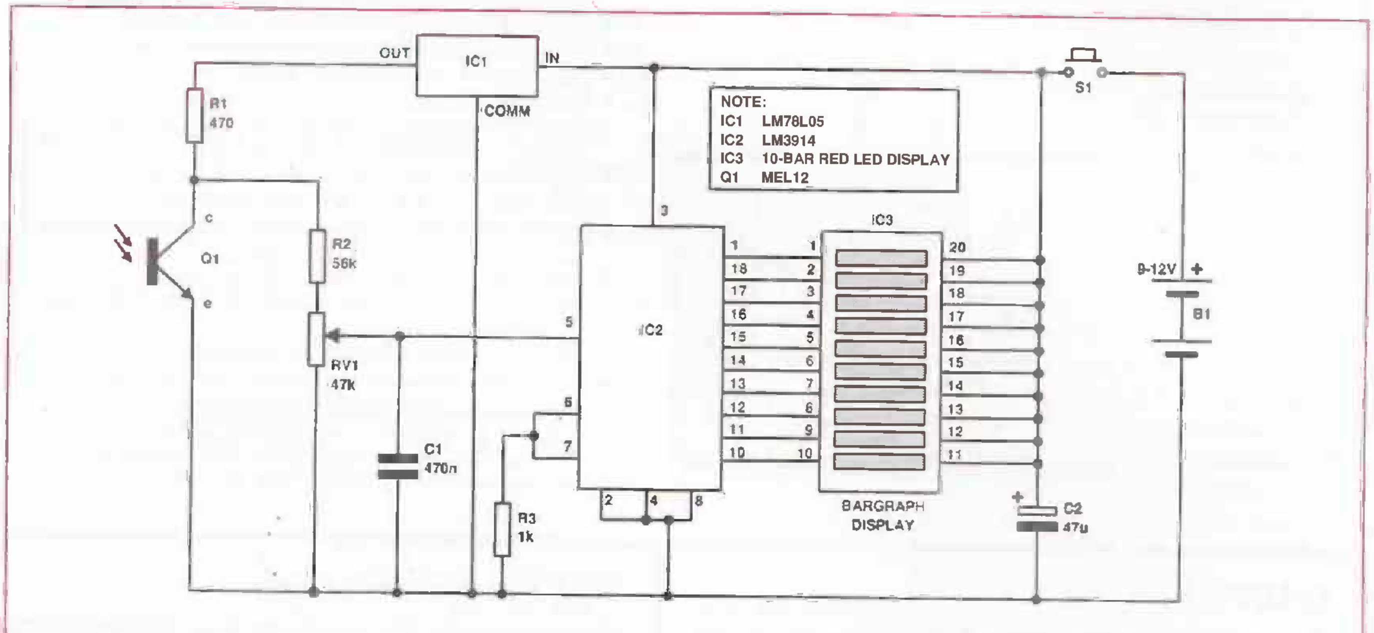
The cheapest and easiest design for a manufacturer to implement is the direct mapped cache, but this will only offer good performance if it has been properly designed. Indeed, if badly designed, a direct mapped cache can actually degrade a system's performance so that it is worse than a cacheless system. This is the result of a process called thrashing and can be a really serious problem when running multi-user operating systems.

Set associative cache offers all the best features of the other two designs but with few of the associated problems. It is fast and flexible and this technique has been used by the Intel designers for the primary processor cache on the 486 and Pentium. It is also the favoured design among top range PC manufacturers and is particularly good with multitasking operating systems.

Next month...

In PC Clinic next month we will be looking at how memory is used and organised in a PC, at upgrading the memory in your system and at tracking down elusive memory faults

VIDEO LIGHT METER



Video light meter circuit

Is it bright enough for good camcorder pictures? Terry Balbirnie's light 'meter' will tell you - instantly!

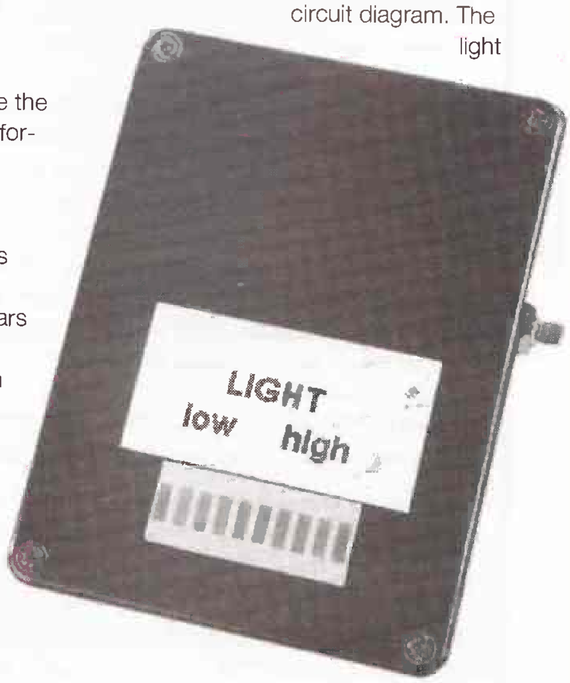
Modern camcorders will operate in extremely low light levels. However, the picture quality is often not very good under these conditions - a fact avoided in the advertising hype. Although some models do perform better than others, insufficient light shows itself with grainy pictures and degraded colours. The black-and-white viewfinder picture gives little indication of performance. Poor recordings will only show up when the tape is played back through a full-size colour TV and it may then be too late for a re-take. If the camera operator had been made aware of the problem at the outset, some extra light could have been laid on or the shots, arranged to exploit the existing light more effectively. Without a lot of practice, the eye itself is not good at judging light intensity, because of its ability to adjust to the conditions.

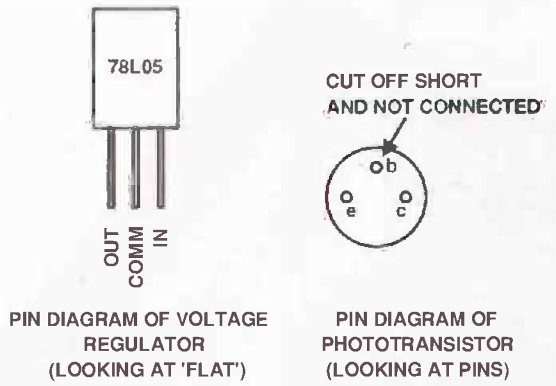
This Video Light Meter will indicate the ambient light level and hence the performance to be expected from the camcorder. In use, it will normally be pointed from the subject position towards the light - that is, it measures incident light. When a push-button switch is operated, one of the LED bars in a display glows to indicate the brightness. Since no current is drawn until the switch is pressed, and even then less than 30mA, a miniature battery will have a very long life.

Circuit Description

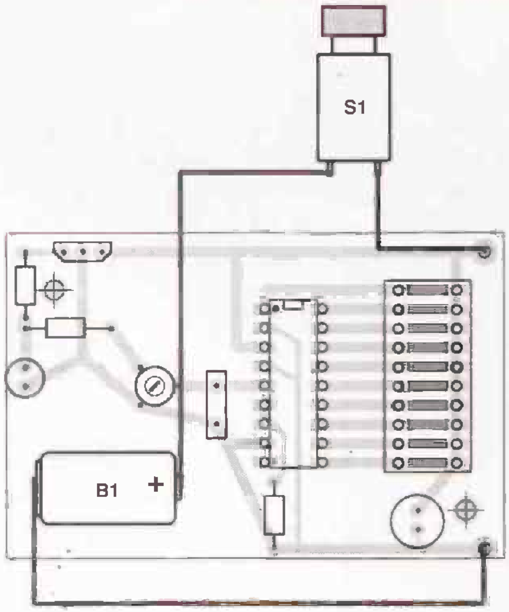
The Video Light Meter comprises four main parts - the light sensor itself, bargraph driver, LED display and stabilised supply for the light-sensing section.

Figure 1 shows the complete circuit diagram. The light

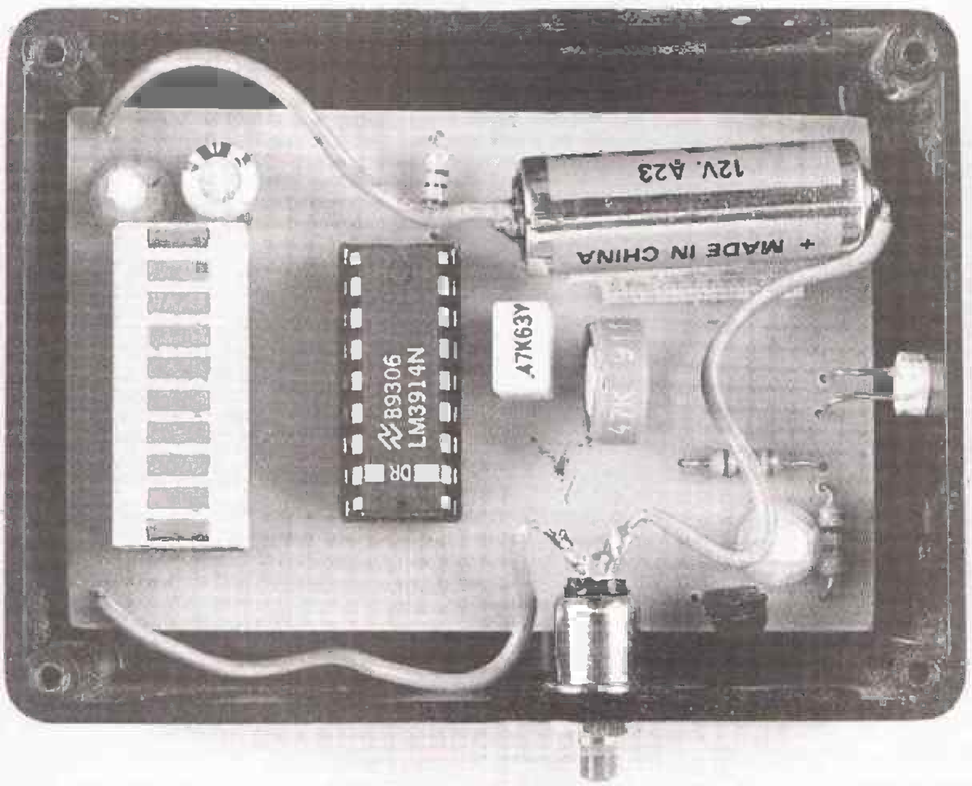




Pin diagrams



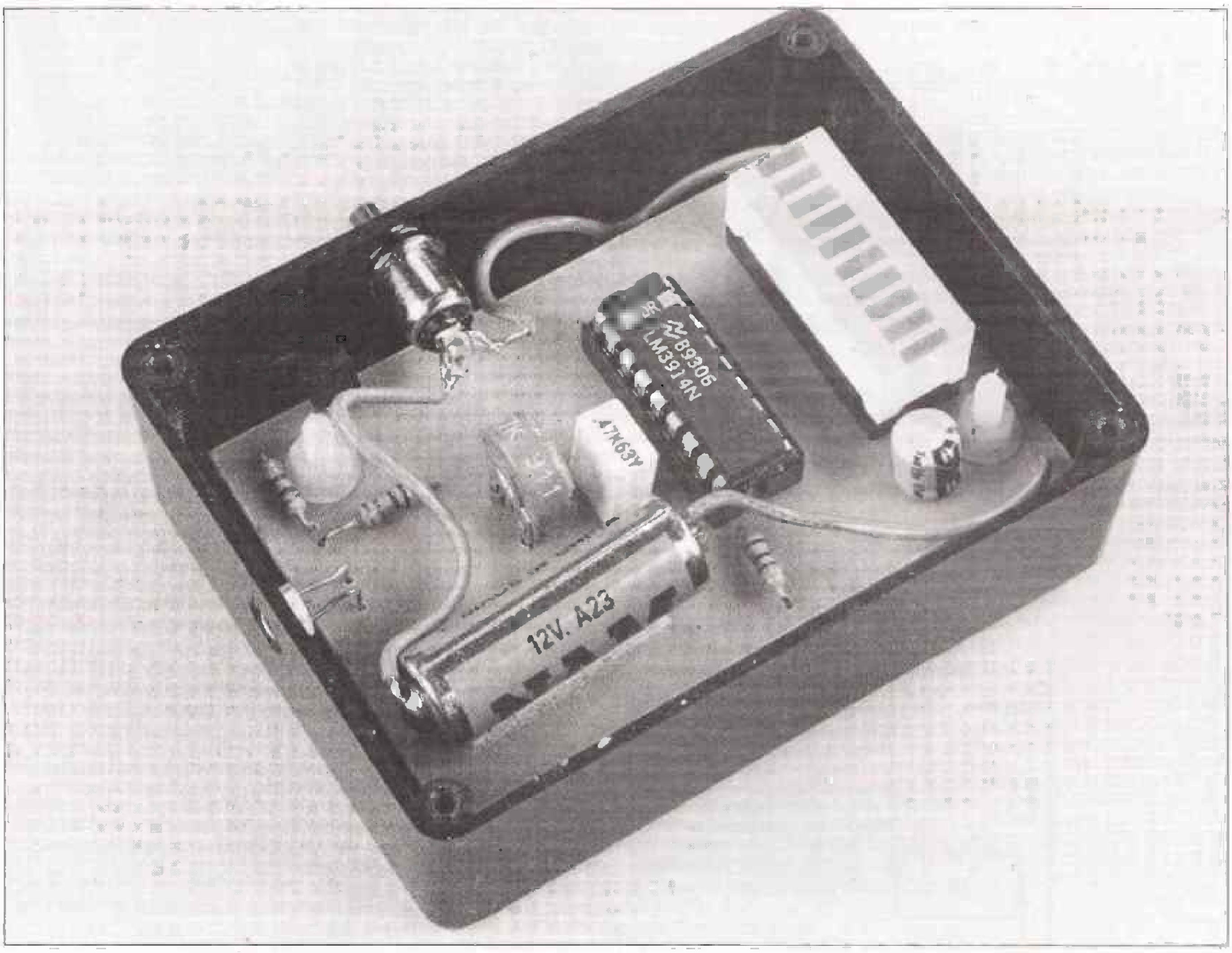
Wiring diagram



sensor is phototransistor, Q1, which has a window in the end that allows light to enter and strike the base-collector junction. The effect is equivalent to a photo diode and the light causes a small current to flow, which is subsequently amplified by transistor action. The brighter the light, the higher this current will be, up to a point. Increasing light intensity will therefore cause an increasing current to flow through load resistor, R1, and this will result in a greater voltage being developed across it. A falling voltage will then appear between Q1 collector and emitter. It is this reducing voltage which operates the rest of the circuit. Note that no bias is needed for the specified phototransistor, so the base is left unconnected.

The circuit is powered by a 9V or 12V battery. However, the phototransistor section is fed from a 5V supply derived from voltage regulator IC1. Without this, the voltage between Q1 collector and emitter would decrease as the voltage available from the battery fell with age. This would be interpreted by the rest of the circuit as brighter light and would upset the bargraph operating points. As it is, the circuit will operate correctly until the regulator fails to deliver a 5V output. This will happen when the battery voltage drops below 7V approximately. After that, the regulator output voltage will fall in sympathy. It is therefore necessary to check the battery every so often and the method for doing this is described at the end.

With phototransistor Q1 in bright light, approximately 0.7V will be developed between its collector and emitter. As the light level falls, it will approach that of the supply, i.e. 5V. This voltage is scaled down by the potential divider consisting of fixed resistor, R2 and preset potentiometer, VR1. It is then applied to the input, pin 5, of bargraph driver IC2. This device accepts a smoothly changing voltage so that as it increases, successive outputs 1 to 10 (pin 1, then pins 18 to 10 respectively), go low in turn to provide current sinks. The first output operates at 0.125V and the tenth one at 1.25V, so the



voltage provided by Q1 collector needs to be divided by four. This is achieved when VR1 wiper is at approximately mid-track position. However, the voltage at the wiper may be adjusted through wide limits. This provides the adjustment for the correct operating levels and will be made at the end of construction. Capacitor C1 promotes stable operation.

The bargraph display, IC3, consists of ten horizontal LED bars. All the positive (anode) ends - pins 11 to 20 respectively - are connected together and hence to the positive supply rail. The other (cathode) ends of the LEDs (pins 1 to 10) are connected to the corresponding IC2 outputs. As each output goes low, the corresponding LED bar glows. No conventional series resistors are required since current-limiting is carried out on chip with R3 determining the LED operating current, in this case 13mA approximately.

Construction

Before proceeding, decide on the type of box to be used as an enclosure. This will depend on the size of battery being used. Any small 9V or 12V battery will be suitable. In the prototype unit, a sub-miniature cylindrical 12V battery of the type used in cigarette lighters was chosen (see Parts List). Using this allows the small plastic box specified in Buy Lines to be used. A PP3 battery may be used if preferred, but the box will need to be larger.

Construction is based on a single-sided PCB and Figure 2 shows full topside details (parts placement diagram). Drill the two mounting holes then solder the two IC sockets into position. Follow with all fixed resistors (flat with the board), capacitors, C1 and C2 (observing the polarity of C2), preset VR1 and voltage regulator IC1 (taking care with the orientation, see Figure 3). Cut Q1 base lead short and gently bend the other two leads at right-angles (see photograph). Solder Q1 into position, so that its top points to the left. Do not insert IC2 or IC3 into their sockets yet. Adjust VR1 to approximately mid-track position.

Solder 8cm pieces of light-duty stranded connecting wire to the pads marked 'S1' and 'Batt -'. If a PP3 battery is being used, solder the negative wire of the battery snap to the pad marked 'Batt -'. Drill the holes in the case for the switch and for circuit panel mounting. Insert IC2 and IC3 into their sockets. It would be wise to touch something which is earthed, such as a water tap, before handling IC2 pins, because this device is static sensitive. The product lettering on IC3 as used in the prototype was on the right hand side - if it is inserted the wrong way round, it will not work.

Mount the circuit panel temporarily and carefully measure the position of IC3. Make a hole in the lid of the box directly above this and the same size. Mount the panel on short stand-off insulators so that when the lid of the case is in position, the display is level with the face of the box. Mark the inside of the box opposite Q1 position, remove the circuit panel again and drill a hole with the same diameter as Q1 at this point. Fit the switch and complete the wiring as shown in Figure 4. Replace the circuit panel and adjust the phototransistor leads so that its face protrudes slightly through the hole drilled for the purpose.

If the sub-miniature 12V battery is used as in the prototype, mount it in the free area of the circuit panel, as shown in the photograph, using a pair of Velcro fixing pads. The connecting wires may be soldered to its terminals using minimum heat from the soldering iron. A PP3 battery could be secured to the base of the box in the same way.

Testing

A basic test can be made by pointing the sensor towards bright light and pressing the switch. By slowly covering the hole with a finger, there should be a response from the LED bars. If this test works, it is then only necessary to adjust VR1 for correct operation. The lid of the case will need to be in position (although not screwed down yet) so that Q2 receives light only through the hole. Adjustment to VR1 is made in a series of small steps with the lid replaced after each one. Cover the sensor with black tape to prevent all light reaching it. It will probably be found to be impossible to adjust VR1 so that all LED bars are off. It will therefore be set for the first bar to represent total darkness. Press the button and adjust VR1 so that the first bar is on and just before the point of changing to the second one.

Set the camcorder on a tripod and zoom in on a detailed picture such a colour magazine advertisement pinned to a wall. Vary the amount of light in the room and make some test recordings to determine the level at which picture quality just begins to degrade. Point the sensor towards the camera from the subject position and note which bar operates. The other bars may then be interpreted and labelled. Colour-coding could be used, possibly red, orange and green, but this was not thought worthwhile in the prototype. Note that it is normal for there to be a slight overlap so it is possible for two adjacent bars to be illuminated at once. After making any final adjustments to VR1, it only remains to secure the lid and put the Video Light Meter into service.

The device may also be used in reflected light mode, by pointing the sensor towards the subject. Experiment to find out which method gives the best results.

Battery Check

The condition of the battery should be checked every so often. To do this, cover the sensor so that no light can enter. Press the button and observe the display. The first bar should light. If a higher one glows, the battery must be replaced.

PARTS LIST

Resistors

R1	470
R2	56k
R3	1k
VR1	47k

Capacitors

C1	470n ceramic
C2	47µ 16V PCB electrolytic.

Semiconductors

Q1	MEL12
IC1	LM78L05
IC2	LM3914
IC3	10-bar red LED display

Miscellaneous

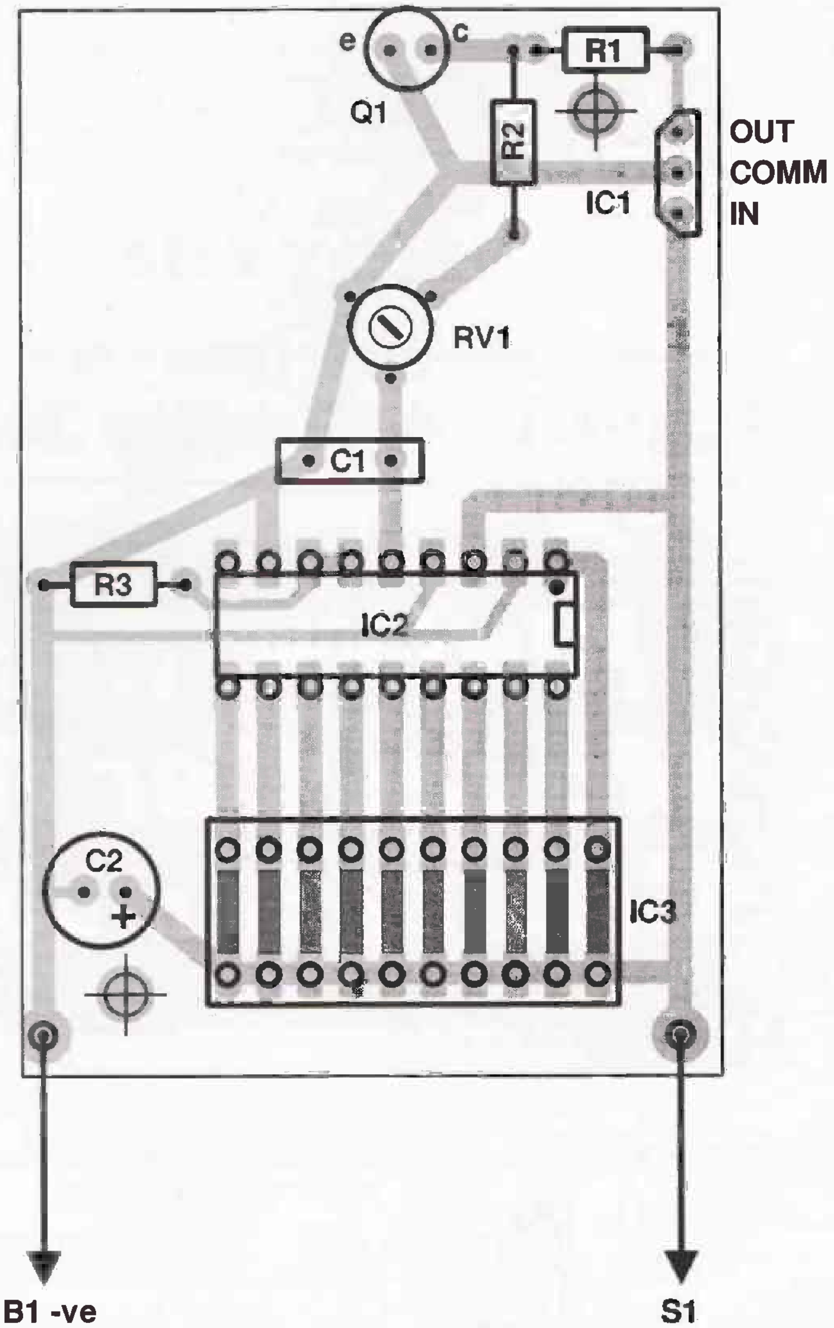
S1 Miniature push-to-make switch

B1 Miniature alkaline 12V battery type GP23A or PP3 battery and battery snap (see text).

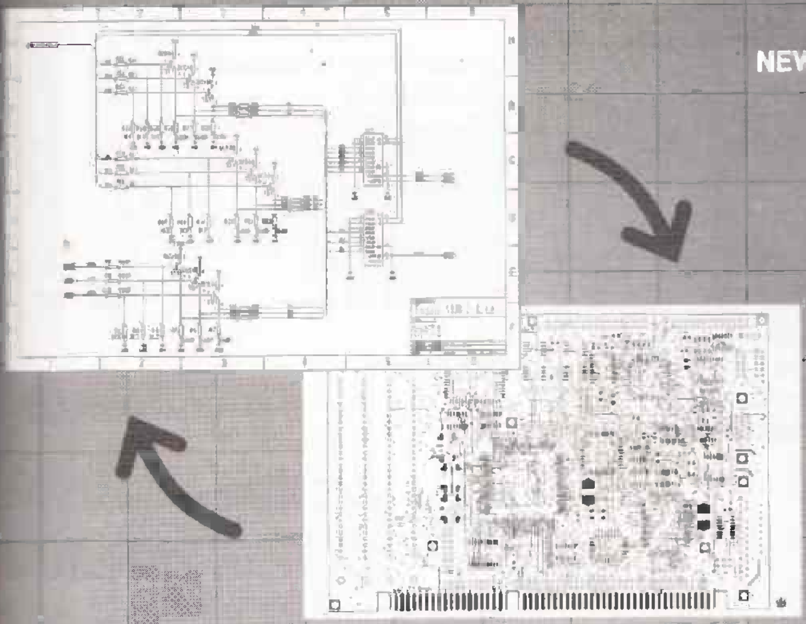
18-pin d.i.l. socket; 20-pin d.i.l. socket. PCB materials, plastic box

Buy Lines

Most of the components for the Video Light Meter are freely available. The MEL12 phototransistor may be obtained from Maplin. The box used in the prototype was type T2 size 75 x 56 x 25 mm from Maplin. A larger one will be needed if a PP3 battery is used.



Vidio liligt meter component overlay




Maker

MAGNETISM AND MAGNETOMETERS

Magnetism is a subtle and mysterious force that influences a lot of things around us. Keith Garwell embarks on a practical exploration of how to measure minute changes in a magnetic field

For the radio enthusiast, changes in the earth's magnetic field can be used to indicate likely changes in propagation. For the astronomer, the same changes are likely indicators to the advent of auroras and similar heavenly signs. Down to earth, measurements of local magnetism are very helpful to the archaeologist, amateur or otherwise. Unfortunately, while one can go into many a local shop and buy a combination voltmeter/ammeter/ohmmeter for only a few pounds, one cannot easily go into one's local emporium and buy a magnetism meter (magnetometer) and certainly not for a few pounds. Hopefully, I am about to redress this balance, at least in part.

Before delving into the nitty gritty, it may be as well to know something of what we are talking about.

The first dreadful shock to older readers will be to discover that Gausses are out and a new unit is in, to whit the Tesla. This is a very large unit - the field which would generate 1V along a wire 1m long moving at 1m/sec.

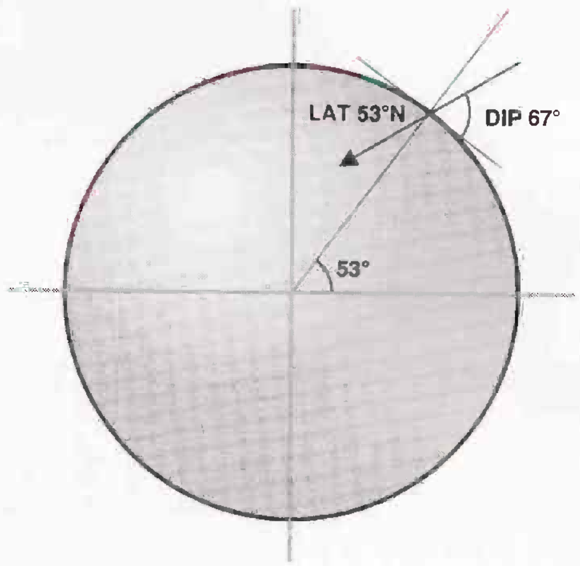
If you cast your mind back to the classroom, you will hopefully remember that the earth's magnetic field has a horizontal component that appears just West of North. Indeed, if you look at your friendly large scale Ordnance Survey map you will find a note giving the deviation between true North and Magnetic North, the Magnetic North being currently some 5 degrees West of true North.

You may also be able to remember something about the 'angle of dip'.

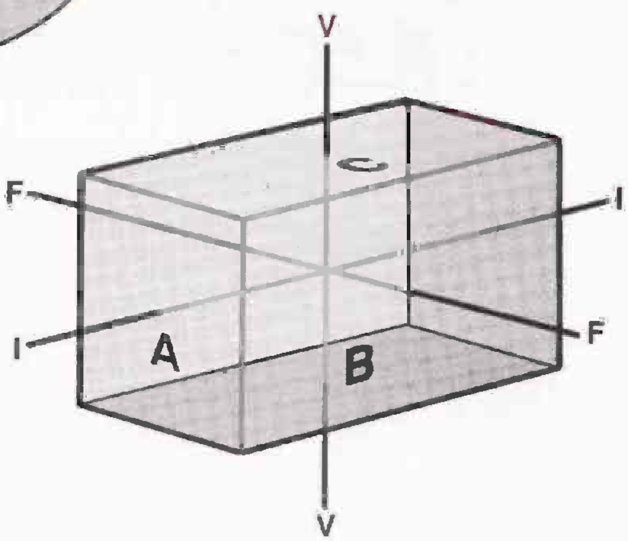
Imagine an ordinary magnetic compass mounted on its side so that the needle could point downwards. Orienting the compass case North/South would leave the needle pointing downwards at an angle of some 67° to the horizontal. Remember, these are approximate UK figures, they differ both locally and globally.

If you think about it, this is all fairly reasonable as the North Pole isn't really where the compass is pointing when it is horizontal, because it will be at a tangent to the earth's surface and the earth being a sphere, it will be pointing out into space. Only if it were pointing downward as well would it be pointing to the true (well, nearly) origin. However, everybody is used to compass needles which only rotate in the horizontal plain and it's much more convenient too.

Figure 1 suggests the situation. Unfortunately, if drawn to scale the situation gets worse. The line set by the dip angle points to the interior of the earth. In fact the source of the earth's field is believed to be due to some form of dynamo effect within the earth's core which has a very high iron content. This is expected to be a fluid or semi fluid movement which will perhaps account for the continuous change in position. My Ordnance Survey map shows the yearly change as 9 minutes of arc to the East.



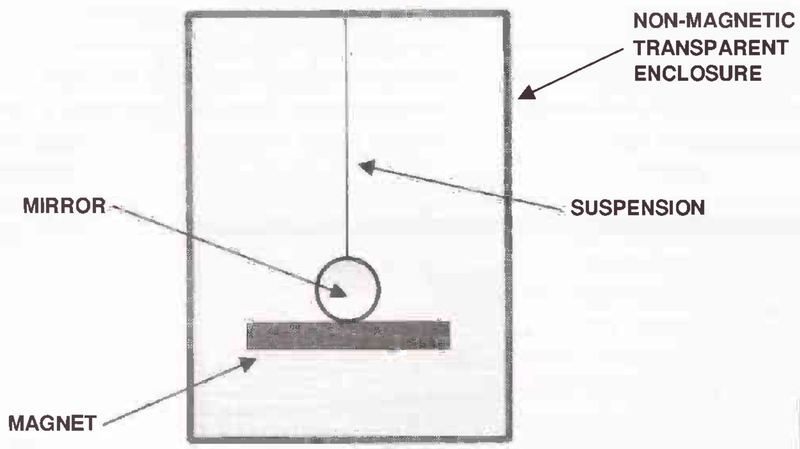
The earth's field, or to give it its more usual name in exalted circles, the geomagnetic field, is quoted as two vectors with respect to true North and a true horizontal (tangent). Where I'm sitting, these are 18.5 micro Teslas at 5.3° West



of North and 48.6 micro Teslas at 67.6°. Further North, for instance, at Eskdalemuir, the figures are 6.3 West and 69.3° (Ref. Dr D R Barraclough. British Geological Survey. Edinburgh).

These figures are from time to time upset by disturbances which have various effects on our environment. The changes are quite small, primarily being a change in direction. There is a small daily variation of around 15 minutes of arc in the horizontal, but a disturbance (often referred to as a magnetic storm) may amount to as much as one degree and last for a day or two. The corresponding variation in field strength is normally about 4 nano T for the horizontal and maybe 20nT for the vertical. A 'storm' may produce a change of a few hundred nT.

This suggests that, for those interested in the earth's field, the equipment should be able to show changes of a few minutes of arc, not necessarily in absolute values.



Types Of Magnetometer And Their Characteristics

There are several types of magnetometer, some more suitable for a particular kind of task than others. They can be classified by the basic principles on which they operate.

The oldest type and one of the simplest to construct is the moving magnet. It consists of a simple magnet, operating in the same way as a compass except that the magnet is suspended by a thread either of a metallic but non magnetic material such as phosphor bronze, or in this day and age nylon or similar. The most important features are that it must not have a twist in its construction, discounting threads such as cotton and it must be thin enough to allow free movement of the magnet.

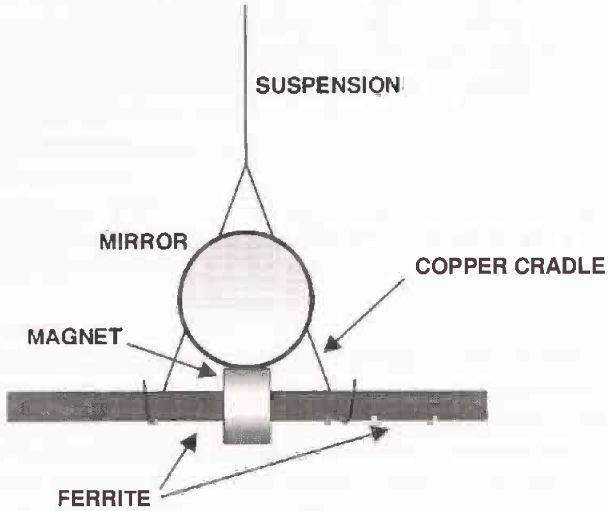
This type of device is not really portable because of the flimsy nature of the suspension. If it is to be ported, then some special feature must be incorporated to support the magnet whilst in transit. Consequently, this type is popular for fixed stations where the interest is primarily in changes of direction in the geomagnetic field. As it is always aligned with the field, it cannot show change in magnitude. I shall discuss later the design of such an instrument in two forms - one that is read by a visible indication and one that is read electronically.

One of the latest types makes use of the Hall-effect. Consider a block of some conducting material (Figure 2), the three visible faces being A, B and C. A current is maintained between face A and its corresponding hidden face, with the flux to be measured applied to face B. This flux will cause electrons to diverge towards the C face or its hidden counterpart, establishing a voltage between the two faces (I seem to remember Fleming had a rule about the direction of motion).

It is now possible to obtain semi-conducting versions of the Hall-effect device. For simple indications of magnetic intensity this type of device is convenient and portable, but the linearity of the devices is more or less in direct proportion to their cost and sensitivity. For example, in the Electromail/RS catalogue one available at around #8 generates 9mV per mT. Changes in the earth's field are rather beyond them and they are not inherently suitable for determining direction. However, they are very small and simple to set up and are thus ideal as probes for investigating magnetic circuits.

The most versatile is the fluxgate magnetometer and modern electronic components have really brought this type to the fore. A fluxgate magnetometer is portable, its sensitivity is good and with care in construction can be very accurate, reading down to nano Teslas. It is also direction sensitive, which has the advantage that it can distinguish more than one field and unwanted fields, such as the earth's, can be balanced out.

Briefly, it consists usually of two ferrite rods, each of which carries a winding. The rods are



arranged side by side and the windings excited by a pure (no harmonics) AC drive. Around the pair of rods is arranged a third winding, the sense winding. Any external field causes the second harmonic of the excitation to be generated and it is this harmonic which is used to indicate field strength. The construction of this type will be discussed in a fairly simple form in detail. The earth's horizontal field (18.5μT) will give an output of around 3V DC on the divide by 10 range. The windings don't have many turns (300 is the most) and the electronics can be assembled on strip board. This will be followed by the enhancements which can be made to improve it further.

There is one other type that must be mentioned, which depends on atomic behaviour - the proton precession magnetometer. This also has the advantage that it is portable and it measures total flux from whatever direction. It is useful in that a general survey of flux density can be carried out, without the necessity of pointing it in the right direction. The other side of the coin is that it is unable to distinguish more than one source of flux.

The principle is that a small container of liquid, usually alcohol, is subjected to a strong steady field, the polarising field, perhaps by means of a coil wrapped round the container. This field is switched off and the frequency of precession of the protons is measured by means of the same coil, or a second one. This frequency indicates the flux strength remaining after the polarisation is removed. The effect dies away in a few seconds, allowing measurements to be repeated fairly rapidly. As it has a limited, use I am not proposing to give more detail in this article.

Moving Magnet Magnetometer

The MMM is constructed fairly easily from items to be found in most bits and bobs boxes. A fair bit of patience is needed with the setting up and a bit of dexterity in making it, but otherwise it should be fairly straightforward. Don't make a start until you have read the whole of this section, as there are one or two points which are critical

It consists of a suspended magnet to which a small mirror is attached. If you know a dentist, then the small surface silvered inspection mirror is ideal. Failing that, a small mirror can be cut from a back silvered mirror, about 3/4 of an inch square will do.

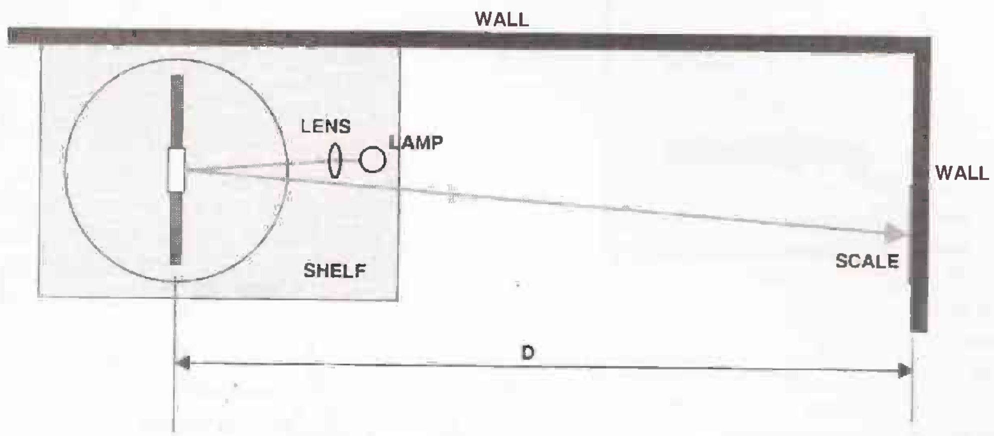
The device will be very susceptible to drafts and therefore must be enclosed within a suitable draft proof enclosure. It must also be transparent, of course. Figure 3 suggests the arrangement. Sweet jars, jam jars and unused gold-fish bowls are all typical of the type of container which is suitable. The gold-fish bowl will require a lid. Don't use any absorbent material such as wood, because it is not dimensionally stable and of course iron or steel is out. The amateur electronic engineer's favourite - aluminium - is ideal.

Since the modus operandi is to shine a light on the mirror and use the reflection as the indicator, moulding marks on glass jars can be a nuisance. However, you will be very unlucky if you cannot find a large enough clear patch as the movement is very small. It may just be necessary to experiment a little when you come to set it all up. An excellent scheme if you are handy with Perspex is to make a case up and there is no need for it to be circular.

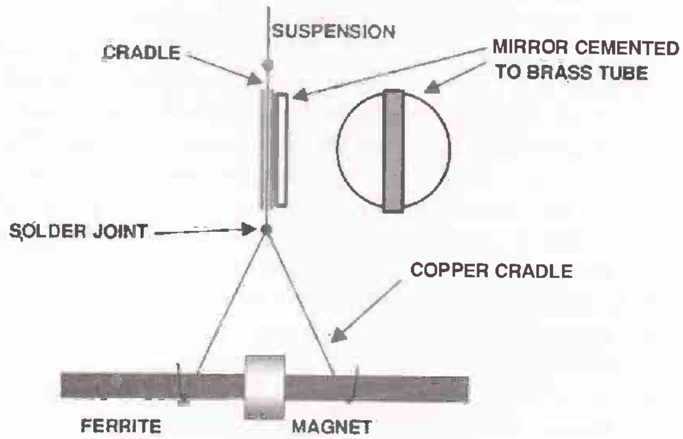
The suspension can be either fine fishing line or very thin copper wire. The fixtures in the fishing line are best sealed by heating. The big advantage of copper wire is that the joints can be soldered and Figure 4 suggests a possible construction.

The type of magnet is not dramatically important. The longer and more powerful it is, the better it will align itself in the magnetic field and the small magnets used to operate read relays and security switches may be too small. However, I can see no reason why several should not be set end to end until the available length is four or five inches.

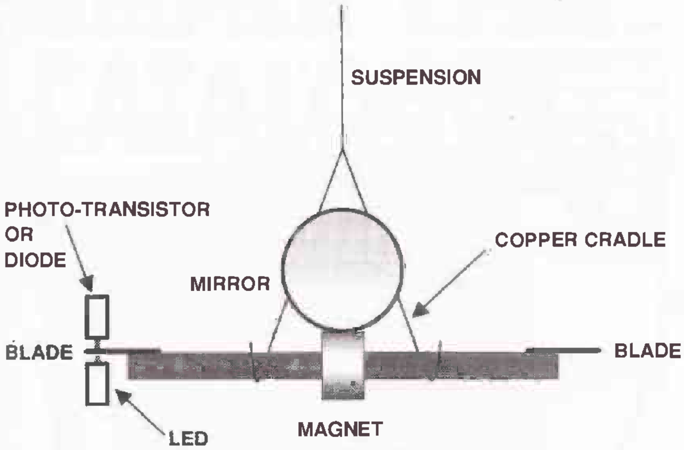
I tried cheating, with quite good results. As it happened, I had some small disc magnets about a half an inch in diameter. A ferrite rod about 5in long was cut in half and the magnet arranged in the centre. Incidentally ferrite rod is extremely hard and you will not be able to saw through it without a diamond saw. Much simpler is to make a small notch at the centre with a hack-saw, then put pressure on this point until it snaps. Maybe I was lucky, but having made the shallow notch I held it against the thumbs of both hands with my fingers and just applied thumb pressure. It snapped with quite a clean break, but in any case the two original ends were quite square so they were used as the inside ends against the magnet. A cradle or stirrup was made from thick copper wire as shown and some Araldite or similar resin will complete this part of the exercise.

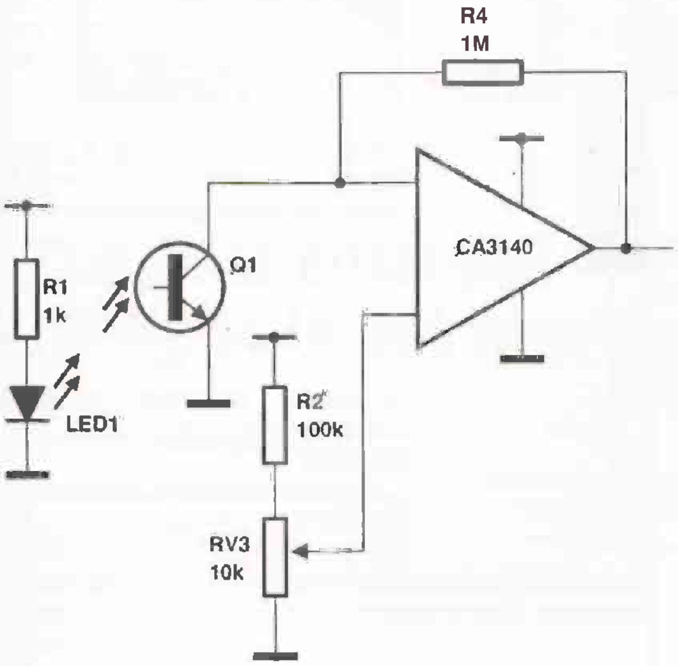


The next requirement is a small bulb with preferably a straight filament, because we shall have to use the image of the filament as the indicator. A round MES 12V is probably the best. Run it from a suitable transformer and either adjust the voltage down or add a series resistor, to extend the life of the bulb and limit any filament movement. Only enough light to see the projected image clearly is needed.



A lens will be required which is capable of projecting an image of the filament onto a surface 2 or 3 metres away. This is





also a matter of experiment. I happened to have one or two lenses in my 'photographic' box and an old projector lens seemed to be best.

Remember, the lens will of necessity be separated from the mirror by the 'anti draft' container. It is best to make a mock up of this part of the device so that you are sure it will work. Clearly, the more elegant the lens, the clearer the image of the filament will be. However, the object of the exercise is really to give a patch of light that has some clearly defined point which can be used as the reference, not necessarily a perfect image of the lamp filament.

If you don't have lenses, how about trying one of the fairly cheap plastic eye glass lenses? Alternatively, a small laser would do the trick. And set you back about £60!

Figure 5 suggests the layout in plan view. Before any construction starts, it is essential to decide on the location to be used. There are one or two restrictions. The first depends on the minimum distance D between the mirror and the scale, the very least is 2m, 4m is nearer the mark. The arithmetic behind this statement comes in a moment.

Just as importantly, there must be absolutely no movement between the support for the magnet, i.e. its enclosure, the lens assembly and the scale. If it's at all possible, much the best arrangement would be to mount the assembly on an aluminium shelf fastened to a brick wall. Then fasten the scale on the brickwork also as suggested in Figure 5.

A wooden building would be unsuitable because there would be too much movement dependant on weather conditions. However, if there is no option, the only suggestion I have is either a rigid aluminium frame to which all the parts are attached, or to mount the magnet assembly and lamp on a concrete base and arrange that the spot from the mirror shines in through a window.

Figure 5 is drawn as if it were attached to a wall which runs due East-West, in which case the magnet will be slewed by just 5° and Figure 5 will work like a charm. In practice walls are not built conveniently and accurately in this way, so as a consequence the mirror may have to be attached at an angle to the magnet. This can best be done by rehashing Figure 4 slightly, so that the stirrup is extended vertically by a piece of the same copper wire, cementing the mirror to a piece of brass tube and sliding it over the extension. Then attach the extension to the suspension. The mirror can then be turned relative to the magnet until it all works and then be fixed with a dab of cement. See Figure 6 for the alternative to Figure 4.

Now some fairly simple arithmetic.

The sort of movement we are looking for is around 5 minutes of arc or less and up to 1°. To arrange that 1 minute of arc gives one millimetre of movement on the scale:

1 minute = 1/(360 x 60)th part of a circle and this must be 1mm. The circumference of a circle is $2\pi r$, but in our particular case the distance D in Figure 5 is the radius, so the circle is $2\pi D$ and this equals 1/(360 x 60).

So, D=360 x 60/2 x π = 3438mm.

However, the reflection from the mirror will turn through twice the angle of the mirror movement so in fact the above distance can be halved to 1719mm, say 1.72m.

The minimum D of Figure 5 is 1.72m and in fact it would be easier to read changes if it could be made greater than this. To cover the general case therefore, given the distance D in metres, one minute of arc will be represented by D x 0.582mm. (D x 4000 x π/360 x 60). If it's more convenient the other way round then, if there are M millimetres of scale per minute of arc, then the required distance D in metres will be M x 1.72.

Setting Up

There are no short cuts, it's just a painstaking job of getting the magnet assembly and lamp lens assembly together on a rigid non magnetic base as the first step.

It may need a fair bit of patience to set the mirror so that the reflection appears in the right place - after the magnet assembly has finished swinging! If the mirror is movable in respect to the magnet, use a dab of cement (one of the resin glues is good) which is not quick setting so that you have time to adjust it before the cement hardens.

Don't take the readings too seriously for a day or so as it does need time to settle.

Making The Moving Magnet Magnetometer Machine Readable

The MMM as built so far can only be read by inspection. However, as we now all have chart recorders (ETI April 94 et seq), a much better picture of the way the geomagnetic field changes can be obtained if the readings are recorded. It also helps to avoid the slightly embarrassing moments when in the middle of a social evening one has to announce "Excuse me a few moments, I just have to go and read my magnetometer".

A quite simple arrangement is suggested in Figure 7, in which the ends of the magnet have been extended with thin aluminium blades. One of these intercepts the light from an LED shining onto a photo transistor and there is no absolute need for a blade at each end of the magnet, it's just a simple way of making sure it remains balanced by adding an identical weight at each end.

It is best to use infra-red devices encapsulated in black infra-red trans-missive plastic to reduce the effect of ambient light. Even so, you may find it necessary to enclose the device in a light proof cover.

One can obtain the two infra-red devices in one moulding, which makes mounting much easier. However, be careful - some of these are switches, the detector includes a trigger so the device does literally switch from one state to the other. Such a device is not suitable for this application as the detector must be a linear device.

A suitable circuit is suggested in Figure 8. This shows a photo transistor as the sensor but a photo diode is a suitable alternative. Two comments are valid here. A photo transistor frequently does not have its base connected and the base connection is often not available. Secondly, the photo diode is usually operated in the reverse biased mode.

I suggest the value of R1 as 1K for the first trial. R2 and R3 are 100K and 10K respectively and R4 is 10M. Using a CA3140 as IC1, output can swing between 0 and approximately 9V. Aim for somewhere round the middle of this range when setting up.

Setting the device up is quite tricky, as the blade of the magnet has to just intercept the beam. To do this, note the maximum and minimum voltages at the output of the op-amp. One is with the blade fully covering the photo device and the other with the blade fully withdrawn. R3 can be adjusted to help get this right. If this is not sufficient, then the value of R4 may have to be changed. A little experimentation may be called for.

The next step is to move the device so that with the magnet free to move and when it has settled down to pointing North, the output from the op-amp is roughly in the middle between the limits noted above.

If using a cover, it may upset the readings when fitted. Try carefully moving the device clockwise or anticlockwise to see if the reading can be restored.

One point which I nearly forgot and may not be obvious. The 12V supply must be regulated. The current consumption is very small, about 20 mA, so the power supply need not be anything very extravagant.

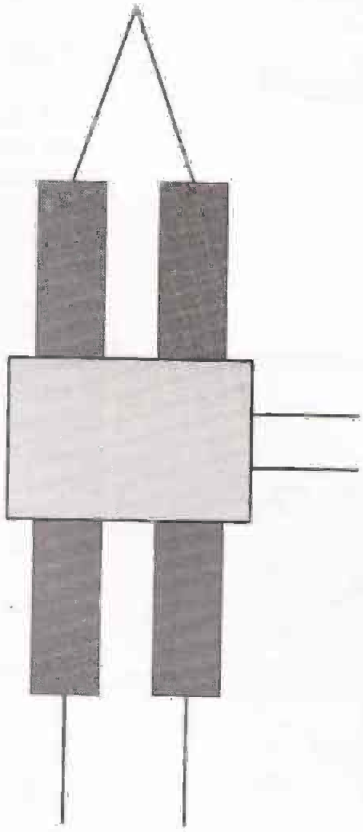


Figure 9a: Plan view of Fluxgate Magnetometer showing sense winding arangement

The Fluxgate Magnetometer

Those who are have worked with magnetic amplifiers or mag-amps will find the workings of the flux gate magnetometer familiar. The FGM to be described illustrates all the principles involved, but leaves the enthusiast room for experiment and enhancement.

It is also designed to be adjustable in gain and offset so that it can be a bit of a jack of all trades, but with adjustment and enhancement at least master of some.

For example, its sensitivity is such that it gives about 3V for the horizontal component of the earth's flux, with the design sensitivity reduced by 10. If required, therefore, the gain can be altered so that it gives 5V for 50mT, 10μT per volt. This is a convenient scale where direct readings of field strength are required, enabling both horizontal and vertical components to be measured.

Similarly, its circular sensitivity is about 3V for 7° as developed, (7mV/minute). This sensitivity to rotation means that the normal small changes in the earth's field (5 to 10 mins of arc) would produce an output change of 35 to 70mV.

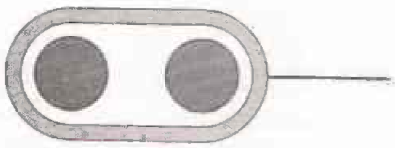


Figure 9b: End view of Fluxgate Magnetometer

Next month...

We will continue with building the fluxgate magnetometer, plus two other magnetometer designs.

Headlight Reminder

Don't let your car battery go flat by forgetting to turn off your lights. L.S. O'Connor builds a lights-on reminder for your vehicle.

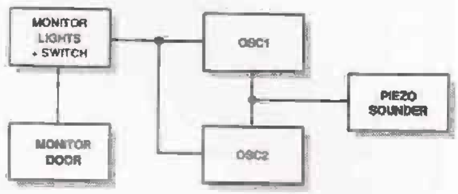
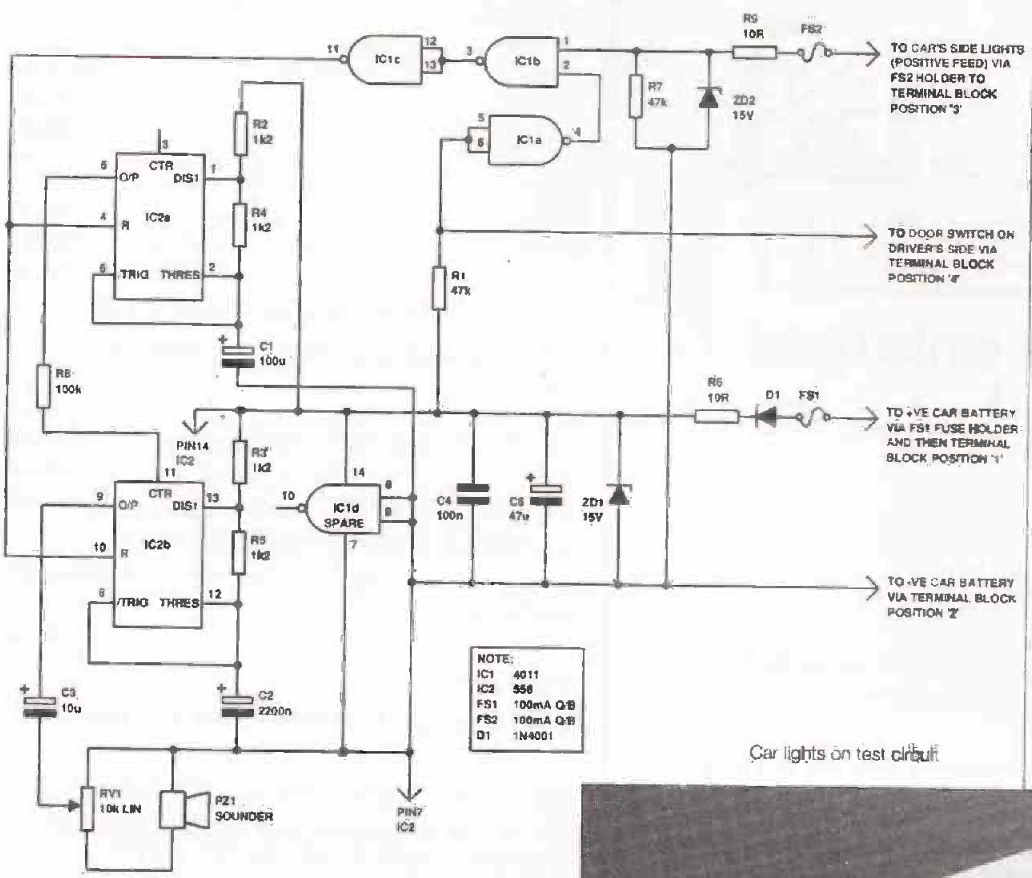


Fig 1.Car lights on test block diagrams



Car lights on test circuit

This car lights reminder circuit warns you with a warbling tone should you try to exit your vehicle with the car lights still on. It has a variable volume control, enabling you to set your own desired volume level and is built from three separate modules - Monitor Lights checks whether the lights are on or off, the Monitor Door checks whether the door is open or shut and the Switch, which is activated if the lights are on and the door is open, switching on the two oscillators that drive the piezo sounder (see Figure 1).

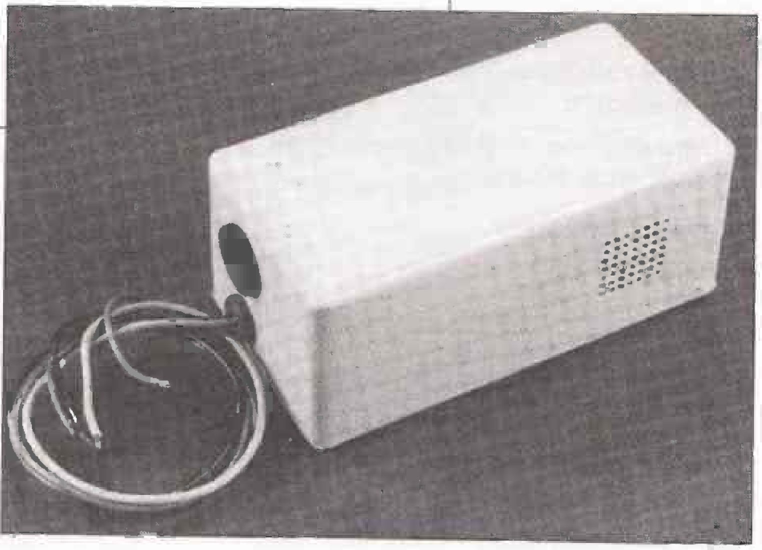
How It Works

The circuit is based upon a quad two input NAND

IMPORTANT

This circuit has been designed for negative earth vehicles only and will not function with the positive earth type.

To determine your car's polarity, look at your battery terminals and note which terminal is connected to the car's chassis. If it is the negative terminal then your car is a negative earth, if it is the positive then it will be positive earth. Most cars are of the negative earth type.



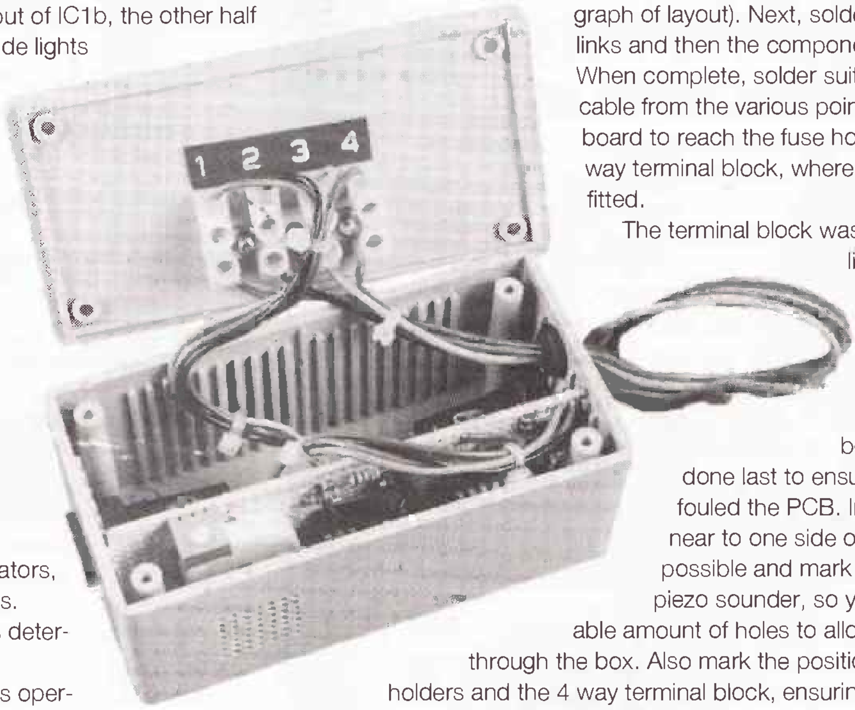
gate, IC1, and a dual version of the 555 timer, IC2. IC1a is connected as an inverter and checks whether the door is open or closed. With the door closed, the door switch is open circuit and R1 pulls the input high, so the output is low (see Figure 3 for truth table). However, when the door is opened, the door switch grounds the input of IC1a, changing the output to a high. This is fed to one half of the input of IC1b, the other half being connected to the car's side lights power feed. R7 is a pull down resistor and ensures that the input is low when the lights are switched off. The output of IC1b remains in a high state until both the inputs are taken high so with the lights switched on and the door open, the output would change to a low. This is fed to IC1c wired as another inverter, which is used to provide the correct logic level required by the IC2a and IC2b reset pins.

Both IC1a and IC1b are connected as astable multivibrators, producing square wave outputs. IC2a is operating at 4Hz and is determined by the formula 1.44/(R2+2R4)C1, while IC2b is operating at 1.8KHz 1.44/ (R3+2R5)C2. Both IC2a and IC2b are held switched off by the low output from IC1c, connected to the reset pins 4 and 10, so therefore they are only allowed to oscillate when the reset pins are taken high. This only occurs when the lights are on and the door is open. The output of IC2a is fed via R8 to the control input of IC2b, which has the affect of modulating the output of IC2b by changing the threshold set internally, giving us the warbling affect.

The output of IC2b is passed through C3 and VR1 to drive the piezo sounder directly, with VR1 setting the desired volume level.

D1 protects the circuit from reverse polarity connections and R6, R9, ZD1 and ZD2 clamp any high voltage spikes present in car electrical systems to a safe level. C4 and C5 smooth the supply.

FS1 and FS2 are there should the circuit start to draw an excess of current due to a fault.

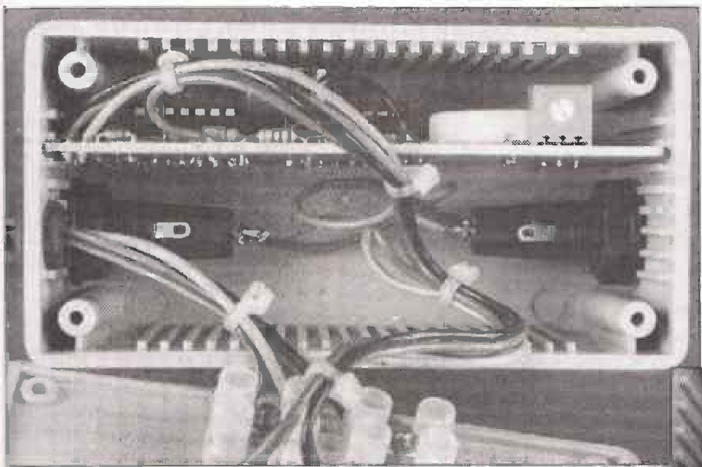


Construction

The prototype used an ABS box from Maplin (Part no: YU52G). This has slotted walls to accept the PCB and internal dimensions of 49.5 x 99.5 x 40mm. The Veroboard was cut to fit the slots and was 39 strips x 14 holes. Using these dimensions, cut the tracks at the various points (see photograph of layout). Next, solder the appropriate links and then the components (smallest first). When complete, solder suitable lengths of cable from the various points on the circuit board to reach the fuse holders and the 4 way terminal block, where they are to be fitted.

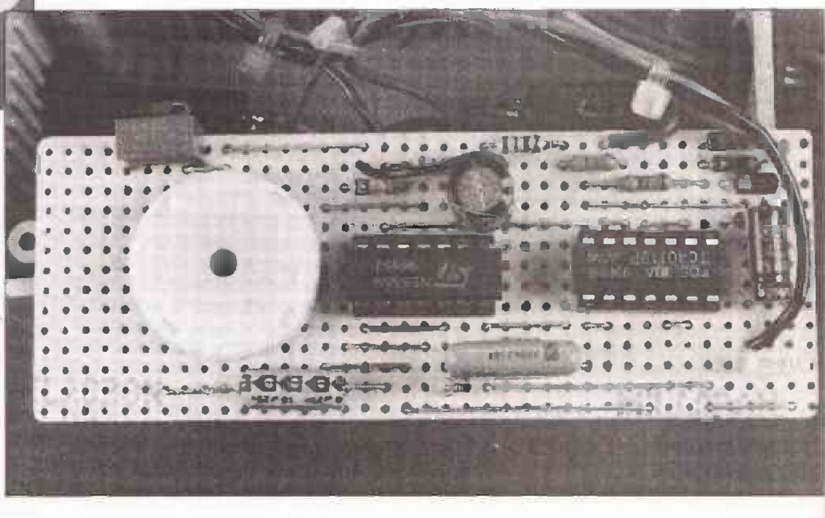
The terminal block was mounted to the lid on the inside, using two 6BA nuts and bolts and the fuse holders at either end of the box. These were done last to ensure that neither fouled the PCB. Insert the PCB as near to one side of the box as possible and mark the position of the piezo sounder, so you can drill a suitable amount of holes to allow the sound through the box. Also mark the positions of your fuse holders and the 4 way terminal block, ensuring that they do not block the PCB. An additional hole was drilled at one end and a grommet fitted, to allow for the through cables connecting to the various points of the car.

Finally, with the fuse holders and terminal block in place, solder the positive feed from the terminal block (position 1) to the fuse holder FS1, and from FS1 to the positive cable from the circuit board. Solder the lights from the terminal block (position 3) to the fuse holder FS2 and from FS2 to the lights feed cable, from the circuit board. Connect the -ve cable from the circuit board to Position 2 and the door switch cable from the circuit board to Position 4 of the terminal block.



Testing

With the unit fully assembled, testing can be carried out as follows. Using a PP3 battery or similar, connect the positive terminal to Position 1 of the terminal block and the negative terminal to Position 2. Link Position 3 to Position 1, which simulates the lights being switched on. Now momentarily link Position 4 to Position 2 to simulate the door being opened



and the sounder should now be operating.

Remove the link from Position 3 to 1 to simulate the lights being switched off. Momentarily link Position 4 to Position 2 and the sounder should remain silent.

If any of the above tests fail, then check all your connections, the cutting of the tracks and that all of the components have been inserted the correct way round. Finally, check the fuses.

Installation

There should be no problem with the installation, provided that you follow these procedures. You will require a suitable multi-meter in order to make the correct connections.

Normally, I would recommend disconnection of the car battery prior to fitting, but due to the ever increasing number of car radios that are security coded and cars fitted with micro-processor controlled management systems which require a constant source of power for their operation, it would be advisable to do the installation with the battery still connected.

Ensure that both FS1 and FS2 are removed and that the car ignition switched off. Locate a constant source of power and using auto type cable, connect to Position 1 of the terminal block, housed inside the control box. If you use the Scotch-Lock type connectors, this will allow you to crimp your cables in parallel with the existing cable and so avoid the need to break the existing cable. Next, find a suitable earth and connect to position 2 of the terminal block.

Now connect position 3 of the terminal block to the live feed of the car's side lights. Switch on your side lights and they should still come on, even with the ignition switched off. I found the best place to make a connection was down by the side light itself, unless of course you have easy access to behind the side lights switch, in which case you can make your connection their.

Wherever you decide, check with your multimeter that it is the live feed for the side lights, by switching the lights off and observing that the power is indeed removed.

Connect Position 4 of the terminal block to the door switch on the driver's side, which operates the car's interior light. If there is a single wire on the door switch, this means that the switch is earthed by the cars' chassis and operation of the switch connects this wire to earth and completes the circuit. All that is required is to make your connection to that single wire. If, on the other hand, you have two wires attached to your door switch, then this means that the switch is of the plastic type and that there is a separate earth to the switch. Operation of the switch just connects the two wires together and you need to make your connection to the non-earthed wire, which can be found by switching your multimeter to the ohms position and attaching one probe to the car's chassis and the other to either of the two wires. Make your connection to the wire that breaks the continuity when the door switch is operated.

Making sure that the side lights are now switched off, insert both FS1 and FS2 into the fuse holders, switch the lights back on and open the door. You should hear the sounder emitting the reminder tone. You can now adjust VR1 to the desired volume level. When you either switch the lights off or close the door, the sounder should cease.

Finally, fit the lid and tuck the control box up under the dashboard. If any of the above fails, then re-check all your connections and fuses.

PARTS LIST

R1, 7 47K
R2, 3, 4, 5 1K2
R6, 9 10
R8 100K
VR1 10K

Capacitors

C1 100µF 25V DC Radial
C2 0.22µf 25V DC Polyester
C3 10µF 25V DC Axial
C4 100N Mylar
C5 47µF 25 V DC Radial

Semiconductors

IC1 4011 CMOS QUAD 2-Input NAND
IC2 556 CMOS DUAL 555 Timer
D1 IN001
ZD2 15V Zener
PZ1 Piezo Sounder

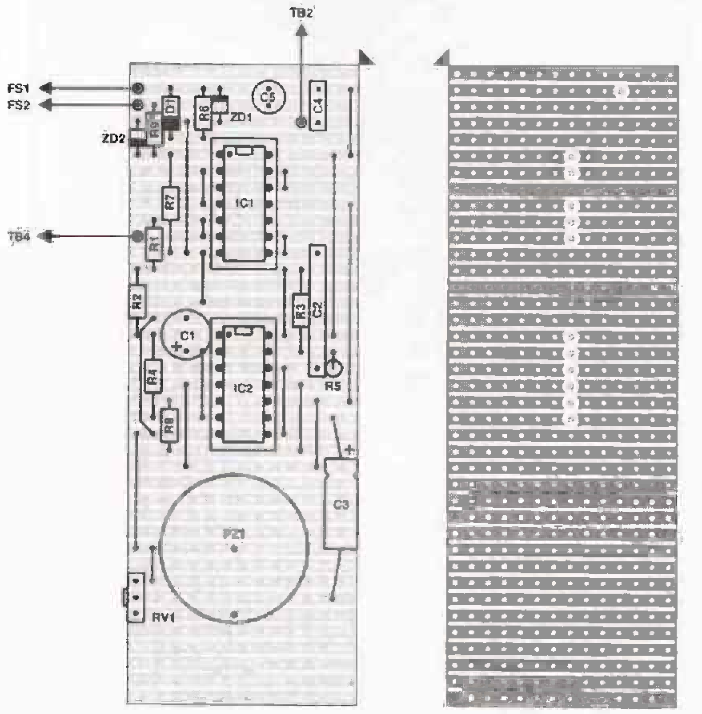
Miscellaneous

ABS Box (Internal) 49.5mm x 99.5mm x 40mm
2 x Fuse Holders 20mm Flush
2 x Fuses 100 NA Q/Blow 20mm
1 x Rubber Grommet
Stripboard 0.1in Matrix, 39 Strips x 14 Holes
4 Way Screw Terminal Block
2 x DIL Sockets, 14 Way
2 x 6BA Nuts and Bolts (counter-sunk)
Required length of Auto Cable (16/0.2mm)

Approximate Cost: £8.00

A	B	C
0	0	1
0	1	1
1	0	1
1	1	0

Logic for car lights on tester



Component layout on stripboard and track cutting positions

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AUTOMATIC TELEPHONE RECORDER ATR1 Adapt the tape recorder included to record telephone calls automatically.	34.95	—	59.00
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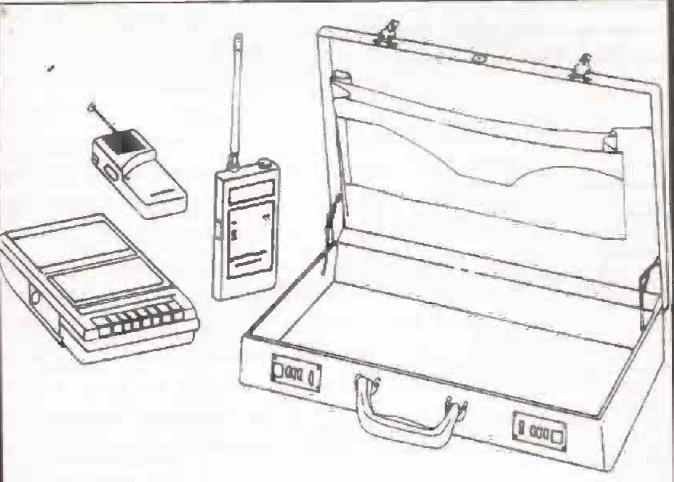

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MIDI EXPLAINED

In Part 3 of Robert Penfold's series on MIDI, he takes an in depth look at channel messages

In last month's article, the subject of MIDI modes was covered, and a start was made on the related subject of channel messages. In this article we will consider all the remaining channel messages in some detail. These are the most important messages, since they are the ones that are used to play notes, provide touch sensitivity and pitch bends, change to a different set of sound generator settings, etc. Every MIDI user needs to know what channel messages are available, and have at least a fundamental understanding of the way in which they function. Anyone who is involved in the writing of MIDI software and/or the design of MIDI hardware needs to understand every bit of every MIDI channel message. Full details of MIDI channel message coding will therefore be provided, for those who need it. If you are not into do-it-yourself MIDI software or hardware, this sort of detailed information is of purely academic importance. As note on and note off messages were fully covered in last month's, article they will not be considered again here.

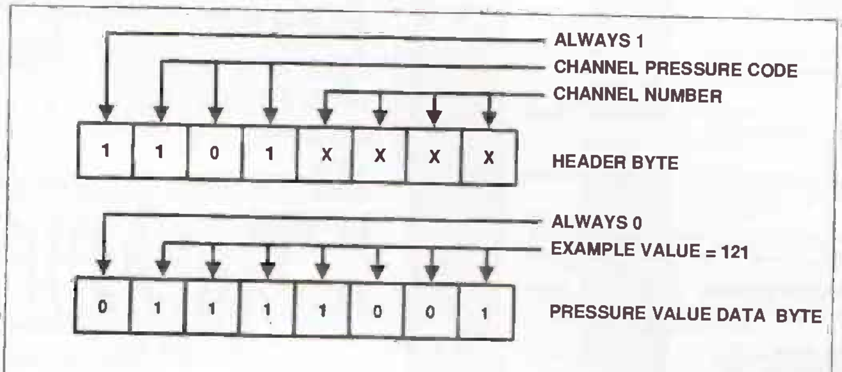


Fig.1. The program change message is a simple two byte type

All Change

Program change messages are one of the most simple forms of MIDI channel message. The name of this message is a slightly perplexing one, but in this context a 'program' is normally a set of sound generator parameters. This message is therefore used with a synthesiser to change from one sound to another. For instance, this message could be used to change an instrument from a trumpet sound to a guitar sound. Although this might not seem to be particularly useful, most instruments will respond to this type of message very rapidly, making it possible to use program changes mid-sequence. This is a form of channel message and it is therefore possible to individually change the sound of each voice of an instrument operating in mode 4 or a multi-mode. This may still seem to be a clever but not particularly useful feature, but it can greatly enhance the capabilities of a sequencer system, particularly a budget system. Suppose you have an eight channel instrument operating in mode 4. On the face of it, this system can only operate using eight different instrument sounds (one per MIDI channel). However, by using program change messages it is possible to use several times this number of sounds. A channel could play a piano sound first, then a cello sound, then a bass guitar

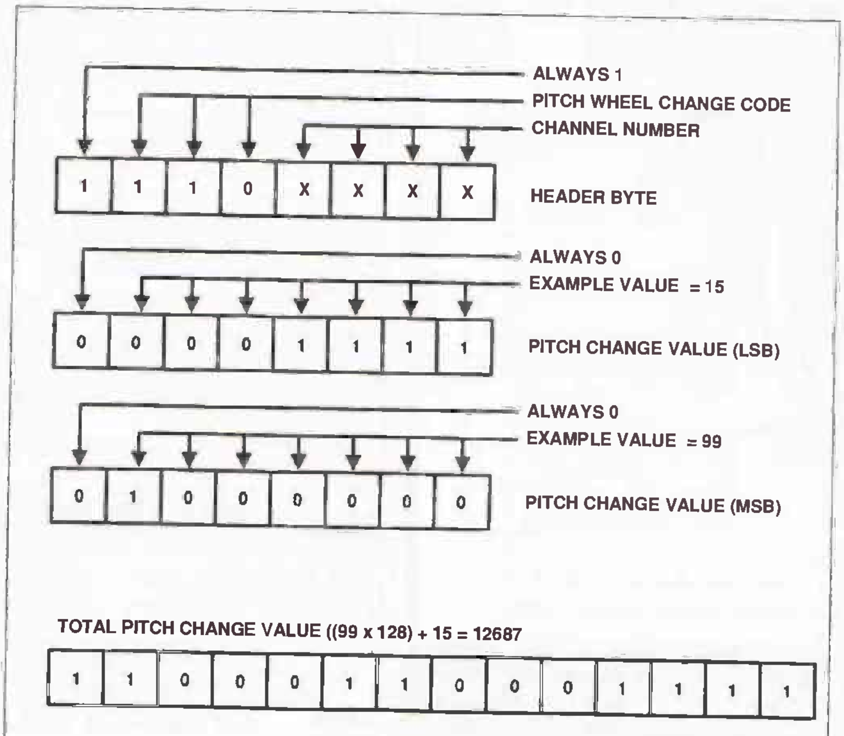


Fig 2. Pitch wheel change messages provide 14 bit resolution

and so on. By having several different sounds on each channel, with each one being played in turn, it is quite possible to have eight channels but a total of a hundred or more different sounds.

There is an obvious limitation in that our example system can provide no more than eight different sounds at any one time. For most users, this is not a major drawback though, since they would not wish to use large numbers of sounds simultaneously. Of course, even with a system that has a separate voice assigned to each of the sixteen MIDI channels, program change messages are still a useful means of squeezing a little bit more power out of the system.

Although only envisaged originally as a means of switching an instrument from one sound to another, program change messages can be used to change any MIDI device from one set of control settings to another. These messages could therefore be used to control a lighting unit, MIDI patchbay, audio mixer, digital effects unit, or any MIDI equipped device. Some non-instrument MIDI units do make use of program change messages, but it is only fair to point out that this method of control is not always used. There seems to be an increasing use of system exclusive messages to control patchbays, mixers, etc. Where an instrument or other MIDI unit can be controlled via program change messages, this is often a very easy and convenient means of control. Generating the right system exclusive messages can be difficult, particularly if it is a slightly obscure piece of equipment that you are trying to control.

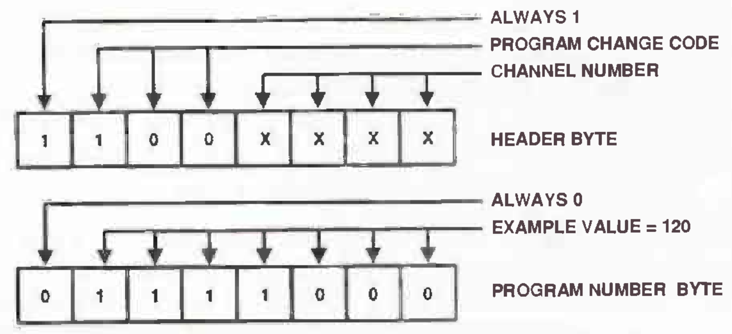


Fig.3. Overall key pressure is the more simple form of aftertouch

Practically any MIDI controller can produce program change messages. Most keyboard instruments can be set up so that they will transmit the appropriate program change message each time they are set to a new program number. Consequently, there should be no difficulty in getting the slave instruments to follow changes implemented on the master instrument.

Program change messages have great potential in sequencing work, but their usefulness in 'live' performances should not be overlooked either. For any user of program change messages, there are a couple important points which must be kept in mind. One of these is simply that this is a form of channel message. If you have several instruments or voices of instruments operating on different MIDI channels and you require them all to switch to a new program number, a different program change message is needed for each channel. This problem does not arise in a simple system that has the slave instruments in an 'Omni on' mode, or all operating on the same channel.

Sequencing using program change messages is usually quite straightforward. It is not normally necessary to become involved in getting a certain sound assigned to a particular program number. There should be no difficulty in using the default settings of the instrument and using the appropriate program numbers in the program change messages. The same is not true for those who use these messages during 'live' performances. The slave units have to be carefully set up so that they always provide the correct sounds, as they follow the program change messages from the master instrument. It should always be possible to assign any set of sound generator parameters to any program number and many instruments have facilities that make it easy to copy a group of settings from one program number to another. Getting everything set up correctly may not be very time consuming, but it is advisable to have a 'dummy run' to ensure that everything will be all right on the night.

General MIDI

The original MIDI specification did not make any recommendations about the type of sound assigned to each program number. There probably seemed to be no point in doing so at the time the MIDI specification was devised, but more recently, music has become available in the form of standard MIDI sequencer files, which can be played on a MIDI sequencing system.

The problem with this approach to recorded music is that it gives a different result on each system, due to different sounds being assigned to each program number. Program 23 might be a grand piano sound on the system used to produce the sequencer file, but it could be a banjo, saxophone, jet plane, or anything on the systems used to reproduce the sequence. It was therefore deemed necessary to add a set of standard sound assignments to MIDI and this is known as General MIDI. This is not a subject we will pursue further at the present time, but if you wish to produce Standard MIDI files that others can play back properly on their systems, you must adhere to the standard sound assignments. If not, you are free to assign whatever sound you like to any program number.

A program change message is a two byte type which uses the method of coding shown in Figure 1. The header byte has the program change code (1100) in the most significant nibble and the channel number in the least significant nibble. This is followed by the program number, which in decimal numbering is in the usual MIDI data range of 0 to 127. Note that equipment manufacturers do not necessarily number programs from 0 to 127. Some use numbers from 1 to 128, others have sounds arranged in banks, giving program numbers such as A-1 and D-7. The equipment manuals should clarify the relationship between the manufacturer's method of numbering and the true program values.

This is not just of academic importance. When using equipment from several different manufacturers it is quite easy to end up selecting the wrong sounds due to differences in the numbering methods. Most modern instruments have the full complement of 128 different sounds, but many older instruments only have 63 or 99. Again, it is a matter of checking the equipment manuals to determine exactly what each instrument can achieve. With some modern instruments, there is the luxury of several banks of sound data, with each one containing 128 different sounds.

Pitching In

In theory, a pitch wheel change message can be generated by any MIDI control unit, but in practice it is unlikely to be produced by any means other than operating the pitch wheel of an instrument. This message is a three byte type which uses the method of coding shown in Figure 2. The header byte has the pitch wheel change code (1110) in the four most significant bits and the channel number in the other four bits. The seven bits of data in each of the next two bytes are combined to produce a 14 bit value.

The first data byte provides the seven least significant bits - the second data byte furnishes the seven most significant bits. In decimal terms, the total pitch change value is obtained by multiplying the most significant byte by 128 and then adding the least significant byte. 14 bit resolution gives a pitch wheel value in the range 0 to 16383. The zero pitch change value is 8192 (01000000000000 in binary). Sending higher values gives an increase in pitch and lower values give a decrease in pitch.

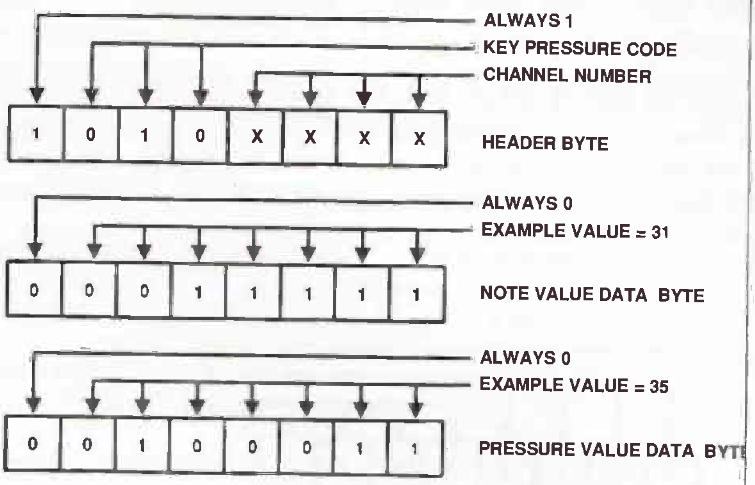


Fig.4. Polyphonic key pressure is a three byte message

The human ear is very sensitive to changes in pitch and can readily detect stepping rather than smooth changes. Even so, 14 bit resolution almost certainly provides a substantial amount of overkill. In practice, it is unlikely that varying a pitch wheel would result in a series of MIDI messages having the data value incremented or decremented one at a time. Doing this would almost certainly result in a severe case of MIDI choke. Pitch wheel changes are a potential cause of MIDI choke anyway, and this type of message is probably best used in moderation.

Under Pressure

As explained in the previous article, MIDI accommodates touch sensitive keyboards via the velocity values in the note on and note off messages. These values are a measure of how hard a key is pressed initially and how quickly it is released.

MIDI has provision for additional touch sensitivity in the form of 'after touch' messages. The data value in an after touch message reflects the amount of pressure applied to the key. After touch messages are only transmitted for notes that are sustained for a reasonably long time and they are therefore only sent after a key has been held down for a suitable length of time. This would typically be after a key had been pressed for about half a second to one second. Any significant changes in the pressure applied to the key thereafter will result in further after touch messages.

I suppose that a keyboard could implement after touch without having normal (velocity) touch sensitivity, but in practice, any keyboard that has after touch will also have velocity sensitivity. The latter controls the initial volume of a note and might also have some effect on the filtering or other sound generator settings. If a note is sustained for long enough, after touch then takes over and varies the volume of the note in sympathy with changes in the pressure applied to the key. Compared to just having velocity sensing, this system clearly gives greatly improved control over the dynamics of an instrument. It is a feature that is certainly more than a little desirable.

Velocity sensitivity was not common in the early days of MIDI, and any form of after touch was virtually unknown. Things have changed over the years and it is probable that all current MIDI keyboard instruments implement at least basic velocity sensitivity. Most now have some form of after touch as well. Of course, after touch is not restricted to keyboards and it can be implemented on practically any form of MIDI controller. MIDI guitars represent the only common exception. With a guitar, it is only possible to control the dynamics of the notes by plucking the strings more or less hard. This can be handled by the velocity values in note on messages and after touch does not really apply to any sound that is percussive in nature and of relatively short duration. It only applies to sounds that can be sustained for a long period (wind, organ, strings, etc.).

MIDI provides two versions of after touch, and the more basic form is channel after touch. This type is also known as 'overall' after touch. The data value in this type of message is a sort of average figure for all the keys that are being played on that particular MIDI channel. Although this gives only a rather unrefined method of control, it is still a great improvement on having no after touch facility at all.

This after touch message is a simple two byte type. Figure 3 shows the bit-by-bit make-up of a channel key pressure message. The header byte carries the channel key pressure code (1101) and the channel number. The second byte is the channel pressure data byte. A value of 0 is used for no pressure, through to 127 for maximum pressure.

The other form of after touch message is the polyphonic key pressure type. This provides individual after touch for each note that is played, which clearly provides very precise control of the dynamics of a piece. In theory at any rate, in terms of the amount of expression that can be put into your playing, it makes electronic instruments the equal of any acoustic instruments. Although polyphonic after touch was a rarity until quite recently, it is now becoming much more common. It is even to be found on some low cost MIDI keyboard instruments. Polyphonic after touch is a three byte message which uses the arrangement shown in Figure 4. The header byte contains the polyphonic key pressure code (1010) and the channel number. The second byte contains the note value. The system of note values used here is identical to the one used for note on and note off messages. The third byte carries the key pressure value.

In Control

Last and by no means least, we reach the MIDI control change message. Originally this type of message was used to control any aspect of an instrument which was not covered specifically by one of the other MIDI message types. This included control over the sound generator circuits. An update to the MIDI specification banned the general use of control change messages to control the sound generator circuits, but control of the sound generator circuits via these messages is still permitted, provided it is done strictly in the prescribed manner. This is something we will consider in detail later.

The MIDI controls are now primarily used as a means of controlling such things as master volume and switching built-in effects units on and off, rather than as a means of making fine adjustments to the sound generator circuits. When using a MIDI instrument that is not as young as it used to be, bear in mind that it might not conform to the current MIDI recommendations and could use MIDI controls for practically any purpose.

There are two broad categories of MIDI control change message. These are the switching and continuous controller varieties. The switch type is only used to switch something on or off, such as some form of effects unit. The continuous type provides variable control and is used for something like a volume or balance control.

A switch type control is operated using a three byte message. The first byte is the header type, which contains the control change code (1011) and the channel number. The next byte is the number of the control which must be changed, which gives some 128 different controls numbered from 0 to 127. The switch type controls are those having numbers in the range 64 to 127, but some of these now have special functions and operate in a non-standard fashion. This includes a few which operate as continuous controls. We will not consider these special cases at the present time. The third byte controls the on/off setting. Originally only two values were recognised here, which were 0 for 'off' and 127 for 'on'. The Detailed MIDI Specification altered this and recent equipment should accept values from 0 to 63 as 'off' and 64 to 127 as 'on'. MIDI controls having numbers from 0 to 63 are the continuous types, but these are used in pairs. If only seven bit resolution is adequate, only controls from 0 to 31 are used. The message then takes the same basic form as a switching type, but the value in the third byte is the new setting for the control. This normally works on the basis of 0 for minimum and 127 for maximum.

The two exceptions to this are controls 8 and 10, which are respectively the balance and pan controls. These have 64 as the central setting, 0 as full left volume and 127 as full right volume. If more than 7 bit resolution is needed, controls 0 to 31 are paired with controls 32 to 63, so that up to 14 bit resolution can be accommodated. Control numbers in the range 0 to 31 carry the most significant bytes, while those from 32 to 63 carry the least significant bytes. Control 0 is paired with control 32, control 1 is paired with control 33, and so on through to control 31 which is paired with control 63. This works in a manner that is similar to the way in which the pitch wheel message provides 14 bit resolution. However, the pitch wheel change message carries the two 7 bit bytes in one message, whereas they are in separate messages for a control change.

Note, however, that it is perfectly in order to change only the higher control number if only minor adjustment of a control is required. Control of the most significant and least significant bytes is totally independent. Figure 5 shows an example six byte sequence which changes both bytes of a high resolution control.

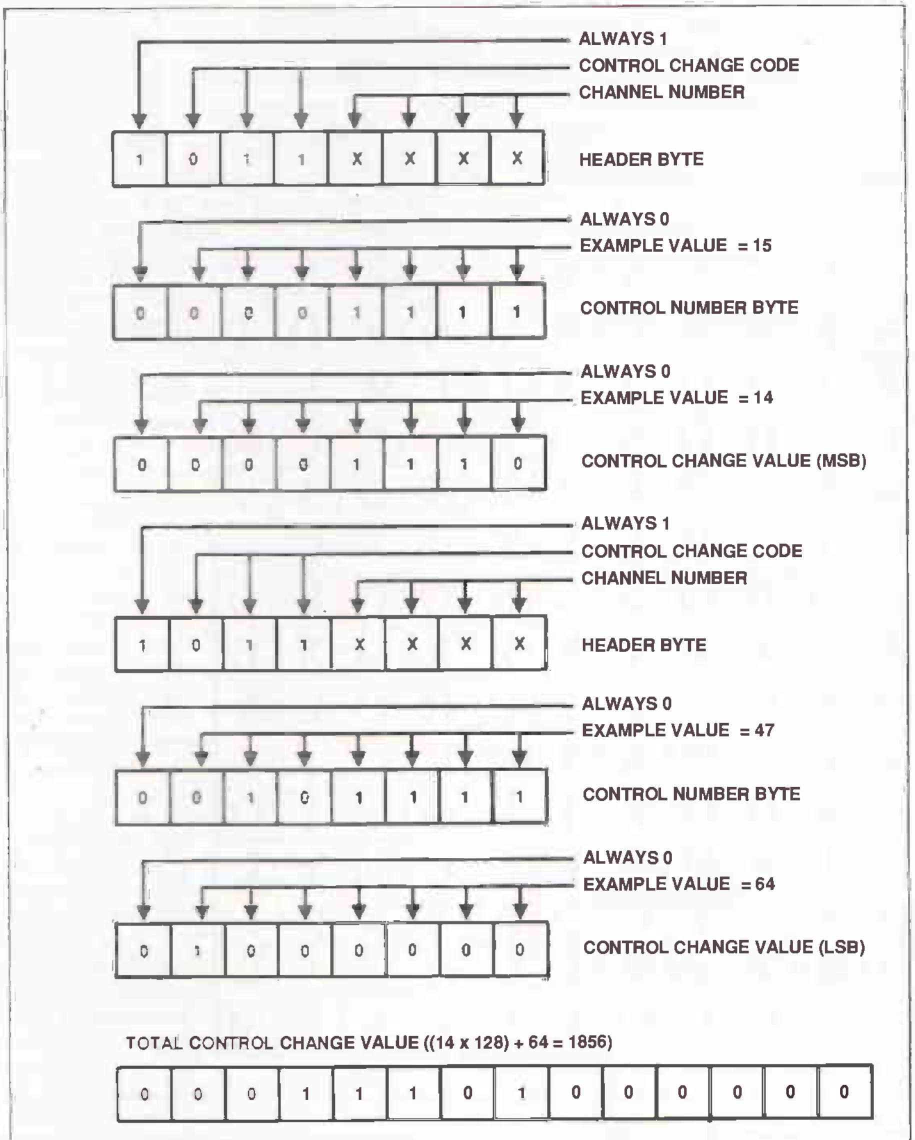


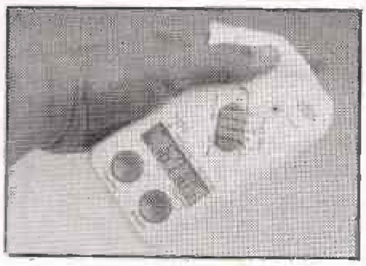
Fig 5. A six byte sequence to change both bytes of a continuous controller

This method of obtaining high resolution control has proved to be something less than universally popular and many consider it to be an inefficient way of handling things. Few instruments seem to utilise the higher control numbers and have 7 bit resolution for the continuous controls. In fact some do not even implement 7 bit resolution and only utilise the five or six most significant bits of the coarse control. However, there are a few instruments which do use the full 14 bit resolution, or something close to it.

Next month
we will consider MIDI controller assignments, special function controls and system messages.

ETI ELECTRONICS TODAY INTERNATIONAL Competition

In this month's ETI competition you could win a sophisticated electronic blood pressure monitor from Maplin Electronics.



With the increasing popular awareness of the importance of living a healthy lifestyle, it is hardly surprising that electronics systems are being employed to monitor body function and warn the user of impending problems, without the need for a lot of medical knowledge and otherwise complex measuring techniques. An example of this kind of electronic device is the newly released Maplin Blood Pressure Monitor.

This is an easy to use digital blood pressure tester which has been specifically designed to remove the complexities of measuring blood pressure and pulse rate, particularly for those who are not familiar with the technique. The monitor takes readings from the left index finger and shows the systolic and diastolic pressures, as well as pulse rate on an LCD display. The system is very easy to use and at various stages in operation will display a 'ready to measure' and 'heart' symbol to indicate the current stage of the operation. The monitor has its own pump, so no manual pumping is required, it will automatically inflate to a pressure of around 200mmHg and then start decreasing the pressure gradually. Once measurement is complete, the monitor bleeps, deflates automatically and then displays the blood pressure and pulse rate. These alternate every few seconds until the monitor is reused or switched off. Also shown is the 'ready to measure' symbol. If it is not reused immediately the monitor will switch itself off automatically after 1 1/2 minutes, to conserve power.

To win this sophisticated blood pressure monitor, valued at £75, simply find all twelve of the hidden words in the following puzzle. To make it easier we will give you one clue - all the hidden words come from the text on this page.

Send your list of the words you have found, written on a postcard or the back of an envelope, to: ETI, Blood Pressure Monitor Competition, Argus House, Boundary Way, Hemel Hempstead, Herts. HP2 7ST.

All entries must be received before August 30th when a draw will be made from all correct entries to decide the winner.

Rules. The competition is open to all UK residents other than employees of ASP and Maplin or their families. The prizes are as stated and there is no cash alternative. The editor's decision is final and no correspondence can be entered into.

B	B	S	G	G	X	C	N	Y	E	U	C	W	R	P
R	V	V	L	N	P	E	V	U	B	W	N	T	D	T
F	F	U	Q	K	Y	O	D	I	S	D	E	W	V	T
T	M	C	T	T	V	H	Q	N	H	C	O	O	C	M
Q	H	G	I	W	F	L	T	F	I	K	T	O	J	V
I	X	E	B	L	I	R	B	L	S	K	O	V	C	O
I	M	F	L	J	O	P	O	A	A	S	G	U	E	D
O	M	M	E	E	U	T	R	T	Y	E	X	M	X	B
E	B	A	E	M	S	N	S	E	I	H	H	D	L	Y
F	L	E	P	Y	Y	L	C	A	S	N	K	O	I	L
H	T	I	S	L	N	D	U	E	I	S	O	G	I	O
V	N	K	B	N	I	W	H	P	V	D	U	M	W	L
G	H	K	D	Q	S	N	Y	C	O	W	T	R	E	L
D	V	J	I	O	R	W	Y	R	F	R	H	T	E	B
Y	O	N	X	F	Y	L	L	M	K	E	V	V	N	M

Talkback

ETI
ELECTRONICS TODAY INTERNATIONAL

Dear ETI

I have developed a small circuit which readers of ETI might find useful. This circuit monitors an 8 bit value on a set of data lines, and latches the peak value onto a further eight data lines. This output could be processed further or, as shown here, be used to drive two seven segment displays. An ideal application for such a circuit would be, for example, a vibration monitoring system where the peak vibration that occurs needs to be stored and displayed.

The circuit is based around a binary comparator, IC3 and a latch, IC1. The comparator constantly compares the input data, on inputs P, with the current peak value on inputs Q. If the input data is greater than the current peak value then the P **greater than** Q line from the comparator goes low. A single NOT gate, IC2a, inverts this signal, causing the data to be latched into IC1. In order for the start-up to be orderly, i.e. the current peak value to be zero, a reset upon power up is provided by R1, C1 and IC2b. IC4 and IC5 are hexadecimal display drivers used to display the higher current value from RS.

The component values used in this circuit are as follows:

IC1	74LS273
IC2	74LS04
IC3	74LS684
IC4, 5	Hex Display (RS 586-734)
RN1	3K resistor SIL
R1	330K
R2,3	330ohm
C1	1μF
Vcc	+5V

T.B.Grant. Glamorgan.

Club contacts

Our regular list of amateur electronics clubs

British Amateur Electronics Club. Contact the club secretary Mr J.F.Davies on 0606 883742

Crystal Palace and District Radio Club, tel: 081 699 5732

Lincoln short Wave Radio Club, Lincoln. tel: 0427 788356.

London Live DIY Hi-Fi Circle, contact Launcelot Dow, 7 Pymmes Gardens South, Lower Edmonton, London N9 9NT.

Midland Amateur Radio Society, tel: 021 422 9787 or 021 443 1189 (evenings only).

Sudbury and District Radio Amateurs, tel: 0787 313212.

Thanet Electronics Club. A youth group for school age people in East Kent. Contact the club secretary Roy Ashley, tel: 0304 812723.

If you run a club that is concerned with some aspects of electronics and computing we would like to hear from you so that we can include your club in our regular listing.

Feedback

Here at the editorial offices of ETI we want to provide you, our readers, with the sort of magazine that you want to read. We can of course guess what you would like to see in each issue of ETI, but a far better way is to rely upon feedback from readers. To help us in this process we are instituting a new concept, the 'Feedback Box'. We are asking readers to take a few minutes and write down on the back of a postcard the ratings which they would award to each article in this issue. Ratings should vary between 1 and 10, with 1 being poor and 10 being brilliant.

A - Where on Earth am I?
B - Computer controlled stepper motor
C - Turbo speed indicator
D - Anglers bite alarm
E - PC Clinic
F - Video light meter
G - Magnetism and magnetometers
H - Car lights on reminder
I - An Introduction to MIDI

Just write the article letter followed by your score for that article and send to
Feedback Box August 94,
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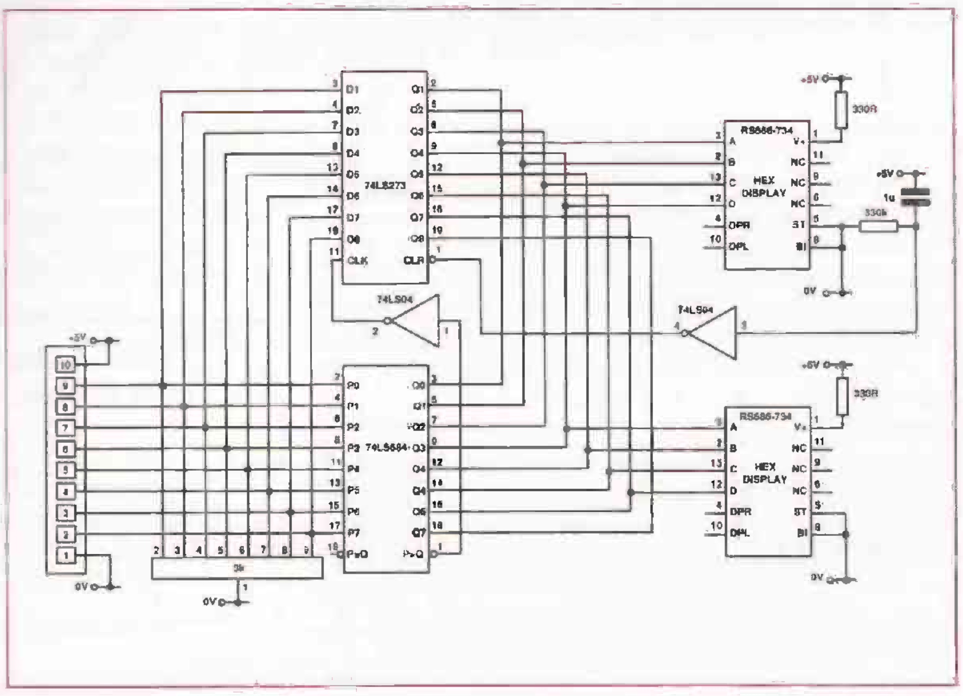
Boundary Way,
Hemel Hempstead, Herts. HP2 7ST.
To add an extra incentive, all replies received before August 30th 1994 will go into a draw and the winner will receive a 'goodies bag' of electronic components.



Practically Speaking

by Terry Balbirnie

Health and Safety

Last month, we looked at the siting of a workshop inside the house. However, this will not be possible for many readers. An alternative idea is to use a partitioned section of the garage or a garden shed. This will be relatively inexpensive to set up, but the drawback is that such places are likely to be damp and certain

aspects of safety must be taken into consideration if mains electricity is to be used.

First decide if mains electricity is really needed. It is possible to operate a workshop without it and if there is any hesitation over safety, this must be the course to follow. Such a mains-free workshop will be discussed next month.

If you do decide to lay on mains power, you should use a qualified electrical contractor to provide advice on how to install it. Unless you know your IEE Wiring Regulations you should not attempt this job. If a supply already exists, it must be checked by a competent electrician to ensure that it was properly installed in the first place and is fit for the purpose. The Electricity at Work Regulations apply to private houses as well as work places - the person installing the supply is responsible for the safety of those using it.

Considerations

These are the most important points to consider. The wiring from the supply must be of adequate current rating, carry an earth conductor and be of the correct physical type. It must terminate in a small consumer unit from where it will feed the circuits for power sockets, heating and lighting.

There will be a double-pole switch and separate fuses - 5A for lighting, 10A for heating and 15A for power sockets (only 5A if used for low-power experimental equipment). Rather than conventional fuses, miniature circuit breakers (MCBs) will be found more convenient because they can be instantly reset. Earthing must be efficient and any exposed metalwork earth bonded according to latest IEE regulations.

For safety reasons, the consumer unit must be of the type containing a RCD (Residual Current Device) - see illustration - or have separate RCDs for each circuit. The H98 PowerBreaker RCBO units are useful, because they combine miniature circuit breakers with RCDs. These are available in ratings from 6A to 32A.

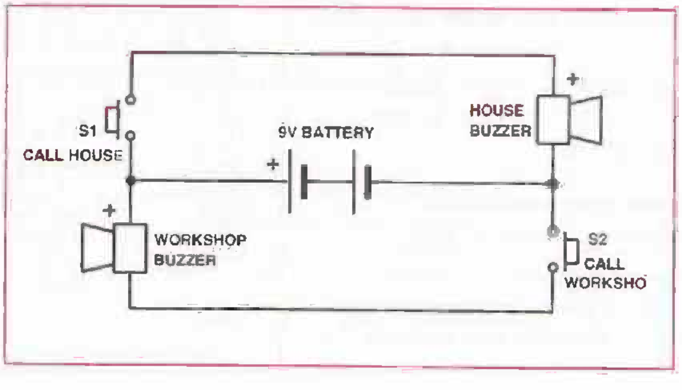
A fluorescent light, rather than the tungsten filament, variety should be used because it is relatively shadow free and promotes safe working. A spotlight could also be used for close work. If a heater is needed, use the infra-red bathroom type rather than a free-standing one. This should be wall-mounted, as high as possible and operated through a cord switch.

You should fit a smoke detector in case the soldering iron or other equipment is left switched on and touching something, causing insulation to melt and burn. This must be of the type which can 'repeat' in the house. An add-on circuit which can provide a repeat facility using an ordinary cheap smoke detector will be given as a project in a future issue.

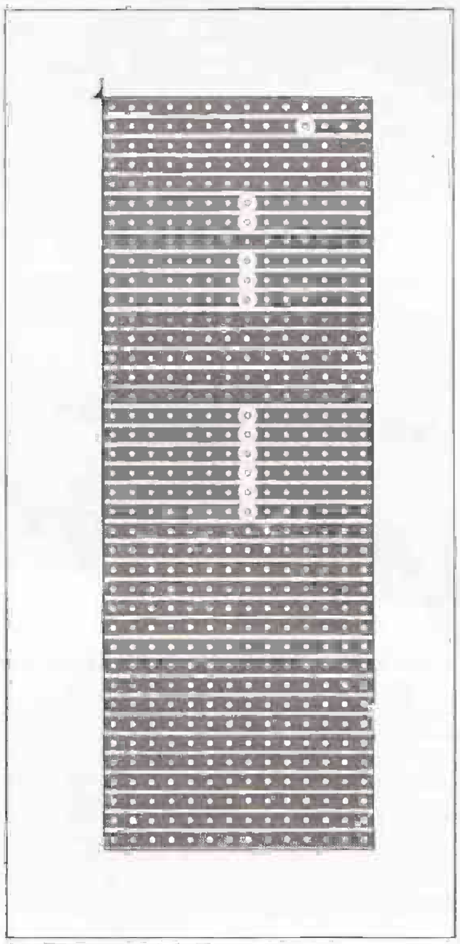
Another must is to provide some means of communicating with the house in an emergency. A simple bell push with a loud buzzer in the house will do, but more useful is a two-way system with a buzzer at each end. This can be built using 3-core wire as shown in Figure 1. Of course, a cheap intercom is even better.

It is essential to provide a good lock on the door - this will prevent a child entering in your absence. You are likely to leave things lying around with their lids removed and this could injure a child playing. They could end up with a very nasty burn trying their hand at soldering! In addition to a lock, it may be necessary to provide an intruder alarm arranged to give a warning inside the house. A circuit for such a simple alarm will also be described as a project in a future issue.

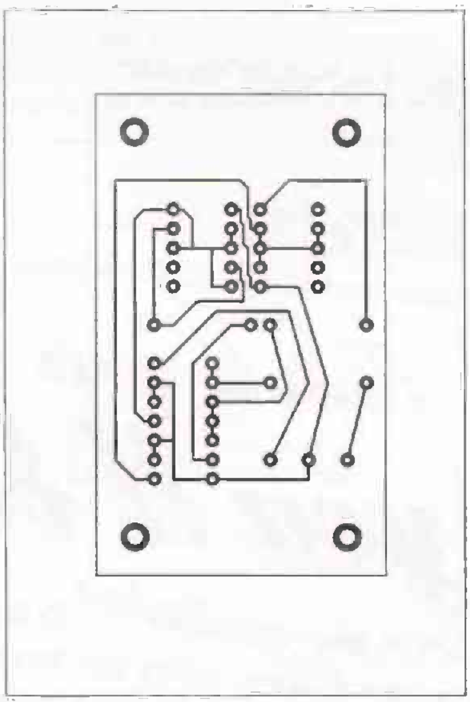
Where a mains supply must be avoided, either because of the cost of installing it or on grounds of safety, then some alternative means of operating the workshop will need to be found. We shall she how this can be done next month.



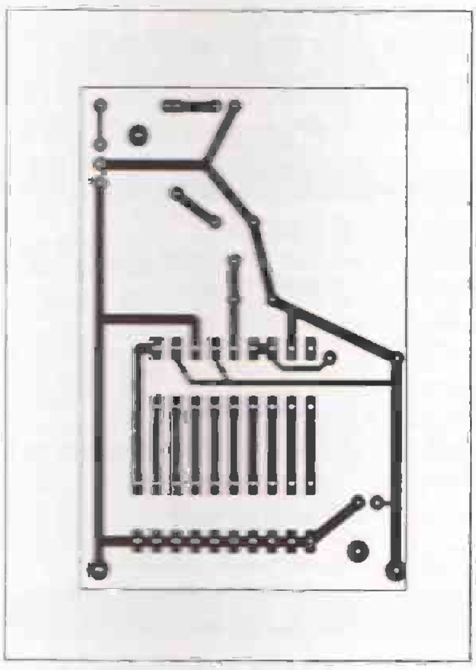
Foils for this issue



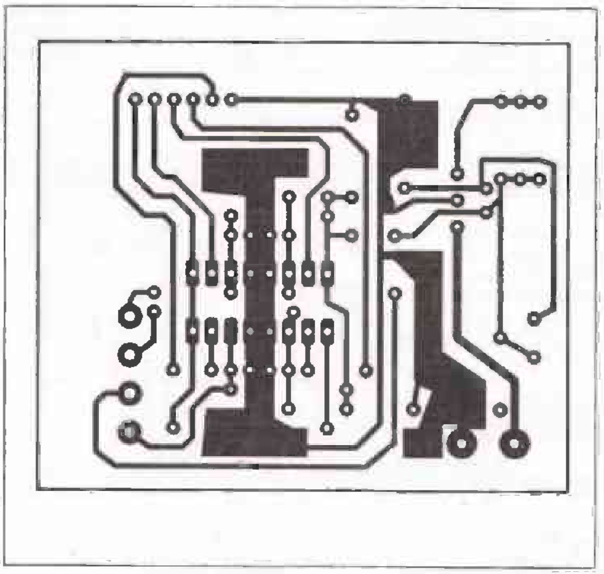
Car lights



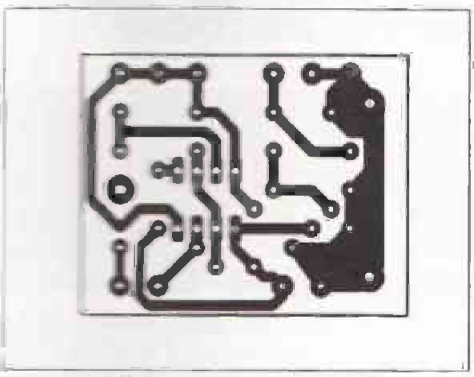
Turbo speed



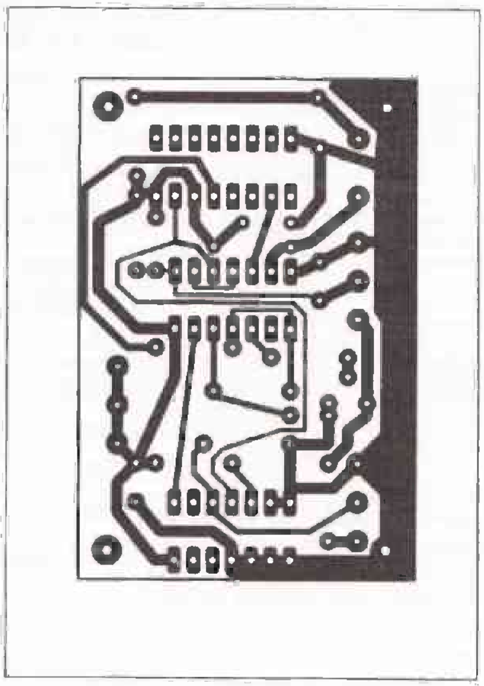
Vidio light meter



Stepper Motor control



Bite alarm 2000



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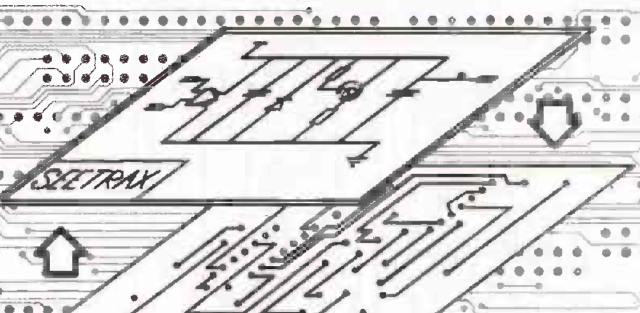

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Open Forum

It is normal practice today for electronics system engineers to incorporate microprocessor systems into their designs. Indeed, you will probably find a microcontroller chip embedded into the most mundane of products. Doing so makes the design simpler, cheaper to make, quicker to design and, of course, easier to change in the face of changing customer needs.

It is hardly surprising, therefore, that chip designers are moving in the same direction. Rather than design a complex chip from scratch as a purely hardware implementation, it is often much quicker and cheaper to use a dedicated embedded microcontroller to do the job. Chip manufacturers have found that such an approach allows complex products to be quickly developed to exploit new niche markets.

In the face of this trend, it is good to discover that a British designed and produced microprocessor is being adopted by two major semiconductor manufacturers as their choice for an embedded processor to be employed in future chip designs.

The British company is ARM, the RISC processor manufacturer set up jointly by Acorn Computers, Apple and chip manufacturer VLSI. The two big semiconductor producers are Samsung, one of the world's top ten, and IBM, who besides being still the world's largest computer company are also, surprisingly, the world's biggest semiconductor company

With licensing agreements like these, ARM has placed itself among the top players at the very leading edge of semiconductor and information technology. It shows what is possible, since this is a company founded by men of technical vision as well as men of commercial acumen. It was not founded by UK Government or EEC directives, or aided by subsidies.

This is a typical high technology venture, one that may have seemed risky to the man in the street and extremely risky to the average bank manager or civil servant, but not to the founders, the men who have the technical vision that others so often lack. Equally importantly, they are men who have faith in their vision and the technical and commercial acumen to turn that vision into reality.

If a country is to succeed in high technology manufacturing then it needs people like this. People like Bill Gates in the US, a man whose vision of what personal computers should be and how they will be used, coupled with his own commercial and technical genius has, in just twenty years, allowed him to build from scratch the world's largest software company and in the process become one of the world's richest men. Or, on this side of the Atlantic in the UK, another example is someone like Robert Madge, a man who foresaw the future demand for computer networks and developed the technology for them. An outstanding businessman and engineer, he has built up a company valued at over £300 million from nothing, in under ten years Just as ARM has been successful without government aid and intervention, so the above two examples and many more like them, have also been successful without and often in spite of, governments, civil servants and their like. Indeed, if the government really wants to foster the growth of new high technology industries, then it should provide the appropriate encouragement for such individuals.

These people are the modern equivalent of the great Victorian engineer industrialists, such as Parsons, Bell and Eddison. Such people are rare, but not that rare. Governments should help them by freeing them to do what they do best, build high technology businesses.

Governments cannot direct the development of high technology, however much they might like to think that they can. They just don't have the expertise for a start. Furthermore, committees of so called experts will never agree on the proper direction for the application of grants and subsidies, the compromise agreements of such committees will always be wrong. Leave such decisions to the engineering entrepreneur, give him tax breaks and free him of red tape, but don't tell him what to do.

Next Month...

In the next Issue of ETI we will be bringing you a number of interesting and useful projects. They include a handy transistor tester from Robert Penfold, a caravan tow bar alarm from Terry Balbirnie and for PC users, a handy little alarm which will warn you if your PC is getting too hot and prevent any damage to expensive components. We will also be concluding the computer controlled stepper motor project and continuing our look at measuring magnetism with the construction of a flux gate magnetometer.

In the next issue we will also be introducing the start of a sensational new computer project, the ETI Transputer board. This high power super-processor board could be the main building block for a parallel computer, a sophisticated robot vision system, or a high speed signal processor.

We will also be continuing our regular series. Robert Penfold will delve further into the mysteries of MIDI and PC Clinic will look at the organisation and upgrading of memory systems. The 'Tomorrow's Technology' feature looks at the fascinating advances being made in the fusion of biochemistry with electronics - the world of bioelectronics.

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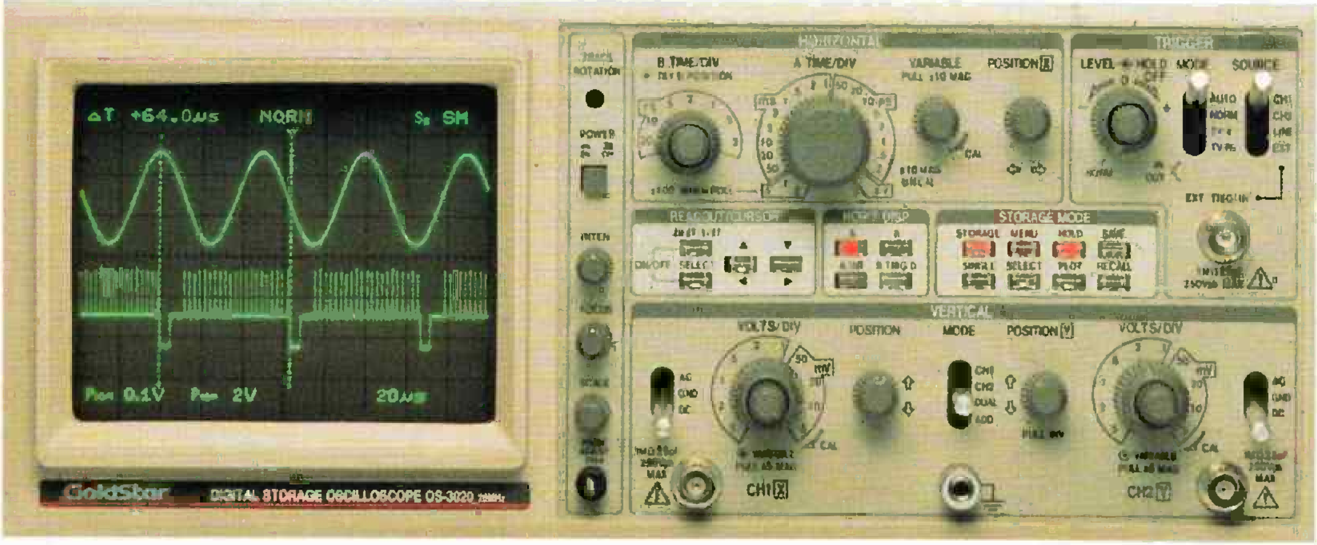

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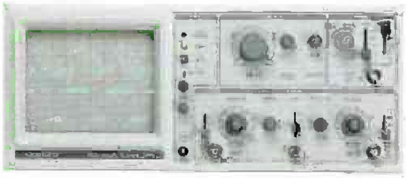

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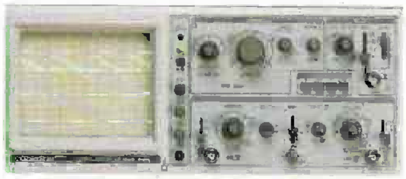

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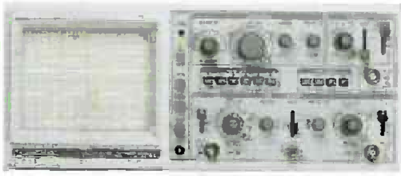

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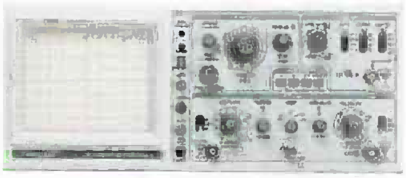

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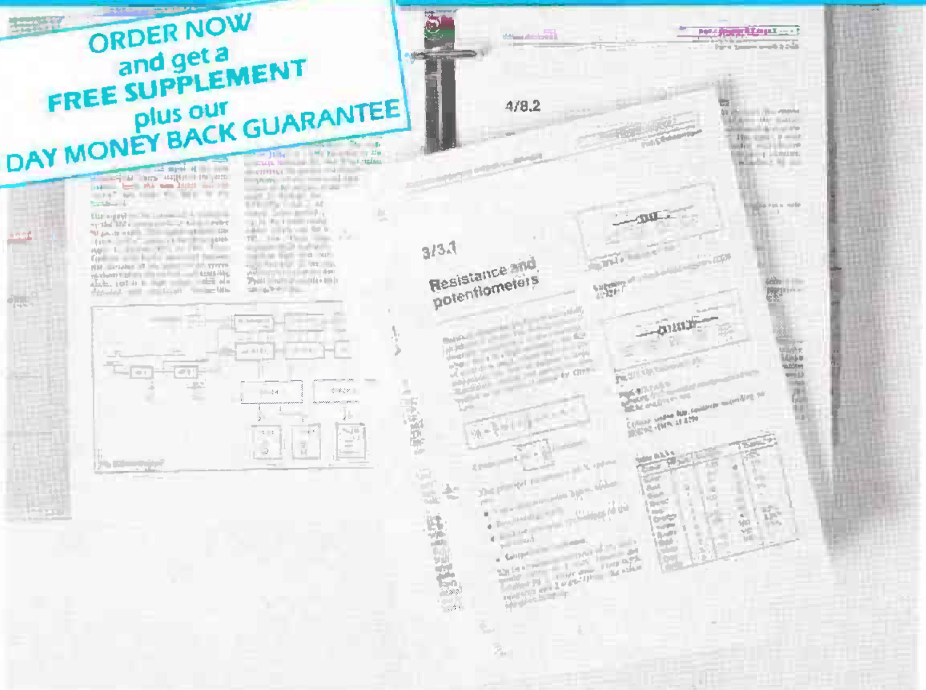

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