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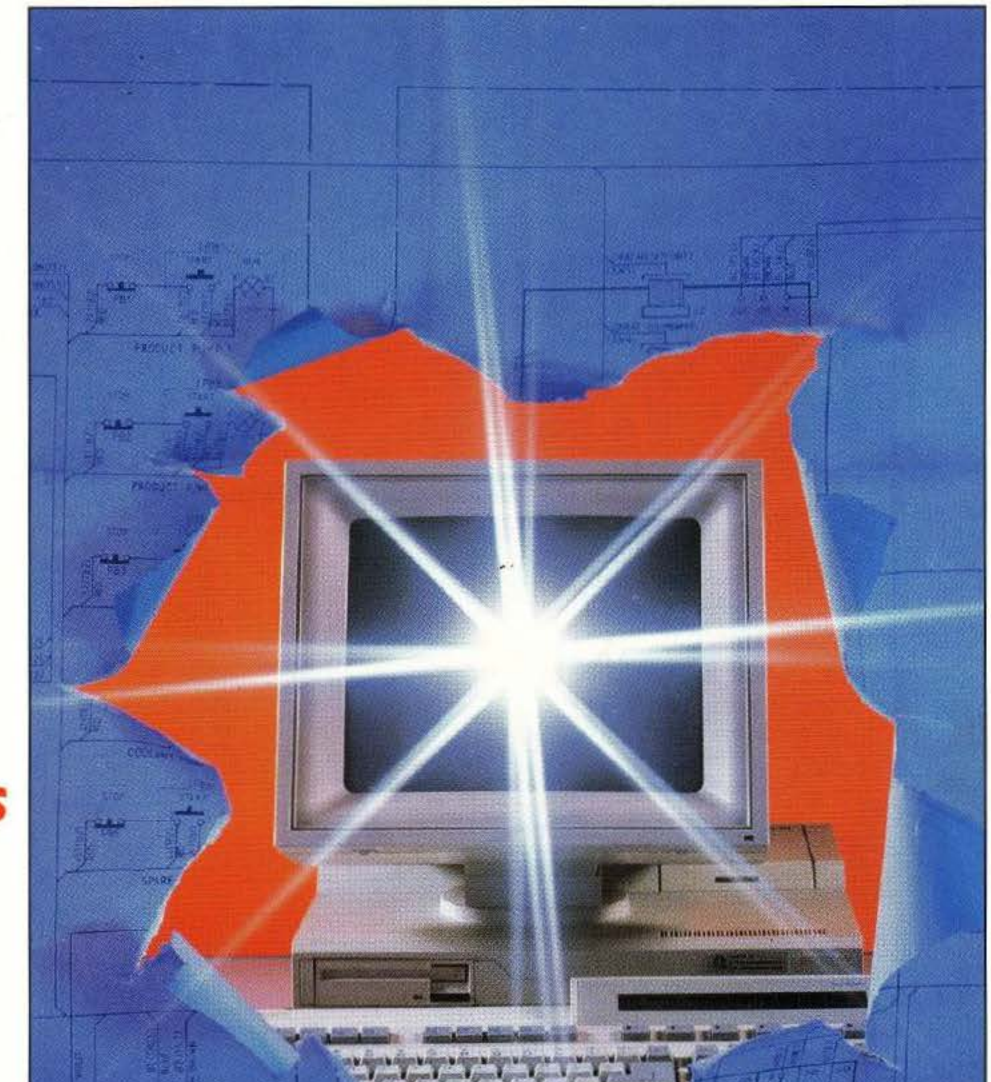

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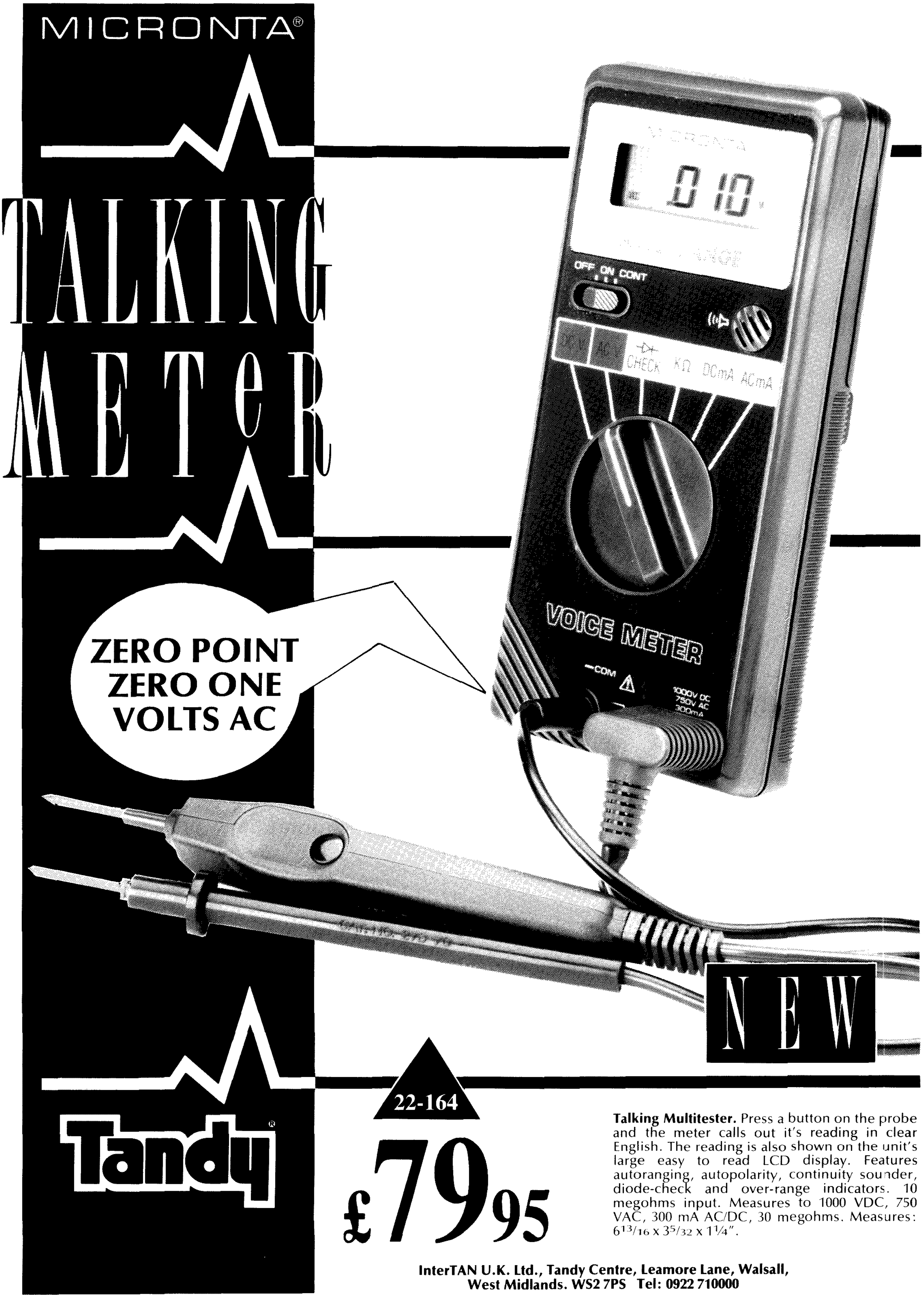
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This month...

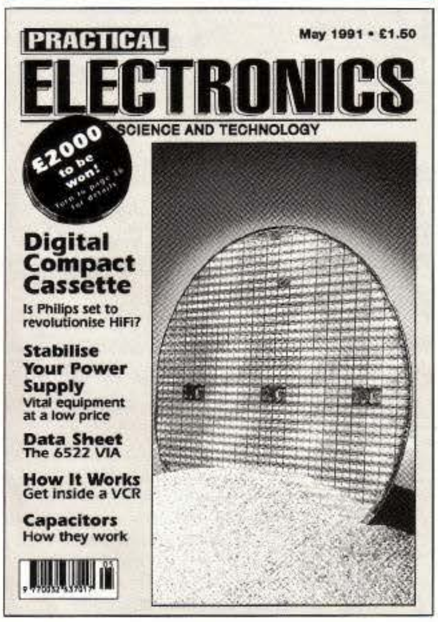
Two new continuing series are introduced this month. How it works examines a piece of functional electronics technology, kicking off with the Macintosh computer, as used here at PE's offices to typeset the magazine. Practical Components scrutinises the resistor, often overlooked but as vital to electronics now as it was 100 years ago.

Hooking up electronic gadgetry to computers can be easy or hard, depending on the machine in question. We take a look at a whole selection of connections with advice and circuits for the BBC, Spectrum, ST and the Commodore Amiga and 64. Also on the subject of interfacing, John Becker's project not only provides an EEPROM programmer for an IBM PC compatible, it looks at the 8255 PPI and 78S40 switch mode voltage converter.

Finally, switches are not what they seem, especially when you turn them on and off. Find out why and what can be done about it on page 24.

Kenn Garroch, Editor

Next month...



Inside next month's PE we are giving away a free Greenweld catalogue.
On sale April 4th

Build It

Features

Regulars

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Wavelengths

If you have any comments, suggestions, subjects you think should be aired, write to PE

Listings Please

I have taken your excellent magazine for the past 25 years and I still have the first copy.

The content is high in information and it is extremely readable and humorous at times, for which I thank you.

However, I have one complaint, the object of which is to improve the magazine. It is when you produce CPU controlled projects.

A hex dump of the program alone is of no value. We experimenters cannot modify, improve (or correct!) from a pure hex dump. What is needed is an assembler formatted listing. This enables such as myself, when pursuing my lifelong hobby, to use assemblers and cross-compilers to provide the final object code. Obviously the hex dump is still required and can be printed alongside.

As CPU electronics projects are becoming more frequent, I hope that you will look into this request as it allows the project builder to customise to suit their needs. Otherwise we may as well buy a ready made unit. A nominal charge is, of course, reasonable. However, I feel that this should be kept to a minimum to allow experiementers to obtain circuits and listings for the purpose of reading them.

I hope my comments have been helpful and contstructive.

S H Alsop
Managing Director DMS Electronics Ltd.
Sheffield

I quite agree and will be implementing something along these lines in future issues. The only problem is one of space in that a hex dump takes up less room that the full assembler listing. Where possible we will offer full listings at a nominal fee of £1.50 – to cover photocopying, P&P.

Reward

Many thanks for the cheque I received under your loyalty bonus award scheme.

I have been fascinated by electronics for quite a few years and chose PE after comparing it with two competing magazines, fortunate perhaps because the other two have since disappeared from the scene.

I have had many hours of enjoyment both from the excellent articles written by expert contributers and from building the projects.

Keep up the good work.

David Randerson
Nottongham

Alternative PCB Route

I read with great interest your review of EASY PC in the December issue and felt inspired to write a few comments on the subiect which may be of interest to you and your readers.

Like you I have recently purchased a leading PCB design program and am left wondering how I ever managed without it. For years I made my own printed circuit boards, usually copied from the pages of excellent electronics magazines such as yours. But rather than use dry-transfer tracks and pads to produce camera-ready artwork on paper, I transferred the pads and tracks directly onto copper. Dry transfer tracks and pads and tracks are quite waterproof and give excellent etch resistant properties.

You can imagine how tedious the above method is though. While it is possible to produce quite - proffessional looking boards this way, there are a number of disadvantages. Firstly, it is limited to fairly simple boards and secondly, the dry transfer material leaves a sticky residue where a piece of track or a pad has been ripped up and this residue is very etch resistant.

So I started to think about buying a PCB design program that would make the production of artwork easier. I had made up my mind that, like it or not, I would have to do the thing properly and have professional transparencies made from my own x2 artwork.

Having bought my PCB design package and learned the basics of using it, the next thing was to buy an A3 size flatbed plotter. The result was beautifully accurate x2 artwork of my PCB patterns all ready for the camera. However, there had to be a quicker way of producing a board than messing around with all those chemicals and photography.

Why not try plotting the PCB pattern directly onto the copper board instead of paper? The plotter has a mechanical accuracy of . 001mm, so I tried it using a new, 0.3 mm permanent, black OHT pen as sold by plotter supply stores.

A quick examination confirmed that the ink had gone on evenly without smearing and the result looked very impressive magnified. There was only one remaining question. Would the OHT ink be sufficiently etch resistant to allow correct etching? At any mornent I expected to see tracks disappearing where the ink hadn't gone on evenly. I took the board out and inspected it. It was perfect! I would not have believed it was possihle to produce such accurate looking result! At last I had a method I could use at home to produce a PCB from start to finishwithout all the mucking about with photography and light-sensitive chemicals done away with at a stroke!

Trevor Rymell
IT Consultant
The British Council, Singapore ■

Chip Count

A new bi-polar IC from Philips (071 636 0394) provides **group listening in** facilities in addition to call progress monitoring and pulse or DTMF tones. The TEA 1085 incorporates a loudspeaker amplifier with a fixed 35dB gain, a dynamic limiter and mute as well as power down circuitry, logic inputs for gain control and a Larsden level limiter to prevent feedback. Being able to develop 40mW into a 50Ω speaker, the chip allows 'hands free' dialing and listening facilities in one neat package.

To enable **NICAM digital stereo** receivers to be built easily and cheaply, Micro Call (0844 261939) is distributing three chips from Finland. The MAS7A101 is a QPSK demodulator incorporating Nyquist filters and PLLs Phase Locked Loops) and is designed to work directly with the MAS7S102 decoder and MAS7A103 dual 14 bit DAC. Together, these chips can demodulate the NICAM 728 signal, de-scramble and de-interleave the original sound samples, check for parity errors and output the results to the DACs.

Another chip from Micro Call is a **2Mbit EEPROM**, the XM-28C020. This is organised as 256kx8 and is made up from four 64kx8 modules on a multi-layered ceramic substrate. To enable the whole module memory array to be written in 10s, the chip supports a 128-byte page write operation which, when combined with the data polling or toggle bit testing, provides a 40μs/byte write cycle.

Northern Design (0224 729533) has launched the XD range of **current transducers** which can give instant indication and position of any failures in a group of lamps. By routing the neutral conductor through the XD10V5, a failing lamp will cause the current to rise and trigger an alarm. Useful in security lighting, prices start at £38 each (ex VAT).

Silicon Systems of Tustin California USA (714 721 7110) has just released a device that will allow a personal computer to have a **COM's port** that will accept virtually any synchronous or asynchronous communications protocol. The SSI 73M650 SPC (Serial Packet Controller) employs novel UART technology that allows the PC to appear to have a normal comms port while being able to accept virtually anything. Other features are the ability to act as a powerful packet controller, a power down mode to save battery life in portables and 32 bit CRC error correction for full V42 compatibility. At a cost of $15 this chip looks set to cure the RS232 blues.

Also from Silicon Systems is a single chip low power quad **modem IC**. The SSI 73K324L conforms to CCITT V21, V22, V23 and V22bis standards. It is designed to be interfaced to microprocessors by direct connection to the

£100 video camera

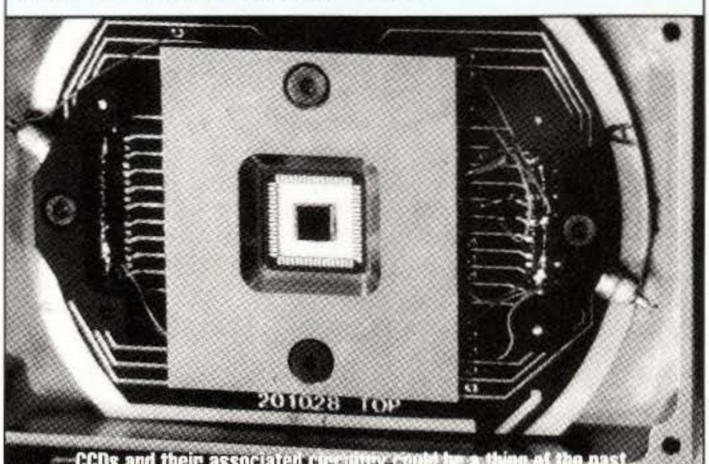
Miniature video cameras for around £100 could be available in the near future if the new technology from VLSI Vision fulfils its promise. Instead of using the normal approach of a CCD (Charge Coupled Device) coupled to an external processing system, the new technique uses ASIC CMOS to implement an array of photo-diodes and a signal processing system all on a single chip the size of a 5p ($25mm^2$). Automated exposure control allows cheap plastic lenses to be cemented directly onto the chip – the large amount of processing power available also allows the output signal to be in a standard format, for example composite 1V peak to peak.

The team from Edinburgh University who developed the idea is also considering a number of other image processing devices. Soon to be announced is a fingerprint verification device that uses 100,000 transistors to perform the two billion integer operations per second needed to differentiate one print from another. As with the single chip camera, the aim is to put as much processing power on the chip alongside the image reception circuitry. The only external device would be a database of fingerprints, providing a complete security system on a chip, perhaps even for use in 'smart cards'.

Originally developed at Edinburgh University the idea of 'personal imaging' has been taken up by Technology Transfer Centre who, in turn, formed VLSI Vision. In practice this is an ASIC design house selling proprietry technology for commercial devélopment in the consumer market.

Future chips and designs being looked at by the company include developing the single chip camera to work in colour, producing a standard PAL or NTSC output and video telephone that uses the H216 standard to compress images into a format that can be squirted down a standard telephone line with all processing circuitry built onto a single chip of about half an inch on its side.

For more information contact VVL (031) 668 1550



CCDs and their associated circuitry could be a thing of the past.

system bus, the chip operating through an eight-bit multiplexed port. All that is needed to build a complete modem is the addition of a phone line interface, a micro-processor and RS232 level converters.

Computers

For those who want to get data into and out of their PCs, the new range of PC bus **I/O cards** from Artistic Licence (081 961 9520) is supplied ready-to-go with software drivers, diagnostics, example programs and manual. The range includes opto-isolated, TTL, Darlington drive, relay, multi-channel analogue output and intelligent stepper motor cards, ranging in price from £125 to £165.

Owners of the **Sam Coupé** computer can now get a number of DOS extensions with Masterdos (£14.95), allowing tree directories, a RAM disk and advanced file handling. Also available is the 1Mbyte memory expansion (£79.95) which, using four of them, allows memory expansion up to 4.5 Mbytes – 256k is available internally. Unfortunately, the memory is external and cannot be accessed from Basic, but when used as a RAM disk, it speeds up file access times.

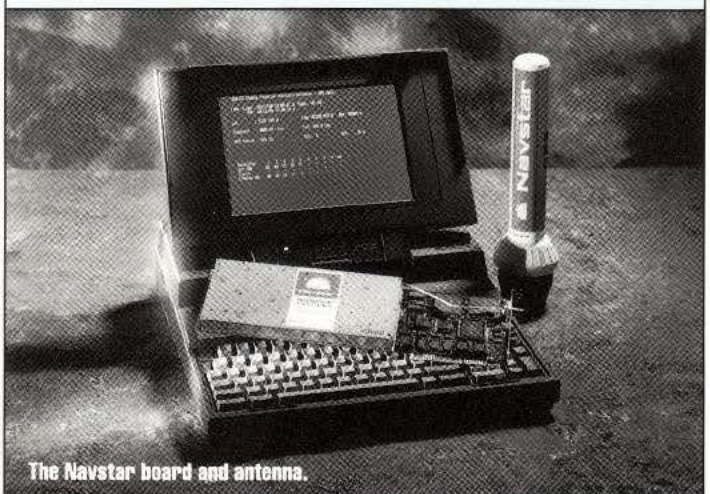
To allow all of the available add-ons to be attached at once, the Sambus (£49.95) interfaces the standard single expansion connector to four other devices, including other Sambuses. An optional extra is another power supply (£19.95) that gives a boost for the increased number of add-ons. For more info. contact Sam Computers Ltd. on 0792 700300.

In position

A unique new global positioning system (GPS) receiver from Navstar enables portable PCs to locate themselves exactly on the earth's surface.

Designed as a full length expansion card for IBM compatible PCs, the XR4-PC comes complete with antenna cable and software and once installed provides posi-tion and navigation data either on screen or in the background – allowing other software to be run at the same time.

As well as finding uses in surveying, astronomy, forestry, and seismology , the new portable system could lead to automated route finding and navigation on land and at sea. Priced at £1575 the XR4 is available from Navstar Ltd. Wardell House, 108-112 High Street, Southampton, S901 OAA..Tel. 0703 333539



The Navstar board and antenna.

The wall hanging picture TV may soon be possible if the new LCD VGA displays from Seiko Instruments are any example of what the technology is capable of. Offering resolutions of 640x480 pixels with side mounted cold cathode back lighting, the G643G and G642G use RC-film technology to implement all the VGA controller circuitry on the display. At 460g and 740g both displays are under 15mm thick.


LCD VGA display.

Devices

The DM 310 from The Instrument Centre (0633 280566) is a new **digital multimeter** that offers a 0.5 inch 3.5 digit display, low battery, auto zero, AC and DC voltage measurement in five ranges to 700V and 1000V respectively and current measurement in seven ranges from 20μA to 10A. Resistance can be measured to 20MΩ and a built in buzzer provides an audible continuity tester. A separate socket allows diodes and transistors to be tested and identified (PNP, NPN) all for £69 ex VAT.

With modern noise exposure limitation legislation, some way of monitoring the hazard is required. A new **dosemeter** from Brunel and Kjaer (081 954 2366) offers a range of facilities including parallel detection of RMS and peak values, data logging, PC data transfer, statistical functions, 20 hours of data storage, a secure keyboard and auto-start and stop operation.

Two new meters are available from Thurlby-Thandar (0480 412451). The first is used to measure capacitances over six ranges, inductance over five ranges and resistance over six ranges – the TC200 is a low cost (£95) LCR meter. The basic accuracy is 1% and the measurement frequency 1kHz with a sample time of 0.4s ensuring a fast response.

The other meter is the TM357 which provides five ranges of AC and DC with a basic accuracy of 0.5% and a resolution of 100µV. Resistance can be measured to a resolution of 0.1Ω over six ranges. A continuity buzzer and diode check facility are also provided in the unit which costs £39 plus VAT.

Also from Thurlby Thandor is the new Hitachi **VC6024 oscilloscope** which offers real time and digital storage functions with a sampling rate of 20MHz, a real time bandwidth of 50MHz. In digital storage mode it can capture repetitive events up to 50MHz and single shots to 5MHz. The memory size of 2000 words per channel allows up to four saved and new waveforms to be displayed at once and a 'roll mode' allows low speed signals to be viewed as a single trace up to 200 seconds in length.

Additional features of the CC6024 are an RS232 interface to transfer data to a computer for further analysis, an averaging function, pre-trigger and cursor measurement. The scope costs £1595 ex VAT and comes with two free probes.

For anyone who needs the best in **cassette recording** reproduction, the new H-1 from Revox uses the Studer four motor mechanism with twin pinch rollers from the Revox 215. Featuring Dolby B, C and HX-Pro, the H-1 also has a fully automatic microproces-sor controlled tape alignment system. For a £1121 (inc VAT) the H-1 is available in black, titanium and gold.

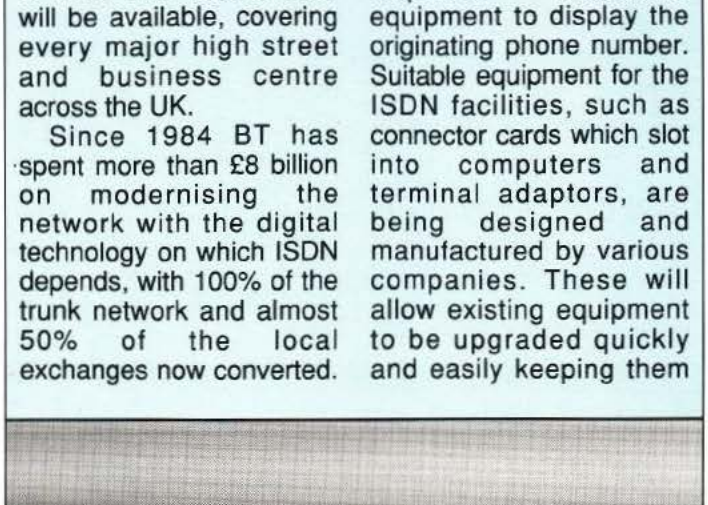
British Telecom set for Video Phone service

BT has launched ISDN 2 (Integrated Services Digital Network) – a new communications service aimed at small to medium-sized businesses and branch offices of larger companies. New applications include rapid fax transmission – an A4 page in 2 seconds, much faster data transfer without a modem, low cost video links allowing customers to see as well as hear each other and improved telephone service with faster connection and clearer speech. By the end of 1991 over 90,000 lines will be available, covering every major high street and business centre across the UK.

Since 1984 BT has spent more than £8 billion on modernising the network with the digital technology on which ISDN depends, with 100% of the trunk network and almost 50% of the local exchanges now converted. The new technology allows the 'twisted pair' wire which connects the phone and network to carry two independent digital communication paths instead of one; this allows one line to carry two data streams, for instance voice and data, simultaneously.

No special connections are needed and users simply plug into the existing copper wire system.

Among other facilities, so-called Caller ID (Caller Line Identification) is provided as an option but requires additional equipment to display the originating phone number. Suitable equipment for the ISDN facilities, such as connector cards which slot into computers and terminal adaptors, are being designed and manufactured by various companies. These will allow existing equipment to be upgraded quickly and easily keeping them



The Revox H-1 four motor cassette deck.

Dentanurse UK (0981 550781) produce a **flexible mirror**, originally designed to be used for amateurs to view their own mouths, which may also be useful to electronics constructors. Able to be bent to allow any angle of view the mirror costs 99p+25p P&P and is available from chemists or Dentanurse UK Ltd., Old Forge Estate, Peterchurch, Hereford, HR20SD.

It may not be widely known but soldering is not exactly **environment friendly**. However, help is at hand from Electroustic Ltd. (0264 33364) who produce a new range of water soluble fluxes which emit no CFC gases or toxic by-products. Over 17 different fluxes are available with solvents of water or alcohol and temperature ranges varying between 120°C and 320°C with metals of copper, nickel, EN and alloy.

Ferguson will be showing its new 16:9 **widescreen TV** at the Brown Goods Show in the Olympia Conference centre between April 7th-10th. It features a high scan 1250 line HDTV compatible display capable of showing programmes in a 16:9 aspect ratio. It also features an on-board satellite receiver, an idea that Ferguson will be pushing in 1991 as the intention is to supply a retrofit option for existing large screen models.

Probing The Interface

Chris Hanson pokes around under the covers of the BBC, ST, Amiga, C64, Spectrum and IBM PC computers to see where the user ports are.

All computers have interfaces of one sort or another, to control the video output, read the keyboard, communicate with disk drives and so on. Unfortunately for the electronics enthusiast, they don't all provide a user port, an interface that can be customised to accept any form of input and output (I/O). Some computers, such as the BBC model B, come with a plethora of interface possibilities, others such as the Sinclair Spectrum and the Commodore Amiga have virtually nothing. However, there are ways around the problem, usually without a great deal of extra hardware – generally a good idea since software is cheaper and easier to develop than than hardware.

User Ports

Of all of the popular home computers, only the BBC micro and the Commodore 64 come with easily accessed user ports. Other machines such as the Atari ST, Commodore Amiga, Sinclair Spectrum and IBM PC all have to either have extra hardware fitted, or use existing interfaces in unusual ways. The basic requirement for a user port is to be able to pass information in the form of +5V and 0V binary signals into and out of the computer.

The normal path for data is via the data bus with the address bus defining where to data is to go or come from. Because the computer processes information so quickly a user port has to have some sort of latching mechanism for outputs so that they are separated from the rest of the data travelling along the bus and held long enough for external hardware to read them. In a similar way, inputs must be held in a buffer until the computer can get around to reading them. To help with these processes, commercial user ports or interface chips, provide a number of handshaking options so that external hardware can signal to the computer that the data is ready, and in return, wait until the computer is ready before using any data output from it.

Port A	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0	DD00
Port B	PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0	DD01
DDRA	Sets the data transfer direction of port A								DD02
DDRB	Sets the data transfer direction of port B								DD03
TA Low	Low eight bits of timer A								DD04
TA High	High eight bits of timer A								DD05
TB Low	Low eight bits of timer B								DD06
TB High	High eight bits of timer B								DD07
TOD 10ths	0	0	0	0	BCD 0-9				DD08
TOD Secs	0	BCD 0-5			BCD 0-9				DD09
TOD Min	0	BCD 0-5			BCD 0-9				DD0A
TOD Hours	AM/PM	0	0	BCD 0-1	BCD 0-9				DD0B
SR	Eight bit shift register								DD0C
ICR	Int enable			FG int	SP int	Alarm	TB int	TA int	DD0D
CRA	TOD 6050	Set i/o	TA ø/CT	LD TA	TA CO	PB6PT	PB6 nTA	TA on/off	DD0E
CRB	TOD/ALM	TB Count		LD TB	TB CO	PB7PT	PB7 nTB	TB on/off	DD0F

Fig. 1. The registers of the 6526 CIA used in the Commodore 64.

Interface Chips

There are two main types of microprocessor architecture used in modern computers. The first is the Motorola design that accesses I/O chips as though they are part of the memory. The 6502, 6800, 68000 types use this method. Outputting data is simply a matter of writing it to a specific memory location – instead of accessing RAM, the computer hardware knows that this should go to the outside world. Reading data in operates in the same way – a particular memory address has the data available as though it were in RAM or ROM.

The other main type of architecture is used in Intel chips. Here, special microprocessor instructions are used to transfer data to and from the outside world – known as IN and OUT. Normally they are used with a number which tells the hardware which in or out is to be used. In practice, the only real difference between the two systems is an extra signal that defines whether the operation is to be memory or I/O. In practice, the Intel system could use the Motorola type of interface but a few more bytes of memory become available if the IN and OUT commands are used.

In both systems, special chips are available to make interfacing easier. For the Motorola technology, common ICs are the 6522 VIA

Port B	PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0	FE60
Port A	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0	FE61
DDRB	Sets the data transfer direction of port B								FE62
DDRA	Sets the data transfer direction of port A								FE63
T1C-L	Write low eight bits ofcounter 1 latch - read low eight bits of counter 1								FE64
T1C-H	Write counter 1 high eight bit latches - read timer 1 high eight bit counter								FE65
T1L-L	Write same as T1C-L - read counter low eight-bit latches								FE66
T1L-H	Write high eight bits of counter 1 latches - read high eight bits of counter 1 latches								FE67
T2C-L	Write counter 2 low eight bit latches - read loaw eight bits from counter 2								FE68
T2C-H	Write counter 2 high eight bits - read counter 2 high eight bits								FE69
SR	Shift register								FE6A
ACR	Counter1 int cntrl		Cnt 2 ctrl	Shift register control			Port A&B latch enbl		FE6B
PCR	CB2 control			CB1 edge	CA2 control			CA2 edge	FE6C
IFR	IRQ	Cnt1 int	Cnt2 int	CB1 int	CB2 int	Shft int	CA1 int	CA2 int	FE6D
IER	Set/Crl	Cnt1 enbl	Cnt2 enbl	CB1 enbl	CB2 enbl	Shft enbl	CA1 enbl	CA2 enbl	FE6E
CRB	Same as port A but no handshake								FE6F

Fig. 2. The 6522 VIA as used in the BBC micro.

(Versatile Interface Adaptor) as used in the BBC, the 6526 CIA (Complex IA) as used in the C64 and the 8520 CIA as used in the Commodore Amiga. Intel chips may be as simple as the 8212 input output port or as complex as the 8255 PIA (Peripheral Interface Adaptor).

The more complex chips, as well as providing the latching and bidirectional I/O lines (allowing signals to travel in or out down the same path), also have timers, shift registers, interrupt controls and handshake lines. The latter can be used to clock data into a shift register with interrupt flags being set when the process is complete –these in turn generate an interrupt to the processor or are periodically scanned (polled). All of the internal registers, bits and flags of the 6526 and 6522 are shown in Figs. 1 and 2 along with the memory addresses for the C64 and BBC computers.

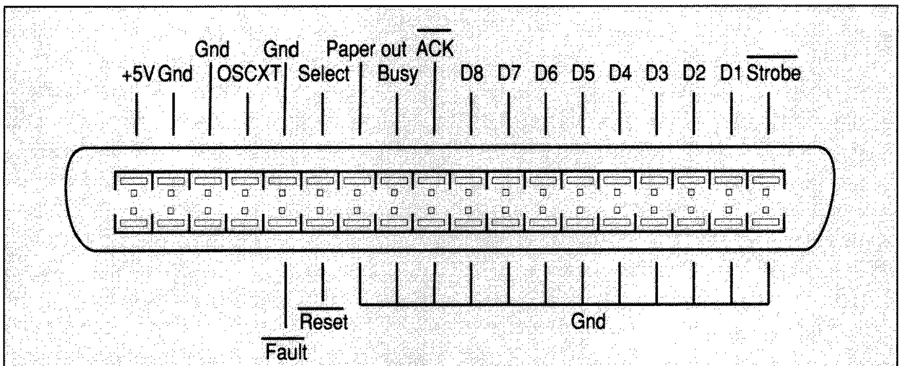


Fig. 3. The standard Cemntronics printer port.

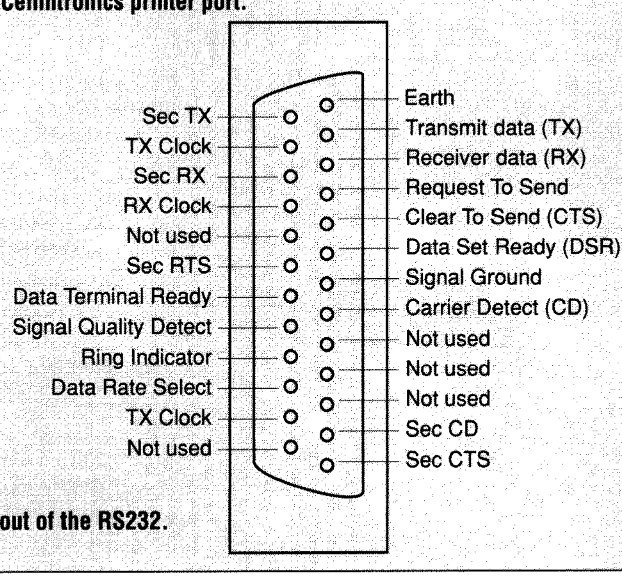


Fig. 4. Complete pinout of the RS232.

Other Ports

One of the most common interfaces available on small computers is the printer port. This normally conforms to the Centronics standard (Fig. 3) and in some systems can be re-jigged to be a user port. It provides eight I/O lines and a few handshake signals. Unfortunately, many systems use buffers and line drivers to protect and boost the signals on the printer port. These are one way and only outputs can be generated. Fortunately, there are ways to get data in over the few available input lines, for example Busy.

The other common interface is the RS232 or serial link. This normally uses signal levels of between ±3V and ±12V– unsuitable for conversion into a user port. Another problem is that special chips such as UARTs (Universal Asynchronous Transmitter Receiver) and ACIAs (Asynchronous Communications Interface Adaptor) are used which don't allow individual control of the lines – see Fig. 4. Where this is the only interface option, the best solution is to design a universal user port which can be controlled using standard RS232 characters, possibly based around a microcontroller giving all of the facilities found in an interface adaptor.

12 Into 3 Will Go

There are times where it is necessary to transfer data into, or out of, a user port from a peripheral that has more data bits than the port itself. An example of this is when using a 12-bit analogue to digital converter (ADC) with an eight-bit port. To get the extra four data bits in, a shift register system can be used as in Fig. 5. As soon as the ADC has finished its conversion, it signals to the computer which then shifts all twelve bits into a single line of the user port. Only three lines, the handshake, clock and data, are needed to access as many bits as necessary. The main drawback of a system like this is one of speed – it takes at least 12 times longer to transfer the data into the computer than when transferring the data directly over a parallel port.

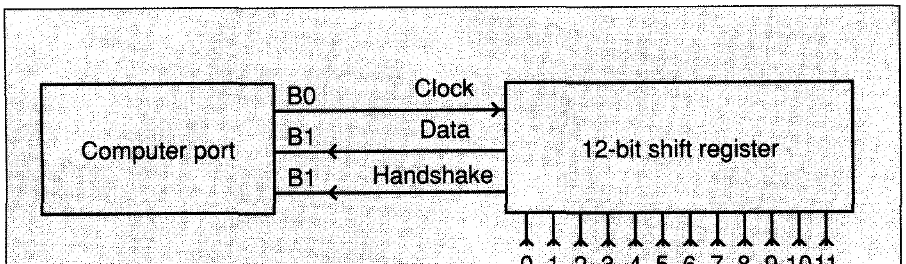


Fig. 5. Using a shift register to expand a port.

Practical User Ports

Experimenting with a user port or possible user port on a computer requires a bare minimum of hardware. Fig. 6 shows a simple test probe consisting of an LED and a resistor. For a normal LED with a maximum forward current (If) of 20mA and a forward voltage of 2V, the value of the resistor is given by:

R=(V-Vf)/If

In most cases, V is 5Volts so R=150Ω to give maximum brightness – in practice, values a little larger than this should be used so that the 20mA maximum is not exceeded. The end of the LED is connected to 0V and the resistor used to test whether output lines are high or low.

A little care should be exercised when poking wires into the connectors on the back of a computer since shorting power lines or high outputs to ground can damage the machine. Systems that use VIA or other interface adapters should give few problems since the outputs are buffered. Others, can easily be damaged and it is a good idea to make sure of the connections before experiments begin.

BBC Micro

As was mentioned earlier, the BBC Micro is probably the most flexible computer available when it comes to interfacing. As well as providing standard features such as Centronics and RS423 (similar to RS232 serial), it also has a set of analogue inputs, provision for a light pen, the 1MHz bus, Tube, disk interface and user port.

The user port connections are shown in Fig. 7. To make life easier, a 20way IDC connector connected to a 20 way ribbon cable with a DIL (Dual In Line) header socket on the end can be hooked up to a prototype board. All of the I/O lines then become available for easy experimentation.

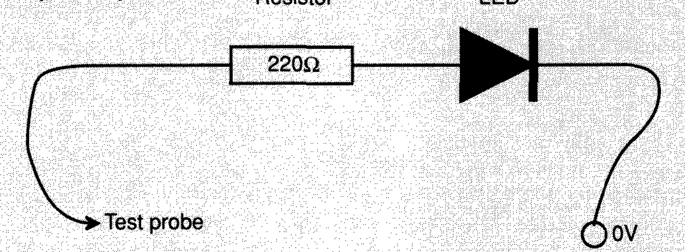


Fig. 6. A simple test probe.

Because the BBC provides a straight forward user port, there is no real need to go into detail about the other interface options. The 1MHz bus can be used to attach a number of other VIA chips, extending the I/O capabilities considerably. The Tube is really only for attaching a second processor such as another 6502 or a Z80 to the system. The analogue interface provides an easy means to read varying voltages into the machine and, like the light pen, is covered in detail in the Advanced User Guide for the BBC micro.

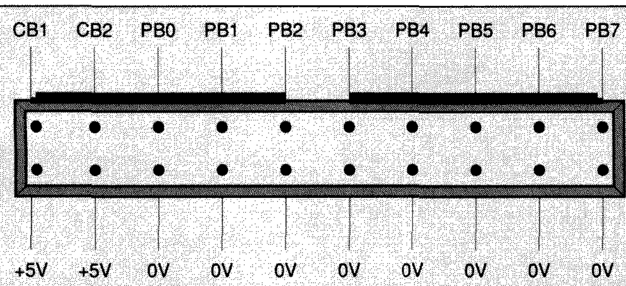


Fig. 7. BBC Micro user port.

Memory Locations

Access to the user port is via the 6522 chip whose full register set is shown in Fig. 2. For simple I/O, only DRB and DDRB need to be used. The first is located at memory location &FE60 (the & denotes hexadecimal notation) and writing to it places data on the PB0 to PB7 lines of the user port. Whether each of these lines is input or output depends on the setting of DDRB at &FE62. Bits set to one define outputs and set to zero, high impedance inputs. This arrangement allows the user port to pass data in both directions at once for example, ?&FE62=241 defines PB7, PB6, PB5, PB4 and PB0 to be outputs and PB1, PB2 and PB3 to be inputs. ?&FE60=254 will set PB7 to PB4 to one and PB0 to zero, PB1 to PB3 are unaffected since the are high impedance inputs. PRINT ?&FE60 will reveal the status of PB1 to PB3 without affecting the outputs.

The drawback with using peeks and pokes, or in the case of the BBC, indirection operators, is that the designer might move the hardware so that in future machines it is no longer at the same memory location. To get around this, programs designed to be used on future machines should use operating system calls rather than direct memory accesses – with the BBC micro this involves the *FX or OSBYTE command. The user port is in an area referred to as SHEILA (&FE00) in memory and the OSBYTE 150 and 151 calls are used to read and write it. The X register contains the offset and Y the value to be written (in the case of FX 151). For read operations, the value is returned in Y. For example, to write 254 to the user port, the A reg would be set to 151, Y to 254, X to &60 and &FFF4 called from Basic this would be:

```
A%=151:X%=&60:Y%=254:CALL&FFF4
```

68000 Assembler

The microprocessor used in the Atari ST and Commodore Amiga is relatively easy to program in assembly language. Anyone with experience of the 6502 will find moving up to the 68000 a snap. Users of the Z80 may have to learn a few new concepts but, again, they should find it easy.

Of the to machines, the ST is by far the easiest to program and also provides easy access to the sound chip and printer port. However, the designers of the system decided that certain areas of memory, notably those to do with I/O should be protected. This uses the privilege violation trap provided by the system which occurs when external hardware senses a memory access in a prohibited area To get around privilege violations, the microprocessor must be put into supervisor mode.

The 68000 has two main operating modes, user and supervisor. A number of instructions and options are only available in the latter so that major system functions cannot be altered by processes that don't have the privilege level. This has the main advantage of stopping run-away programs making a complete mess of the system – for example, it can't mess up any I/O since this is in reserved memory. Getting from user mode to supervisor mode can actually only be done from supervisor mode but fortunately, user mode is able to cause exceptions. These are software interrupts normally used to access frequently used portions of program. One feature of them is that they always enter supervisor mode – normally they return to user mode when the end so programs can't accidentally go into supervisor mode.

To switch from user mode to supervisor mode (and back) a special system call (GEMDOS) is available.When first used a zero on the stack tells it that supervisor mode is required. Using it with any other value on the stack returns to user mode – the value passed to the is actually the address of the stack for user mode. The general routine to enter supervisor mode is:

```
CLR.L    -(SP)          Zero on the stack
MOVE     #$20,-(SP)     GEMDOS Super command
TRAP     #1             Call GEMDOS
ADDQ.L   #6,SP          Correct stack
MOVE.L   D0,STKSVE      Save the old stack pointer
```

a return to user mode can be made with:

```
MOVE.L   STKSVE,-(SP)   Old stack pointer on stack
MOVE     #$20,-(SP)     GEMDOS Super command
TRAP     #1             Doit
ADDQ.L   #6,SP          Correct stack now in user mode

STKSVE   DS.L 1         Set aside space for pointer save
```

Atari ST

The Atari ST is even more dependent on system calls for I/O than the BBC micro. It has a much more complicated operating system and design changes mean that the memory locations of certain chips have been changed.

As it stands the ST doesn't have a user port. However, the Centronics connection is not buffered in such a way as to preclude inputs and can be used instead. Unfortunately, access is through the sound chip – note that this only applies to older 520s and 1040s which use the YM2149 or equivalent PSG (Programmable Sound Generator).

Only two memory locations are used to access the 15 registers in the PSG. The first, at $FF8800 ($ is used to denote hexadecimal notation unlike the 'non-standard' BBC) and, when written to, selects the desired PSG register. Reading from this location returns the value held in the selected register. $FF8802 is used to write data to the selected register. A minor complication is that the 68000 microprocessor has to be in supervisor mode when directly accessing these locations from machine code – see box.

Other I/O options available on the ST involve the multi-function peripheral (MFP) chip which provides a few extra lines on the video port, the RS232 and the printer port.

One other option that is sometimes used is the cartridge slot. This doesn't actually have a write line available to it so, at first sight, outputs are not possible. However, by clever use of the large range of memory addresses, an eight-bit I/O port can be set up. Fig. 8 illustrates the idea in block form. By using external logic to interpret one of 256 addresses as a number between 0 and 255, eight bits of data are simulated. For example, to set bit 7, the 128th address in the range is read from. The external logic sees that this is in the correct range and sets the top bit of the port. Reading in is straight-forward since there is a read line available.

Accessing the ST's PSG

Unlike many VIA chips, the PSG only allows its I/O port to be all inputs,or all outputs. The direction is set by bit seven in register seven. One defines output and zero input. The port register itself is 15 and when the port is set for output, any data written here will appear at pins D0 to D7 on the centronics port. Setting the port for input and reading port 15 allows any data on the port to be read into the computer. The process in 68000 machine code, after going into supervisor mode is roughly as follows:

```
MOVE #7,$FF8800   Select register 7
MOVE $FF8800,D0   Read register 7
AND  #127,D0      Set I/O bit to in
MOVE D0,$FF8802   And write it back
MOVE #15,$FF8800  Select reg 15
MOVE $FF8800,D0   And read it.
```

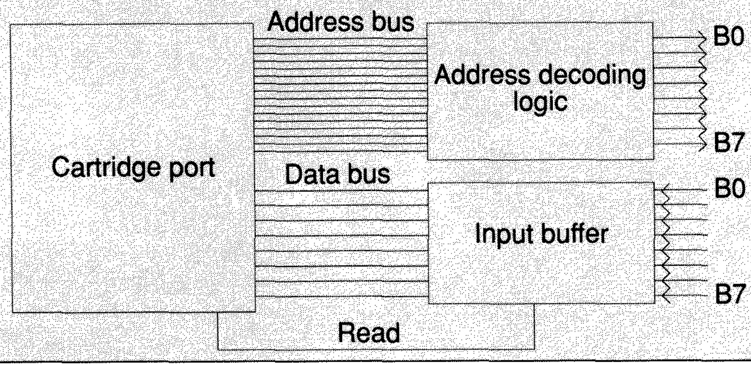
This can be done from Basic with Peek and Poke but care should be taken since the operating system can reset PSG registers when the bell rings or the key clicks.

An alternative method of access is to use the system calls with the giaccess xbios routine – it also doesn't need to go into supervisor mode. For example:

```
MOVE #128+15,-(sp) Write to reg 15
MOVE #1,-(sp)      A one
MOVE #28,-(sp)     Giaccess call
TRAP #14           Call xbios
ADDQ.L #6,sp       Correct stack
```

This will write one to register 15. The 128 added to the value tells the routine to write rather than read. Note that when reading, the data will be returned in register D0.

Fig. 8. Block diagram of read only output port.



Amiga

Like the ST, the Amiga doesn't have a user port as such but is able to use its parallel printer port instead. This is driven by an 8250 interface adaptor chip and, as in the BBC, allows the direction of each bit to be set independently. Note that the following memory locations probably only apply to the Amiga A500.

The data direction register is at memory location $BFE301 and the port itself at $BFE101. As usual, one defines an out and zero an input and the eight-bits of parallel data appear and can be read from D0-D7 of the centronics connection. Care should be taken when experimenting with the Amiga's ports as they are not particularly well protected and shorting them out can harm the machine.

Commodore 64.

As well as its cartridge, cassette, serial IEEE and joystick ports, the C64 has a built in user port. This operates in a very similar way to the BBC – the registers in the 6526 CIA are shown in Fig. 1 and the connections in Fig. 9. The port address is at 56577 ($DD01) and the eight bits correspond to PB0-PB7. The data direction register is at 56579 ($DD03) and as usual, one denotes output and zero, input.

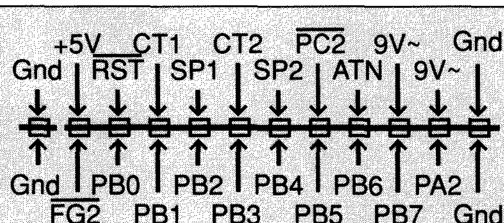
From Basic, PEEK and POKE can easily set up the user port to perform simple ins and outs. For example, POKE 56579,240 sets PB7-PB4 to output and PB3-PB0 to input. Looking at the user port connection in Fig. 9. there are a number of lines available other than the eight that form the port. In practice, the C64 has two CIA chips and some of the spare control lines from the second chip also appear – to differentiate between them, they are numbered 1 and 2. The four CIA control lines, CT, SP, FG and PC are used for handshaking and RST goes to the C64's microprocessor reset – taking this low will make the machine re-boot. ATN and PA2 are from parallel port A. ATN should really be labelled PA3 since this is where is comes from. They are normally outputs but can be re-configured by altering data direction register A bits 2 and 3. The power supply output +5V can be used to drive circuitry but beware of placing heavy loads on it. The 9V AC outputs come from the computer's power supply and need stabilising and regulating if they are to be used.

The control lines are used to help with the transfer of data either through the parallel or the serial port. The SP line connects directly to the CIS shift register and can be input or output depending upon the setting of bit six in control register A. Data is transferred under the control of timer A or the CT line allowing synchronous (external clocking) or asynchronous (internal clocking) transfers to be made. When a complete shift of eight-bits has been made in or out, the SP interrupt flag is set in the ICR allowing the processor to read in the data from or load some more into the shift register.

The FG or flag line is simply connected to a bit in the ICR. When it is moved from high to low, the interrupt bit is set. Reading the ICR will clear any set bits allowing the next FG input to be observed. This is a useful function since it allows external hardware to signal the processor when data is ready. For example, an ADC (Analogue to Digital Converter) could pull this line low when it finishes a conversion so that the computer only reads data in when it is ready.

The PC line is used to handshake with devices transferring data over the user port. The line goes low once clock cycle after data has been read or written through port B – PB0 to PB7. Any external device can then sense this and put or get some more data from the port. This lines allows data transfers to take place at a very high speed, generally set by the speed of the computer program reading and writing the port.

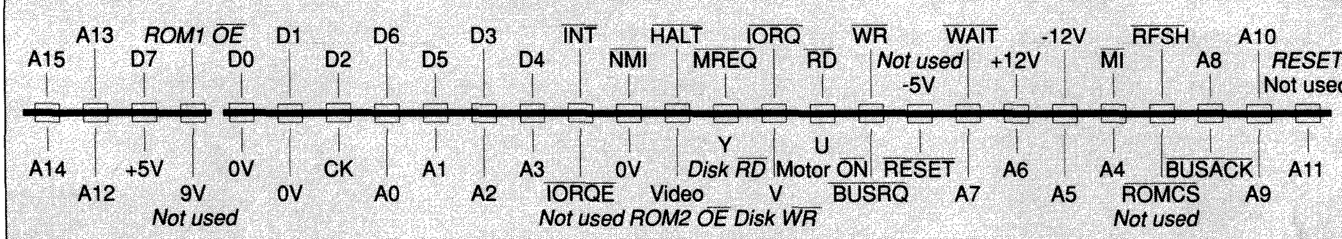
Fig. 9. C64 User Port pinout.



Spectrum

The old Sinclair Spectrum provides no easy way to attach a user port since it doesn't have any interfaces as standard – newer models come

Fig. 10. Spectrum expansion bus – italics denote later models.



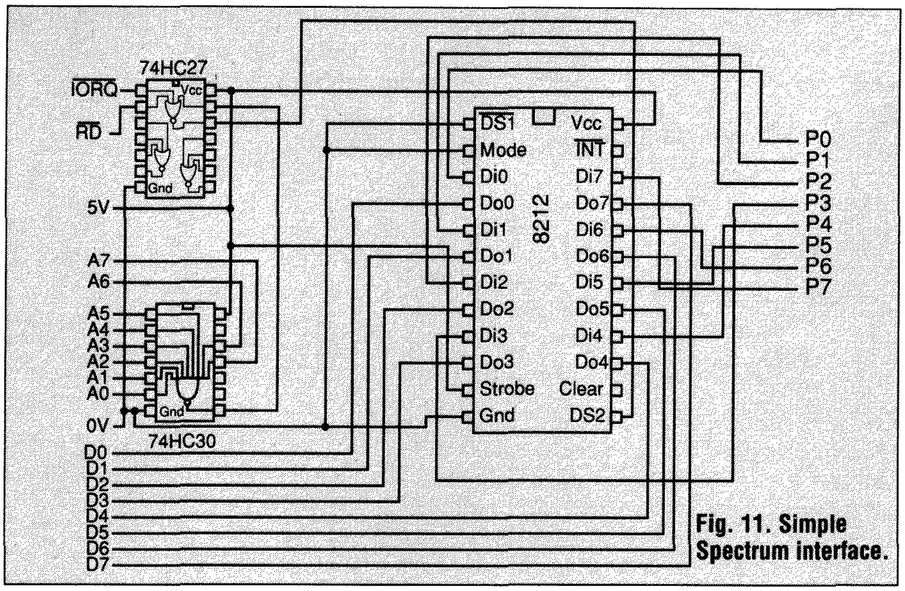


Fig. 11. Simple Spectrum interface.

with disk drives, printer and serial interfaces but the main expansion bus is virtually identical. The differences are not vitally important and are shown in Fig. 1 in italics.

A simple interface for the Spectrum is shown in Fig. 11. his decodes the address and handshake lines and uses an I/O chip to feed the data onto the data bus.

The commands available in the Spectrum are IN and OUT which both take a port number and send or receive data. The port number is put onto the address bus and the IORQ line is sent low. Depending on whether a read or write is taking place, the appropriate line is also sent low. The address can be detected by an eight-input gate, in this case, NAND which also produces a low output when the correct address appears. The three low signals can be sensed by the NOR operation which then signals the 8212 and enables its outputs on the the Z80 data bus. The Spectrum then reads this in and either places the value into a variable or onto the screen.

One result of only using eight address lines is that the port appears at a number of addresses in the I/O address space – any that have address lines A0 to A7 high which are 255, 511, 1023, 2047 and so on... This means that PRINT IN 255 will give the same result as PRINT IN 511. To decode the address further, another eight input NAND must be used and both the outputs NORed and inverted to give a 16-bit address.

To get a user port that gives outputs, the same sort of arrangement can be set up but the 8212 is reversed and the WR line is sensed. The port must also be placed at a different address – alternatively, the same address can be used by the activation of the WR and RD lines can be used to differentiate between the two 8212s. To get another address, one of the spare inverters in the 7427 chip – connect all three inputs together to form one input - can be used inserted where one of the address lines goes into the eight-input gate. For example, putting this into line A0 makes the port address 254 (and multiples), that is, all lines high with A0 low but inverted to give a high. The only thing to watch out for when connecting ports up to the Spectrum is to avoid clashing with existing system ports. However, there are 65536 to choose from so a spare one or two can usually be found.

IBM PC

PC compatibles provide expansion slots to which extra equipment can be added. Attaching a user port requires the use of an interface adaptor, say the 8255 PPI for complex systems or an 8212 for simple I/O. The connections are shown in Fig. 12 with the important ones being: I/O read and write, the data bus D0 to D7, address latch enable, the address bus A0 to A19. When a valid address appears on the bus, ALE is sent high. An I/O read or write is signaled by sending I/O read or write low and the data can be transferred over the data bus – the Basic supplied with the machine usually has INP and OUT instructions. The AEN line is used to define whether the microprocessor or a DMA (Direct Memory Access) is taking place. AEN should be high for an I/O read or write from the microprocessor. A circuit similar to that for the Spectrum could form a simple user port, all that is needed is a little more decoding. ■

Pin	Name	Pin	Name
B1	Gnd	A1	I/OCHCK
B2	Reset DRV (reset cards)	A2	D7
B3	+5V	A3	D6
B4	Interrupt ReQuest IRQ2	A4	D5
B5	-5V	A5	D4
B6	DMA ReQuest DRQ2	A6	D3
B7	-12V	A7	D2
B8	Reserved	A8	D1
B9	+12V	A9	D0
B10	Gnd	A10	I/OCHRDY
B11	Memory Write MEMW	A11	Address ENable AEN
B12	Memory Read MEMR	A12	A19
B13	I/O Write IOW	A13	A18
B14	I/O Read IOR	A14	A17
B15	DMA ACKnowledge DACK3	A15	A16
B16	DRQ3	A16	A15
B17	DACK1	A17	A14
B18	DRQ1	A18	A13
B19	DACK0	A19	A12
B20	CLocK CLK 4.77 MHz	A20	A11
B21	IRQ7	A21	A10
B22	IRQ6	A22	A9
B23	IRQ5	A23	A8
B24	IRQ4	A24	A7
B25	IRQ3	A25	A6
B26	DACK2	A26	A5
B27	T/C DMA complete	A27	A4
B28	Address Latch Enable ALE	A28	A3
B29	+5V	A29	A2
B30	OSC 14.31818 MHz	A30	A1
B31	Gnd	A31	A0

Fig. 12. Pinouts of the IBM PC expansion connector.

Getting It All Down On Silicon

John Becker shows how easy it is to use a PC-compatible computer for programming PROMs and looks at the 8255 PPI and 78S40 switch mode regulator in the process.

This project enables an IBM PC-compatible computer to program three varieties of PROMs (programmable read only memories). The main unit is for use with EEPROMs (electrically erasable PROMs) and Lithium battery-backed memories (also known as NVMs or non-volatile memories and, strictly speaking, RAMs, random access memories). An optional secondary unit extends the project to include UV-erasable EPROMs. The basic operation of the system is shown in Fig.1.

In addition to the main object of producing a programmer, three aspects of the design are of additional interest to experimenters. Practical examples are shown of PC-bus decoding, use of the 8255 programmable peripheral interface (PPI), and use of the 78S40 switch-mode voltage converter.

On The Buses

Typically, PC-compatible computers have at least three expansion slots for use with add-on peripheral cards. They are directly connected to the computer address, data, control and power buses. Of the 64 lines available, this PROM-programming unit uses only 22: address lines A0, A1, A3-A9, data lines D0-D7, AEN, RD, WR, +5V and 0V.

The standard PC memory map has the hex-block addresses \$0300-\$031F reserved for use with prototype cards. In Fig. 2, IC1 and IC2a are used to decode this block into eight sub-blocks, any of which may be used as the controlling address base. This allows the unit to be accessed at unique addresses which do not conflict with other expansion cards that may be on the bus at the same address. In the circuit diagram, the decoder is shown connected for use with address block \$0300-\$0307. In conjunction with IC1, IC2b gates the WR (Write) line, and IC3 gates lines A0, A1 and the RD (Read) line.

8255 PPI Programmable Peripheral Interface

Although it is possible to program high-speed PROMs by connecting them directly to the computer bus, slower devices such as EPROMs require longer control pulses. Typically, EPROMs need a write pulse of between 10ms and 50ms. Pulses of this length cannot be sent directly from the computer bus and a form of pulse expansion needs to be used, ensuring that the EPROM control lines remain stable for the required duration. There are several techniques that could be used, including discrete serial or parallel latches. In this project, multiplexed parallel latching via an 8255 PPI (IC4) is used.

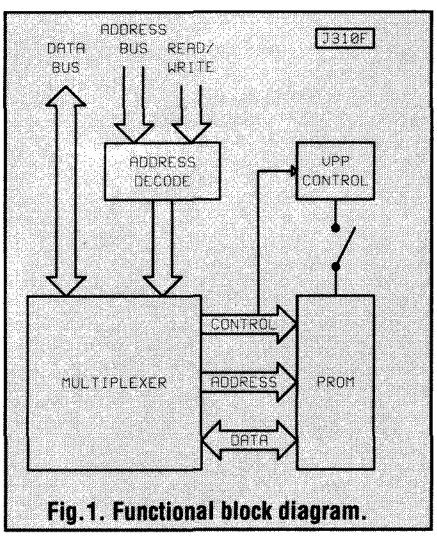


Fig.1. Functional block diagram.

The 8255 has an 8-bit bi-directional data port (D0-D7) and three 8-bit input-output registers (PA0-7, PB0-7, PC0-7). Fig. 3 shows the basic idea.

There are three modes in which the 8255 can be used:

Mode 0: Basic input/output, also called Bit I/O
Mode 1: Strobed input/output
Mode 2: Bi-directional bus.

Mode 0, the simplest of the three is used in the project. Its control functions are selected by setting the control register in accordance with the data in Fig.4 and Fig.5.

Any of the ports A-C may be set as inputs or outputs by changing the control word data. However, it should be noted that writing to the control register automatically clears any data within the port registers. This inconvenience must be allowed for when writing software control programs.

Port Selection

In this project, Port PB0-7 acts as the input/output port conveying data to and from the PROM, shown as IC5 in Fig.2. Port C outputs address line data to IC5 A0-A7. PA0-PA2 control address lines A8-A10. PA3 is inverted by IC6b and controls the Write/Vpp input of IC5. With EEPROMs and NVMs, the output of IC6b is switched by S2 directly to the Write pin (pin 21). IC6b also controls the programming pulse voltage (Vpp) generator used when programming EPROMs, S2 being used to switch the generator into circuit.

PA4 controls the Output Enable (OE) pin of IC5, while PA5, inverted by IC6a, controls the Chip

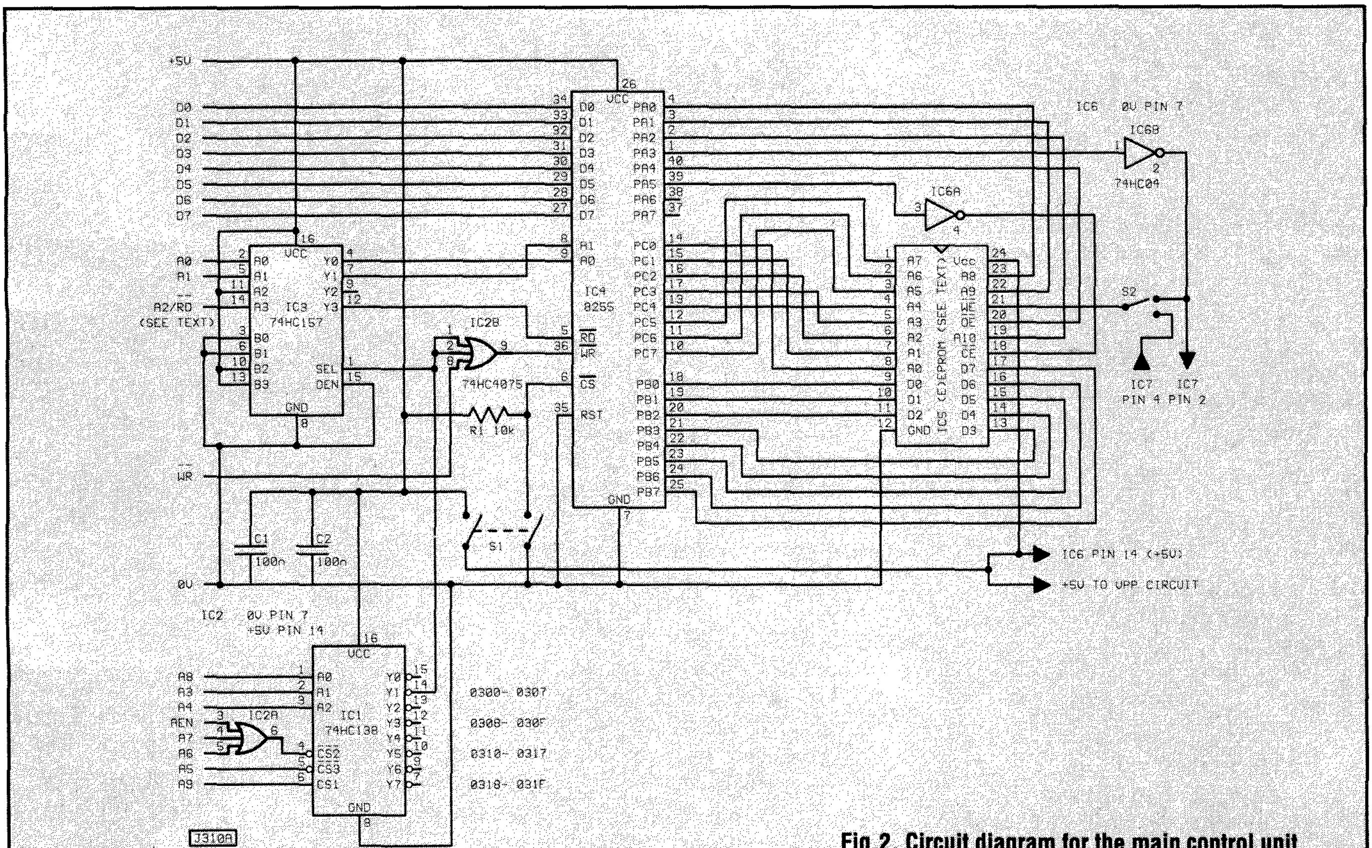


Fig.2. Circuit diagram for the main control unit.

Enable (CE) pin. PA6 and PA7 are not used.

Basic Ins And Outs

The controlling software program is written entirely in Basic. The variant used in the listing of Fig.6 is GW-Basic – probably the most common available to PC users. When using the program with other versions of the language, the principal change that may need to be made is the possible substitution of PEEK and POKE for INP and OUT in the input and output routines. Some dialects may also need the statement Z$=INKEY$ to be replaced by Z$=INKEY$(0) or GET Z$.

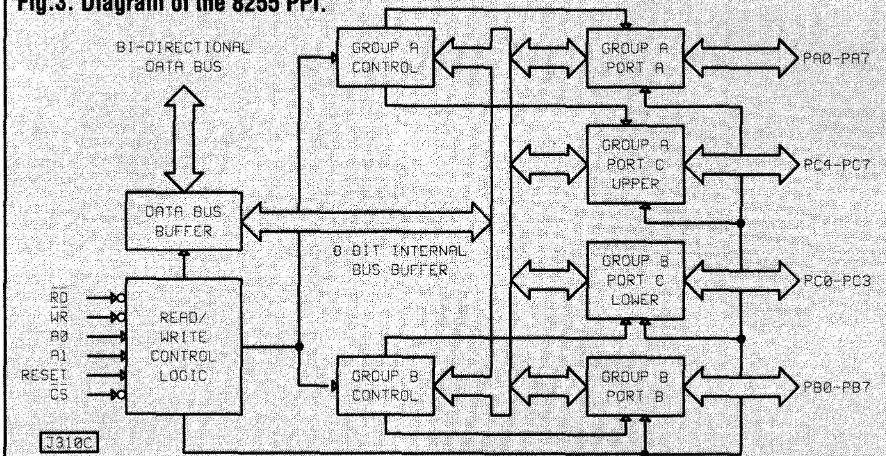
The memory-map address at which the programmer is accessed is set by the value of A in line 110. The value of 768 is the decimal equivalent of hex $0300. The other control addresses are automatically offset in line 110 using 'A' as the base.

There are five program menu options. They apply to all three PROM varieties. Option 1 is used when programming individual PROMs. It prompts for the address within the PROM at which the programming is to start, and then asks for the start and end addresses within the computer memory of the data to be transferred. An error intercept routine then asks confirmation that the data is correct.

Once the data is entered, the 8255 is set with all three ports as outputs, and the PROM programming is carried out as a continuous write operation. On completion of the writing, Port B is set as an input, while Ports A and C remain as outputs. The program then checks that the data programmed into the PROM is correct. If any errors are detected, their values and locations are displayed on screen.

If data errors occur when programming EEPROMs or NVMs, the correct data can be selectively reprogrammed into the required locations. Errors occurring with EPROMs, though, will usually require the EPROM to be erased and then reprogrammed. (There are instances where erasing may not be necessary. A high, Logic 1, bit can be selectively reprogrammed low. However, a low bit cannot be reprogrammed high. If there is an error, examine its binary code against that of the desired number to see whether selective bit setting can be used without the need for erasure.)

Fig.3. Diagram of the 8255 PPI.



Menu option 2 is used when several PROMs need to be programmed with the same data. The initial data is set via option 1, then for each subsequent copy, option 2 is called.

Option 3 allows for separate checking of PROM data between the addresses originally entered in option 1. Option 4 provides for PROM contents to be displayed on screen. A 'Pause' facility enables the display to be halted, and then continued or aborted.

The final menu option is only used for checking the unit once it has been constructed. The routine resides at lines 450-600. The REM notations state the function controlled by each line. They may be omitted when keying in the program.

The test routine simply increments a counter, writing the counter value to the PROM address of the same number. At the end of the write loop, the PROM contents are checked and displayed. In line 480, the loop values in the statement FOR B=0 TO 25 may be changed to suit requirements.

Power On

The unit draws its power directly from the computer +5V power supply, via the expansion socket interface PCB. IC1-IC4 remain continuously powered while the computer is switched on. IC5 and IC6 are only powered when S1 is switched on. The program has screen prompts which advise when S1 should be switched on or off. These must be obeyed otherwise erroneous data may be written into a PROM. S1 also controls the $\overline{CS}$ pin of the 8255 removing internal power levels from all pins of Ports A-C. This allows PROMs to be inserted or removed safely once S1 has been switched off.

High Voltages

EPROMs require a programming voltage of greater than +5V. The value depends on the EPROM type, typically ranging between 12.5V and 25V. The value will be stated in EPROM data sheets, or advised by suppliers.

This project's Vpp generator is shown in Fig. 7. It can be set by VR1 for any voltage within the 12.5V to 25V range, and with a fair margin to either side.

The heart of the unit is IC8, a 78S40 voltage converter. The chip is a versatile switching voltage regulator that can be used to perform a variety of voltage control functions, including step-down, step-up and inversion. It is used here as a step-up regulator. The chip's power is supplied from the computer's +5V line, via S1, and controls an output voltage which is generated across the external inductor, L1.

An oscillator within the chip has its frequency set by C5. The clock pulses cause current to be switched through L1, which, in simple terms, converts the current changes into voltage peaks of an amplitude related to inductance value, frequency and load. The inductor's output is rectified by the chip's internal diode and stored in C3. A proportion of the resulting DC voltage is fed back to the chip via the chain R6, VR1 and R7. The chip then controls its switching process so that the output voltage remains constant at the level set by VR1.

The pulsing requirement for an EPROM calls for a high voltage on its Write/Vpp pin to 'burn in' the data for a duration of between 10ms and 50ms, depending on the EPROM type. At the end of the pulse the level must revert to around +5V.

An optically coupled isolator, IC7, is used to control the Vpp pulsing. The chip consists of an internal LED and a light sensitive transistor. The transistor only conducts when the LED is turned on. IC8b controls the LED under direction of line PA3. When the LED is off, the EPROM's Write/Vpp pin is held at +5V via R2 and D1. For the duration of the programming pulse, the LED is turned on, allowing the opto-isolator's transistor to conduct the Vpp voltage from IC8 to the EPROM. D1 prevents the higher voltage from affecting the +5V line, while R1 speeds the Vpp discharge once the transistor has closed.

Variation of the Vpp control pulse length has not been allowed for in the controlling software. It was found that with the program written in Basic, the inherent pulse length was satisfactory even for the 50ms requirements of some EPROMs. On faster computers, a holding loop can be inserted in the program between the two OUT CTL commands in line 300. For example:

OUT CTL,120 OR HI:FOR PP=1 TO 50:NEXT:OUT CTL,112 OR HI

Amend the maximum loop count value by experimentation or measurement of the pulse monitored at IC8b.

Note that when using the unit, the Vpp voltage must be preset before inserting the EPROM, measuring the level with a multimeter. A test point is provided on the PCB.

A0	A1	$\overline{RD}$	$\overline{WR}$	$\overline{CS}$	OPERATION
0	0	0	1	0	READ PORT A
0	1	0	1	0	READ PORT B
1	0	0	1	0	READ PORT C
0	0	1	0	0	WRITE TO PORT A
0	1	1	0	0	WRITE TO PORT B
1	0	1	0	0	WRITE TO PORT C
1	1	1	0	0	WRITE TO CONTROL REGISTER
X	X	X	X	1	NO TRANSACTION
1	1	0	1	0	ILLEGAL
X	X	1	1	0	NO TRANSACTION

X = DON T CARE

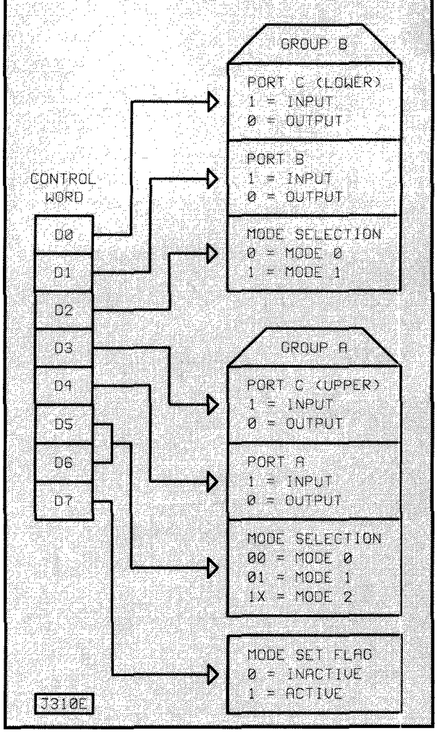
J310D

Fig.4. Access codes for the 8255 PPI.

Putting It All Together

There are three PCBs for this project: the main control unit (Fig.8), Vpp generator (Fig.9), and the third (Fig.10) for plugging into the computer's expansion socket. The latter board is double-sided

Fig.5. Bit definitions for the 8255 PPI control register.



```
100 REM BUS/8255 (E)EPROM PROGRAMMER 17 JAN 91
110 COLOR 15,1:A=768:RS=A+7:AL=A+6:DW=A+5:CTL=A+4:DR=A+1:DIM A$(8)
120 A$(1)="PROGRAM (E)EPROM":A$(2)="REPEAT "+A$(1):A$(3)="CHECK "+A$(1)
130 A$(4)="VIEW (E)EPROM":A$(5)="TEST CHECKOUT":A$(6)="(E)EPROM START
ADDRESS"
140 A$(7)="MEMORY START ADDRESS":A$(8)="MEMORY END ADDRESS"
150 OUT RS,128:OUT CTL,112
160 CLS:COLOR 15,1:PRINT:PRINT TAB(30);"SWITCH OFF POWER":PRINT
170 COLOR 14,1:PRINT:PRINT:FOR V=1 TO 5:PRINT:PRINT TAB(25);V;A$(V)
180 NEXT:PRINT:PRINT TAB(26);:INPUT "WHICH";Z$
190 V=VAL (Z$):IF V<1 OR V>5 THEN 180
200 L=LEN (A$(V)):T=38-(L/2)
210 CLS:COLOR 14,1:PRINT:PRINT:PRINT TAB(T);A$(V):PRINT
220 COLOR 15,1:PRINT TAB(23);"INSERT (E)EPROM, SWITCH ON POWER":GOSUB
610
230 ON V GOTO 240,270,320,390,450
240 CLS:COLOR 14,1:PRINT:PRINT:PRINT:PRINT:PRINT TAB(26);A$(6);:INPUT
ES:PRINT
250 PRINT TAB(26);A$(7);:INPUT MS:PRINT:PRINT TAB(26);A$(8);
260 INPUT ME:GOSUB 610
270 IF V=2 THEN GOSUB 650
280 M=ES-1:COLOR 15,1:FOR AD=MS TO ME:D=PEEK(AD):M=M+1:HI=INT(M/256)
AND 15
290 LO=M-(HI*256):OUT CTL,112 OR HI:OUT AL,LO
300 OUT DW,D:PRINT D;:OUT CTL,120 OR HI:OUT CTL,112 OR HI:NEXT:PRINT
310 COLOR 14,1:PRINT:PRINT TAB(31);"CHECK (E)EPROM":PRINT
320 E=0:IF V=3 THEN GOSUB 650:PRINT:PRINT TAB(34);"CHECKING":PRINT
330 OUT RS,130:OUT CTL,96:N=MS:FOR B=ES TO M:HI=INT(B/256) AND 15:LO=B-
(HI*256)
340 OUT CTL,96 OR HI:OUT AL,LO:D=INP (DR):IF D=PEEK(N) THEN 370
350 COLOR 12,1:PRINT TAB(20);"ERROR ";D;TAB(31);"AT LOC";B;
360 PRINT TAB(42);"SHOULD BE";N:E=1
370 N=N+1:NEXT:PRINT:COLOR 14,1:IF E=0 THEN PRINT TAB(33);"CHECKED OK"
380 COLOR 31,1:PRINT:PRINT TAB(30);"SWITCH OFF POWER":GOSUB 610:GOTO
150
390 REM view (e)eprom
400 CLS:PRINT:PRINT:PRINT TAB(28);"PRESS ANY KEY TO HALT":PRINT:PRINT
410 OUT RS,130:OUT CTL,96:FOR B=0 TO 2047:HI=INT(B/256) AND 15:LO=B-
(HI*256)
420 OUT CTL,96 OR HI:OUT AL,LO:PRINT INP (DR);:Z$=INKEY$:IF Z$="" THEN
440
430 PRINT:PRINT:PRINT TAB(26);"LAST MEMORY LOCATION ";B:GOSUB 610
440 NEXT:PRINT:GOSUB 610:GOTO 150
450 REM eeprom test checkout
460 OUT RS,128:REM set all 8255 registers as outputs
470 OUT CTL,112:REM A8-A10 = 0, eprom OE off, READ on, CE on
480 FOR B=0 TO 25:REM set loop length - may be varied
490 OUT CTL,112:REM A8-A10 = 0, eprom OE off, READ on, CE on
500 OUT AL,B:REM set A0-A7 to value B
510 OUT DW,    B:PRINT B;:REM send B as data to eprom and print to
screen
520 REM above may be rewritten for other values, eg OUT DW,255-B
530 OUT CTL,120:REM OE off, WRITE on, CE on
540 OUT CTL,112:REM OE off, READ on, CE on
550 NEXT:PRINT
560 OUT RS,130:REM set 8255 REG B as input
570 OUT CTL,96:REM OE on, READ on, OE on
580 FOR B=0 TO 45:OUT AL,B:REM step through low addresses
590 PRINT INP (DR);:NEXT:PRINT:REM display eprom contents
600 GOSUB 610:GOTO 150
610 COLOR 14,1:PRINT:PRINT TAB(26);"[M] MENU   [BAR] CONTINUE":PRINT
620 Z$=INKEY$:IF Z$ = "" THEN 620
630 IF Z$="M" OR Z$="m" THEN RUN
640 RETURN
650 CLS:COLOR 15,1:PRINT:PRINT:PRINT
TAB(30);"CURRENT SETTINGS":PRINT
660 COLOR 14,1:PRINT
TAB(26);A$(6);ES:PRINT
670 PRINT TAB(26);A$(7);MS:PRINT:PRINT TAB(26);A$(8);ME:GOTO 610
```

Fig.6. Complete Basic software listing.

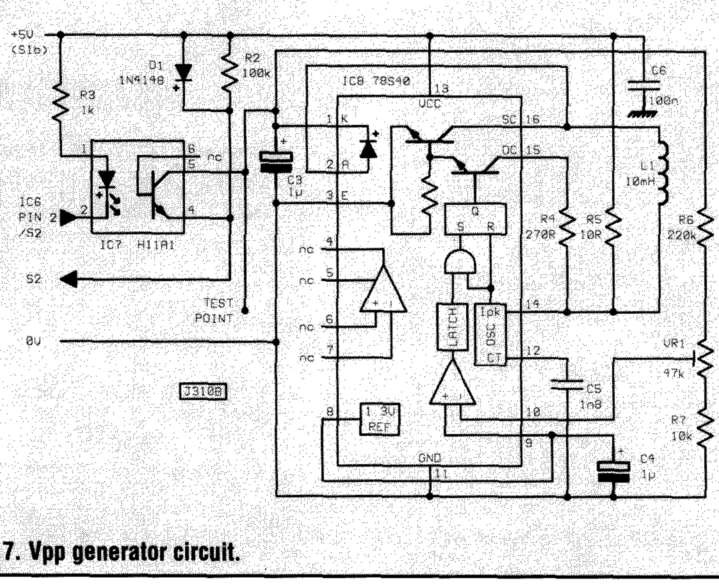


Fig.7. Vpp generator circuit.

and has been designed as a general purpose connector allowing access to all expansion socket lines for use in other applications. Only those connections required by this project need to be made. The remainder are left unconnected.

If you are making your own PCBs and do not have facilities for double-sided boards, the connector can be made as two single-sided boards, plugging each into a separate expansion socket. Ensure that you observe the correct track polarities!

Take care when soldering on the main PCB as many tracks run between the IC pins. Sockets should be used for all ICs. A ZIF (zero insertion force) socket is recommended for the PROM position, allowing ready insertion and removal of chips without damage to their pins.

If the unit is to be used without the Vpp board, the use of a box is questionable as there is little to be protected. If you are using the Vpp board, it can go in a box with the main board and the switches mounted on the top or lid. Alternatively, mount the boards and the switches on a piece of aluminium or fibreglass sheet to which stand-off feet are mounted. The feet should allow clearance for protrusion of the switches below the assembly.

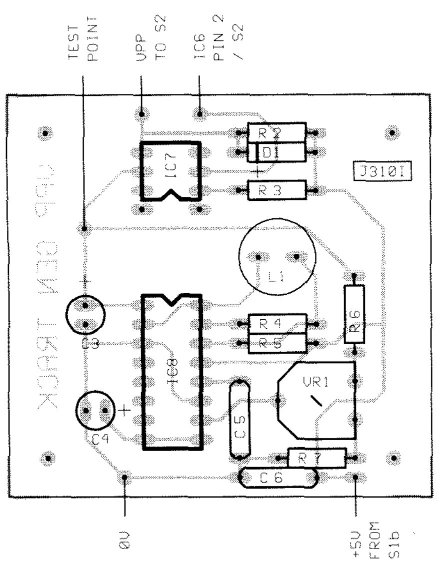
Before connecting the unit to the computer, check with a multimeter that no shorts exist. It is highly undesirable that the computer should be subjected to adverse loads caused by faulty unit assembly. Consult your computer manual for the orientation of the expansion sockets. If the computer fails to respond as normal when first switched on, immediately switch off and recheckthe work.

If all is well, run the test checkout routine to confirm correct functioning of the board. It is best to use an EEPROM or NVM for the initial checking, so avoiding the possible need to erase EPROMs.

Other Computers

It some instances it may be possible to use the unit with computers other than PC-compatibles providing that there is direct access to the microprocessor bus. The unit has, for example, been used with a Commodore 3032 – 6502-based that

Fig.9. Vpp generator board.



does not have separate read/write lines, just a common line controlling both. The necessary wiring change to the unit is simple. The RW line was brought to the unit's WR point and computer address line A2 brought to RD point. The software has been written to allow for this eventuality without modification.

It may be necessary to change the overall memory map address block used in the software to suit non-PC type machines. With the 3032, the unit was plugged directly into an unused socket located at address block \$9000-\$9FFF. The value for A in line 110 was then amended to decimal 37632, hex \$9300. (Note the importance to the unit's decoder of the '300' part of this hex address).

The 3032's equivalent of the PC's AEN (address enable) line is the CS (chip select) line allocated for the \$9000 block. Had a different block been used, the respective CS line would have been substituted and the software memory map address amended accordingly. Apart from the Basic language changes, the only other amendment necessary was the dropping of the Color commands.

PROM Variations

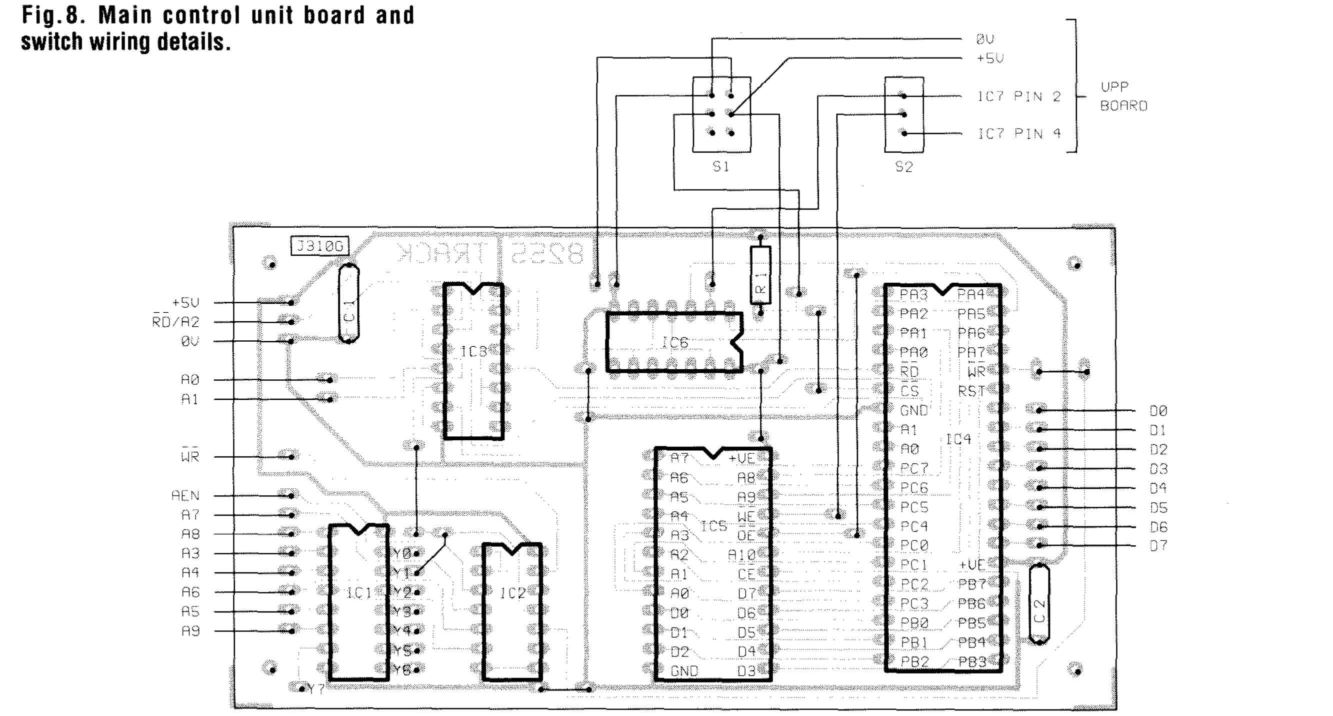
The unit has been proved with EEPROM type 2816, EPROM type 2716 and NVM types MK48Z02 and MK48T02. Fig.11 shows the designations for pins 18, 20 and 21 of these devices (the D0-D7 and A0-A10 pin-outs are common to all). Other types can probably be used instead, providing their pin-outs are the same. Experienced constructors will also recognise that by slightly amending the PCB and software, the unit can be used with 4 kbyte devices. For example, with the 2732 EPROM (Fig.11 bottom right), the additional address line A11 needs to be taken to pin 21 and Vpp to pin 20. The use of this device would necessitate re-routing the 8255 lines PA3 and PA4, and amendment of the associated software commands.

Adventurous readers are recommended to examine the data sheets for various 4 Kbyte devices to establish their requirements. ■

COMPONENTS

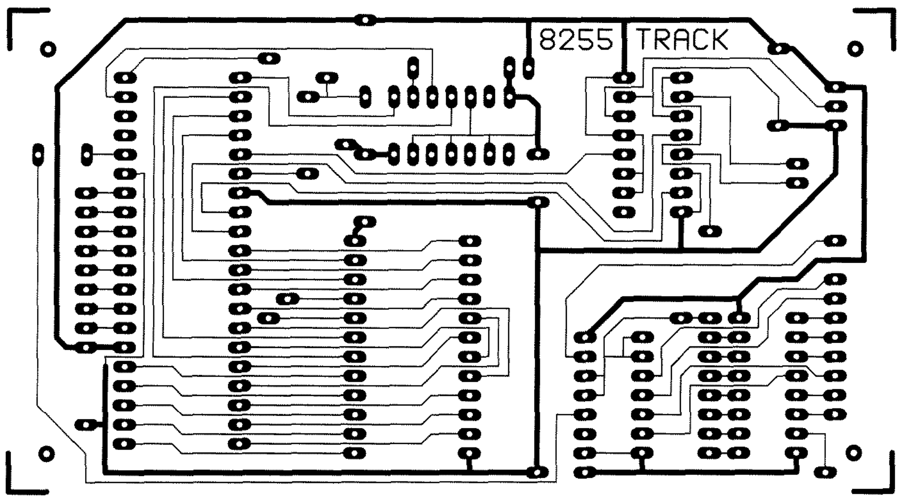
RESISTORS	
R1, R7	10k
R2	100k
R3	1k
R4	270R
R5	10R
R6	220k
All 0.25W 5% carbon film or better	
POTENTIOMETER	
VR1	47k min horiz preset
CAPACITORS	
C1, C2, C6	100n polyester
C3, C4	1µ 16V electrolytic
C5	1n8 polystyrene
SEMICONDUCTORS	
D1	1N4148
IC1	74HC138
IC2	74HC4075
IC3	74HC157
IC4	8255
IC5	PROM (see text)
IC6	74HC04
IC7	H11A1Z or OPI2046 etc
C8	78S40
SOCKETS	
6-pin dil (or 8-pin dil), 14-pin dil (2 off), 16-pin (3 off), 24-pin, 40-pin.	
SWITCHES	
S1	SPDT min toggle
S2	DPDT min toggle
MISCELLANEOUS	
10mH inductor, printed circuit boards, 22-way interconnecting ribbon cable (approx 1 metre), PCB	

Fig.8. Main control unit board and switch wiring details.

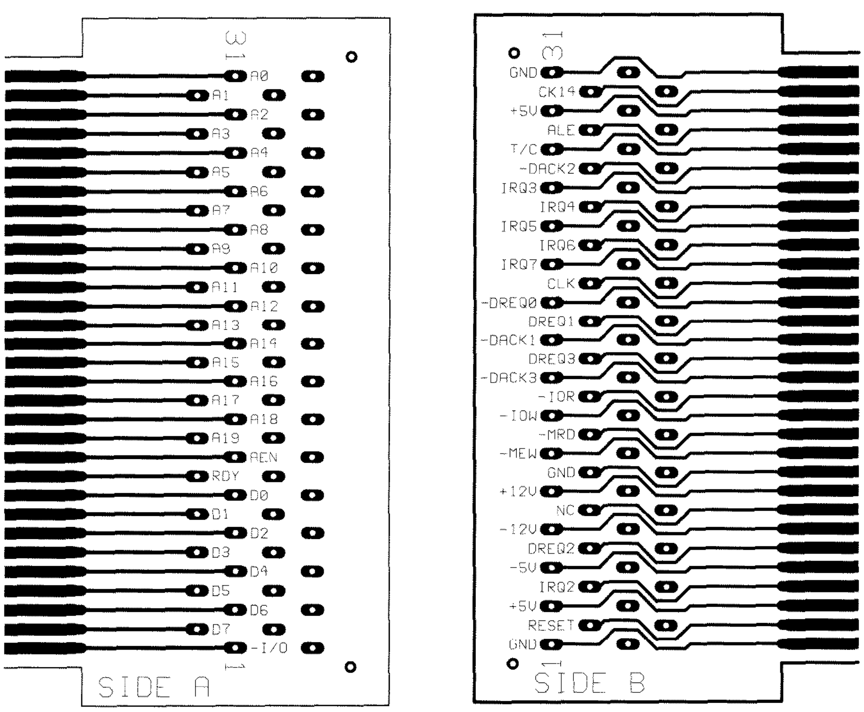


The PCBs

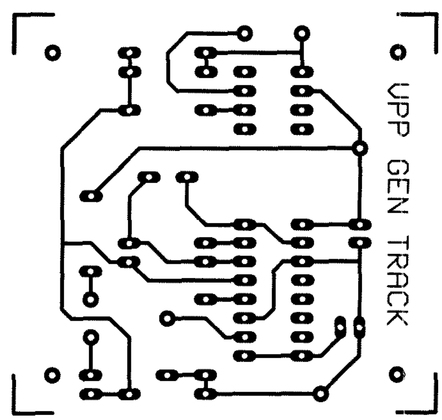
For those who want to build their own boards, 100% reproductions are shown below.



Main control unit board.



PC slot connector sides A and B.



Vpp generator board.

The Merest Flick Of A Switch

When is a switch not a switch? Anthony Smith BSc. checks out some rubber switches and suggests some ways to stop them bouncing.

Ask anyone of an electronics persuasion what they consider to be a particularly useful and common component, and you're likely to get a variety of suggestions:

"The resistor...the capacitor...a BC108...a signal diode...a 741...and LED...a D-type flip-flop...ceramic decouplers...those coily things that get rid of RFI..." and so on.

Without doubt, the humble switch should figure in this list. After all, how many times do we operate a switch of one kind or another during a typical day?

Important Contacts

The switch has been around for more than a century and has become indispensable to everyday life. To describe it as simple is, perhaps, a gross error: it may seem simple, especially when represented on a circuit diagram – just a collection of contacts which make or break as a result of some mechanical action.

However, interfacing just one SPST (Single Pole, Single Throw) switch to an electronic system can be far from simple and as the number of switches increases (up to say, a full computer keyboard), so does the complexity of the interface circuitry required.

The three main functions required of a switch are:

- Switching current to a load;
- Switching electronic signals:
- As a logic input

In the first case the load may have to be capable of handling as little as a few amperes. On the other hand, it may require thundering great big contact breakers to cope with some applications.

The second situation represents any application where electronic information must be switched along a particular route. Here, power is not usually of great importance; instead, it is the information contained in a DC or AC current or voltage which matters.

The final case is not concerned with switching power or routing signals. Instead, it is the state of the switch that's important: it is either open or closed, off or on, that is, it deals with binary information.

Unfortunately, the problem in controlling digital circuitry with mechanical contacts is that they usually generate too many inputs – far too many!

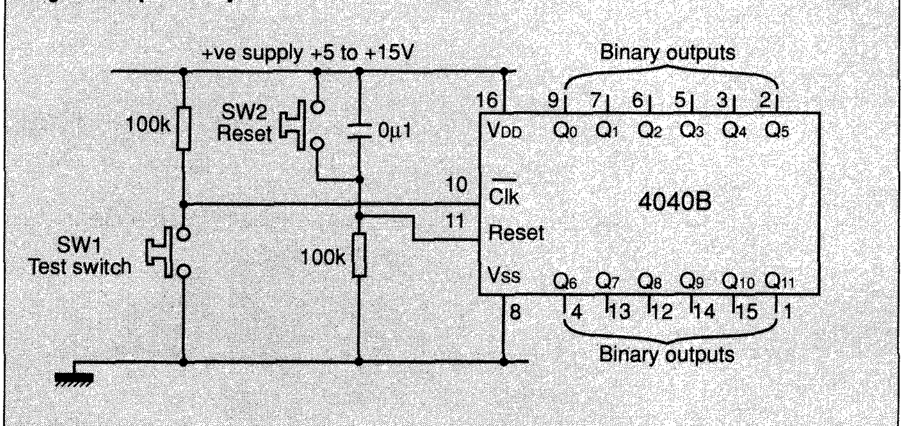
Fig.1 shows a simple circuit which can be built to illustrate this drawback.

The IC is a 12 stage binary counter. Each time a negative transition appears at its clock input (each time pin 10 is pulsed low), the 12-bit binary output is incremented just once. Output Q_0 is the least significant bit (LSB), and Q_{11} is the most significant bit (MSB). (Note that other devices could be used for IC1. For example, a 4020B 14-stage counter or 4024B 7-stage counter will suffice equally well).

To test the circuit, connect a suitable pushbutton for SW1 and apply power from a DC source in the range 5 to 15V. On power-up, the 0μ1 capacitor will pull pin 11 momentarily high, thus reseting the IC (all outputs should be low).

Now press SW1 just once, and observe the outputs using a logic probe or similar device. For an ideal switch, a single closure should increment the count from zero to one and only output Q_0 should be high. However, the chances are that several outputs will go high, corresponding to a count of anything from six or seven to over a hundred, depending on how many times the switch bounces.

Fig. 1. Simple binary counter.



Ups And Downs

Contact bounce is a fact of life for most mechanical contacts. Most of them have some inherent elasticity;

when they close, the kinetic energy in the moving parts leads to a bounceback of the operated contact. Thus, the contacts bounce back and forth many times before finally settling down. The result is a series of contact interruptions, each of which will generate a short pulse when used in an electronic application such as the circuit of Fig. 1. The duration of the bounce period (the time during which the contacts are not stable), and the number of pulses generated will depend on the type and quality of contacts used. Bounce periods of a few milliseconds are common, although this may be as long as 20ms for some devices.

Incidentally, bounce also occurs when contacts open, although this is usually less severe than when they close, and is often a result of contact resistance changes occurring when the contacts separate.

Returning to the counter circuit, reset the outputs to zero by momentarily closing SW2, and press SW1 again. Each bounce pulse generated as the switch closes is interpreted by the counter as a valid clock pulse. The resulting count can be any random number depending on how many times the contacts bounce.

Obviously, this kind of random behaviour could cause havoc if left unchecked and some way of debouncing the contacts is required.

There are times when bounce is not a problem and whether or not it will cause trouble depends on the type of input the switch is driving. For example, the bounce associated with the RESET switch (SW2) in Fig1 causes no problems, since only the first bounce pulse is required to reset the counter - subsequent bounce pulses have no effect.

As a general rule, it is usually edge-triggered inputs, such as the clock inputs of latches, flip-flops and counters, where bounce is likely to cause problems.

No Bounce

There are two approaches to solving the bounce problem. The first is to eliminate the bounce at source – this is true debouncing. The second involves some kind of hardware or software to obviate the effects of the bounce. Although such techniques are usually referred to as debouncing, they don't actually eliminate the bounces at the contacts, but instead get rid of them at some point before they can cause trouble.

True debouncing requires the use of switches or relays which simply don't exhibit contact bounce. For example, some bounceless switches make use of a moving light source. For example with an LED and a photodetector – when the switch is operated, the change in light intensity falling on the detector causes a change in the electrical output of the switch.

Other switches employ a capacitive effect, where a movable plate when pressed towards another plate causes a change in the capacitance between them. Suitable circuitry, either integral to the switch or external to it, detects this change and generates an output.

A variation on this theme employs a magnet fixed to the switch plunger which, when operated, passes over a static reed switch causing the contacts to close. Provided the contracts are bounce-free, a clean output is produced. (Incidentally, this kind of switch sometimes incorporates up to four reed switches connected in parallel

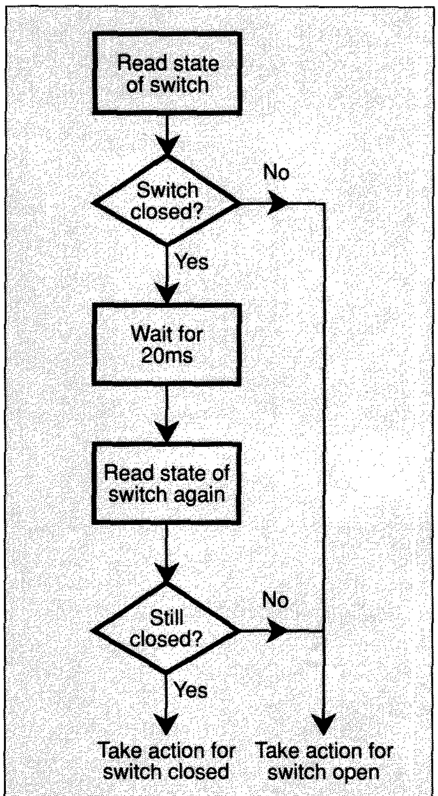


Fig. 2. Software debounce routine.

for applications requiring ultra reliability).

Hall effect switches are another kind of bounceless switch which make use of a changing magnetic field to produce a clean output.

As well as their inherent lack of bounce, most of the above switch types often benefit from prolonged life - as many as 10^8 operations or more. Unfortunately, most of them tend to be more expensive than the simple, mechanical-contact types.

Wetter Is Better

Bounce-free relays are usually typified by those with wetted reed contacts. In this class of relay, the contacts are formed by thin metal strips, or reeds, encapsulated in a

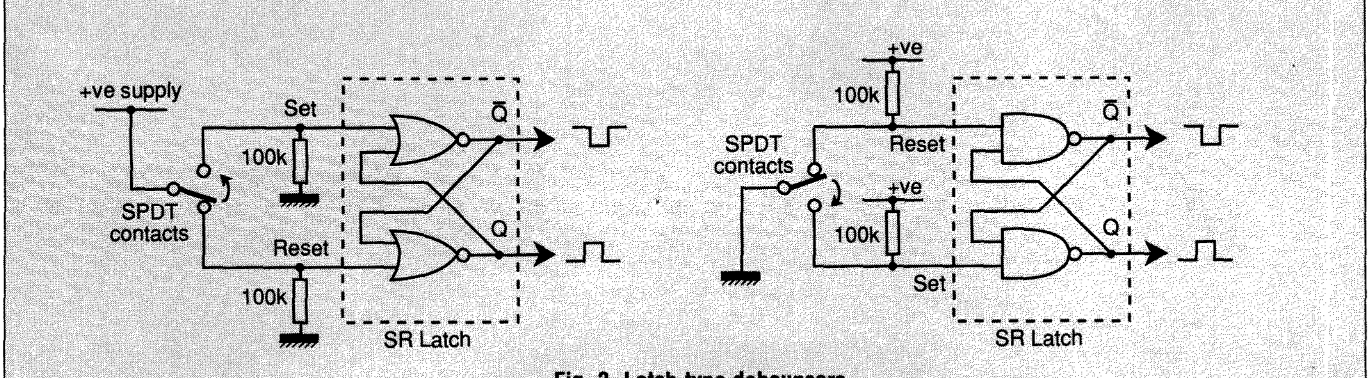


Fig. 3. Latch-type debouncers.

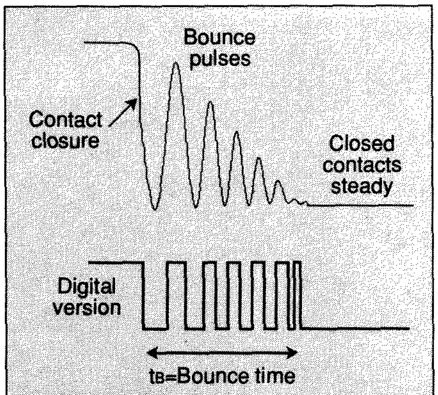


Fig. 4. Typical bounce waveforms.

glass envelope. The reeds are wetted by a thin film of mercury which provides a cushioning effect on closure, thus ensuring bounce-free operation. This also ensures reliable switching and extends the life of the relay.

For applications where cost is not restrictive, and where reliability and contact lifetime must be maximised, the bounce-free switches and relays described above are likely to be the best choice.

The Soft Option

When interfacing switches and relays to microprocessor based systems, software routines can be used to eliminate the effects of bounce. The algorithm required is fairly simple, and is represented by the flow chart of Fig. 2.

When a switch closure is detected, a delay is initiated during which time the contacts will bounce. 20ms is usually adequate for most switches. At the end of the delay, the switch status is again checked: if the contacts are still closed, the switch operation is treated as valid, and the appropriate course of action is taken.

Although elegant, this technique is sometimes undesirable since it uses up valuable processing time which could be better spent on other tasks. Consequently, where processing power is at a premium, or for systems which simply don't have any processing capability, hardware debouncing methods must be used.

Bounce Killers

There are plenty of hardware techniques available for getting rid of bounce. Monostables, latches and Schmitt triggers can all be used in one way or another to clean up the spurious outputs from switches or relays. There are also specialised ICs available for cases where an array of switches must be debounced.

First on the list is the monostable technique. This method requires simply that the monostable pulse width be set slightly longer than the maximum bounce time anticipated from the contacts. The switch is connected to the monostable trigger input. Thus, the first bounce pulse triggers the one shot. Further bounces have no effect, since the monostable generates only one output pulse when the contacts close.

Almost any monostable device can be used – a standard 555 timer (or low power version) is ideal. The only drawback is cost – for every set of contacts which need debouncing, a 555 plus six or seven passive components are required.

The technique is extremely useful, however, where only one set of contacts needs debouncing and where there is a spare monostable in the design. For example, many CMOS and TTL monostables are dual devices. The 452j8B, 4538B, 74HC123 and 74HC221 are typical examples. If only one monostable is required in the design, the other can be pressed into service as a debouncer. These devices also have the advantage that only a single resistor and capacitor are required to set the pulse width.

On The Latch

As an alternative to monostables, the simple SR (Set-Reset) latch can be used as a debouncing element. Two variations are shown in Fig.3. Both are SR latches and provide the same function, the only difference is in the gates used. For both versions, the input contacts are shown in their rest (non-active) positions – this resets the latch such that output Q is low, and Q* is high.

When the contacts change over, the first bounce pulse arriving at the SET input causes Q to go high and Q* to go low. Further bounce pulses have no effect. In order to generate a subsequent transition at the outputs it is necessary to switch the contacts back to RESET and then over to SET again.

The disadvantage of this techniques is that a change-over (SPDT - Single Pole Double Throw) switch is required – this will rule out the use of many simple pushbuttons which are only SPST devices.

Two Gates

The debouncers of Fig.3 have a further drawback in that two gates are required. However, the latch-

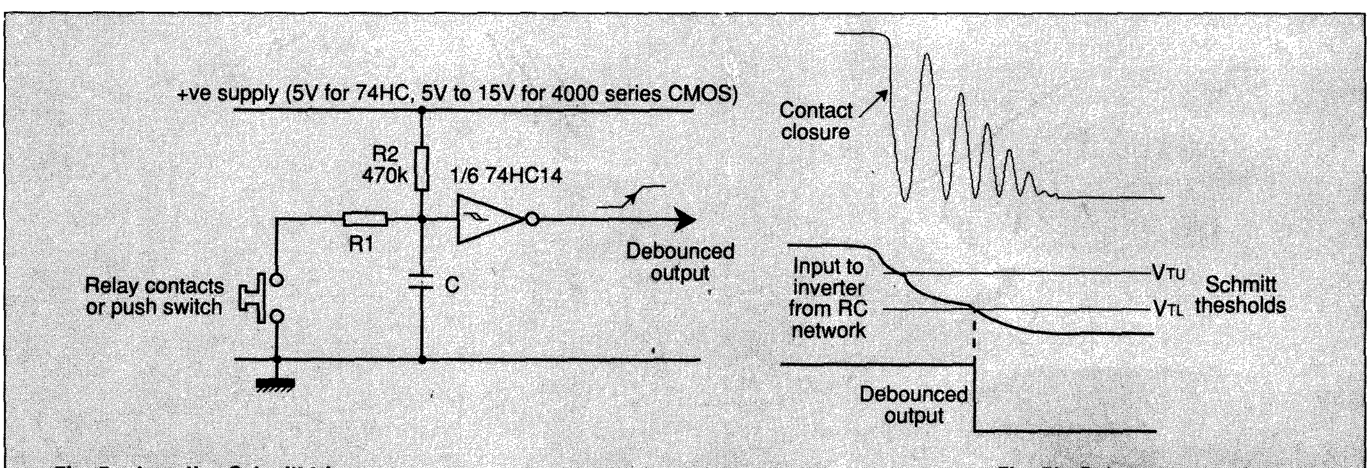


Fig. 5a. Inverting Schmitt trigger. **Fig. 5b. Debouncer waveforms.**

type debouncers are simple, reliable, and there's no need to bother with any timing components.

The NOR version can be built using gates from a 74HC02 or 4001B, whereas gates from a 74HC00 or 4011B can be used in the NAND version. Alternatively, dedicated latches such as the 4043B quad NOR SR latch can be used, as can flip-flops with over-riding SET and RESET inputs, such as the 74HC74.

To test the operation of the latch debouncer, connect one of the outputs to the clock input of the binary counter in Fig. 1. Operating the switch should increment the output by just one count. For a counter like the 4040B having a negative-transition clock input, connecting latch output Q should increment the count when the switch is moved to the RESET position, whereas connecting output $\overline{Q}$ should advance the count when the contact is switched to the SET position.

Bounce Filters

Schmitt triggers can be used as a simple and effective tool in eliminating contact bounce. However, simply feeding the contact signal directly to the Schmitt is not the solution. This will result in a series of well-defined bounce pulses as shown in the lower waveform of Fig. 4.

The signal from the contacts can be thought of as a low-frequency signal with a high-frequency bounce component. Because the bounce pulses are of a much higher frequency than the opening and closing of the contacts, they can be filtered out using an RC low-pass filter. This is the basis of the simple debounce circuit of Fig. 5a, where R1 and C are the low-pass components. When the switch is closed, C must discharge via R1 in order to take the Schmitt inverter input low, and thus generate a single, positive-going transmission at the output. With the right values of R1 and C, the bounce pulses are filtered out – they simply do not have sufficient energy to discharge C fully as in Fig. 5b.

The Schmitt inverter is shown in the diagram as being a 74HC14 device, although a 74C14, a 4584B or a 40106B could all be used equally well – and they all have the same footprint as the 74HC14.

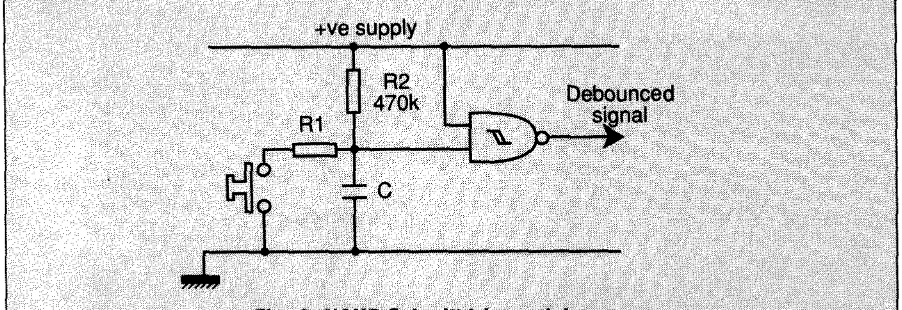


Fig. 6. NAND Schmitt trigger debouncer.

If a Schmitt inverter isn't available, the debouncer can be built using a Schmitt NAND gate, such as the 74HC132 or 4093B.

Special Circuit

In comparison with the previous debouncers, the specialised debounce circuit of Fig.7 looks unnecessarily complicated. However, there is a good reason for including it.

The shift register has four outputs at Q_0, Q_1, Q_2, and Q_3, four parallel inputs at P_0, P_1, P_2 and P_3, and a serial input (formed by the connection of the J and K inputs).

When pin 7 is high, data at the parallel inputs can be loaded into the respective outputs on the positive-going clock edge; when pin 7 is low, the logic level at the serial input is shifted to output Q_0 on the first clock edge, then into Q_1 on the next clock edge, and so on. The operation of the circuit can be seen by referring to the timing diagram Fig.8.

Assume the switch has just been closed, such that a positive bounce pulse occurs at clock edge 1. The circuit output at Q_0 is low (the register has been reset on power-up by the RC network at pin 5). Thus, at clock edge 1, the EX-NOR output is low, causing the high level at the serial input to be shifted to output Q_0, as shown.

At the second clock edge, the switch is still bouncing, and there is a low level at the serial input. At this point, the EX-NOR output is high, and so the low level from output Q3 is loaded in parallel fashion into all outputs - thus, Q_0 goes low.

At clock edge 3, the switch has stopped bouncing, and there is a stable high level at the serial input. Because the EX-NOR output is low, the high level is shifted into Q_0. It is then shifted into Q_1 on the clock edge 4, into Q_2 at clock edge 5, and into Q_3 (the debouncer output) at clock edge 6. Thus, the output has gone high, like the signal from the switch, but without the bounce pulses.

Opening Bounce

A similar analysis applies when the switch opens. At clock edges n+1 and n+2, the switch has opened, but the contacts are still bouncing. However, at clock edge n+3, the

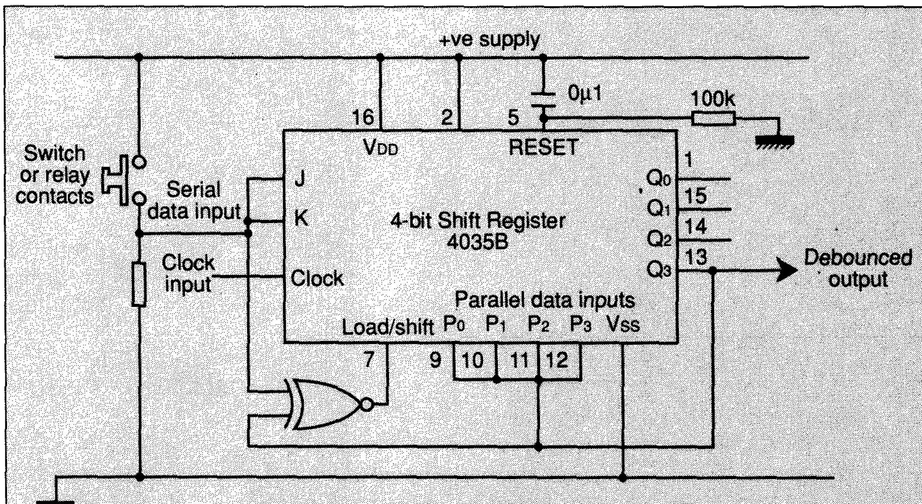


Fig. 7. Shift register debouncer,

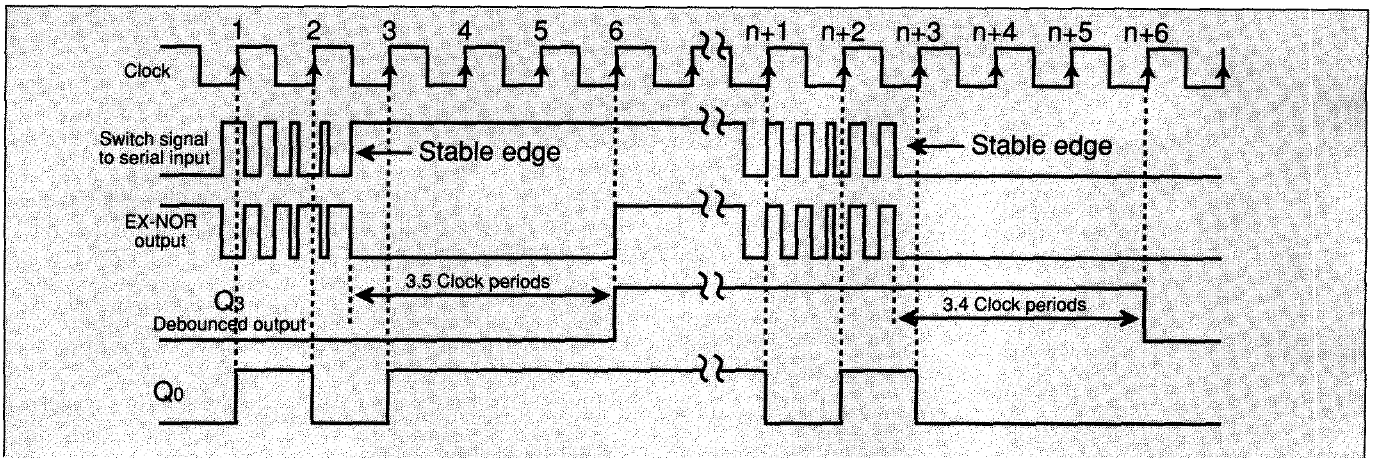


Fig. 8. Typical waveforms of a debouncing operation.

serial input has a stable low level, and so this is shifted into Q_0. At n+4, it is shifted into Q_1, at n+5 it shifts into Q_2, and at n+6 it is shifted into Q_3 such that the circuit output is now low like the switch signal, but again without the bounce.

Note that there will always be a delay of between 3 and 4 clock periods between the stable input edge and the output following suit. For this particular example the delays are 3.5 and 3.4 clock periods.

The circuit can be built using a 4035B 4-bit shift register, and the EX-NOR is provided by a 4077B. It is important to make the clock period long enough to accommodate the worst bounce anticipated. For example, if the bounce time is likely to be as long as 20ms, a clock period time of 10ms (100Hz) should be adequate.

Digital Filter

The shift register debouncer is a rather clever little circuit. It is, in fact, a digital low-pass filter; that is, the high frequency bounce pulses are filtered out using purely digital means.

Naturally, this presents a variety of possibilities in applications (other than debouncing) where a high frequency component must be removed from a digital signal of lower frequency.

Fig.9 shows a suitable example where the composite input signal is a 100Hz squarewave mixed with 10kHz tone bursts. With this signal fed to the circuit's serial input, and the clock frequency set at 3.5kHz, the output at Q_3 is a displaced, jittery version of the 100Hz squarewave, but without the tone bursts.

The output is jittery because its transitions depend on the instantaneous relationship between the input signal and the clock. In other words, because the output periods must equal an integer number of clock periods, there is bound to be jitter, unless the low frequency input signal and the clock are phase coherent.

Naturally, it follows that the jitter can be minimised by increasing the clock frequency, which effectively increases the resolution of the output signal, since the clock periods are now much shorter.

For example, with the clock frequency increased to 35kHz, the output jitter is hardly noticeable. Furthermore, the amount of displacement between the input and output signals is also minimised as a result of the shorter clock periods.

However, the clock frequency cannot be increased indefinitely because it effectively dictates the corner frequency or break frequency of the filter. For example, with the clock at 60kHz, one or two of the tone burst pulses from the input signal find their way to the output, and at 90kHz, practically all the burst pulses get through.

For correct filtering, the clock frequency must be high enough to let through the low frequency signal, and yet low enough to eliminate the hight frequency component. It is worthwhile setting up the circuit to tune the clock frequency and see the burst pulses in the output signal gradually disappear as the corner frequency is adjusted.

Six In One

Motorola manufacture the MC14490, a hex contact bounce eliminator containing six individual debounce circuits which are almost

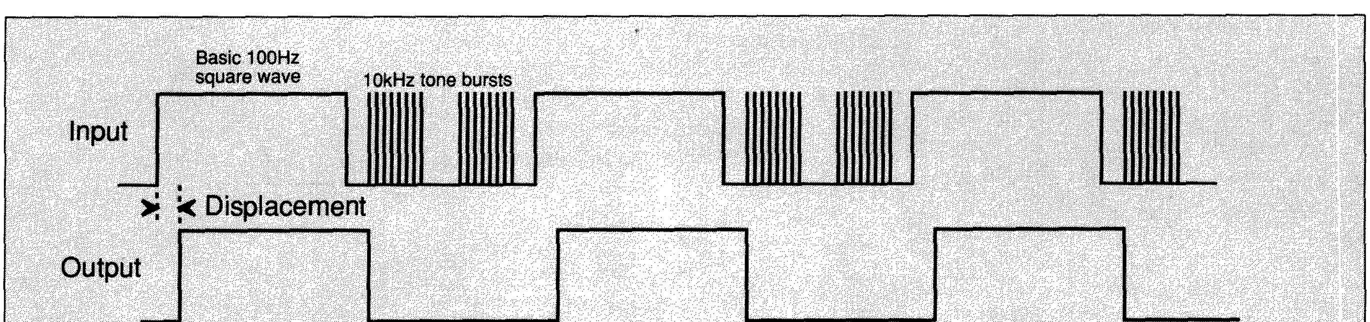


Fig. 9. Digitally filtered waveform.

identical to the circuit of Fig. 7. With six circuits in the one IC, it is possible to debounce six individual sets of contacts.

The IC is a CMOS device, housed in a 16-pin DIL package, and has an operating voltage range of 5 to 15V. The pin-out is shown in Fig.10.

The clock frequency can be derived from an internal oscillator (requiring only an external capacitor between pins 7 and 9), or can be driven from an external clock connected to pin 7. The only requirement of the clock frequency is that four clock periods do not occur whilst the input signal is bouncing, otherwise one or more bounce pulses could get through. Making the clock period equal to, say, half the maximum likely bounce duration should be satisfactory.

Like the circuit of Fig. 7, the six inputs to the MC14490 each require a SPST type contact. However, unlike Fig. 7, the contacts must be connected between the input and ground (all inputs have internal pull-up resistors). The advantage of switching ground rather than the positive supply is that system faults (such as shorts to ground on the input signal lead) are unlikely to cause excessive currents in the wires and contacts.

Simplicity vs Cost

Although the MC14490 is undoubtedly a useful device and is simple to apply it is, unfortunately, a little expensive. It works out considerably dearer than using a hex Schmitt inverter along with a handful of resistors and capacitors to make six debouncers of the type shown earlier in Fig. 5a.

Keypad Interface

Debouncing half a dozen or so switches is a fairly straightforward task. Interfacing to a larger number of switches, such as a 16-key keypad or even a full size computer keyboard, presents more of a problem.

Once solution is to connect all the switches via separate lines to an input/output device, such as the 6821 Peripheral Interface Adaptor (PIA), or the Z80 PIO Peripheral Interface Controller. However, for sixteen keys, this would require sixteen lines, thus taking up both of the 8-bit ports contained in each of these devices.

An alternative, and much more elegant solution is to arrange the sixteen switches in a 4x4 matrix, such that only eight interconnection lines are required. These can then be connected to just one 8-bit port of the I/O device as shown in Fig.11. The sixteen circles represent SPST pushbutton switches each connected across a vertical and horizontal line.

The upper four bits (B4 - B7) of the port are configured as output lines, whilst the lower four bits (B0 - B3) are used as inputs. When operated, each of the 16 switches will connect one output line to one input. Two techniques - either polling or an interrupt scheme - can be used to detect switch closure.

Inelegance

Polling is a software technique which scans the switches at regular intervals (say twenty times per second) to check if a key has been pressed.

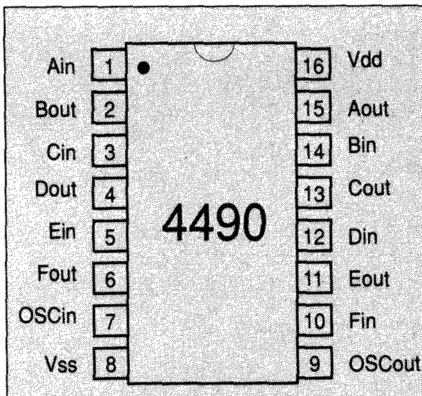


Fig. 10. The 4490 pin positions.

Scanning is performed by driving each output low in succession, while the others are high. In this way, a logic zero moves from B4 to B5 to B6 to B7, then back to B4 again, and so on – known as a walking zero.

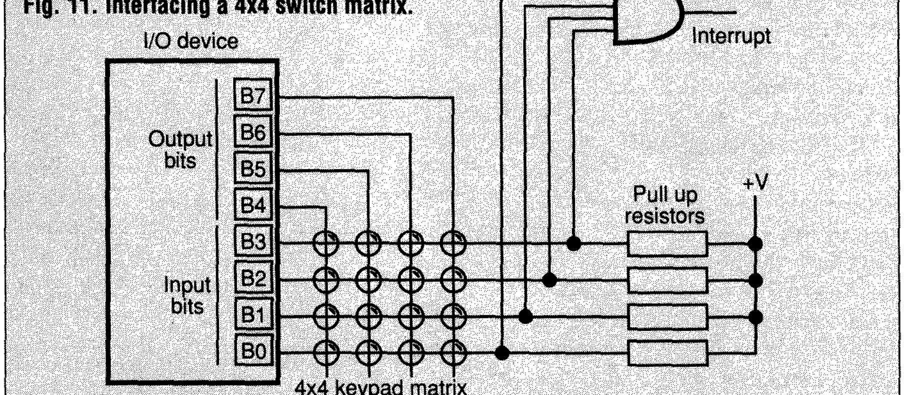
Every time one of the outputs goes low, all the inputs are checked. If they are all high, the scan moves on to the next output. However, if one of the inputs is low, it signifies a closed switch, and the combination of the particular output and input lines determines which key is pressed. For example, if input B1 goes low when output B6 is low, key 10 must be the one pressed. In this way, the processor can determine the address of each switch in the matrix. Unfortunately, polling is wasteful in terms of processing time because the CPU can only carry out its other tasks during the time between polls.

A Solution

A better way to use the computer's time is to use an interrupt. The processor latches the four outputs low and goes off to perform its other tasks. Whenever a key is pressed, the corresponding input to the AND gate is pulled low, generating a negative-going interrupt transition at the AND gate output. The processor responds to this interrupt by executing a scanning routine (such as the one described above) in order to determine which key is pressed.

However, both polling and interrupts have the disadvantages that an I/O port is completely taken up, and a software routine is required for the keyboard scanning (the software is also required to debounce the switches and to detect multiple switch closures). ■

Fig. 11. Interfacing a 4x4 switch matrix.



Dry Joints

This is a section of the mag that shouldn't appear very often but here are a few errors that cropped up.

Jan 91 Low Cost Car Alarm
Fig. 2 IC2 should be NOR. The parts list for the shock sensor shows IC1 as a 4903, it should be a 4093 quad 2 i/p NAND. In Fig. 3, the four letters showing the relay leads ABCE should be ABCD
Figs. 5 and 6 the right side of terminal four (relay) to read terminal 4 to horn (button side) to agree with Fig. 2 and 18. Fig. 14 R6 should read 270k for 0.5 second flash every 3 seconds.
Thanks to Alan Hoggett for pointing them out.

Feb 91stated in Digital Compass that the Hall effect voltage in good conductors is small since "the charged particles move too fast to be deflected in substantial quantities". This is not true, the Hall Effect voltage is proportional to the velocity of the charge carriers which is very small in good conductors.
Thanks to Andrew Chadwick. ■

floppy disc drive. A wire carries text and data from the portable either to a PC or printer, or via a modem for phone line transmission.

But wire transfer needs a tailor-made lead and control software. Do not be fobbed off with shop floor promises of how easy it is. Before buying, insist on a demonstration of a full working system.

The sad truth is that there is no free lunch. With a bright screen and busy disc drive, the charge in a small set of batteries will last only a few hours. Different countries have different mains supplies, 200-240 volts in most of Europe, 100-120 volts in Japan and the USA. If your computer works only with its own rechargeable batteries and the charger cannot cope with both voltages, you can end up unable to do any further work once the batteries have gone flat.

In any case, most long haul flights and train journeys last longer than the batteries in a bright screen, disk driven portable. So there is a real advantage in choosing a portable with removable rechargeable battery pack; you can then carry a fully charged spare. All this comes as a nasty shock to anyone upgrading from the Tandy 100, which was very economical on expendable pen cells, available anywhere in the world.

Check what happens when you change batteries. There should be a capacitor or small rechargeable battery inside the unit which holds the memory secure even after the machine has shut down for a battery change. Words cannot describe the fury that comes from losing large volumes of data because the RAM lost power. (Exactly the same thing applies if you have a digital watch or calculator with phone number memory).

Psion was probably the first company to use the name "Mobile" for computers. The object was to distinguish from early portables which were soon dubbed "luggables" because they were far too heavy and clumsy to carry further than the car. A folding design gives a large LCD screen and large typewriter keyboard. Intel's "Flash EPROM" needs only small amounts of electrical power to store large quantities of text and data, without the need for battery back-up. So small, light batteries can hold more than enough juice to keep the computer working for even the longest flight.

Psion refuses to sacrifice battery life for the convenience of a disc drive. So the user is once again stuck with the need to get work out of the computer by wire. It helps that the control software is frozen in, but this can never be as convenient as swapping floppies. Psion sees the longer term solution as persuading MC users to connect a Flash EPROM reader device to their office PC. But there is no sign yet of this concept catching on.

If you want a personal recommendation, based on nearly ten years of trying to work on the move, and both borrowing and buying a lot of portable computing kit, I would now only consider a unit which has a full size keyboard, switchable backlight, universal voltage charger and floppy disc drive that directly matches my desk top PC. ■

Barry Fox is a winner of the UK Technology Press award.

A Chip To Remember

This month's data sheet starts with a look at a much used chip that is also featured in the PC EPROM programmer project.

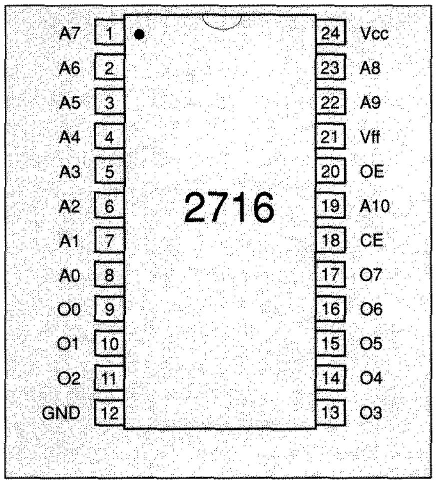
The 2716 EPROM is a16k bit device that has been the mainstay of UV erasable memory for a number of years. It is arranged as an array of 2048x8 bits to make for easy interfacing to microprocessor systems. Once data has been programmed into the chip it is stable until erased with a 15 to 20 minute dose of of 2537 Angstrom (UV) radiation from a 12000µW/cm2 lamp. Direct sunlight will erase the chip in approximately three days and flourescent lighting should do the job inaround three years.

There are five modes of operation, read, standby, program, program verify and program inhibit.

Read
To get some data at the outputs, the chip enable (CE) should be sent low to power up the device and output enable (OE) also sent low to enable the data outputs. With a correct address, data will become available 120ns after OE has gone low.

Standby
To reduce power consumption to around 25% of the normal level (525mW to 132mW), CE should be placed high. The outputs will go into tri-state (high impedence) and the state of OE will be ignored.

Program
After the 2716 has been erased, all of the memory cells are in a high or one state. Programming sets the appropriate cells to zero and leaves



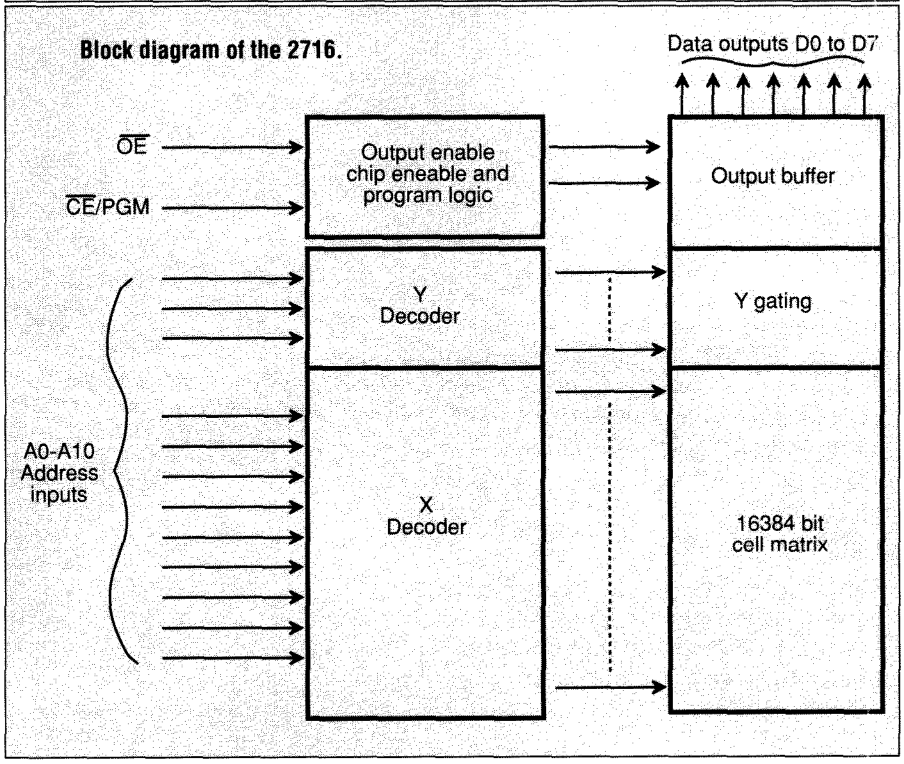
ones alone. To start programming 25V must be applied to Vpp and OE set high. The data is placed as eight bits on the output bus (O0-O7) and the address for the data placed on the address bus (A0-A9). Once the data and address are stable, a 50ms pulse is appled to the CE/PGM pin to burn the data into the memory. The whole chip can be programmind in around 100s.

Program Inhibit.
It is possible to program multiple chips at once by connecting all of the relevent inputs in parallel. The CE/PGM pin is then used to differentiate between them

Program Verify
To make sure that the data programmed into the chip is correct, a verify can be performed with Vpp at 25V.

Mode	CE/PGM	OE	Vpp	Vcc	Outputs
Read	Vil	Vil	+5	+5	Dout
Standby	Vih	don't care	+5	+5	tri-state
Program	Vil to vih	Vih	+25	+5	Din
Program verify	Vil	Vil	+25	+5	Dout
Program inhibit	Vil	Vih	+25	+5	tri-state

Block diagram of the 2716.



Operating characteristcs

Operating temperature	0°C to 70°C
Power supply (Vcc)	5V±5%
Input voltage low (Vil)	-0.1 to 0.8V
Input voltage high (Vih)	2V to Vcc
Prog voltage(Vpp)	-0.3 to 26.5V
Prog current (Ipp)	5mA max

The 8212 Input/ Output Port

Also this month, data sheet looks at a highly flexible chip that can be used in a number of microprocessor I/O applications.

The 8212 is a general purpose input/output port that finds a number of applications in computer circuits. Originally designed for use with the Intel 8080 family of logic chips, it can be used with any microprocessor system that requires a simple parallel communications port.

On its own it forms a uni-directional gating system that can be controlled either by the device selects or the mode input. The outputs can be tri-state (high impedance), follow the inputs or be latched versions of them. The first state is useful in common bus arrangements where a number of devices have to share the same data pathway, for example microprocessors. In the second state, the outputs follow, a useful facility for data logging systems where continuous data must be fed to a device, for example a digital to analogue converter (DAC). The third state allows data to be frozen so that the output can be read by a device that is not synchronised with the input, for example in microprocessor output ports.

Back to back

Using two 8212s a bi-directional buffering system can be built which will pass data along a common data bus. The direction is controlled by a single line so that, for example in a microprocessor system, the read/write signal can be used to control the transfer. By making additional use of the strobe this circuit can also form a bidirectional latching port.

For more complex systems, the $\overline{\text{INT}}$ output can be used to drive a microprocessor interrupt input so that as data becomes available, the microprocessor can halt its current task and examine the data at the port. The output buffers are activated from the microprocessor so that data from the 8212 doesn't appear on the bus until it is needed.

The operation of the 8212 can most easily be determined from tables one and two. The first defines how the outputs behave in conjunction with the control lines. The two main states are with MD=0 and MD=1. In the first case the device selects define whether the output is active or not.

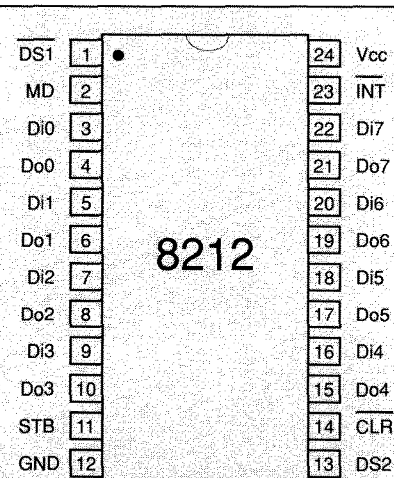
When the output buffer is enabled, the STB line moving from one to zero latches any data at the input. If the STB line is left at 1 then the data in is the same as the data out and will change at the same time. Setting STB to one freezes the data on the outputs.

When MD is one the STB line has no effect on the outputs and the device selects switch between a transparent and frozen buffer. When the device is not selected, the outputs come from the latches, when the select becomes active the data on the outputs is the same as the data on the inputs.

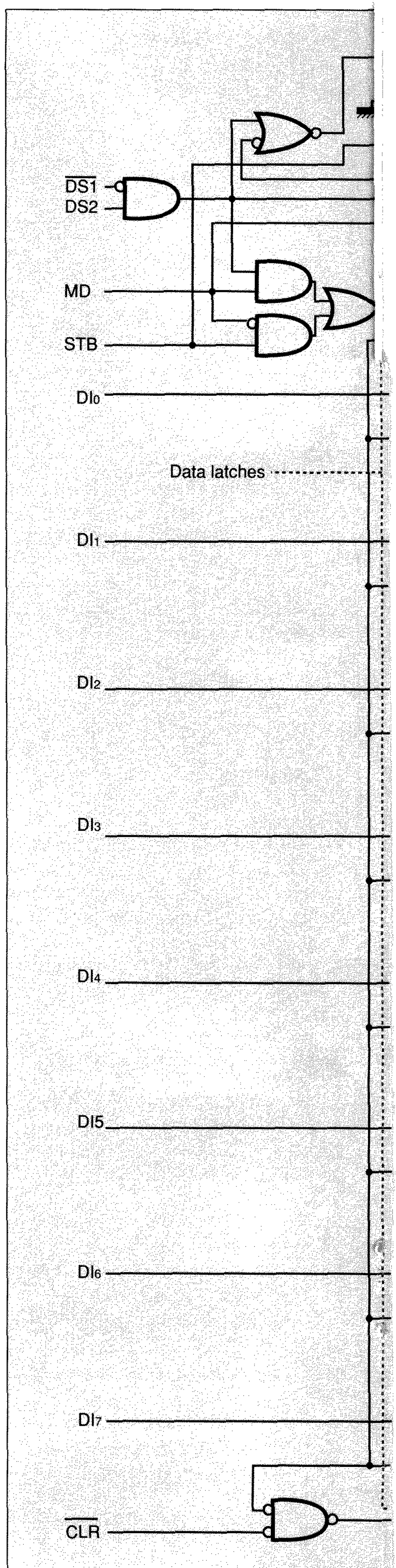
Table two defines how the $\overline{\text{INT}}$ output is generated through the service request flip-flop. ■

Absolute Maximum Ratings.

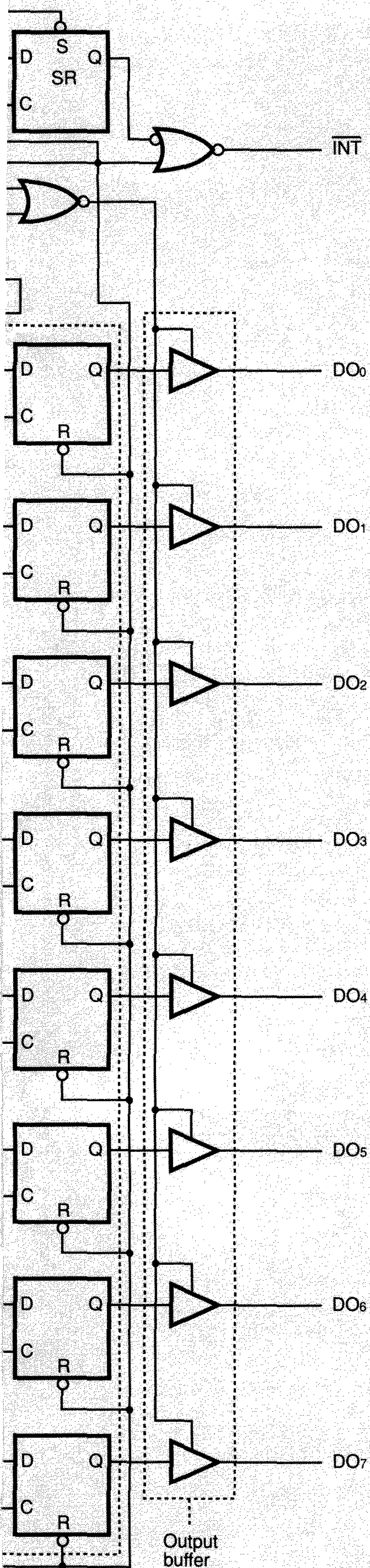
Operating temperature	0°C to +70°C
Storage temperature	-65°C to +160°C
Output or supply voltages	-0.5 to +7V
All input voltages	-1.0 to 5.5V
Output currents	100mA



The chip and its pins.

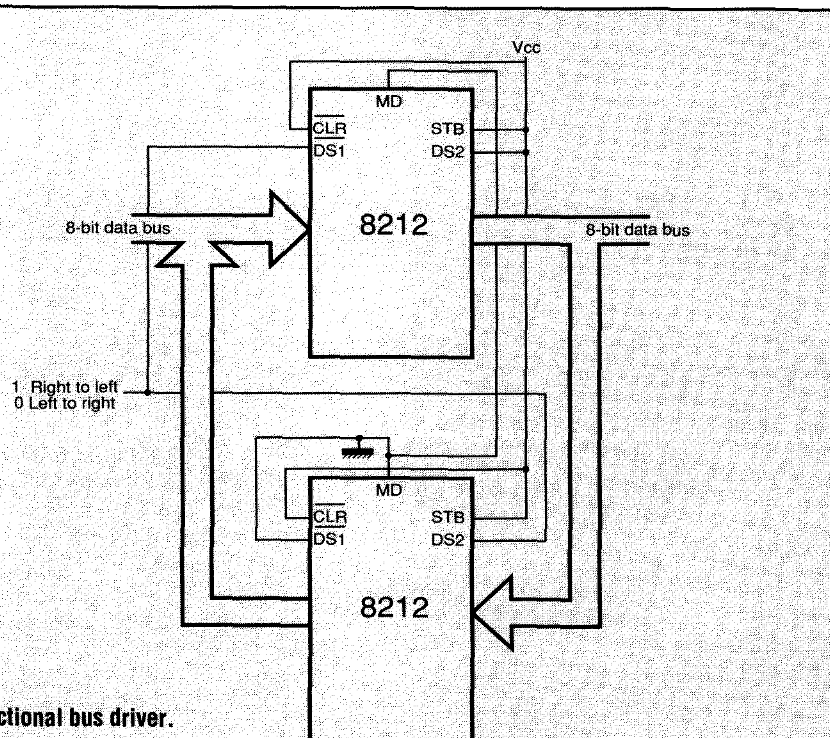


Logic di



agram.

Pins	Name	Function
1	$\overline{DS1}$	Device select. Taking this line low when DS2 is high enables the output buffer and sets $\overline{INT}$ low. It also puts a low on the S input of the service request (SR) flip-flop which will clock through at the next strobe transition (STB).
2	MD	Mode. Setting this high will enable the output buffers independently of the device select signals. The clock for the data latches will come from the device selects. When mode is low the device select control the output buffer and the clock for the data latches comes from the strobe (STB).
3, 5 7, 9,16 18, 20, 22	Di0-Di7	Data inputs.
4,6, 17,19,21	Do0-Do7	Data outputs. 8,10,15, These are driven by tri-state latches and when disabled go high impedance allowing more than one device to use the output bus.
11	STB	Strobe. When MD is low, STB acts as the clock for the data latches. It also resets the SR flip-flop on its negative edge.
12	GND	Ground. Connected to 0V.
12	DS2	Device select 2. See $\overline{DS1}$.
14	$\overline{CLR}$	Clear. Taking this low clears the data latches but has no effect on the output buffers.
23	$\overline{INT}$	Interrupt. This is driven by the device select or the service request flip-flop and can be used to tell a receiving system that the chip has gone active and that data is available.
24	Vcc	Supply voltage. This is normally set at +5V.



Bi-directional bus driver.

STB	MD	$\overline{DS1}$.DS2	Data out is
0	0	0	High impedance
1	0	0	High impedance
0	1	0	Data latch
1	1	0	Data latch
0	0	1	Data latch
1	0	1	Data in
0	1	1	Data in
1	1	1	Data in

Table 1.

CLR*	$\overline{DS1}$.DS2	STB	SR†	INT
0	0	0	1	1
1	1	0	1	0
1	1	$\searrow$	0	0
1	1	0	1	0
1	0	0	1	1
1	1	$\searrow$	1	0

† internal service request flip-flop.

Table 2.

The Resistor

There is more to the humble resistor than immediately meets the eye. Without it, electronic circuits would be impossible.

Resistors are one of the most useful passive components in electronic circuits. They can be made from a variety of materials, all of which have a similar property; they are able to conduct electrons. The conductivity of the material depends upon the amount of impurity in it. Pure copper has around 10^{29} conduction electrons per cubic meter and when a voltage is connected across it, the electrons accelerate from the negative to the positive end. There are other electrons in the material but these don't conduct since they are not free to move, hence the term conduction electrons. The impurities cause the electrons to be deflected from their path through the material and slow down the overall flow – see Fig. 1.

At some stage, the electromotive force of the battery (voltage) reaches an equilibrium with the resistance of the conductor resulting in a steady flow of electrons – known as the drift velocity. In normal copper wire it takes about an hour for one electron to drift one metre, which may not seem very much but there are an awful lot of electrons. The resistance (R) of a conductor is proportional to its cross-sectional area (a) according to the following formula:

R=r/a

where r is the resistivity in ohm metres. Some typical values are shown in Fig. 4.

This drift velocity or flow gives rise to a current measured in Amperes and in an electrical circuit, the following formula connects voltage, resistance and current:

V=RI – Ohms Law

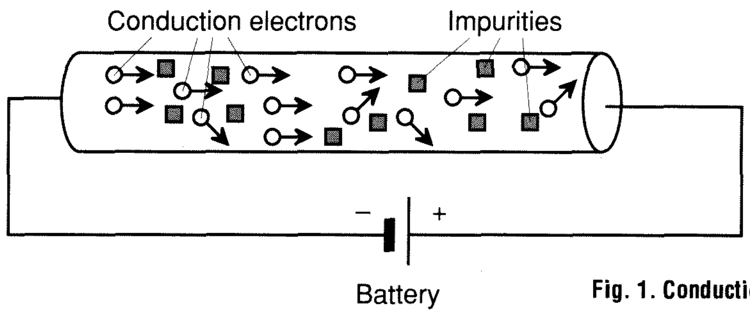


Fig. 1. Conduction.

Making A Resistor

There are three main ways in which resistors are constructed, carbon composition, carbon film and wire wound. The most common are the composition types where a mixture of carbon and a suitable binder are moulded onto two connections, one at each end as in Fig. 2. The resistance can be set by altering the ratio of carbon to binder, the more binder, the higher the resistance. The tolerance of carbon composition resistors is not usually very good and is normally in the 10% to 20% range. To obtain better accuracy, an alternative method of construction is to use a film of conductor over an insulator,

Fig. 2.

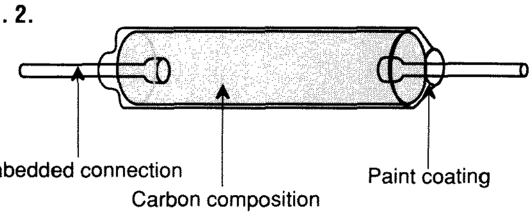


Fig. 3.

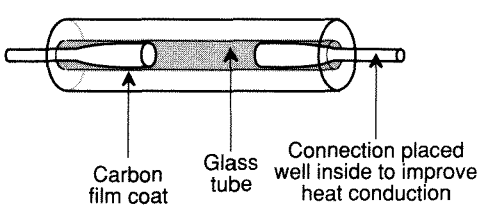
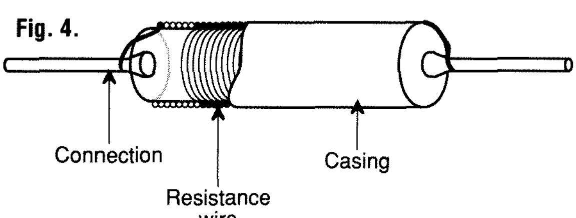


Fig. 4.



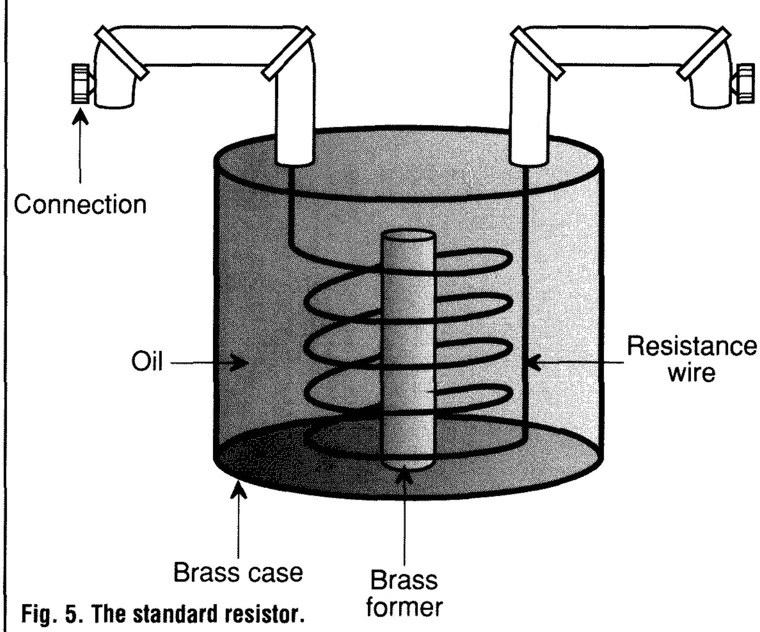


Fig. 5. The standard resistor.

usually a ceramic or glass tube. The thickness of the film determines the resistance of the component, see Fig. 3.

Carbon film resistors offer tolerances in the 5% to 10% range and for more accuracy, metal or metal oxide film can be used instead. This brings the rating into the 1% region and is the best commonly available.

Another main characteristic of resistors is the amount of power they can cope with. Carbon composition are generally used in the 0.5 to 2.5 Watt range. Film resistors have their connections seated deep withinto conduct the heat out (Fig. 3) and operate in the 0.125W to 1W range. For high power ratings than this, wire wound resistors are used (Fig. 4) and are able to provide accurate resistances (5%) with ratings up to 25W or more.

The stability of resistors with temperature can be quite important in some circuits and the temperature coefficient may be given on the packaging. The most stable are the wire wound resistors followed by film and composition. There are times when it is desirable to have the resistance of the component change with temperature. Thermistors are made from mixtures of the oxides of manganese, nickel, copper, cobalt, uranium, iron, zinc, titanium and magnesium. The negative temperature coefficient means that the resistance decreases as the temperature increases. The rate at which this happens is determined by the proportion of oxides in the mixture which are usually molded into a ceramic to form the actual component.

Setting The Standards

The National Bureau on Standards in Washington DC use resistors of the type illustrated here to maintain standards for values above 10Ω. Manganin resistance wire is wound around an insulated brass former and cemented in place. This is then baked and assembled into a brass case surrounded by moisture free oil – Fig. 5. Resistors used in electronic circuits also come in standard sizes based on the following numbers:

10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91

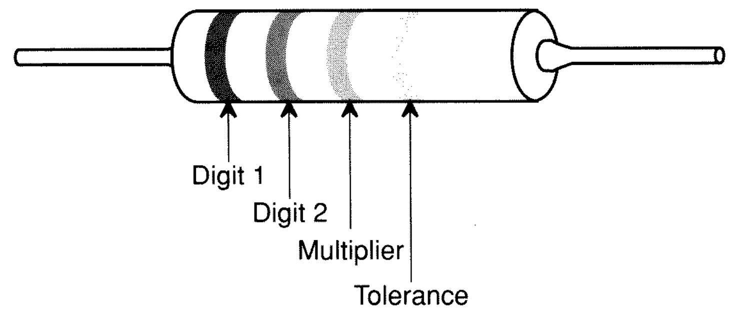
These are available for both composite and film multiplied by 0.1, 1, 10, 100, 1000 and 10000. Certain values are also available multiplied by 100000. Wire wound resistors are available in other sizes which may or may not follow the standards. ■

Resistivity

Aluminium	2.86×10^{-8}
Brass	6.6×10^{-8}
Lead	22×10^{-8}
Copper	1.72×10^{-8}
Silver	95×10^{-8}
Diamond	10^{12}
Glass	5×10^{9}

Fig. 4.

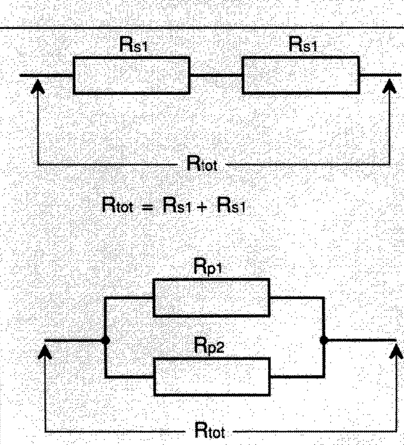
Colour codes



Most resistors use a standard colour coding scheme based on three, four or five bands painted on the body of the component. The value is always read from the band closest to one end with the first two defining the first two digits of the resistance. The next band defining the amount that these two digits are multiplied by and the fourth band the tolerance or accuracy of the resistor. The fifth band, if it is present, indicates the how much the resistance will change with temperature. For example, a component coded yellow, violet, orange, silver has a value of 47 (the first two figures) times 1000 or 47kΩ and a tolerance of 20%. If the orange was red then the value would be 47 times 100 or 4700Ω which is normally written 4k7 for 4.7 thousand ohms.

One problem many people have is telling the colours apart – especially men who are colour blind (around one in 20 males are red, green colour blind). The solution is not to give up on electronics but to get a reliable multimeter which will give an accurate reading that can't be mistaken.

Colours	Digits	Multipliers	Tolerances	Temp coeff
Black	0	1		200ppm/°C
Brown	1	10	1%	100ppm/°C
Red	2	100	2%	50ppm/°C
Orange	3	1000		15ppm/°C
Yellow	4	10 000		25ppm/°C
Green	5	100 000	0.5%	
Blue	6	1000 000	0.25%	10ppm/°C
Violet	7		0.1%	5ppm/°C
Grey	8			1ppm/°C
White	9			
Gold		0.1	5%	
Silver			10%	
None			20%	



$$R_{tot} = R_{s1} + R_{s1}$$

$$\frac{1}{R_{tot}} = \frac{1}{R_{p1}} + \frac{1}{R_{p2}}$$

$$R_{tot} = \frac{R_{p1} R_{p2}}{R_{p1} + R_{p2}}$$

Resistors in serial and parallel.

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The Box That Bites Back

This month Owen Bishop presents a portable personal alarm unit which can be triggered in a number of ways.

This project may not explode but, when touched, it emits a piercing scream. It is a portable alarm device with many applications. Placed in a bicycle bag, it sounds off when the bicycle is moved. It can be used in a similar way in a car or to protect a briefcase. Placed on top of a video recorder, it defies anyone to remove the recorder without arousing attention. It also has many other less serious applications as a general attention-getter, triggered by tilting or vibration.

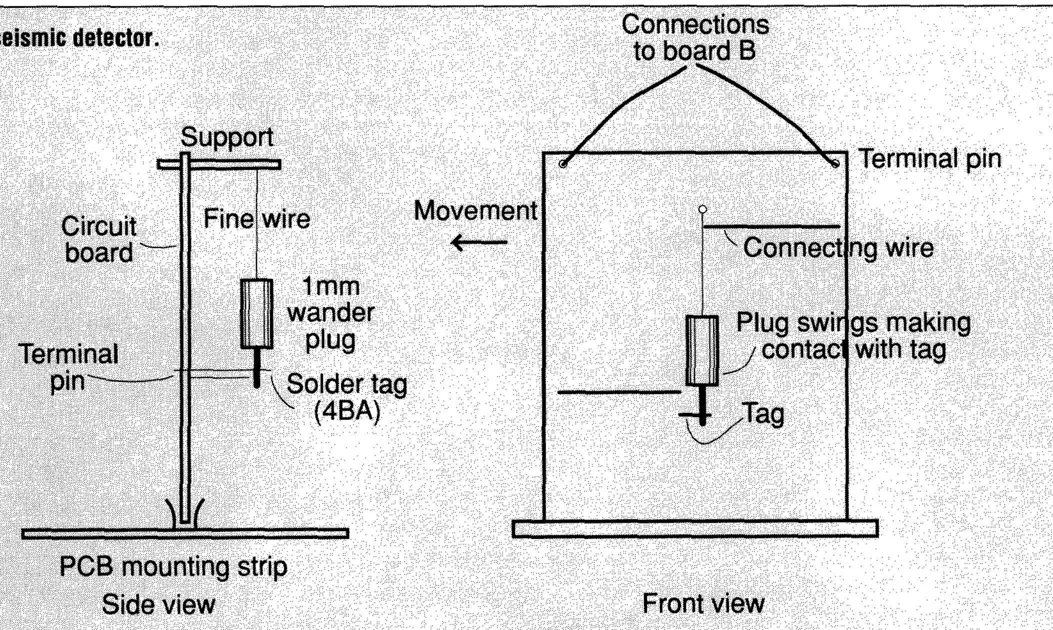
The prototype looks like a small-scale version of the monolith from 2001. It is just a black rectangular box with no external features. Closer inspection shows a grille of fine holes on one side for the loudspeaker but, apart from that, there is nothing else. The device operates without any external controls, making it difficult for anyone to disarm it. The lack of knobs and switches means that there is no problem in disguising the the alarm as an innocent-looking object. It can be made to look like a book, a video cassette, a box of chocolates, a box of paper tissues, or even a block of wood.

Switched On

The system diagram (Fig. 2) shows that the device has 4 (optionally 5) control switches, each operating on a different principle. The first is a tilt switch which consists of a sealed capsule with a pair of contacts and a small quantity of mercury. The mercury bridges the contacts when the switch is tilted.

The next switch is seismic and responds to tilting and small vibrations. It is optional and is wired instead of or as well as (in parallel with) the tilt switch. It should be used if the alarm is to be sensitive to vibration. As there is no ready made switch available, the design shown in Fig. 1 can be made up. This comprises a wander plug on a short length of fine wire, its tip being surrounded by a metallic loop. When the switch is disturbed, the mounting moves but the plug stays put. The tip makes contact with the loop and completes the circuit. The PCB switch is a miniature slide switch, with two sets of contacts designed so that one set is closed when the other set is open. As used in this project (for sensitivity selection), it functions as a single-pole double-throw switch (S2). The microswitch is employed as an anti-tamper switch and its lever is held depressed by the lid of the case, holding the switch on. Any attempt to remove the lid releases the pressure and the alarm sounds.

Fig. 1. The seismic detector.



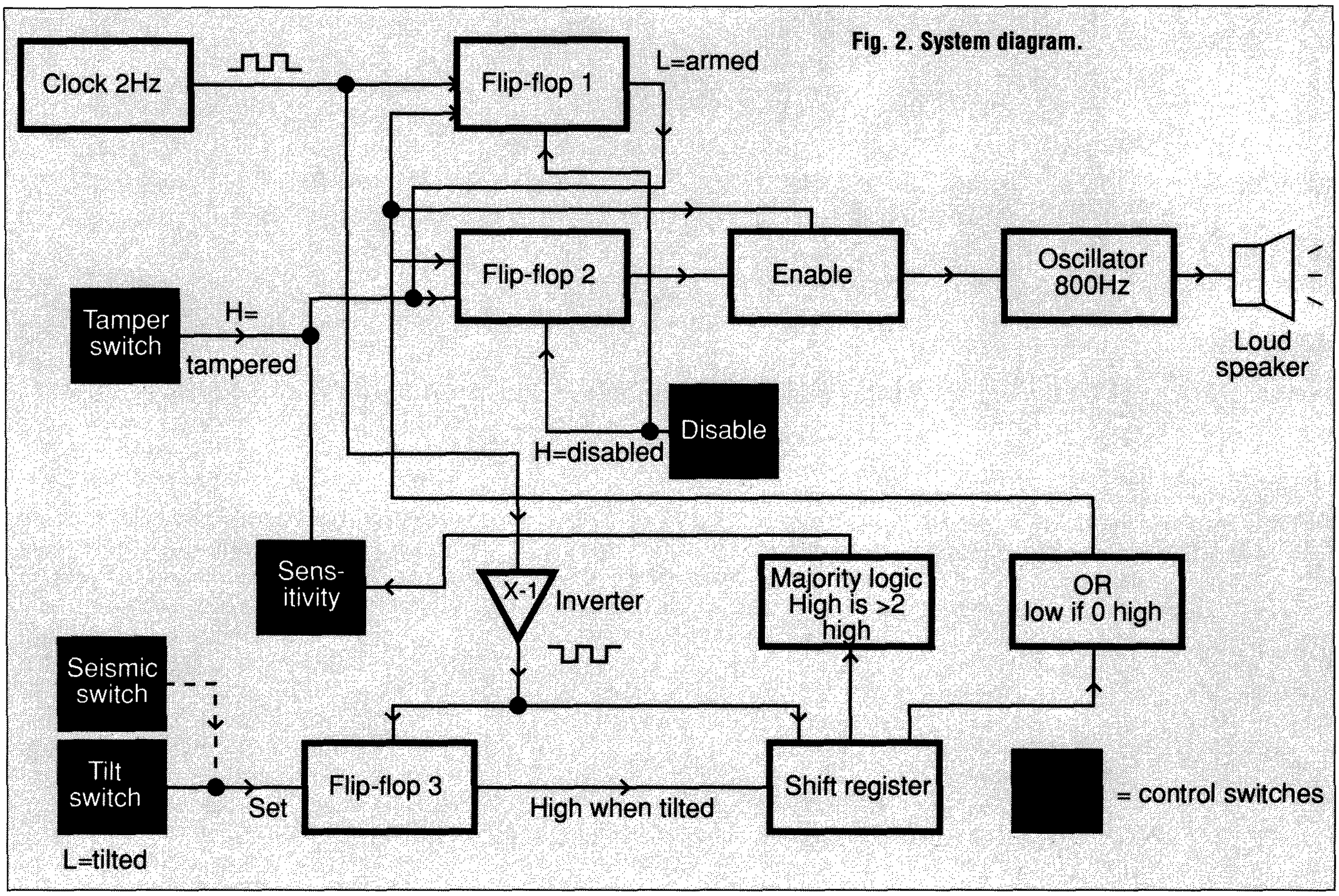


Fig. 2. System diagram.

The final switch is a reed switch which is used to arm and disarm the alarm It has a pair of contacts that close together in a sufficiently strong magnetic field. The switch is mounted on the inside of the wall of the case. A magnet placed against the outside operates the switch and only the constructor knows whereabouts on the outside of the case to replace the magnet when disarming the alarm.

Operating Logic

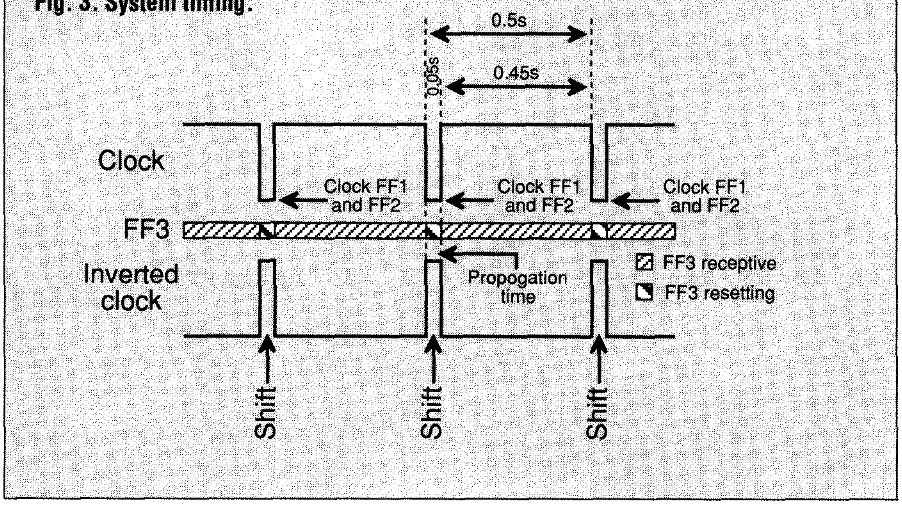
The system (Fig.2) is co-ordinated by a master clock, pulsing at 2Hz. The mark-space ratio is approximately 9:1. In other words, the highs last about 0.45s and the lows last about 0.05s – Fig. 3. This signal is fed through a capacitor to bistable flip-flop three. A low logic level resets it. If the tilt switch is disturbed during the next 0.45s, the logic low from the switch sets flip-flop three and its output goes high.

The shift register is clocked by the inverted signal from the master clock, shifting occurring on the rising edge. Thus, if a disturbance has occurred during the previous 0.45s, a high is loaded into the first register. Then flip-flop three is reset and waits for further disturbances. The eight registers thus hold information about the disturbances detected during almost consecutive 0.5s periods during the past 2s (except for the brief periods while FF3 is being reset).

The contents of the shift registers are analysed by two logic gates. The first is a majority logic gate which has a high output if the majority of its inputs are high. This checks the contents of the first 5 registers. If disturbances are detected in more than two 0.5s periods during the previous 2.5s, its output goes high. The other gate is an OR gate (actually NOR followed by NOT). Its output goes low when all eight registers contain a low. This gate is used when arming, giving time for all vibrations to die away before the device becomes armed.

The behaviour of the system is determined by flip-flops one and two. These are J-K flip-flops wired to act as clocked set-reset. The reason for using clocked flip-flops instead of ordinary cross-connected gates (as in flip-flop three) is that this avoids the problem of logic races. Small propagation delays in

Fig. 3. System timing.



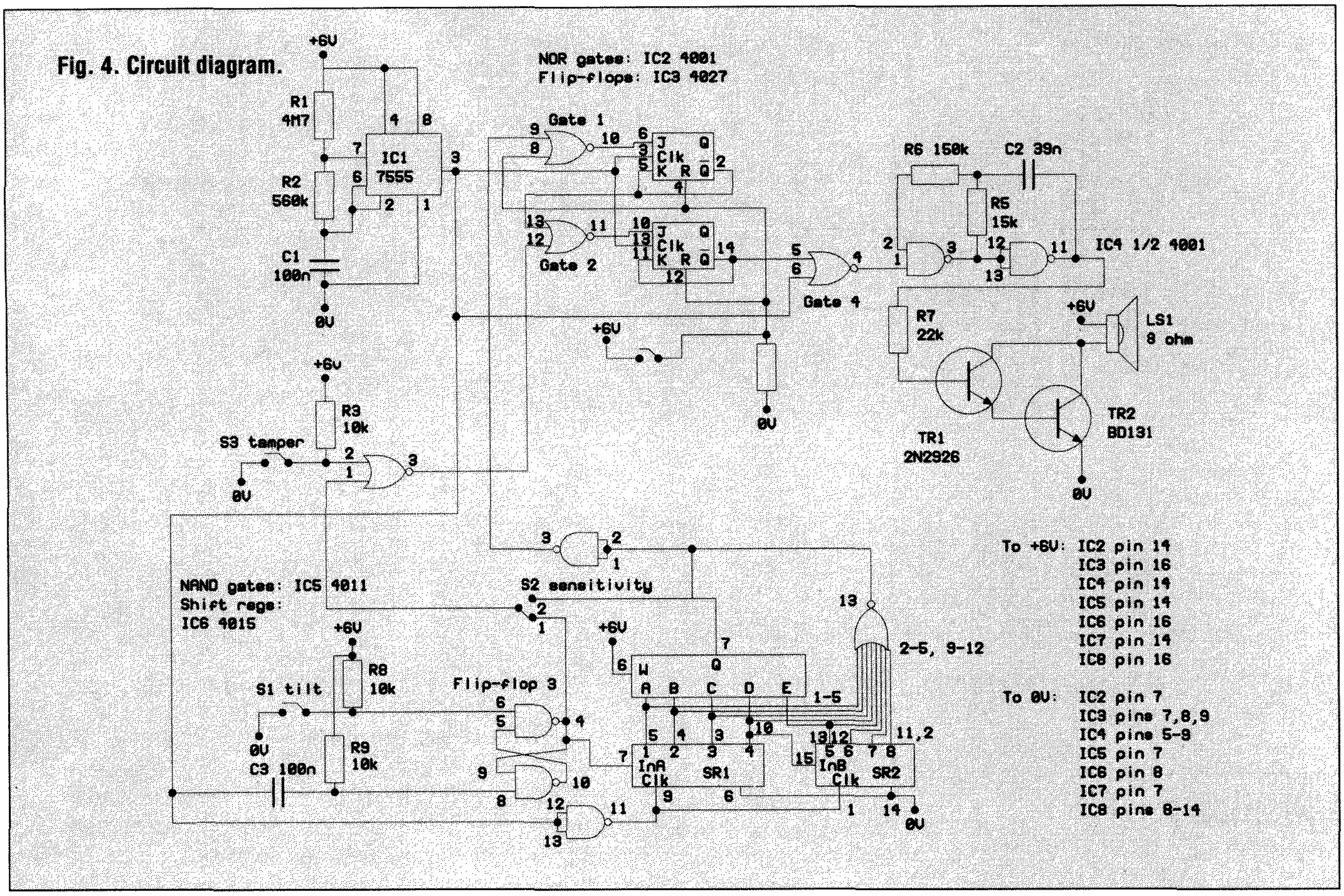


Fig. 4. Circuit diagram.

the action of flip-flops and gates can result in changes of state that occur a nanosecond or so earlier or later than intended. Clocking gives 0.05s after shifting for the logic level at the J input to reach its correct value. At that instant, and if J is high, the flip-flop becomes set. Resetting is not affected by the clock state but this does not matter. A high on the reset input resets the flip-flop instantly and it stays reset for as long as the reset input is held high. In this device the reset input comes from the reed switch. As long as the magnet is in place, flip-flops two and three are held reset, they can not change state and the alarm is prevented from sounding.

Referring to Fig. 5 and starting in the OFF state (no battery) with the lid removed, the device is put directly into its RESET state by placing the magnet by the reed switch and connecting the battery. The lid is then screwed down. Removing the magnet now arms the device, provided that all eight registers hold logic low. This gives time (four seconds) for vibrations of the tilt (and optional seismic) switch to die away.

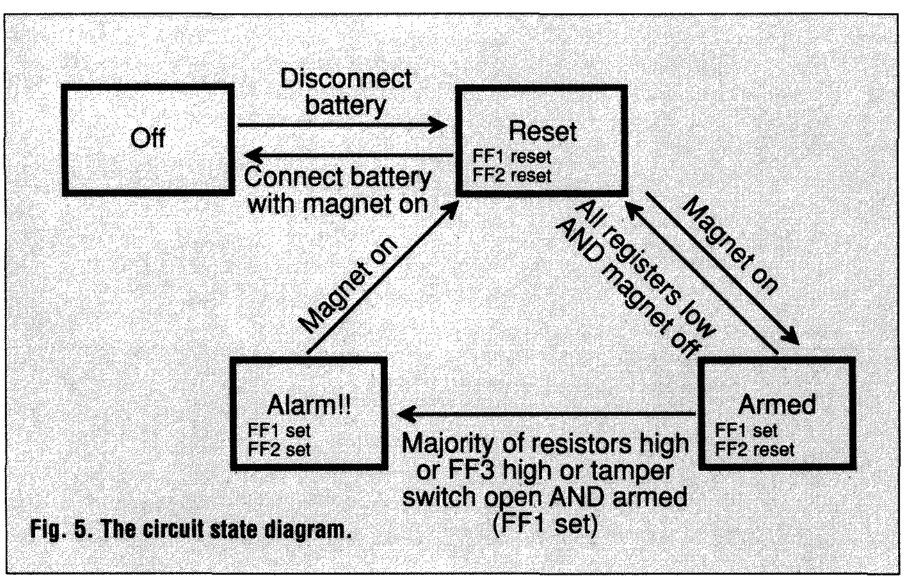
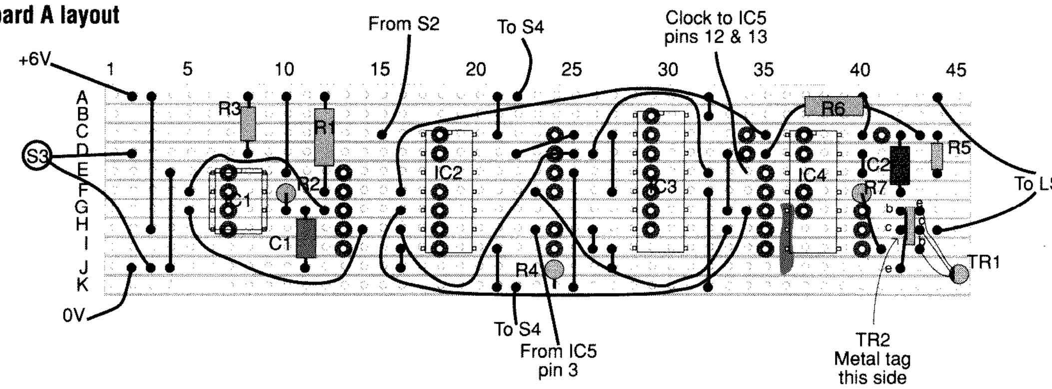


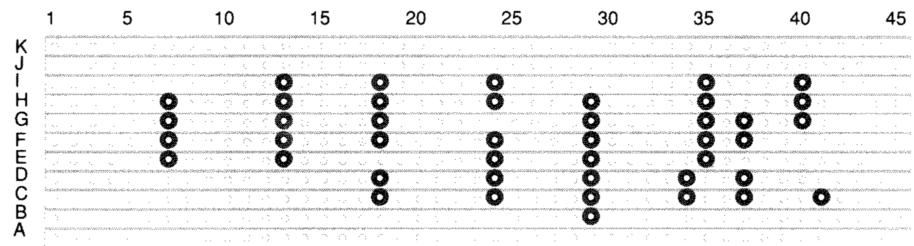
Fig. 5. The circuit state diagram.

In Fig.3, the arming logic is arranged by a single NOR gate, gate 1. The output of this goes high when both its inputs are low. On the next high-going edge from the clock, flip-flop two is set arming the device. The not Q output of flip-flop one is now low, and is fed to gate 2. When the output from the majority logic gate goes high, or the tamper switch snaps open, the output of gate 3 goes low. Thus, if the device is armed and there is excessive disturbance or the lid is loosened, flip-flop two is set on the next clock pulse. This enables the oscillator and the alarms sounds. The enabling gate (Gate 4) also receives the 2Hz signal from the clock, so the alarm sounds as a series of short 'pips', which is more attention-catching than a continuous tone.

The device is now in its alarm state and continues to sound even if there is no further vibration or if the lid is re-tightened. The only way to silence the alarm (other than by completely removing the lid and disconnecting the battery) is to replace the magnet, returning the device to its reset state.

Fig. 6. Board A layout





The copper side of board A showing the cuts.

Sensitivity

An alarm which cries wolf is soon likely to be ignored. This is the reason for having the majority logic gate in the circuit. In certain applications an occasional vibration is no cause for alarm. In other circumstances it is vital for the device to respond to any disturbance. In this instance the output from flip-flop three is used directly. The sensitivity switch allows a choice between the output from flip-flop three and that from the majority logic gate.

Circuit Details

The circuit diagram (Fig.4) is laid out with the main sections positioned similarly to the system diagram (Fig.2). The clock is the familiar 7555 (IC1) in astable mode. The output from this goes to a Darlington pair (TR1, TR2) which provides sufficient current amplification to drive the loudspeaker. TR2 is a high power transistor. IC8 contains two gates but only one is used. The unused inputs (pins 9 to 14) are all connected to 0V.

The circuit requires only 1.3mA when quiescent, so can be powered from a small battery. With 4 AA alkaline cells in a battery holder it should run for about 1500 hours. If space is limited, use 4 AAA cells (700 hours) or a 9V PP3 alkaline battery (400 hours). Using the 9V battery gives a slightly louder alarm sound with no alteration to the circuit.

How To Make It

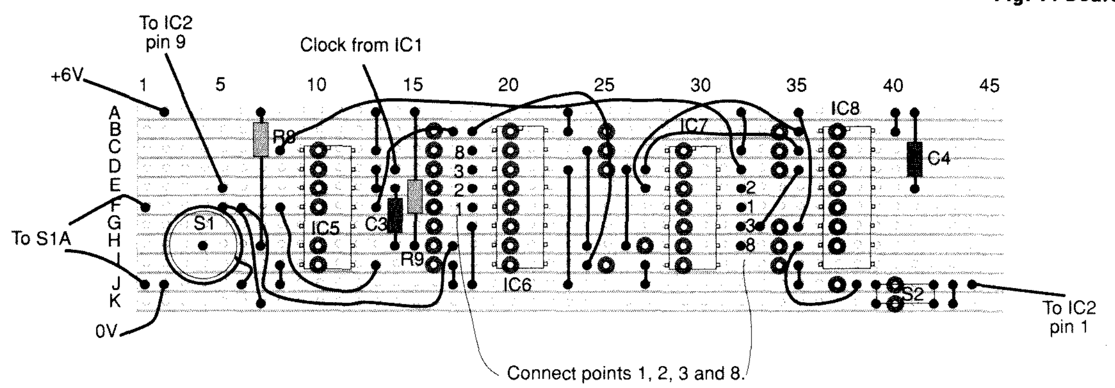
The circuit is constructed in two sections which may be assembled on separate boards (Figs. 6 and 7). However, if it is more convenient, the circuit can be assembled on one board, 22 strips deep. Begin with Board A which carries the clock, control flip-flops and the audio generator. Assemble the clock (IC1 and associated components) and check that its output is approximately 2Hz (use an oscilloscope or connect an LED and a 180-ohm resistor in series between pin 3 and the 0V rail). Next assemble the oscillator (IC4) and amplifier circuit. A loud note is heard when pin 1 is connected to the positive rail. To complete board A, wire up ICs 2 and 3. For testing, oin the pins at C15, D2 and H23 to the 0V rail, and the pin at K22 to the +6V rail. Connect the battery. The circuit is in the reset state and there is no sound. Remove the connection to K22 (equivalent to removing the magnet from S4); no sound. Remove the connection to D2 (equivalent to opening the tamper switch, S3); the alarm sounds. It is silenced by remaking the connection to K22 (replacing the magnet). Remake the connection to D2, remove the connection to K22 and then connect C15 to the +6V rail. The alarm sounds.

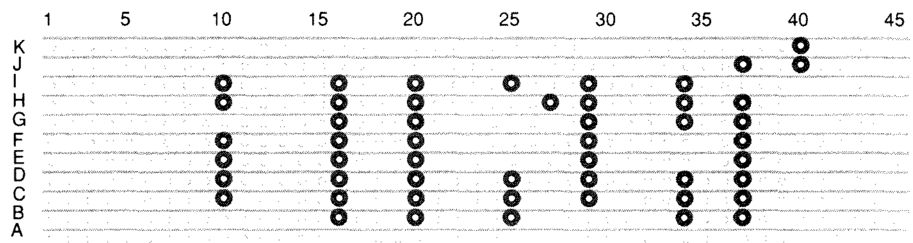
Repeat the sequence above, but first connect H23 to the +6V rail. No sound is heard at any stage as the circuit is not able to leave the reset stage unless H23 is low.

Begin board B with IC5 and its associated components, including the tilt switch S1. The type specified has a single axial terminal pin; slightly enlarge the hole in the stripboard to accommodate this. The other connection is a wire from J6, soldered to the case of S1. To test, connect pins 1 and 2 (at C8) to the +6V rail; connect D14 to the clock (pin at E34 on Board A). Apply power to both boards; the output at pin 4 is low. It goes high if the board is tapped or shaken, but almost immediately goes low again as the next clock pulse arrives.

Complete the wiring of the other ICs on this board. C4 is a decoupling capacitor (100nF) wired between the 6V rail and the OV rail, to prevent spikes on the power rails affecting the operation, especially IC8. If odd behaviour is experienced with any of the ICs try connecting other 100nF capacitors across the supply rails close to the affected chips.

Fig. 7. Board B layout





The copper side of board B showing the cuts.

To test board B, connect the clock from board A, as before, and set switch S2 to connect the pin at J44 directly to IC5 pin 4. Output is low but goes high briefly when the board is shaken. Alter S2 to connect to IC8 pin 7. Output at J44 is low and remains low if the board is shaken briefly. Prolonged shaking makes it go high, after a delay of a 1-2 seconds.

Make all inter-board connections and connect the off-board switches. If you are using a 9V PP3 battery holder with 4 AA cells, fit a battery connector with press-studs.

The way the circuit is set out in the case depends upon the type and shape of case used. To obtain maximum volume, the loudspeaker must be firmly mounted. A grille is made by drilling fine (1mm) holes in the wall. To obtain even spacing, temporarily clamped a scrap of strip-board against the box, using its 2.5mm matrix as a template for positioning the drill.

The reed switch is glued to the wall of the case in any suitable location. It may be fixed inside the lid if preferred. The switch can be aligned vertically, horizontally or at an angle. The main consideration is that is should not be easy for anyone except the constructor to work out where the magnet has to be placed to reset the alarm. ■

Components

Resistors (carbon, 0.25W, 5%)

R1	4M7
R2	560k
R3,R4,R8,R9	10k
R5	15k
R6	150k
R7	27k

Capacitors

C1,C3	100n polyester layer
C2	39n polyester layer
C4	100n polyester

Semiconductors

TR1	2N2926G NPN low power transistor
TR2	BD131 NPN high power transistor

Integrated circuits

IC1	7555 CMOS timer
IC2	4001B CMOS quadruple 2-input NOR gate
IC3	4027B CMOS dual J-K flip-flop
IC4,IC5	4011B CMOS quadruple 2-input NAND gate (2 off)
IC6	4015B CMOS dual 4-bit shift register
IC7	4078B CMOS 8-input NOR gate
IC8	4530B CMOS dual 5-input majority logic gate

Miscellaneous

S1	Mercury vibration switch
S2	Dual-in-line single-pole double-throw single switch
S3	Miniature micro-switch, single-pole single or double throw
S4	Reed switch and magnet, security type, surface-mounting
LS1	Miniature (e.g. 38mm diam) loudspeaker, 8-ohm

suitable enclosure, approximately 160mm x 95mm x 50mm

2.5mm matrix stripboard, 11 strips by 45 holes, plus scrap for making seismic switch (Fig.2)

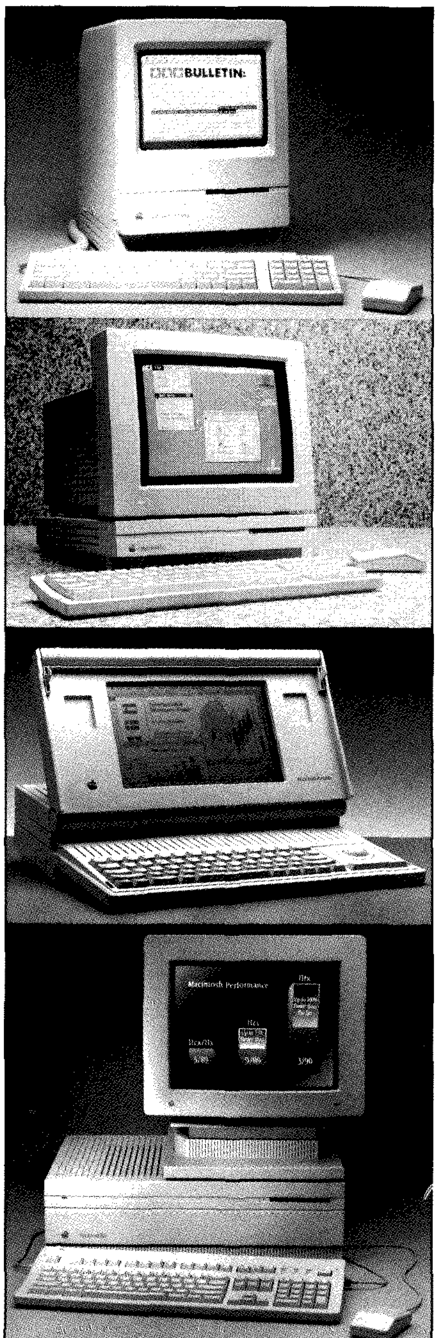
1mm terminal pins (17 off)
8-way DIL socket
14-way DIL sockets (4 off)
16-way DIL sockets (3 off)

Battery box (4xAA or 4xAAA), unless 9V PP3 battery used
Battery clip, PP3 for 9V battery or 4xAA battery box

Materials for making seismic switch (see text) and for mounting boards.

How it Works... The Apple Macintosh

PE roams through the innards of the computer that started out as a WIMP and ended up as one of the most widely used graphics platforms of the decade.



From top to bottom:
Mac Classic, LC (Low Cost)
Portable and Mac IIfx

The most famous spinoff of the Macintosh family of computers is the WIMPS (Windows Icons Mouse Pointer) user interface. This was originally developed by Xerox (of photocopier fame) and first introduced to the world on the Apple Lisa. Unfortunately, though this was a pretty amazing machine, it was rather expensive and had no mass market appeal. Its offspring, the Apple Macintosh or Mac was relatively cheap and looked great.

The first Mac had 128k of memory, a 400k disk drive, a nine inch monochrome screen and, of course a keyboard and mouse. Bundled with the package were two programs or applications, MacPaint and MacWrite. These took full advantage of the graphic user interface with the picture on the screen being reproduced exactly on the printer – WYSIWYG (What You See Is What You Get).

The toy Mac

After the initial rave reviews, the 128k Mac was seen as something of a toy since it had a tiny memory – other computers around at the time had at least 512kbytes and more likely 1Mbyte – and only a single, low density, floppy disk drive. To remedy this, Apple soon brought out an upgraded version known as the 'Fat Mac' or, occasionally, 'Big Mac'. This sported 512k of memory but was still stuck with the old disk drive. This then paved the way for the Mac Plus, SE, the high powered Mac II range and recently for the new Classic, LC and the SI.

On the software side, Apple provided a set of rules which developers had to follow to produce compatible programs. Apart from the standard graphics routines, one of the main features was the WIMPs idea that allowed data, text and graphics, to be passed from one application to another via a clipboard – allowing all applications to communicate.

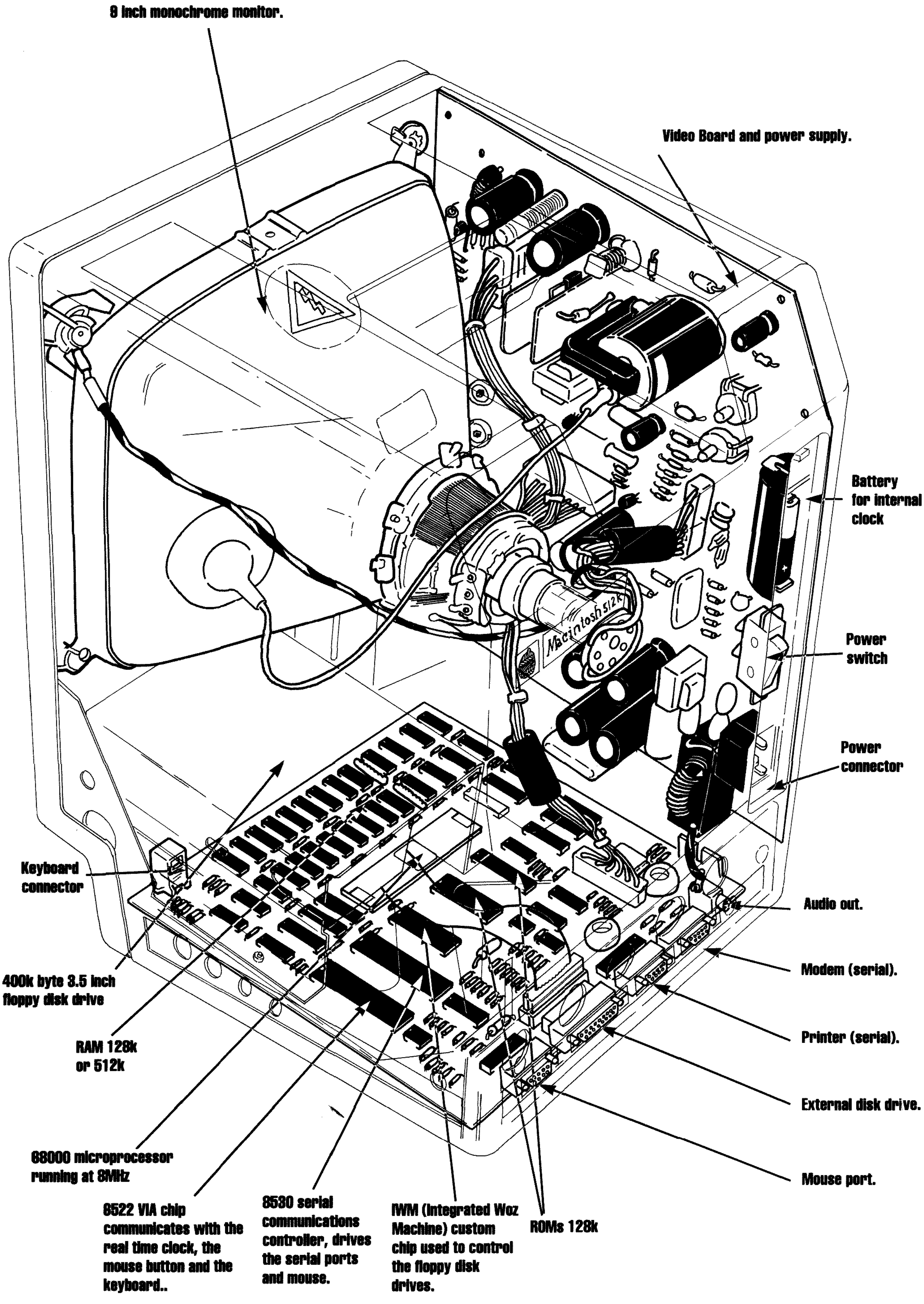
Mac vs IBM PC

The hardware of the Mac has always been based around the Motorola 68000 family of microprocessors, unlike the other major business computer, the IBM PC, which is based on the Intel 8086 family. To begin with, the Macs easily outperformed the PCs since the 68000 was such a powerful processor. However, the latest Macs are based on the 68030 and the newer 80386s and 486s are beginning to have the edge – on the other hand, they are being asked to perform many of the Mac type functions with the introduction of MS Windows and other graphic interface software.

End of an era

The old 128k and Fat Macs are no longer made but looking back it is obvious that they introduced the software and hardware technology that everyone else eventually followed. These days, mice are available for most machines as are WIMPs systems. A less obvious influence is one of style and fashion. By encasing the Macintosh in a box that also held the monitor and disk drive with colour coordination and neatness, Apple paved the way for the sleek modern machines seen everywhere today.

The Mac Revealed



100 Years Of Electromedicine

Medical electronics has progressed from primitive electric shocks to the latest microprocessors in under a century. Douglas Clarkson takes a look.

Advances in medical electronics have always had to follow in the wake of fundamental electronics. While medical technologists are always seeking to exploit new discoveries as they become available, there was just as much scientific interest and curiosity 100 years ago.

Medical applications reveal some obvious paradoxes. For example, in the life threatening condition of cardiac fibrillation, where the heart loses its synchronisation, the patient is subject to massive disturbances of voltage and current. Normally electric shocks are considered quite dangerous and great care is taken not to subject patients to them.

With The Beat

Everybody is familiar with the electrocardiogram or ECG. It was a Dutchman, Willem Einthoven, who first developed sensitive recording techniques using an early string galvanometer in 1903. In his work as professor of physiology at Leiden University he was able to study both normal and abnormal ECG traces and lay the foundation of modern ECG recording and analysis. This early work was very much in the realm of scientific research and it was a few years before it was applied to routine clinical situations. The development of the diode valve in 1904 and the triode valve in 1907 eventually provided a means of amplifying small signals, typically around 1mV, to allow less sensitive galvanometers to be used. Fig. 1 shows a typical cardiac cycle with the characteristic peaks and troughs designated as P QRS and T.

It was not until the late 1960's that bedside monitoring using cathode ray tube displays became commonplace. This was coincident with a rising toll of heart disease and the requirement to actively monitor patients. Transistors had replaced most valve equipment by this time and integrated circuits were finding increased use. A key parameter was the heart rate which was calculated with analogue circuitry. High and low alarm limits could be set and waveforms displayed as a bouncing ball on a cathode ray tube using long persistence screen phosphors to make the trace visible.

There was a very rapid uptake of microprocessor technology during the 1970's, which improved the reliability and the range of functions of cardiac monitoring equipment. One major advance was the use of memory mapped display systems which allowed the persistent trace waveforms to scroll smoothly off the side of the monitor screen. Fig. 2 shows the function of a typical ECG monitor.

Considerable thought has to be given to noise reduction and electrical isolation between the patient and the equipment. There are generally two aspects to isolation. One is the supply of power to the patient and associated circuits and the other is the return of information. The first aspect is usually undertaken using isolation transformers and data is often transferred from the patient using optical isolation circuits or pulse transformers.

An important element of front end design is protection against high voltage signals such as those created during defibrillation. This can be achieved by connecting voltage limiting devices across the input lead terminals.

Even the most basic ECG monitors are now microprocessor based. This implies that the functions of calculating heart rate, setting and checking alarm limits and displaying traces and parameter values are essentially part of an EPROM resident operating system.

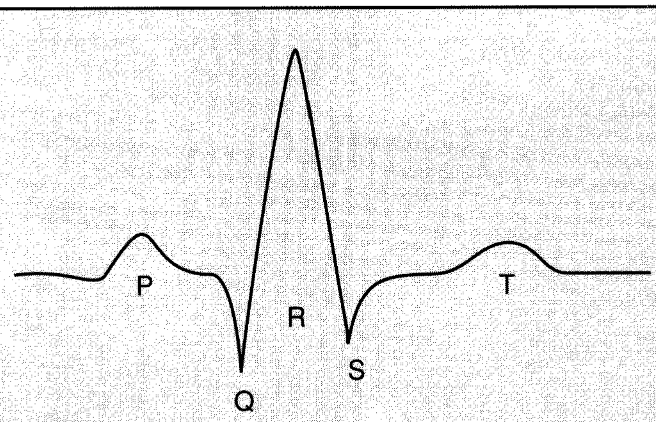


Fig. 1. Normal ECG trace.

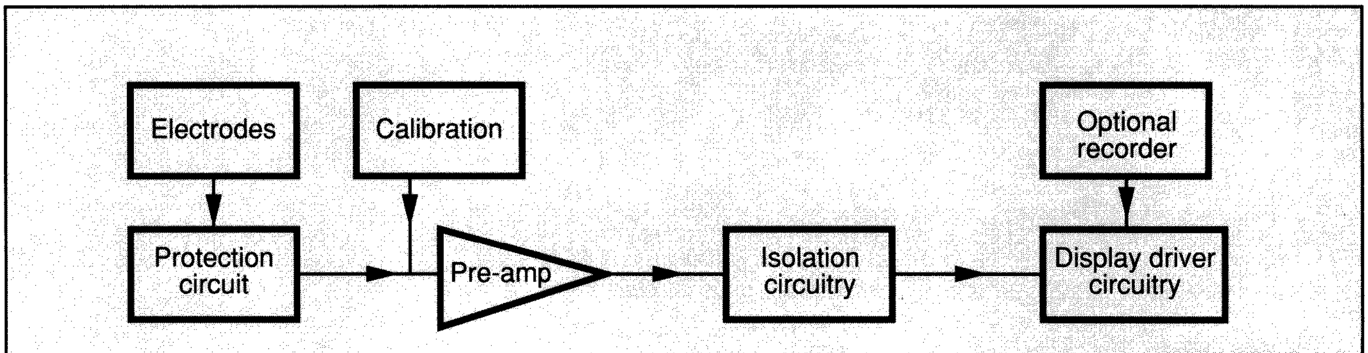


Fig. 2. Operatioion of an ECG monitor.

Sheer heart attack

The cardiac defibrillator has become an important element in the arsenal of medical technology. During cardiac fibrillation, or a heart attack, the myocardial cells of the heart lose their normal rhythm and contract asynchronously. The normal pumping action of the heart is lost and, unless resuscitation of some form is provided, irreversible brain damage occurs within minutes. A defibrillator seeks to restore the heart's normal cycle of electrical activity.

First it was discovered that merely applying an alternating voltage between 150V and 600V could defibrillate the heart. The switch control mechanism would deliver a series of unrectified pulses within a 250mS time period.

Experiments showed that the design of the so-called capacitive discharge DC defibrillator shown in Fig. 3 was more effective and was less likely to damage heart tissue. When the capacitance C is charged up to a voltage V, the output is discharged through a series inductance L and the effective resistance R of patient.

Normally the output of an adult defibrillator is set to deliver energy into a standard 50Ω load. Fig. 4 shows how the energy of this type of defibrillator is delivered in typically a 10mS time interval. The energy stored in the capacitance is given by:

$$E = (CV^2)/2$$

There is significant resistance at the skin/paddle interface which can reduce the levels of current passing through the heart system. Special conductive electrode pads or gel are therefore attached to the electrode surfaces.

When the heart is experiencing fibrillation there is no rhythm to identify so there is no time when the defibrillation pulse may be delivered.

Most modern defibrillators incorporate an ECG monitor to display the waveform and also appropriate circuitry to synchronise when cardioversion is selected.

The cutting edge

It was the engineer Nicola Tesla who first observed in 1891 the heating effect on tissues of shortwave electromagnetic radiation and suggested the application of his discovery in medicine. The term diathermy, meaning heating through, was coined by the German physician K.F. Nagelschmidt in 1909. The most important application of diathermy is in surgical procedures where tissue must be either cut or coagulated.

In diathermy equipment high densities of current are made to flow through tissue to achieve the required effect. Fig. 5 shows how different waveforms can be used to produce a cut (disruptive) effect or a coagulation (localised heating) effect. The blended waveform results in both cut and coagulation.

At first, spark gap oscillators were used to produce the required waveforms and, though some systems are still in use, these have generally been replaced by high power vacuum triode generators.

The current is made to pass between two electrodes which are a short distance (a few mm) apart in bipolar systems or through more widely separated electrodes in monopolar systems. In the latter a return electrode is placed in contact with the patient (usually on the buttocks) and the active tip is

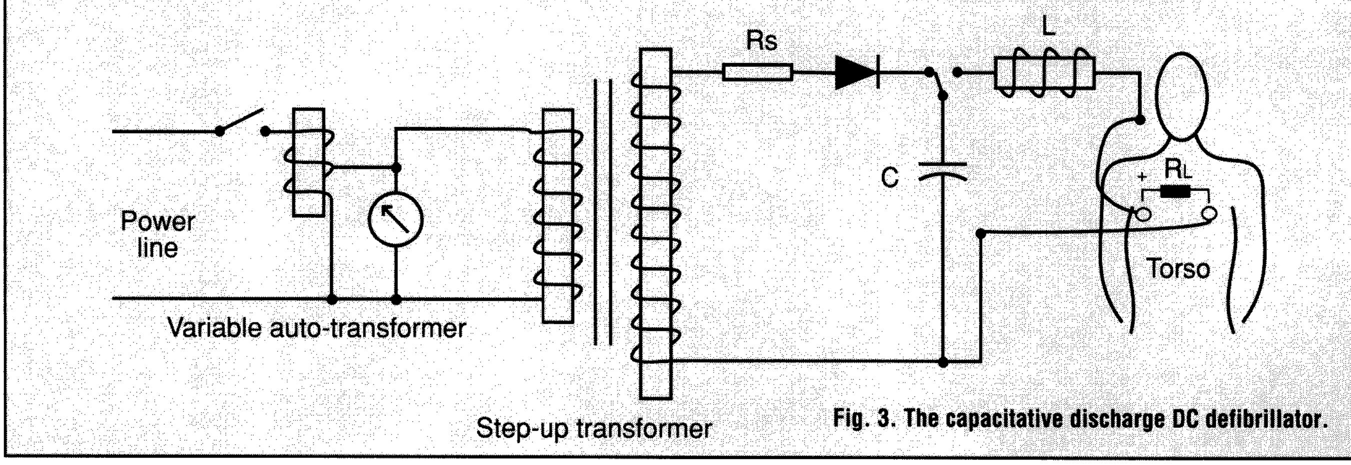


Fig. 3. The capacitative discharge DC defibrillator.

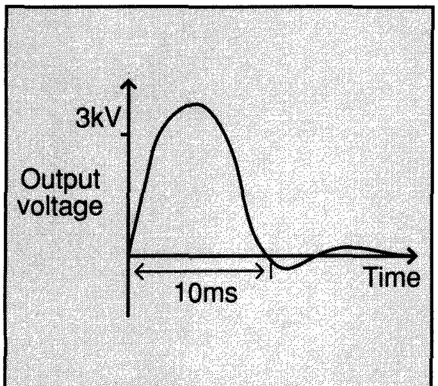


Fig. 4. Defibrillator energy delivery.

placed at the location where the localised effect is required. Because of its larger size, the current density over the return plate is insufficient to cause appreciable heating. The active tip, on the other hand, concentrates the current to create an arc which when held over tissue vaporises it. When directly touched to tissue, for example a bleeding blood vessel, localised heating produced by the current flow cauterises it and stops the blood flow.

In use, the operator presses a footswitch to select cut or coagulate modes. When the unit is energised, current at the shortwave frequencies passes through the patient's body between the return and active electrodes. Fortunately, the high frequency of the current does not tend to interfere with the electrocardiogram.

While the technique may appear crude, it is very effective. Every surgical operation will make use of diathermy equipment or have it available as a contingency. Some procedures would be almost impossible without it. Diathermy makes possible a significant reduction in operation times and has probably been the most significant electronic aid developed for the surgeon.

The main problem of diathermy comes from its use of high frequencies at high currents. These tend to produce massive electrical interference to other electronic systems such as ECG monitors and in order to minimise any currents induced along the electrodes, series inductances are placed in each cable.

Even today, with surgical laser systems being increasingly used, applications involving diathermy continue to develop. Attachments can be secured to the tips of fibre optic endoscopes for inspection and treatment of tissues in the upper and lower intestinal tracts. The use of 'ring' diathermy in treatment of cancer of the cervix – where a 'ring' of tissue is cut and removed – is proving more popular than CO_2 laser procedures in some centres.

Blood mix

The measurement of blood gas parameters, pH and partial pressures of oxygen and carbon dioxide, a vital part of assessing the condition of a patient. Unfortunately, these are invasive procedures and cannot be used continuously. The amount of oxygen bound chemically to hæmaglobin in the blood is a most useful parameter and can be monitored non-invasively using a technique called pulse oximetry. It gives rapid indication of the onset of cardiac failure or, equally important, reduced cardiac output. There is additional need to monitor patients connected to anasthetic systems or ventilators where the supply of oxygen may become disconnected.

Haemoglobin can exist either in oxygenated, HbO_2 or reduced, Hb, form. The arterial oxygen saturation, SaO_2, is defined as the ratio:

$$\frac{HbO_2}{HbO_2 + Hb}$$

This relates to chemically bound oxygen and is not the same as dissolved oxygen in the blood, which still needs to be confirmed by conventional blood gas measurements. Typically its value is around 96%.

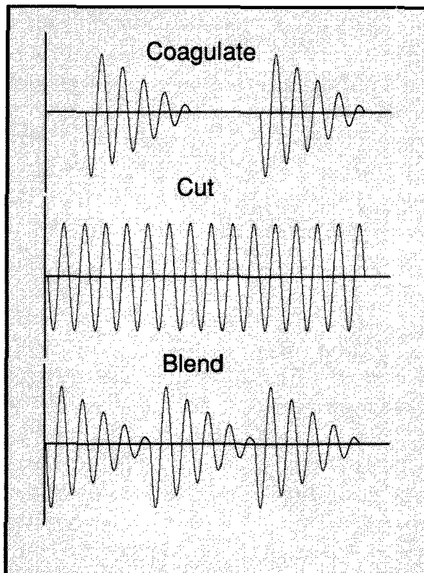


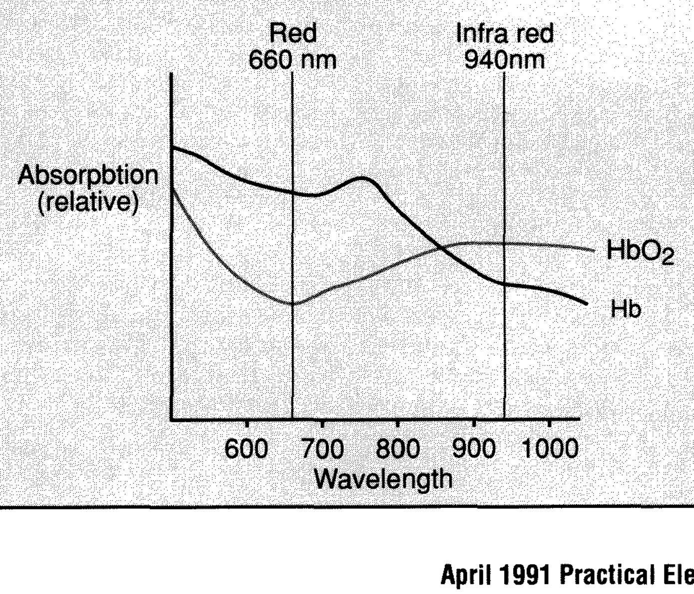
Fig. 5. Diathermy operating waveforms.

The two forms of haemoglobin have different absorption curves as shown in Fig. 6. Two separate LEDs, with outputs at 660nm (red) and 940nm (infra red) are driven alternately and the signals detected by a photodetector. Levels of background light also have to be measured to allow for signal correction.

Values of SaO_2 are typically computed 25 times per second and a weighted average value displayed over an interval of several seconds. The OXI pulse oximeter manufactured by Radiometer, uses a Z8002 microprocessor unit to perform all control functions and parameter calculations.

The heart rate can be independently computed from the dynamic waveform and the SaO_2 value indicated is derived from the

Fig. 6. Haemoglobin absorption curves.



peak value of the waveform, Alarm limits for SaO_2 and heart rate can be independently set. In many cases pulse oximetry is an ideal way to assess patient condition. Problems of patient electrical isolation are also considerably reduced since the measurement is essentially an optical one.

Hot stuff

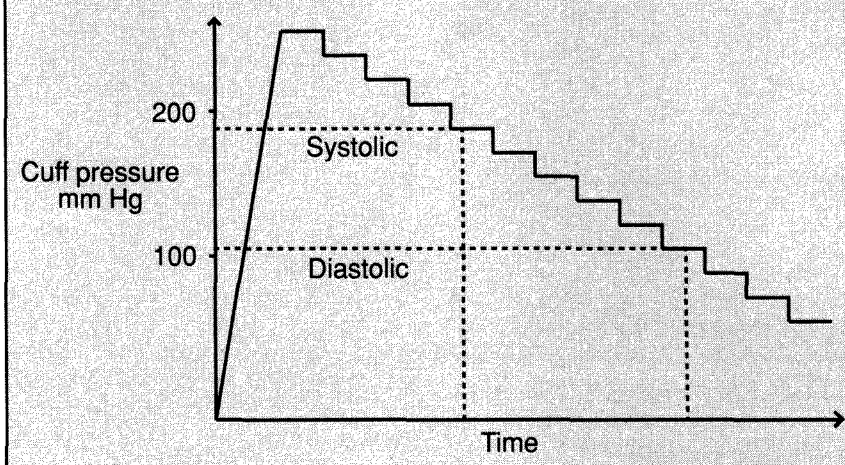
Even the humble mercury clinical thermometer has been overtaken by technology. New generation microprocessor based electronic thermometers operate by predicting ahead to an end point temperature they would in time attain. Consequently the time taken to make a measurement is reduced. These devices can also be driven in monitor mode, where the actual tip temperature is monitored continuously.

The IVAC model 2080 unit uses an NEC µPD7503 microprocessor with 4k bytes of program memory and 224 x 4 RAM. The microcomputer includes a multiplexed LCD driver, I/O ports, counter timer and clock generator. The function of the device even includes a display element to indicate if a good thermal contact has been made, for example within the mouth. When the predicted value of temperature is obtained the instrument bleeps the nurse.

Drip feed

A considerable part of modern medicine relates, not surprisingly, to the delivery of fluids and drugs to patients. When fluids are being administered to maintain fluid balance, volumes of hundreds of millilitres per hour (ml/hr) must be delivered. In control of pain, values of a few ml/hr may be required. Equipment has been developed to cater for a broad range of applications. The development of microprocessor based systems has increased accuracy, reliability and the ease of use of such equipment. The Graesby Medical M52000 syringe driver uses a Toshiba TMP80C39AP microprocessor chip to oversee and control system function.

Before the advent of equipment to control the rate of infusions, nursing staff merely regulated a throttle on a gravity fed line.



Cuff pressure cycle of blood pressure monitor.

Subsequently, drip controllers were developed to count the number of drops being drawn down by peristaltic pump action. Developments of volumetric pumps allowed accuracy levels of better than 5%.

The earliest syringe drivers were fixed rate clockwork devices but electronic versions now totally dominate the market. Microprocessor technology has again been implemented to control all aspects of the function of such equipment such as flow rate and volume to be infused. Syringe drivers function by pushing the plunger of a syringe at a controlled rate (mm/hour) in order to deliver fluid at a controlled rate (ml/hour). Syringe drivers use either stepping motors or highly geared DC motors to drive the threaded cam mechanism. Such systems could break down due to a range or mechanical or electrical failures. To cope with this they feature a range of safety mechanisms including battery backup and detectors which sense the build-up of pressure in the driving mechanism or pump malfunction. If any of these happen then an alarm can be set off to warn the operator.

The design of infusion equipment is subject to exhaustive risk assessment since any failure which causes either under or over infusion can be life threatening. Designs must be validated, for example, against electromagnetic interference and static charges. The risk of both of these is highly likely in a hospital situation.

Under pressure

There are times when it is desirable to make frequent measurements of blood pressure. To do this, the traditional method of cuff inflation and listening with a stethoscope to pick up change of pulse sounds has been automated. The cuff is attached to the patient's arm in a conventional way but the inflation and detection of pulse is performed automatically.

Fig. 7 indicates how the cuff pressure surpasses systole level blocking off the blood flow, and then drops in steps of (typically) 8mm Hg while a sensitive pressure transducer measures the static pressure and the minute pressure oscillations. This data is analysed by a microprocessor to measure the systole pressure (the upper value of the pulse pressure) and diastole (the lower value of the pulse pressure). The equipment can be set to repeat measurements after a given time interval. It can also measure heart rate and is routinely used in operating theatres to monitor patients undergoing surgery.

Looking back

From humble beginnings, modern electronics has now reached the stage where many medical techniques would be almost impossible without it. At the start of the century, the technology used was rather primitive. Hopefully writers 100 years hence will have the same opinion of modern techniques. ■

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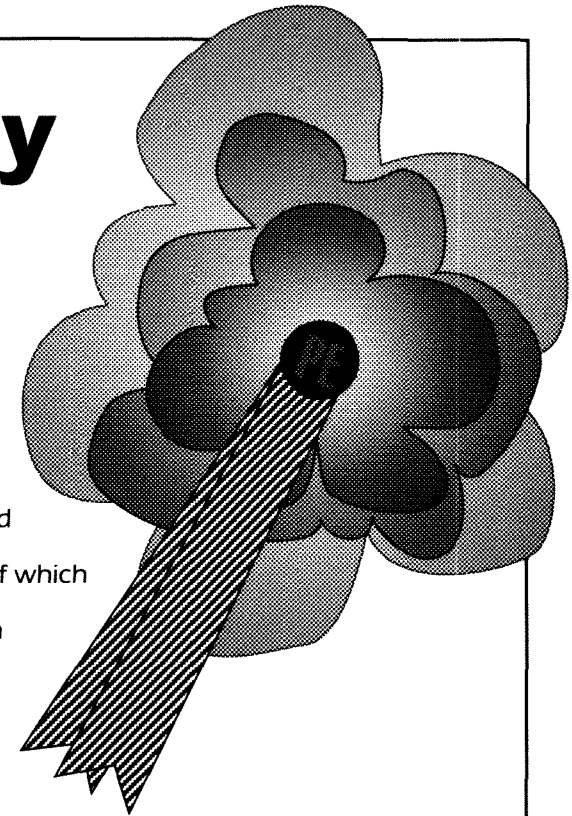

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E. Devey of Leicester reclaims the £22 spent with Bull Electrical. .

D. Webber of Long Buckby claims his £16 also spent with Bull Electrical.

See page 36 for more details!

Philips Set To Break Digital Sound Barrier

The Winter Consumer Electronics Show is visited by Ian Burley who gets a private viewing of Philips' new Digital Compact Cassette system.

The place to go to see electronic gadgets to make life in the home just that little bit less tiresome or even more entertaining has to be the twice-yearly Consumer Electronics Show in the US. The New Year started off with the Winter CES Show in Las Vegas. With recession setting in on both sides of the Atlantic, it was noticeable that this year's CES was quieter than usual – and this was a week before the Gulf War broke out. However, there was no shortage of interesting products and though the number of attendees was well down, well over a thousand companies were there to show their wares. Everything was there from watches, HiFi, video through to phones, answering machines, microwave ovens and home computers.

DAT Rival Appears

The clear show stopper was the privately unveiled Digital Compact Cassette from Philips – a direct challenge to digital audio Tape (DAT). This is a new system, which preserves backwards compatibility with traditional cassettes.

Philips claims that DCC, which should go on sale in about 18 months, will be considerably cheaper and physically more robust than DAT. The Japanese, lead by Sony, developed and pushed DAT although it has been a failure to date. DAT undeniably has excellent sound reproduction quality, but a row with the music publishing industry over tape piracy issues has left DAT virtually still-born five years after it was ready for the domestic market. It uses the relatively delicate helical scan recording system rather like a miniaturised video recorder, complete with a spinning drum recording head.

DCC retains the much cheaper and less delicate fixed-head system, though nine tracks are recorded per side. All DCC decks will offer auto-reverse as standard. Electronics buffs might immediately ask the question how can you pack enough data onto ordinary tape with a fixed recording head? In fact Philips uses a potentially revolutionary encoding system which eliminates parts of the audio signal which even the best human ears cannot detect. This enables DCC to make do with just a third of the data DAT stores.

Philips emphasise that the system, which is closely modelled on characteristics of the human ear, does not compress the audio information. Instead it simply retains what's audible.

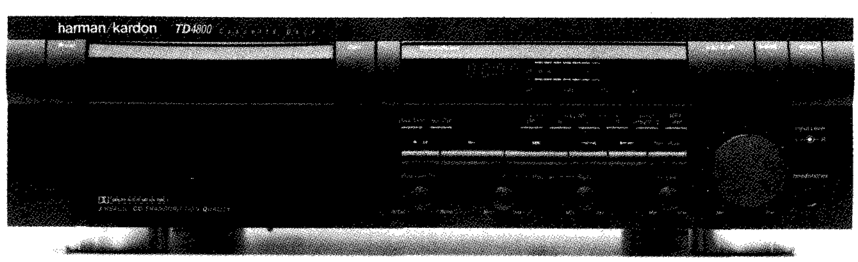
The encoding system employed by Philips is incredibly clever and very different to most other systems used in audio processing. The technology used by DCC could occupy a whole article on its own.

DCC is bound to be controversial with the HiFi purists, but Philips says it has employed extensive expert listening panels and feels sound quality has reached the point where it is indistinguishable from compact disc comparison sources.

Despite the fact that DCC wasn't on public display at CES, it sent a wave of reaction through the show, prompting a rash of defensive statements from several DAT proponents, including Sony.

Philips has another card up its sleeve; a major Japanese partner, rumoured to be Matsushita, better known for its Panasonic and Technics brand names. Philips has often been good at coming up with bright ideas, unfortunately it has usually taken others to exploit them. With DAT on the rocks, DCC could be a success story for Philips and European technology.

Staying with audio, Harman Kardon announced the world's first production Dolby S cassette deck. Details of Dolby S noise reduction, an improvement on Dolby C, were revealed at last year's Winter CES. This is more unwelcome news for DAT fans as it offers another incentive to hang on to the familiar compact cassette format.



The world's first Dolby S cassette deck.

New Visions

On the video scene, tiny camcorders were undeniably the products to see at CES. Here there was some good news for Sony as several big name firms previously committed exclusively to the JVC-lead VHS standard announced new 8mm models based on the Sony developed standard. Meanwhile, Panasonic unveiled a video printer for video fans who simply can't be bothered to lug a conventional still camera around with them as well as a camcorder. Sharp made a few waves with what it claims is the first home camcorder with a colour viewfinder.

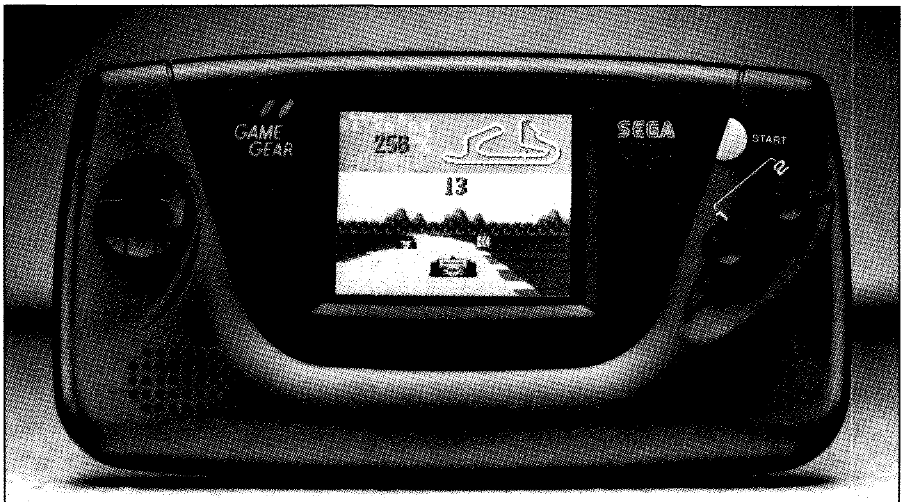
Toshiba wheeled out its high definition TV monitor system, we first saw at CES Summer in Atlanta last June, to wow the crowds. But there was more to high technology from Toshiba in the form of a two inch thick, 10 inch diagonal portable flat screen LCD TV. With its 640 by 480 pixel screen the picture is excellent, and a match for any comparable CRT colour display, though the completely flat display was a touch disconcerting at first. The mind is programmed to expect distorted pictures!

Several other firms displayed flat screen colour LCD monitors including Casio and Sharp, the latter also showing off its latest LCD video projectors – including an HDTV model linked to a prototype HDTV laserdisc player.

Watch That Phone

We've already seen watches for joggers and under-sea divers but now Casio has come up with a watch which can measure both your pulse and blood pressure. The watch has a pair of tiny finger-tip sensors and it can even build up a bar chart of measurements to indicate how an exercise regime is affecting your cardiac health.

In the telephone department there were a couple of firsts from Phonemate and AT&T in the form of all-digital solid state answering machines. The AT&T model looks very futuristic and unlike any answering machine I've ever seen - it was designed by one of the firms which works for Apple Computers. Neither machine offers very long recording, between 5 and 14 minutes depending on how much memory is fitted, but advantages include no tape-jamming, time and date stamping, near-instantaneous message searching and in the case of the more expensive Phonemate model, extensive remote control message shuffling.



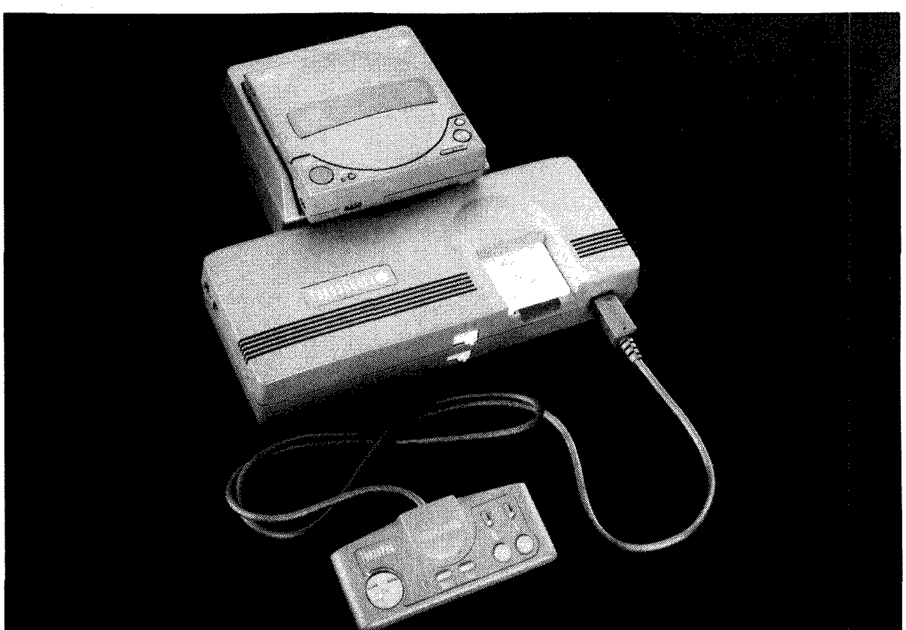
Sega's full colour hand held games console.

Sega Gamegear

On to computers and CES was full of the latest computer video game hardware and software. Sega launched its Gamegear hand-held unit complete with a colour LCD screen while Atari launched a redesigned Lynx to compete with the Gamegear. The Gamegear has one advantage in that it will take an add-on TV tuner. Nintendo was also present to demonstrate its new 16-bit Super Famicom games console which will probably continue the firm's complete dominance of the world video game market well into the 90s. Closer to home, Psion's recently announced deal with Memorex to market the innovative MC mobile computer range in the US was there in the metal, or should that be plastic. Besides the MRX-G designation replacing the Psion MC model name, the US-spec Psions look identical to their European siblings. Let's hope this turns out out be a British success story in the US for once.

Fuzzy Cooking

Finally, only the Japanese could do it, but what about applying fuzzy control logic to something as humble as a microwave oven? Sharp has done exactly that. Hooked into a barrage of sensors the Sharp oven can detect temperature, moisture and even consistency in order to ensure your baked potatoes are just right. ■


TurboGrafx-CD, the first compact disc system to play games.

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The Latest Books Reviewed

The book of the month is The Satellite Book, which shows that there is a great deal more to satellite TV than first meets the eye.

At first look The Satellite Book is simply an overview of the state of the art in satellite TV. However, on closer inspection it reveals information on: how, why and where satellites are placed in orbit for telecommunications use, how to attach receiving dishes to the side of a house (including a section on the safety aspects of using a ladder and customer care!), the cables that should be used, how microwaves work when used in satellite systems, antennas and dishes, video distribution systems, transmission standards and encryption, plus much more. If you wanted to know anything about satellite TV, you'll find it in this book.

To ensure its authority, The Satellite Book was not written by one person, the editor has brought in an expert on every aspect and a chapter is written by each. This means that subjects get a density of coverage, complete with a plethora of black and white diagrams and pictures, not possible from a single author. For example, the section on satellite footprints – the area where the signal of a particular transmitter can be received – covers all of the current TV satellites, with a map being given for each, receiving antennas covers not just the standard dishes, but also zone plates and squarials. This attention to detail is maintained throughout the book and although it makes reading a little heavy going at times, there are enough easy bits to make it quite an enjoyable book to leaf through on a rainy Sunday afternoon. The subject matter ranges from from interesting, for example, how the Ariane launcher gets its payload to synchronous orbit, to difficult – how to work out the gain and slant of a receiving dish. Definitely a recommended book for anyone with an interest in the modern uses of electronics.

Title: The Satellite Book. A complete guide to satellite TV theory and practice.
Editor: John Breeds
Publisher: Swift Television Publications
Cost: £27.95
ISBN 1 872567 01

An enjoyable book to leaf through on a rainy Sunday afternoon.

Counted Out

Starting off from the very basics of digital circuitry – defining such things as LSI and chip shapes and sizes, Practical Digital Electronics goes on to describe the basic logic families and circuit functions. Bistables, monostables and timers have their own sections and are dealt with reasonably painlessly. The author then moves on to microprocessors (eight-bit only), memories and I/O (input/output), all covered very quickly but in reasonable detail.

The second half of the book moves on to discuss the standard RS232 and IEEE 488 interfaces plus basic microprocessor bus systems. This section is quite short and is followed by the first appendix, a list of the most commonly used7400 and 4000 series of logic chips showing their operation and pinouts. To fill up a few pages, some useless decimal, hex and binary tables are also given – it would have be far more informative to explain how to convert between bases arithmetically than to just give the tables with no explanation of what they are for or how they work.

Appendix two gives constructional details for some test equipment: regulated power supply, logic probe, logic pulser, pulse generator, IC tester, current and logic tracers, an RS232 breakout box and a frequency meter. The next appendix describes the operation of the oscilloscope and the final two sections provide a bibliography and advice on City and Guilds courses in electronics.

This is a reasonably good value book for the beginner. On the other hand, anyone who regularly buys an electronics magazine will find that most of the projects have appeared before as has the information in the rest of the book.

Title: Practical Digital Electronics Handbook
Author: Mike Tooley
Publisher: PC Publishing
Cost: £4.52
ISBN 1 870775 00 7

Techniques

Andrew Armstrong begins a new series of questions, answers and technical tips.

Cheap circuits

Is there a way I can use my computer to help design circuits, other than by buying circuit analysis programs such as Spice, which are far too expensive for my needs?
H Jones
East Sussex

For professional design purposes, it is often necessary to model device parameters accurately, and the commercially available programs are a good way to do this. However, they are a very costly solution to simple problems. A technique I have used in the past to model simple linear and nonlinear circuits is to write a program to apply simple DC equations to the circuit, and then repeat the calculation at very small intervals of time.

The best way to explain this is by example. The circuit of Fig. 1 is complicated enough to demonstrate the technique, without being so complicated as to obscure the principles. Assuming that at the start, there is no current or voltage anywhere in the circuit, and that at time 0 a voltage is applied to the input, the following equations can be written:

$$\delta I1=tx(V0-V1)/L1$$
$$\delta V1=tx(I1-I2)/C1$$

and so on, where t is a very small time period, so short that, for example in the first equation, V0-V1 can be assumed to remain constant. If t is short enough compared with circuit time-constants, the error caused by this assumption will be slight, though the program will take a long time to run.

Listing 1 shows a sample program to calculate and plot a graph for this circuit, using the component values shown. It is written in GWBasic to run on a PC/AT computer with an EGA display — but it could easily be adapted to run on most machines.

The listing is almost self explanatory, so a few notes should be an adequate introduction. The component values set in lines 40 and 50 are in their basic units: henrys, farads, and ohms. The time step is in seconds.

Line 60 selects a graphic mode; lines 70 to 90 draw the axes and the unity scale line.

In the calculation loop, there is a further loop to do the calculation ten times for each point that is plotted. This reduces the error while retaining a reasonable scale on the graph. The value of timestep is chosen by starting with 1% of the shortest simple time-constant in the system, running the program, and altering the value until the result looks right. If reducing the time-constant does not affect the values, but only spreads the graph out, then the value is small enough.

In line 150, the calculation of the Y position is because the screen positions are numbered from the top left hand corner. The LOCATE statement in line 170 makes sure that the final "OK" is printed clear of the area of interest.

This is the bare-bones approach. Much more comprehensive scaling would be appropriate in most cases, and the graphics could have been handled better by printing the screen image from within the program, rather than using the graphics printscreen function provided in the operating system. A program employing these techniques would have been much longer, and would have obscured the simplicity of this analysis technique.

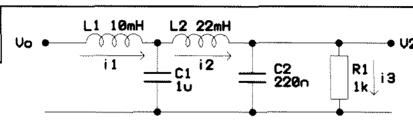
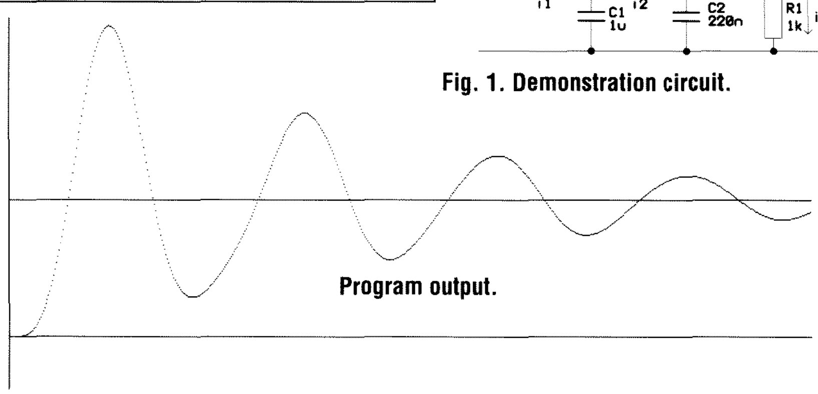


Fig. 1. Demonstration circuit.



Program output.

```
10 '***********************************************
20 'Circuit Analysis Program - A. Armstrong 27/12/90
30 '***********************************************
40 V1=0:V2=0:I1=0:I2=0:I3=0:L1=.01:L2=.022:C1=.000001
50 C2=2.2E-07:R1=1000:TSTEP=.0000005:V0=1
60 SCREEN 9:CLS
70 LINE (1,300)-(600,300)
80 LINE (1,170)-(600,170)
90 LINE (1,1)-(1,350)
100 FOR N=1 TO 600
110 FOR M=1 TO 10
120 I1=I1+TSTEP*(V0-V1)/L1:V1=V1+TSTEP*(I1-I2)/C1
130 I2=I2+TSTEP*(V1-V2)/L2:V2=V2+TSTEP*(I2-I3)/C2:I3=V2/R1
140 NEXT M
150 PSET (N,(300-V2*130))
160 NEXT N
170 LOCATE 23,1,0,7,6
180 END
```

Listing 1.

One final point: this example has used a DC voltage applied at time=0, but there is no reason why an excitation signal which is a function of time should not be used. A sinewave, for example, would be easy to apply, calculating the sine as a function of MxN (using the loop variables in the listing). It would even be possible to vary the frequency, and calculate the frequency response of a filter. Of course, the computing time could could be long enough to need overnight calculation .

Balancing Act

I am the sound man for a small band, and I sometimes have problems with the public address system. In some venues, where the power amplifier is plugged in to a mains outlet some distance from the mixing desk, there is mains hum which I have not been able to eliminate.

It is not a clean sinewave hum, and there seems to be interference from light dimmers, thermostats and the like. Can you suggest a solution?
H Rawlinson,
Chipping Norton

From what you say, the probable cause of the unwanted noises is that the power amplifier and the mixer are connected to mains earth at different points. Earth loops have long been known to cause hum, but the increasing number of interference-producing items connected to the mains has multiplied the problem.

One good answer would be to encode the sound onto an optical fibre link, avoiding any electrical connection between the mixing desk and the power amplifier. I do not know if this solution has ever been used for public address applications, though I do know that Meridien use fibre to distribute the signal to their active loudspeakers. Probably a more practical approach would be to use a balanced link between the mixing desk and the power amplifier. Some good quality mixing desks use balanced outputs, but lower cost ones invariably use unbalanced jack outputs.

A properly balanced link will reject all common mode signals, such as those caused by the earth voltage being different at each end of the cable.

Fig. 2 shows a balanced audio output, while Fig. 3 shows the simplest form of balanced input. The balanced output stage includes a non-inverting amplifier as well as the inverting one, so that the delay in each half of the signal is similar.

The input stage is nominally balanced, and may be good enough to eliminate a minor hum problem, but it has imperfections. First of all, if the resistor values are equal the impedances seen by the inverted and non-inverted signals are not equal.

The input resistance of the non-inverting input is R3+R4, but the impedance of the inverting input is less obvious. If there is no input signal on the non-inverting input, then the input resistance of the inverting input is R1, because the inverting input of the op-amp is a virtual earth point. If, on the other hand, there is a balanced signal, then a signal of half amplitude and opposite polarity will appear on the inverting input of the op-amp. The virtual earth point will be two thirds of the way along R1 from the input, so the effective input impedance to the wanted signal will be 2/3 R1.

Unwanted signals only appearing on the inverting input will see an input impedance of R1, but common mode signals will see an impedance of 2xR1, because a half amplitude in-phase signal appears on the op-amp's inputs.

These figures matter more in some situations than in others. The component values shown in Fig. 3 take account of the above to the extent of equalising the effective input resistance on each side for proper balanced signals.

The other drawback of this type of circuit is that inaccuracies in the resistor values limit the rejection ratio for common mode signals. Using 1% resistors with the worst possible combination of tolerances, common mode signals will be reduced to 4% of their input level.

One answer to this is to use matched resistors. The other is to use an improved circuit such as that in Fig. 4. In this circuit, the first stage amplifies differential input signals while serving as a unity gain buffer for common mode signals. A differential gain of 10 here increases the common mode rejection ratio by 10 times. The signal may be at a high enough level that gain is not appropriate here, but if gain would be used in any case, it is better to provide it at the input stage and so improve the common mode rejection ratio.

As a guideline, I have used the circuits of Fig. 2 and Fig. 3 successfully to remove noticeable problems from a public address system with a 50m cable run. ■

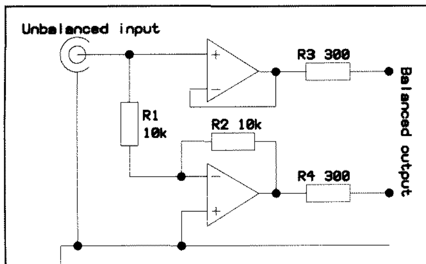


Fig. 2. Balanced audio output.

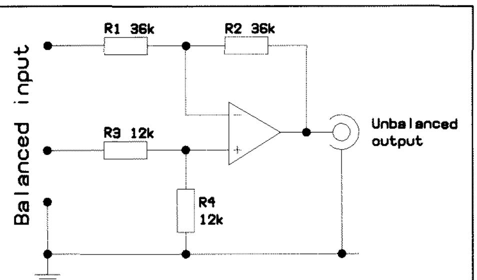


Fig. 3. Balanced audio input.

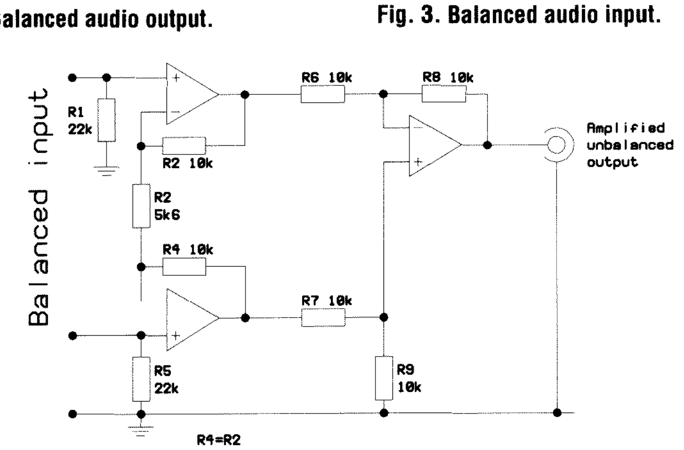


Fig. 4. Improved balanced audio input.

PRACTICAL
ELECTRONICS
SCIENCE AND TECHNOLOGY

We chart the changing face of electronics with a look at the past 25 years of PE.

April 1966

There were a number of interesting articles in Vol. 4 issue No. 2. The Electronorama section, 'Highlights from the contemporary scene' showed a photograph from the first soft landing on the moon. This was received by Jodrell Bank radio telescope and showed the surface of the moon a few feet from the touch down. Also in Electronorama was the smallest television set ever produced with a 1 inch tube and microchips. It measured 4.5x3.5x2inches and was developed for the Westinghouse Defence and Space centre in the USA.

1976

The Semiconductor Update section was recruiting people to the microprocessor bandwagon. The ITT7150 was said to provide enough processing power to control the most sophisticated washing machines. In the 1990s, washing machines still use the cam and timer method of the 70s, obviously modern microprocessors are now too powerful to be used for such mundane tasks as taking care of the washing. Projects included an envelope shaper, PE digi-probe, a DC millivoltmeter and the quick reaction game, Shoot – this zoomed a lit LED across a darkened row until the player 'shot' it down by pressing the fire button – one of the first portable electronic games.

1981

One of the main features gave the low down on all the latest gadgetry at the CES (the Consumer Electronics Show). This included the first pocket sized LCD TVs, which were an 'amazing' 6.8x3.2x0.7 inches and weighed just 10.5 oz. Also new were the world's first computer controlled cassette deck and an early example of the midi Hi-Fi rack system from Akai. Projects this issue were the PE Digisounder – a depth gauge for sailors, a speech processor, drill PSU and an ultrasonic intruder alarm.

1986

PE made an attempt this month to set a standard for interfacing all home micros with the PE Hobby Bus. This was based on the STE bus standard, connecting up to the computer via its data and address lines. Unfortunately, the whole idea seems to have fallen by the wayside as nothing has appeared in PE to fit the bus for a few years now. Also in this issue were a sound switch, analogue interface for the Spectrum or Amstrad, a photographic trigger unit and a scratch and rumble filter.

The Fox Bites Back

Just how portable are portable computers?

Some practical advice this month, prompted by the new buzz phrase in the ever-expanding dictionary of jargon - "Mobile PC". It replaces "laptop" and turns the technology of portable computing through a full circle.

The advertisers' image is of a busy traveller, cheerfully working on the move with a personal computer the size of a notebook. Letters and sales statistics keyed into the machine are either printed out, swapped to a desk-top PC back or fed back to the office by connecting the portable to a hotel telephone.

If only it were as easy as they suggest. Virtually everyone who buys a portable PC discovers too late what they should have bought instead. I am personally convinced that the people who write the adverts can never actually have used what they are encouraging others to buy.

The full circle began in the early 80's when Tandy started selling the Model 100. Although these units now look old-fashioned, and Tandy was slow to follow through with comparable innovation, the 100 defined benchmarks for portable computing which have never been bettered. It became a standard working tool for journalists, especially in the USA.

Like today's Mobiles, the 100 was of A4 notebook size. The keyboard was full-size and solid to the touch, like a typewriter. Essential software, a card index, simple word-processing and comms program for sending ASCII text by modem down a phone line, were permanently stored in ROM.

The screen was an LCD, but it did not have a back light to make the text legible in poor light. It also displayed only eight lines of text. Modern portables display much larger chunks of text. They have backlights too. It saves on battery power if the light can be switched off when there is plenty of natural light to illuminate the screen. All too often this commonsense feature is missing.

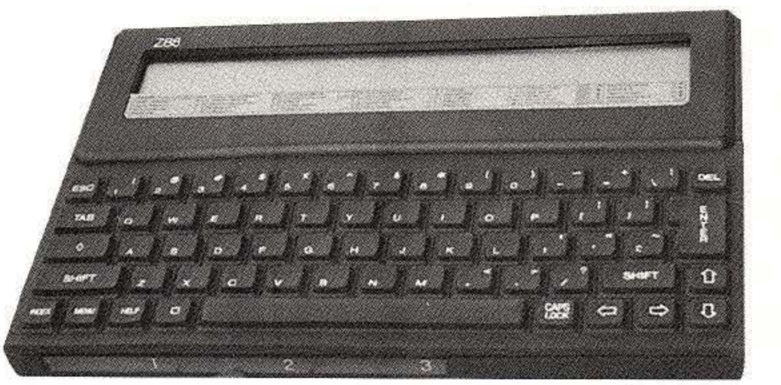
The sad truth is that there is no free lunch...

Sir Clive Sinclair was the first to compete seriously with Tandy. His Z88 was a similarly sized but lighter unit, with finer text screen, but less chunky keyboard.

Several firms (such as Atari with the DIP Folio and the Poquet) have tried taking the idea a stage further with smaller units which fold in two to reduce size even further. The keyboard is, however, very small. Be sure to try typing on one for a while before buying. Practice helps but coping with a fiddly keyboard distracts from useful work.

Likewise, before buying, try keying data into the large capacity pocket electronic databases which are now available. Like Tandy with the 100, British company Psion set benchmarks with its range of Organisers. Sharp and other Japanese companies followed. The adverts boast large memory capacity to store thousands of phone numbers. Psion's Organiser uses EPROM chips which store up to 128 K of data even when the power is switched off. But think about how you are going to fill such a big memory with data, using only a tiddly alphanumeric keypad which is more like a tv remote control than keyboard.

The trick here is transfer, by wire, from a desk top PC. In this way an electronic organiser becomes a pocket version of the office database. The same technique must be used to transfer work out from a portable which stores it only in solid state memory, or on hard disk, and does not have a built-in



The Cambridge Z88 portable.

Turn to page 30 for the continuation of this article ➡