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OUR NOVEMBER ISSUE WILL BE ON SALE FRIDAY, OCTOBER 4th, 1985 (see page 27)

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Practical Electronics · October 1985
21 YEARS

Next month PE has been around for 21 years. I do not intend to go on too much about it now as we will be carrying a special feature (and an extra eight pages) next month. In the feature we will look at the history of PE, some of the "landmark" projects along the way, the personalities, the moves, some advertisers etc. In addition to the special anniversary issue we will increase the size of the magazine—by adding about 20mm on the height. This is the second time in the history of PE that the page size has been increased—if you do not know when it happened before, find out next month!

Twenty one years is a long time in electronics, however, it may surprise some younger readers just what hobbyists were building all those years ago. Although I was in no way connected with PE when it was launched, there are still people on the staff who were; people who have made it a success and who, with your help, ensured the magazine prospered and continued. In fact when PE was launched, I was just starting an apprenticeship with the Ministry of Aviation and never dreamed I would eventually edit the exciting new magazine we apprentices read so avidly.

Interestingly, our history is based on three sets of seven year periods with major changes at the end of each seven years—and strangely it does seem to be happening again now!

PRICES

Perhaps it is unfortunate that we have to keep up with all aspects of progress; I am thinking of inflation and the way it affects the cost of the magazine. With this in mind I must tell you that from next month PE will cost £1.10. For some time our cover price has been lower than our competitors and we have maintained this situation for as long as possible, but economics now force us to go up 10p. For your information the first issue cost 2/6 (12½p for those who do not remember £s.d.); that's about 750 per cent inflation in 21 years. However, a single transistor was then around 5/- (25p) which would be equivalent to over £2 now, instead of the 15p or so we actually have to pay.

For those who may consider the 10p price rise is to pay for extra paper the new size issue will require, let me assure you that due to the complexities of Web Offset printing the size increase has not added to our printing or paper costs.

We do try our best to contain the cover price and keep up the quality and content of each issue. You may have noticed that our type size is much smaller than some publications which means more words per page and, therefore, more information in each issue.

Mike Kenward

BACK NUMBERS and BINDERS...

Copies of most of our recent issues are available from: Post Sales Department (Practical Electronics), IPC Magazines Ltd., Lavington House, 25 Lavington Street, London SE1 0PF, at £1 each including Inland/Overseas p&p. When ordering please state title, month and/or issue required.

Binders for PE are available from the same address as back numbers at £5.50 each to UK or overseas addresses, including postage, packing and VAT.

SUBSCRIPTIONS

Copies of Practical Electronics are available by post, inland for £13, overseas for £15 per 12 issues, from: Practical Electronics, Subscription Department, IPC Magazines Ltd., Room 2816, King's Reach Tower, Stamford Street, London SE1 9LS. Cheques, postal orders and international money orders should be made payable to IPC Magazines Limited. Payment for subscriptions can also be made using a credit card.

Phone: Editorial Poole (0202) 671191

We regret that lengthy technical enquiries cannot be answered over the telephone.
ROOM FOR EXPANSION

According to British Telecom sources, if the whole of the telephone network could be 'monitored' at any one time during the average day, 25 per cent of numbers being dialled would be unanswered. If BT could persuade more people to employ answering machines then, of course, those calls could be answered. The potential increase in turnover further broadening the smiles of shareholders.

Since the majority of big businesses now have well established intercommunications set-ups, it is the smaller businesses and the man in the street that are presently being courted by BT marketers. The machines displayed in a recent exhibition were aimed at this market.

Items of particular interest were multi-function desk phones with many switching capabilities that will undoubtedly in the long run make the standard switchboard (and it's operator) redundant. Also in the pipeline are "desk phones of the future" which might well incorporate a mini data printer, it is expected, by then, that the telephone system will be essentially digital as will the desk sets—making present-day modems obsolete.

The data-transmission field has just been boosted with the launch of BT's communications service enabling the transmission of text, photo's, data and speech. This new service Integrated Digital Access (IDA) will, according to Mr Kane (BT Director of Marketing), "Transform communications in the UK and have a major impact on the business community".

The system at present is only linked from London to several key areas in the south. As the Advanced Integrated Services Digital Network (ISDN) is progressively expanded, the facility will become available to us all. It is planned that by 1987 around 190 centres in the UK will be able to use IDA.

A similar innovation is already in use, using the analogue system (via A/D converters), IMTRAN (Image Transfer) consists of a portable receiver/transmitter unit which plugs into a standard telephone socket. It can be connected directly to a body-scanner, or to a TV camera focused on X-ray pictures or medical records etc. High resolution images are received on a TV monitor screen, enabling doctors to analyse the pictures at far off locations soon after they have been taken.

SOUND INVESTMENT

A 'sound-meter' kit is now available from Cambridge Kits, with £4 off for PE readers. This self-contained, hand-held unit, designed to BS 5969 with "A" weighted frequency response to compare both low and high frequency annoyance, measures all types of sound and checks whether legal limits in factories and residential areas etc are being met. It is ideal for comparing appliances, lawn mowers, paper shredders etc. or measuring the effect of sound proofing or double glazing.

There is a built-in calibrator and the measurement range is from 40dB (public library) to 120dB (overhead jet take-off). It features peak sound level response, even with pulsating or irregular sounds. There is a linear dB sound scale and knob to set the measurement level, which makes an i.e.d. flash when exceeded, or the operator can watch the i.e.d. and turn the knob to measure the sound level—there is no flickering meter needle to guess at. The meter runs from an internal PP3 type battery or external 9V supply.

The kit is available at an introductory price of £23.20 including VAT and UK postage if ordered from Cambridge Kits, 45 (3J) Old School Lane, Milton, Cambridge, before the end of October 1985. Allow 28 days for delivery. From 1 November 1985 the regular price will be £27.20.

Also available from the same supplier is the 'Monaco' DMT 700, a handy-sized (67 x 112 x 25mm) 31 digit i.e.d. digital multimeter—ideal for the hobbyist/service engineer.

Ranges as follows: 0–1kV d.c. (4 ranges); 0–500V a.c. (2 ranges); 0–200mA d.c. (3 ranges); 0–2kΩ (4 ranges); Diode test; Overload protection; Auto-polarity.

This manageable, well-priced multimeter is being offered to PE readers at the special price of £29.95 inc. VAT.

For readers interested in robotics (see: Experimenting with Robots, page 46) it should be noted that d.c. motors, micro-switches, relays and other 'robotalia' can be sourced at this address: Croydon Discount Electronics, 33 Lower Addiscombe Road, Croydon, Surrey CR0 6AA (01-688 2950).
CLEAN MAINS

Most home computing enthusiasts will perhaps by now be aware of the frustrating problem of an unstable mains supply creating havoc with a micro. Mainsborne 'spiky' transients and r.f. interference can crash a program or hopelessly corrupt data, necessitating many hours of further work. Several surge-filtering devices are presently available, and the peace of mind that comes with one could well be worth the purchase price.

New from Tony Firshman Services is the competitively priced 'Computer Cleaner'. Housed in a typical double-adapter casing the basic unit incorporates capacitive filtering (1-300 MHz), an inductive element for r.f., up to about 130 MHz; and a mains transient suppressor. The unit is capable of protecting more than one computer, but has only one outlet. A double-adapter could be plugged into the unit for this purpose. A four-way trailing socket version is also available for those with a need to supply larger amounts of laundered power. The basic 'Computer Cleaner' plug costs £14 and the four-way socket £24, prices inc. VAT and p&p. (Allow 28 days for delivery). From Tony Firshman Services, 43 Rhyl Street, London, NW5 3HB. (01-267 3887).

POINTS ARISING...

MODEMS Part 3
August '85

The telephone number given for access to the Prestel 'Enterprise' computer (page 24) cannot be used from outside the London area. If in London 618 1111 is correct; unfortunately it cannot be prefixed with '01-' as printed. People outside the London area should ring the Prestel Information Office on 01-822 1122 for the number relevant to their area.

CYLINDER THERMOSTAT
May '85

The tendency of the cylinder thermostat relay to 'chatter' is the result of mains spikes (generated when the relay contacts open and close) being picked up by the sensitive parts of the circuit.

The easiest cure is to put a time delay in the circuit so that short interference pulses do not get through to operate the relay. In most cases a 100μF/10V electrolytic capacitor connected across R11 will provide a complete cure. This value can be increased to 1000μF or more in severe cases. The negative terminal of the capacitor is connected to the end of R11 nearest to the centre of the board.

It is also possible that interference may enter the circuit via the sensor lead in situations where the environment is particularly prone to electrical noise. To prevent this a 10 KΩ resistor should be inserted between the inverting input of IC2 and the sensor terminal block TB2.2. This can be inserted by breaking the pcb track where it passes between TR1 and VR2 and soldering the resistor across the break. It may also be advantageous to increase the value of C2 to 100nF.

The amount of electrical interference generated when switching inductive components such as pump motors and boiler solenoids is surprising. With hindsight it is clear that the modifications should have been designed in. Perhaps this experience will be of help to those designing similar circuits in the future.

Briefly...

Availability of a BBC-B interface for the 'Memoon Crawler Robot' has been announced by Red Giant. It will retail at £6.95. In the near future a further BBC-B interface will be launched for the Fischertechnik Robot Kit. This will cost around £25 with a 20 per cent reduction for schools. Details from Red Giant Software Ltd., 3a Oakcroft Close, Pinner, Middlesex.

The new Greenweld catalogue has just been published. It contains a wide range of components, books, meters, connectors and all the usual requirements of the electronics enthusiast. A special listing within the catalogue (list No. 21), offers exceptional prices on a wide range of 'returned' goods. The catalogue's one pound purchase price can be redeemed with discount vouchers. From, Greenweld Electronic Components, 443 Millbrook Road, Southampton S01 0HX (0703 772501).

DID YOU KNOW that Prestel charge 6p per minute for computer time between 8 a.m. and 6 p.m., Monday to Friday and between 8 a.m. and 1 p.m., Saturday. However, at all other times the service is FREE.

Countdown...

Please check dates before setting out, as we cannot guarantee the accuracy of the information presented below. Note: some exhibitions may be trade only. If you are organising any electrical/electronics, radio or scientific event, big or small, we shall be glad to include it here. Address details to Brian Butler.

Compeq Nov 12-15. Olympia K2

Personal Computer World Show Sept. 18-22. Olympia 2 M
Electron & BBC User Sept. 27-29. UMIST, Manchester L
Amstrad User Exhibition Oct 5/6th. Novotel F2
Cellular Communications Int. Nov. 5-7. Wembley Conf. Centre. O
Electronic Publishing Nov. 5-7. Wembley Conf. Centre. O
SINCE ITS introduction the BBC microcomputer has been widely accepted in education, industry and the home with over 400,000 units having been sold to date. This has given birth to a large quantity of software such as alternative languages to BBC BASIC, e.g. PASCAL, FORTH and LISP, and a wide range of utilities such as word processors, data bases, and machine code monitors. Much of the above mentioned software is only available in Read Only Memory (ROM) or Erasable Programmable Read Only Memory (EPROM). These are devices, programmed with the code for that particular utility, which retain their data when power is removed.

The BBC microcomputer is designed to support up to 16 of these ROMs, called “SIDEWAY (or PAGED) ROMs”, numbered 0 to 15, but has only room for 4 such devices on its printed circuit board. BASIC and Disc Filing System (DFS) being the two commonly fitted ROMs. In order to allow the full complement of 16 ROMs to be available to the user, an additional printed circuit board has to be fitted to the BBC microcomputer.

This article describes BYTEBOX, a system that fulfils this and other requirements.

DESIGN PHILOSOPHY

The experiences and views of several users in education and industry as well as those of home users were considered when the design of BYTEBOX was undertaken. The system was therefore designed to allow simple installation with no soldering being necessary.

A second view expressed was that of overheating. Some people had found that the inside of their BBC microcomputer became too hot when an internal ROM board was fitted, particularly if it was also powering a disc drive and/or other peripheral devices. This they said caused “funny things” to happen after the computer had been switched on for some time. Some had cured this by running the BBC microcomputer with its cover removed. However, they found this impractical as they then tended to drop screwdrivers, coffee and the like into the exposed circuitry, sometimes with disastrous results. With this in mind the design allows the system to be housed in an external box of similar finish to the BBC microcomputer.

Most users said that they would, at some time, if not immediately, require some Random Access Memory (RAM) in their system. Some people required 16K of RAM, whilst others only wanted 2K or 4K as they found it hard to justify the £70 or so required for two 6264s. Others said that they wanted battery backed RAM with write protect facilities. In order to provide all these requirements it was decided to provide 16K of optional RAM as standard, but also to provide additional plug-in units for greater versatility. Whatever RAM was to be used it was considered essential that this would be automatically selected whenever the SIDEWAY memory area was written to. In addition the fitting of RAM onto the main board should not require links to be altered and still allow 15 ROM/EPROMs to be supported.

EPROMS

It is well known that the BBC’s printed circuit board is designed for ROMs rather than EPROMs, with the result that some EPROMs from certain manufacturers will not function correctly. This is caused by incorrect, as far as EPROMs are concerned, termination of one of the ROM’s pins. This was to be rectified in the design so that any make of EPROM could be used.

The inclusion of a Zero Insertion Force (ZIF) socket was thought to be a very useful addition, especially by users who evaluate or frequently change ROMs, who are developing their own or have more than 16 utility ROMs. This socket, which was to be accessible from outside the unit, was therefore included in the design specification.

The 27128 type EPROMs are expensive and sometimes difficult to find. However, 2764s are easier to find and the cost of two such devices is less than that for one 27128. An option was therefore included to allow two 2764s to replace one 27128.

In order to fulfil the first requirement, i.e. easy to install, it was necessary to find a suitable way of extracting all the required data, address and control signals as well as power via a single socket. As with all computers and microprocessor based systems it is the Central Processing Unit (CPU) that generates these signals. In the BBC microcomputer a 6502 microprocessor is used (see Fig. 1). There is only one socket in the BBC microcomputer from which all this information is available, namely, the 6502 socket.
The decision was therefore made to design a system in which the 6502 microprocessor is removed from the BBC microcomputer and located in the external system. This system is then connected to the BBC microcomputer via a 40-way ribbon cable which is plugged into the socket left vacant by the 6502.

The additional circuitry necessary for the full complement of 16 ROM/EPROM/RAMs to be supported would impose unacceptable loading on the 6502 microprocessor’s outputs. Therefore one of the design objectives was to buffer all address, data, and control lines used by the system. All of these objectives have been achieved in the BYTEBOX system described in this article.

**SIDEWAY (or PAGED) ROM**

Before BYTEBOX can be discussed in detail it is necessary to understand the concept of sideway or paged ROMs as they are sometimes called. The reason that they are called sideway ROMs is due entirely to their physical location within the BBC, in that they are located on the side of the printed circuit board, hence "SIDEWAY".

The BBC microcomputer is an 8-bit (one Byte = 8 bits) machine with 16 address lines that enable it to directly access $2^{16}$ (65,536) bytes of memory. This is normally called 64K bytes as 1024 is referred to as 1K. However, it can be seen that as each ROM can contain 16K bytes (if 27128 type devices are used) and, as there can be 16 such ROMs in the system the total memory contained by the ROMs alone is 256K bytes. This is far in excess of the address range of 64K. In addition, the BBC microcomputer has a further 16K of Operating System (O.S.) ROM and 32K of System RAM, thereby making a grand total of 304K of memory. How can this be so when it can only access 64K bytes?

The memory map of the BBC microcomputer is shown in Fig. 2. It can be seen that all 16 SIDEWAY ROMs in fact occupy the same memory area between &8000 and &BFFF (Addresses are in Hex notation, a convention that will be used throughout the article and denoted by &). This is acceptable as only one ROM can be selected at any one time, thereby occupying the 16K bytes available. This can be likened to a book containing 16 pages, only one of which can be read at a time, hence the term PAGED ROMs.

In practice the BBC microcomputer may appear to use more than one ROM at a time, but what is in fact happening is that the Operating System is constantly switching between ROMs. For example, if one is running a program in BASIC (one ROM), it is possible to call a * command contained within another ROM; say *CIRCLE in a graphics generator ROM. In this case the Operating System will find the graphics ROM, execute the *CIRCLE command, and then return to the BASIC ROM. Whichever ROM is selected is called the “current ROM”. The method by which the current ROM number is decided is complex and outside the scope of this article, but is well detailed in books such as “The Advanced User’s Guide”.

ROMs and EPROMs have a pin designated "chip select" (CS) which, when taken to logic 1 disables the device. This in effect removes that device from the system and it no longer plays an active role. However, if this pin is now connected to logic 0 the device is enabled and can now take an active role in the system. The trick therefore of having 16 ROMs in the system is to only enable one at a time.

In the BBC microcomputer this is achieved by arranging for a hardware 4-bit latch, located at address &FE30, to contain the number of the currently selected ROM. Only the upper two bits are decoded thereby limiting the number of usable ROMs in the BBC microcomputer to four. BYTEBOX, however, uses all four bits of its latch which are subsequently decoded to provide 16 chip select lines. The circuit is designed such that only one of these 16 lines can be at logic ‘0’ at any one time, thereby preventing a number of ROMs trying to access the system at the same time.

**BYTEBOX**

BYTEBOX was designed as an external system, housed in its own case and taking its power from the host BBC microcomputer. The block diagram, Fig. 3, outlines the system design, with Fig. 4 showing the circuit in detail.
BUFFERS

The main printed circuit board forms the heart of the system and contains all the buffers and decoders required to support the 16 ROM/EPROMs.

As mentioned above, the design philosophy requires that the 6502 microprocessor, normally located inside the BBC microcomputer, is moved onto this board. The BBC microcomputer is connected to the Romboard, via a 40-way ribbon cable that is plugged into SK1. The 6502 (IC1) is connected in parallel with this, thereby allowing all the signal lines to pass to the BBC microcomputer as normal. However, the signals required by the Romboard are also fed to a number of buffers to prevent the additional circuitry loading the original system.

It can be seen in Fig. 1 that the 6502 microprocessor has an output called R/W on pin 34. This signal is used to inform the remaining circuit of the data flow direction. This signal is buffered by two inverters, IC5a and IC5b, which are part of a 74LS04. The 6502 microprocessor also produces a clock signal @1 on pin 3, the inverted form of which is required later. IC5c is used to provide this whilst also acting as a buffer.

The sixteen address lines, A0 to A15, are fed to IC2 and IC3, two 74LS244 non-inverting tri-state buffers. In this design there is no need for these devices to be tri-stated therefore their mode select inputs, pins 1 and 19, are connected to logic '0'. Address information only travels in one direction, out from the 6502 microprocessor, so no flow direction information needs to be supplied to these buffers.

This is not the case, however, with the data bus (D0 to D7). The microprocessor not only needs to write data to the remainder of the circuit, but must also be capable of reading data from the memory devices. Therefore the type of buffer required, has to be bi-directional, with the direction of data flow being selected by the 6502 microprocessor. IC9, a 74LS245, is employed to provide this facility. The R/W line from IC5a is fed to the data bus buffer's direction control input, pin 1, to allow it to transmit data in the correct direction.

The circuit requires two sets of address decoders, one to enable the current ROM latch and the other to enable the ROM/EPROM/RAMs. First consider the decoding for the current ROM latch. As mentioned above the BBC microcomputer stores the number of the current ROM at address &FE30. However, the latch can in fact be addressed by any value between &FE30 and &FE3F, i.e. 16 memory locations. Normal convention is to denote this range by &FD3X, where X can be any hex value.

ADDRESS DECODING

The BBC microcomputer generates a signal called ROMSEL covering this range, but as this is not available on the 6502 microprocessor socket it also has to be generated on the ROMBOARD. This is achieved by using two interconnected chips, IC4 a 74LS30 and IC6 a 74LS138. The decode circuit and the bit code for &FE3X are shown in Fig. 5. The only time that the output for the 74LS30 NAND gate can be logic '0' is when all its inputs are logic 1. For this reason its inputs are connected to A8 and A9 to A15, all of which are logic 1 when the address is &FE3X. IC6, a 74LS138, is a 3 line to 8 line decoder which also has two active low and one active high chip select inputs. Only when these chip select inputs are valid will the data on the A, B and C inputs be decoded. The output from the 74LS30, is inverted by IC5f and fed to one of the low chip select inputs of the 74LS138, the other low chip select input being connected to A8, and the high chip select input to A4. All these inputs are valid when the address is &FE3X. A7 and A6 are both logic 0 for &FE3X which when combined with the R/W signal and the other decode circuit inputs mentioned above, will produce a logic 0 on the Y0 output of the 74LS138, i.e. A, B and C will all be logic 0. But why use the R/W line? This is used to ensure that the current ROM latch is enabled only when it is written to. We have therefore reproduced the same ROMSEL signal as the BBC microcomputer.

In addition to the ROMSEL signal described above, the BBC microcomputer also generates an output enable signal OE. As with ROMSEL, OE is not available at the 6502 socket and therefore has
Fig. 4. Complete circuit diagram of the Bytebox system
to be generated onboard. Fig. 6 shows the circuit and bit pattern relating to this ROM/EPROM/RAM enable OE output. This has to be valid for the address range &8000 to &BFF as indicated by the BBC microcomputer’s memory map (see Fig. 2). This is achieved by a 74LS20, a four-input NAND gate. Like the 74LS30, this chip has to have all inputs at logic 1 to produce a logic 0 at its output.

Fig. 6 shows the bit pattern for the address range &8000 to &BFF. It can be seen that only A15 and A14 remain constant over the range, therefore only these two address lines need to be considered by the decoding circuit.

In the section on buffering it was stated that the 6502 generates a clock signal Ø1. This is also used by the decoding circuit to ensure that the ROM/EPROM/RAMs are accessed when the address and data lines are valid. In order to provide the 74LS20 with logic 1’s on all its inputs it is necessary to invert the A14 line by means of IC5c, part of a 74LS04. The fourth input to IC7 is unused and is therefore tied to logic 0 to ensure correct operation.

We now have the two decoded address signals that are essential to the remainder of the circuit.

**CURRENT ROM LATCH/DECODER**

As stated above the BBC microcomputer writes the current ROM number into a 4-bit latch at address &FE3X, the data being present on the lower four data lines, D0 to D3. These four data lines are therefore fed to IC10, a 4-bit latch type 74LS375, and the ROMSEL signal described above is fed to its enable inputs, pins 4 and 12. The data is written into the latch whenever ROMSEL is active, i.e. whenever the address is &FE3X during a write cycle.

The outputs from the latch contain the current ROM number in hex form. However, 16 separate chip select lines are necessary as each of the memory devices requires its own chip select line. IC8, a 4-line to 16-line decoder type 74LS154, is therefore incorporated in the circuit. This device has two enable inputs, pins 18 and 19, which have to be at logic 0 before the device will decode the input data. One of these inputs, pin 18, is connected directly to logic 0 whilst the other is connected to the R/W line. When the system tries to write to the sideways memory, this signal is at logic 1. This disables IC8 thereby turning all the ROM/EPROMs off, which prevents data bus conflicts which would otherwise produce faults.

However, if RAM is fitted in the system it is necessary to generate a chip select signal for ROM/EPROM/RAM position 15 during a write cycle, for it is here that RAM will be located. In addition, this chip select line must be automatically generated irrespective of the value stored in IC10, the current ROM latch. It is therefore evident that some additional circuitry is necessary. To this end IC11, a quad two-input NAND gate type 74LS00, is incorporated. The output enable OE signal is inverted by IC11a and gated with R/W line by IC11b to produce a signal, on pin 6, only when a SIDEWAY write cycle occurs. IC11c acts as an OR gate to combine the position 15 read select (from IC6 pin 17) and the write select (from IC11b pin 6) signals. Thus an active high chip select signal for memory read or write cycles is available for memory device 15. The memory devices require the chip select signal to be active low, the active high signal from IC11c pin 8 is therefore inverted by IC11d.

The three memory devices that can be used with the main printed circuit board are; the 27128 type (16K Byte ROM/EPROM), the 2764 type (8K Byte ROM/EPROM) and the 6264 (8K Bytes RAM).

It can be seen that they are extremely similar, this is by design rather than accident, as they conform to a JEDEC standard. They only differ in 3 of their 28 pins, i.e. pins 1, 26 and 27. Pin 1 is not used by RAM or ROM but is by EPROM.

The BBC microcomputer’s printed circuit board is designed to support ROM, consequently pin 1 is not connected. However, it is specified in EPROM data sheets that pin 1 must be connected to logic 1, if not spurious faults can occur. Some manufacturer’s EPROMs are more prone to giving errors, when used in the BBC

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**Fig. 5. Decoding for address &FE3X**

**Fig. 6. Bit pattern for the enable output (OE)**

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Practical Electronics October 1985
**COMPONENTS**

**MAIN BOARD**

**Semiconductors**
- IC1  6502*
- IC2  74LS244
- IC3  74LS244
- IC4  74LS30
- IC5  74LS04
- IC6  74LS138
- IC7  74LS20
- IC8  74LS154
- IC9  74LS245
- IC10 74LS375
- IC11 74LS00
- IC12–IC26  ROM/EPROM* (as required)
- IC27  ROM/EPROM or 6264*
- IC28  6264*

**Capacitors**
- C1–C20  100n disc ceramic (20 off)

**Miscellaneous**
- Printed circuit board; through link pins; i.c. sockets*; 40-way IDC d.i.l. connector (2 off); 40-way ribbon cable; case*; insulated pillars.
  * See text

**6116 RAM BOARD**

**Semiconductors**
- IC101–IC108  6116 (8 off)
- IC109  74LS138

**Capacitors**
- C101–C105  100n disc ceramic (5 off)

**Miscellaneous**
- Printed circuit board; i.c. sockets; 14-way plugs (2 off).

**BATTERY BACKED RAM BOARD**

**Semiconductors**
- TR1,TR2  BC109 (2 off)
- D201  OA47
- IC201–IC202  6264 (2 off)
- IC203  74LS00

**Capacitors**
- C201  10μf tantal.
- C202  100n disc ceramic

**Resistors**
- R201  1k5
- R202, R203, R207  10k (3 off)
- R204, R206  1k (2 off)
- R205  4k7

**Miscellaneous**
- P.c.b. mounted 3.6V battery; SW1 single pole p.c.b. mounted switch*; printed circuit board; 14-pin plugs (4 off); i.c. sockets.
  * See text

**2764 EPROM BOARD**

**Semiconductors**
- IC301–IC302  2764* (as required)
- IC303  74LS00

**Capacitors**
- C301–C302  100n disc ceramic (2 off)

**Miscellaneous**
- Printed circuit board; i.c. sockets; 14-way plugs (2 off).
  * See text

**ZERO INSERTION FORCE (ZIF) SOCKET ASSEMBLY**

- 28-pin Textool ZIF socket
- 28-way ribbon cable
- 28-way IDC d.i.l. connector*
- Printed circuit board
  * See text

**Constructor’s Note**
All components, including EPROMS, printed circuit boards, case, or complete kits as well as ready built units are available from: PERIPHERAL PROJECTS, 25 Braycourt Ave, Walton-on-Thames, Surrey KT12 2AZ.
Please send SAE for details.

**NEX T MONTH: P.c.b. designs, constructional details and installation. Also battery backed-up RAM and alternative memory boards.**
Jitters

Measured by investor confidence it was a long hot summer. The electronics industry lost its sparkle and this time round you couldn’t say it was just a result of the old stock exchange maxim “sell in May and go away”.

The collapse earlier in the year of Sinclair and Acorn started the rot. After all, these two enterprises had seen off a number of smaller competitors, had been profitable and looked sound enough until the PC market turned sour. Unhappily the investing public tends to equate highly publicised outfits in the consumer and entertainment sectors with the electronics industry as a whole. Rather like condemning the performance of a department store just because the toy fair had suffered a bad season.

Booms and busts are nothing new in the consumer market. The boom in video recorders in 1982 and 1983 had turned into a near slump by 1984 when deliveries to the trade fell by half. There is such a thing as saturation in any market and, when prices are falling, consumers hang back in the expectation of lower prices later on, or the novelty merely wears off.

The problems of the consumer sector of the industry were not confined to the comparative tiddlers. The giants with heavy consumer market business were also suffering. Philips in the UK had a record turnover, topping £1 billion for the first time, yet trading results showed heavy losses in 1984.

Then came warnings from chairmen of reduced profit expectations, not least from GEC and Racal. So electronic shares were marked down all round.

There were other factors which possibly contributed to a spasm of selling. Continued high interest rates, increasing wage costs, rising value of the pound, continued squabbling in the EEC, downturn in the US economy and uncertainty in oil pricing.

The mood of dejection persisted even when companies turned in good results. Cable & Wireless profits rose 29 percent from £190 million to £245 million but the share price was clipped by 20p. Ferranti profits were up 19 percent at £46 million and their shares dropped. Investment sentiment was decidedly nervous and made more so by gloomy news from Thorn EMI and STC.

It is exactly a year since I recorded on this page the purchase for £95 million by Thorn EMI of the Government holding in Inmos. My comment was that the Government was pleased to pass on a responsibility no longer welcome and to recover the taxpayers’ investment. Last July Inmos announced redundancies both in the UK and USA. Also a year ago I was writing of STC’s expansion plans which included the creation in STC of 3,000 new jobs. Alas, a year is a long time in the electronics industry.

Work Patterns

Scotland’s Silicon Glen is a perfect example of a shifting pattern of employment in the industry. The workforce over a period of six years from 1978 to 1984 declined from 36,800 to 36,650 while output doubled and redoubled. As a proportion of the whole the unskilled operators employed fell in this period by 18 percent while scientists and technologists increased by 94 percent and technicians by 26 percent. Even the number of craftsmen declined by 9 percent.

Although electronics may be regarded as a special case this is not entirely so. According to John Cassels, director general of the National Economic Development Office, the pattern is generally the same throughout industry. In short, the unqualified will have little hope of employment.

The trend is confirmed by the scramble by progressive companies for new graduate intake with employment prospects firmer than for many years. One report claimed that 20 percent of vacancies for graduates were unfilled with the highest proportion in industry.

Another shift, this time at workbench level, is the no-strike, single-union workforce pioneered by the EETPU now under the able leadership of Eric Hammond. Universally hated by left-wing militants, he expects to double the number of no-strike deals by the end of the year.

His present membership is 365,000 but if a projected merger with the engineering workers and with the white-collar ASTMS can be agreed, then the new grouping would be 1.7 million strong. This could provide a powerful influence on the whole of the labour movement in its attitude to wealth creation and consequent security and prosperity for workers.

Even if no merger took place the electronics’ example would remain that there are more sensible ways of conducting negotiations than walking out on the job which, in effect, is merely soiling one’s own nest.

Pressing On

Despite difficulties in some sectors the electronics industry remains in good shape with plenty of major contracts being signed. The size of some of the orders brings the state of the industry into proper perspective.

Ten years ago the annual turnover of the Racial Electronics Group was just short of £80 million. In one three-month period up to mid-summer this year, Racial-Tacticom received orders for tactical radio equipment to the value of £81 million, and this for a single product line.

Marconi Radar in a £38 million deal is supplying an extension and update to the Sultanate of Oman’s integrated air defence system. This is an enhancement of air defence capability with which Marconi was involved in 1976 and 1979.

Then there is a nice contract worth 150 million dollars to a consortium headed by British Aerospace. This is for a new generation of Inmarsat communications satellites. Almost without our noticing it ships-to-shore communications by satellite has had a healthy growth rate with 43 member states now participating. The first of the second generation Inmarsat will be ready for launch in 1988, as yet, it has not been decided whether the Space Shuttle or Ariane will be the launch vehicle.

Of course not all recent contracts are in the multi-million pound or dollar bracket but there are plenty of £1 million and upwards.

Electronics research is also healthy despite the chronic shortage of engineers. GEC has just drawn together into a single research company the three great but separate strands of the Marconi Research Centre at Great Baddow, the Hirst Research Centre at Wembley and the Engineering Research Centre at two locations in the Midlands. All the research effort will now be coordinated more efficiently in the new company, GEC Research Ltd.

The total complement of GEC Research is currently 2,500 people of whom 1,300 are scientists and engineers with first or higher degrees. Over 10 percent of the professionally qualified staff are women. Income of the company is some £60 million per annum, roughly one tenth of the total R & D spend within GEC.

There is good news for those who grouse about the Japanese who use the UK only as production units within the EEC. Matsushita, better known by the brand name Panasonic, is to set up R & D labs in the UK headed by an as yet unnamed British scientist.
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Confused

Sir—May I make a couple of suggestions for articles in your magazine Practical Electronics. The ideas spring from an excellent series of articles by Tom Gaskell, namely Digital Design Techniques which started in August 1981. Paragraph three in the introduction to the series says it all.

From a more theoretical understanding of digital electronics I am now able to design with confidence using the series as a "bible". Without this series I would neither have had the time, money and in some cases knowledge to sift through manufacturers data sheets to extract the relevant information.

Suggestion one—I am rather confused by all the new logic families, so how about an up-date article giving relevant practical information set out in the same easily understood way of Tom's earlier article?

Suggestion two—As my designs get more sophisticated and use more i.c.s (my latest design for a burglar alarm so far contains 15 transistors) the question of can I use a microprocessor instead raises its head. The answer must be yes, but where do I start? What are the practical hardware considerations to be taken into account, which is the best microprocessor to concentrate on, what about software—does it practical to use it to create large time delays, how about connecting a small key pad etc. etc.? I do not possess a microcomputer nor do I really want to, or learn a language. I understand '1's and '0's, i.e. machine code. Perhaps the first practical project for the series would be a "programmer" for entering the '1's and '0's in the ROMS.

I have a theoretical understanding of microprocessors but lack the practical knowledge (refer again to paragraph three in Tom's series).

I hope you will be able to use my suggestion.

Brian McWhinnie,
Glasgow.

Points taken—see Introduction to Microprocessor Systems (page 20). How about that for service?

Twenty Years of Stagnation

Sir—I welcome your editorial (July issue) on what appears to be the lack of development of "electronics" as a subject available within the curriculum of our secondary schools.

I speak as a mathematics/physics/electronics teacher with 25 years teaching experience in Scotland and England and also on the continent and in Africa. Perhaps I am most concerned with what is happening, or rather not happening, here in Scotland, although I should say that I have an enlightened headmaster, himself a physicist, who was prepared to stick his neck out and introduce the A.E.B. 'O' level Electronics course in this school. Scotland, however, has a national policy, recently stated by the Scottish Education Department, NOT to introduce electronics as a separate subject, although Scotland is reputedly host to some 40 per cent of the European electronics industry.

It is very difficult to pin-point the reasons for this apparent apathy, or in some instances, outright opposition. I see some of them as follows:

(i) Electronics and microelectronics are somehow seen as synonymous with computing and microcomputing.
(ii) The government, in its wisdom, has seen fit to deluge schools, including primary, with computers. We now have perhaps more computers per capita in schools than any other country in the world—however, it is a known fact that the vast majority of these are underused or misused with the result that the average pupil's concept of the computer and its applications extends to being able to load a program from a tape or disc and spend countless hours playing 'Space Invaders' and similar mindless games, whilst the government and the majority of teachers think they are being exposed to 'electronics'—99 per cent will never see a transistor or a silicon chip!
(iii) These computers were largely introduced to mathematics departments where teachers rapidly became fluent in the new vocabulary without in most cases (not all, of course) having the faintest idea of how a computer works or the practical applications to which it can be put. "Interfacing" to them means plugging in another bit of hardware and producing another bit of "magic". Teachers with applied science or engineering backgrounds were probably the last to be equipped with a computer—some are still waiting!!
(iv) Teacher training in this field (electronics) is grossly inadequate, probably because the trainers themselves don't have the skills. Regional education authorities no longer provide suitable in-service training or indeed refuse to allow teachers to attend such courses, even during their holidays, except at their own expense.

I myself was refused the funding to attend an excellent national course on interfacing, I was instead expected to become fully proficient, along with less experienced colleagues, in the art of interfacing by attending a 3-day "crash" course organised by my employees. When I tried to inquire into this policy, I was told that if I became better qualified I might leave and another regional authority would benefit.

(v) There is a very pronounced "no man's land" between the frontiers of pure physics and pure engineering in schools, and it takes a bold man to attempt to cross onto his neighbour's ground. Indeed, in many schools, teachers from either department are barely on speaking terms.

Again, I am fortunate in this respect. A few schools have successfully implemented courses in Technology where the fields of physics and engineering overlap.

(vi) Change in education in Britain is incredibly slow. Ten years is not uncommon—I was piloting a 16+ combined physics course in England in 1974—where are we now? We have thousands of working parties, consultative committees, pilot schemes etc. whereas with a little goodwill, common sense and adequate finance, even major changes could be introduced in a matter of months.

The teachers on the whole are willing. It is their masters, the bureaucrats, who no longer ever see a pupil or indeed who may never have seen one, who are responsible for the chaos in education today.

Opinions of practising teachers are sought, in the guise of "consultation", but it seems to me that these professional opinions are then all too often ignored. The end result is that unwanted changes are then introduced, resulting in a disgruntled, disillusioned and demoralised teaching profession.

A Clear Distinction

To conclude, I think it is high time that some or all of the following steps be taken to avoid the present chaos in education and to ensure that today's youngsters leave school prepared for the new technology without which this country will continue its head-long decline:

(1) A clear distinction must be made between "microelectronics" and "microcomputing".
(2) The government must ensure that adequate provision is made in the
school curriculum for microelectronics either as a separate subject or as part of physics or technology courses. In particular, more care must be taken to ensure that course choices are realistic so that pupils are not for example forced to make the choice between electronics and several other traditionally girls' subjects such as domestic science or secretarial studies.

(3) Resources must be made available, particularly when the expertise is at hand. It is pointless putting vast numbers of microcomputers in schools where there is no expertise and even less motivation.

(4) Teachers must be given the opportunity to re-train by attending in-service courses run by experienced, and preferably practising, teachers.

(5) Teacher-training courses in colleges must be up-dated so that at least some of the new entrants to teaching have some awareness of electronics. Far too many of the older generation of pure physics teachers are either 'afraid' of electronics or downright opposed to becoming involved.

(6) Finally, teachers' pay must be improved in order to attract suitable entrants. My 24 year old son, a graduate electronics engineer, has a far higher income than mine.

Andre H. G. Saunders, B.Sc.,
Kelso High School,
Roxburghshire.

Don't Bank on IT

Sirs—As a member of a band of home computer constructors, which has a good newsletter, lots of software, including two BASICS and FORTH. I took the trouble to write to five top chip manufacturers asking for details and data sheets on various i.c.s. for instance, interfacing, real time clock, D/A's, etc.

The idea was to build up a "Data Bank" so members could get the information that they need to use that special chip. It may have even appeared as a newsletter article describing its function and use.

However, things went wrong as only one manufacturer bothered to reply; this was Ferranti, who supplied a good deal of useful information. In fact, I wrote again and they sent details of the ZN447-9 ADC's and the ZN105E programmable timer (0-01 sec to 3 months) MPU bus compatible, to name but two—Well done, Ferranti!

To those who, like Motorola, Nat Semi, G.I., etc., who found it all too much trouble. I say shame on you; we the public are the ones who buy your products, you should keep us informed—it can only help your sales!

Lastly, to anyone out there in the manufacturing or retail business; like to send us data sheets or details? They would be most welcome!

Mel Saunders,
7 Brunswick Road,
Thurmby Lodge,
Leicester LE5 2LH.

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UK101 cassette, 24K, basic 5, codekit, toolkit, Cemphon, J1 board, ROM-board, 8120 ZX81 £10. ASC11 keyboards £3 each. A. Pearson, Gilmore, Wythes Lane, Fishtoft, Boston, Lincs. Tel: 0205 65309.

Please publish the following small ad. FREE in the next issue.

Name & Address:...
The microprocessor began its life labelled by many as a solution in search of a problem. Since the early seventies, however, microprocessor systems have developed at a quite breathtaking pace. Indeed, hardly a day now passes without an announcement of some new way in which the microprocessor will revolutionise an aspect of our everyday lives. One consequence of this change is that there is now quite widespread awareness of the fact that microprocessors can do many things better, faster and/or cheaper than ever before. However, for most people a considerable mystery still surrounds the question: "What is a microprocessor and how does it work?"

Introduction to Micro Systems is a new PE series aimed at providing readers with a basic understanding of the concepts involved in using microprocessors. Examples of applications will be used wherever possible to make the series as relevant and meaningful as possible. The examples used will, as far as possible, be taken from the type of control applications encountered in everyday life.

At this point, we should explain that the term "micro" will be used in the series to mean microprocessor, not to be confused with a small/home computer based on a microprocessor (which we will think of as a microcomputer).

To cover the subject of micros in full detail would probably involve using all of the available pages in PE from now until some time in the next century. This is clearly not very realistic for an introductory series. Fortunately it is not necessary in order to give a basic appreciation of the fundamental concepts. Then, once the basics have been grasped, it should be possible to make use of the mind-boggling variety of books available on individual micros and micro techniques to answer detailed or specialist queries. This series is thus by way of an introduction to the subject of micros, and we will start by looking at a few of the basic concepts.

**Basic Concepts**

There are a number of basic ideas and techniques which inevitably come up sooner or later in any discussion of micros. Two which are fundamental to this series are digital logic and binary number systems. Regular readers will know that the former topic has been dealt with at some length in two previous PE series: Introduction to Digital Electronics and Sequential Logic Techniques.

For the benefit of new readers of PE, however, we will also be giving suggestions for suitable background reading as the series progresses. Before we start, however, it seems appropriate to briefly review some of these basic terms and concepts from the viewpoint of their use in this series.

Micros and micro systems are designed around electronic circuit blocks which operate on signals which can be in one of two stable states. These binary states are usually represented by two different voltage levels, and the circuits which manipulate them are referred to as logic gates.

In this series we shall be using positive logic notation, where the level closest to 0 volts is referred to as a logic 0, and the level furthest from 0 volts (usually close to the +5 volt supply level) is referred to as a logic 1. These logic levels are often referred to as simply 0 and 1, respectively. A typical range of voltage levels for these logic levels is shown in Fig. 1.

![Fig. 1. Standard logic levels](image)

Micro applications are frequently involved in counting or representing more than just two possible values or options, e.g. the temperature of a room may take a value from 0 to 30°C. It is clearly undesirable to have a different logic signal to represent each of the possible temperature values; in the example this would need 31 such signals.

Instead, the normal way of using the binary states of digital logic to represent a larger range of values involves the binary system of numbers. This provides a method of effectively coding a number of signals to represent a much larger number of combinations, and relies on the principle of binary numbers.

In the decimal number system, each digit can take one of ten different values (from 0 to 9). Each digit represents units of 1, 10, 100, 1000, etc, i.e. increasing in powers of 10. Thus, for example, the decimal number 325 is 3 x 100 + 2 x 10 + 5 x 1. In the binary number system, however, each digit can only take the values of 0 and 1. Each binary digit is known as a bit (a contraction of binary digit), and the increasing bits in a binary number have values which go up in powers of 2. The decimal equivalent of the digits in a binary number are therefore, 1, 2, 4, 8, 16, 32, 64, etc. Thus, for example, the binary number 10101 has the decimal equivalent of: (1 x 16) + (1 x 4) + (1 x 1) = 21.

Using the binary system, therefore, a small number of logic signals can be used to represent a large number of different values, and in our temperature example, 5 bits (one signal for each) are enough to represent the temperature range. In fact, 5 bits would be enough to allow us to represent a temperature range of 0 to 31°C.

**The Hex System**

One problem with the binary system is that numbers can be cumbersome to write down, particularly for large values. Even worse, they are almost impossible to remember when they have a large number of bits; for example, 16 bits would be required for a decimal number of up to 65535. The hexadecimal system (i.e.
numbers in base 16), is therefore frequently used as a convenient and useful shorthand instead of binary.

A hex digit represents exactly four bits, and increasing hex digits count in units of 1, 16, 256, etc. To allow each digit to be expressed in only one character, the hex system uses the numeric characters 0 to 9 and A to F to represent the decimal values 0 to 15. The correspondence between decimal, binary and hex digits is shown in Table 1.

Table 1: Digit values

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Hexadecimal</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0000</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0001</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0010</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0011</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>0100</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>0101</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>0110</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>0111</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>1000</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>1001</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>1010</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>1011</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>1100</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>1101</td>
</tr>
<tr>
<td>E</td>
<td>E</td>
<td>1110</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>1111</td>
</tr>
</tbody>
</table>

As an example of the advantage of hex, the decimal number 61680 has a binary equivalent of 1111000011100000, whereas in hex the equivalent is F0F0. Binary numbers in micros usually have a number of bits which is a multiple of four, typically 8, 16, 32 or even 64; eight bits is usually known as a byte.

LOGIC GATES

As has been mentioned, a logic gate is an electronic circuit whose input(s) and output(s) are all logic levels. The way in which the input and output signals are related depends on the logic function of the gate—a typical logic function (an AND gate) is shown in Fig. 2.

These gates are usually found in convenient groups in single integrated circuits, often referred to as "chips". The number of logic functions which can be put inside a single chip has risen steadily as technology has advanced, and the micro represents one of the most complex examples of this trend. Modern micros have the equivalent of many thousands of individual gates inside a single chip.

Digital systems are concerned with the processing of logic signals, and one of the most important elements in a digital system is the memory cell. Each cell is usually in the form of a "flip-flop", which is able to remember (or "store") the value of a single logic level (i.e. 1 or 0), even after the original signal has disappeared. There are many different types of flip-flop, depending chiefly on the way in which the storage action is to be triggered. However, the same basic storage principle applies to them all. The internal circuit for a typical MOS technology memory cell is shown in Fig. 3.

Groups of 8, 16, or 32 memory cells are often found inside micros. They are usually arranged so that all the cells in the group are loaded or cleared in the same operation. These memory cell groups are usually referred to as registers. When used in a register, all of the memory cells are usually loaded and cleared at the same time. Hence registers are used a great deal within a micro for storing binary numbers.

A CHOICE OF MICROs

Now that we have covered the basics for the series, it is time to start looking at some actual micro systems. As we have said, this is a series aimed at practical aspects of micros, and as such it is important that the examples are based as far as possible on real micros. The problem otherwise is that it can be difficult to translate the theory into practice. However, this raises the inevitable question: "Which Micro?" to use in the series.

The difficulty with this question is that there is no single answer which will satisfy the needs and preferences of everyone. Inevitably, different micros are often used in similar applications. At the other extreme, in many cases we may need to add to an existing system, where the choice of micro has already been made. Instead of settling on a single micro for the whole series, therefore, we will instead be using a number as the series progresses.

We are starting with the Motorola 6800 micro, which although no longer quite in the "state-of-the-art" category, still has many points in its favour. Its clean and simple architecture is readily understood, and the micro is widely available with its range of support chips at low cost, e.g. the basic micro is now available for around £2 from a number of advertisers in PE. Once the principles have been grasped by studying the 6800, it is then a much easier step to move on to the later generations of micros. The other micros we shall be looking at will include the Z80, 6809 and 6502, all of which are used in home computers.

It is fashionable in certain circles to consider that 16-bit processors like the 68000 are the micros of today, and that nothing else is worthy of consideration. However, at around £30 for just the basic chip, these devices are still beyond the reach of the hobbyist;
Even worse, they have often been the subject of early promises from imaginative manufacturers, who haven't even got samples available yet!

For around £10, on the other hand, it is possible to buy the chips off-the-shelf to build a complete 6800-based micro system. It is also true that many of the "simpler" micros are still better suited to the type of control applications found in everyday life than some of their more prestigious and sophisticated successors. It's not so much that the 16-bit machines wouldn't work in these applications, it's more a matter of their being a sledgehammer to crack a nut. After all, you would not consider using a Formula 1 racing engine to power a lawnmower. As the saying of the sage has it, a good designer is someone who can do for £10 what any fool can do for £100; a good point to bear in mind when reading of the attractions of the new wonder chips.

**MICRO SYSTEMS**

The internal organisation of a basic general purpose micro system is shown in Fig. 4 as a simplified circuit block schematic. An alternative way of representing this type of system, shown in Fig. 5, can be used to illustrate the typical information flow in a control application; the micro effectively forms the information switching centre of the system. We will be looking at each of the blocks in these schematics in greater detail as the series progresses, but for the moment a brief summary of each will be enough to get us started.

![Figure 4: Micro system block schematic](image)

**Fig. 4. Micro system block schematic**

![Figure 5: Block diagram showing information flow](image)

**Fig. 5. Block diagram showing information flow**

A micro-based system almost inevitably now consists of a number of interconnected integrated circuits. Fig. 4 shows these as including a central processing unit (CPU), memory for storing instructions and data, and some input/output (I/O) capability. These basic units are connected together by a series of buses which carry binary number values and control signals. The actual width of each bus (i.e. the number of bits used to represent a value) depends on the chip family (group of related chips) used to build the system, but typical values are 8, 16, 24 or 32 bits. The control signals are used to coordinate and control the correct operation of the system, and usually include various timing signals.

The CPU is the heart of the system. Its role is to execute arithmetic and logical functions in accordance with the program of instructions stored in the memory. In passing, it is worth noting the use of the short form spelling "program" as the accepted practice in the micro field.

The memory is an array of one-bit memory cells, which are usually arranged in groups of eight bits (bytes). In some micro systems these groups can be 16 bits (words) or even 32 bits (double-words), but internally they usually remain organised as bytes. This organisation means that each byte can store values ranging from 00000000 (decimal 0, hex 00) up to 11111111 (decimal 255, hex FF). Each byte is accessed by means of its location (its address) in the array, although only one byte can be addressed at a time. This memory organisation is illustrated diagrammatically in Fig. 6.

Memory comes in two main types: read/write and read-only. The first type is known as random access memory (RAM), and is used to store, temporarily, data which is subject to change during the running of the program. In some systems, where more than one program may be loaded from an external store (e.g. programs loaded from a floppy disc into a microcomputer), the program is also stored in RAM. However, this is not common in control applications.

The second type of memory is read-only memory (ROM), which is used to store fixed data and programs. The contents of the ROM must be "blown" during the development or manufacture of the system, and they cannot easily be changed thereafter. This permanent storage system means that the program is saved even when the power is switched off, and is immediately available at switch-on.

---

Fig. 6. Schematic diagram showing the organisation of semiconductor memory as a matrix of cells. Each address identifies a byte of data.
It must be stressed at this early stage that there is nothing physically stored in the memory which distinguishes program bytes from data bytes. It is only a matter of how the system is organised that determines how a byte is used, and it is not at all uncommon for the two to get confused during debugging; the results can be bewildering.

The system is here shown interfacing to external hardware, usually known as peripheral hardware. This hardware can take many forms, from the keyboard and display on the now-familiar home computer, to all sorts of control valves and switches, as might be found in a central heating system. The important point is that in a system of this type, the I/O forms the link between the micro and the real world. Without it, the micro would be confined to talking to itself. As you might guess, therefore, the range and ease of use of the I/O has a significant effect on the usefulness of any micro system.

Now that we have identified the major building blocks of a micro system, we can go on to look at each of them in a slightly more detailed way. Whenever we look at a new system, it is always a good idea to start by trying to identify the basic blocks just described. This then gives us a good start in the process of working out the system's basic structure. Once this structure has been established, it is then much easier to fill in the detail, already knowing how the major parts fit together.

A BASIC MICRO SYSTEM

A more detailed version of the type of system outlined in Fig. 4 is shown in Fig. 7. This system is based on the Motorola 6800 family, and represents a basic system of the type that might be found in, say, a home security system. As we go on to look inside the individual system elements in detail, it is useful to compare this schematic with the earlier one. This will provide a useful background against which to consider the workings of the individual components; the problem otherwise is that you can end up looking at the details of all of the parts of the system before you get any idea of how it works at all.

The sequence we are going to follow is typical of the order in which one might analyse a newly encountered system in order to work out how it is organised.

THE CHIP SET

The first step in analysing any micro system is a simple one, and it is to identify the micro family being used. This is usually found by looking at the larger chips' part numbers. Ignoring an alphabetic prefix (which is the manufacturer's identity code), the first two digits, and the number of digits in the part code usually give the best idea of the micro family, e.g. 68xx chips are from the 6800 family, 99xx are from the 9900 series. Once this is known, the appropriate manufacturer's data sheets can be consulted for further details. Table 2 gives examples of CPUs and typical peripheral chips from popular micro families.

### Table 2: Micro Chip Sets

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>CPU Device</th>
<th>Peripheral Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorola</td>
<td>6800</td>
<td>6821 (PIA), 6850 (ACIA)</td>
</tr>
<tr>
<td>Zilog</td>
<td>Z80</td>
<td>Z80-P10, Z80-S10, Z80-CTC</td>
</tr>
<tr>
<td>MOS Tech</td>
<td>6802</td>
<td>(6522 (VIA), 6551 (ACIA))</td>
</tr>
<tr>
<td>Intel</td>
<td>8080</td>
<td>8253 (FIT), 8251 (USART)</td>
</tr>
<tr>
<td>Motorola</td>
<td>6809</td>
<td>Same as 6800</td>
</tr>
<tr>
<td>Intel</td>
<td>8085</td>
<td>Same as 8080</td>
</tr>
<tr>
<td>TI</td>
<td>9900</td>
<td>9901 (PP6), 9902 (ACC)</td>
</tr>
</tbody>
</table>

As mentioned, the system in Fig. 7 is built around chips from the 6800 micro family. The CPU is the 6800 itself, and in the following discussion this should be viewed as the heart of the system. The memory shown in two parts, one part is RAM (the 6810) and the other is ROM (the 6830). The I/O interfaces are provided by the 6821 Peripheral Interface Adapter and the 6850 Asynchronous Communication Interface Adapter. The remaining elements of the system are the clock and the start-up circuits.

ADDRESSING

The CPU addresses the system devices (ROM, RAM, PIA and ACIA) via the address bus. The bus used by the 6800 is 16 bits wide, and is thus capable of addressing 65536 unique memory locations (hex: 0000 to FFFF). The individual lines are labelled from the least significant (A0) up to the most significant (A15) to indicate their binary significance, i.e. 2^0 to 2^15, respectively. Thus, for an address of F000, address lines A0-A11 are all set to logic 0, while lines A12-A15 are all at logic 1.

The address bus is a unidirectional bus which carries a 16-bit address value generated by the CPU to the remainder of the system. The devices on the bus are arranged so that only one responds to a particular address. To simplify the problem of a device recognising when it is being addressed by the CPU, individual devices are usually allocated blocks of consecutive addresses.

During the design or analysis of a micro system it is usual to draw out the allocation of addresses on what is usually called an address map. These maps show the whole addressing range of the micro, with address 0000 at the bottom and FFFF at the top for a micro with a 16-bit address bus. Blocks of addresses are then marked in to show how they are used, making it easy to identify any gaps or overlaps. Fig. 8, for example, is the address map for the system in Fig. 7. Although a very simple idea, an address map is an extremely useful tool in micro system design.

In smaller systems, the allocation of addresses to system units is usually arranged so that it is easy to detect which device is being addressed. For example, if addresses from 8000 (hex) upwards are...
allocated to the program memory, the most significant address bit (A15) can be used to select the ROM area, without looking at any other address lines. This helps to explain why not all of the parts of the system are connected to the whole width of the address bus in Fig. 7.

Indeed, by careful allocation of addresses, it is possible to avoid the need for special (address decoding) logic circuits in small systems. In larger systems, however, address decoding logic is invariably required because there are not enough address lines spare to allow this simple approach to be used.

DATA BUS

Once the CPU has addressed one of the system devices via the address bus, it needs a means of transferring data to or from that device. This is provided by means of the bidirectional data bus. In general, it is the width of this data bus which is used to categorise micros. In 6800 systems the data bus is 8 bits wide, and the 6800 is therefore referred to as an 8-bit micro; other examples include the 8080, 8085, Z80, 6809, and the 6502. The Z8000, 8086, and 68000, on the other hand, are examples of 16-bit micros. There is even a chip which has only a 1-bit data bus. The 8-bit data bus in the 6800 system thus allows one byte to be transferred at a time to/from the CPU.

MEMORY

The memory in this simple system is composed of one block of ROM and one block of RAM. Looking at the ROM first, this is a 6830 device, which has a capacity of 8192 memory cells, arranged as an array of 1024 bytes. In addition to the memory elements, the chip also includes a number of enable inputs to simplify address decoding. The configuration shown is arranged so that the ROM is mapped into addresses C000 to C3FF; address lines A14 and A15 are used to select the ROM.

The RAM block is provided by a 6810, which is an array of 1024 memory cells arranged as 128 bytes. The on-chip decoding is a little different from that in the ROM, but the result is the same. The RAM is mapped into addresses 0000 to 007F.

INPUT/OUTPUT DEVICES

The I/O devices in the system are connected directly to both the address bus and the data bus, and operate under program control. Each of them is controlled by a series of internal registers which appear as memory locations as far as the CPU is concerned.

![Home computer](image)

A home computer (above) is an example of a microprocessor system. The machine shown is based on a standard 8-bit micro.

The various registers allow data to be transferred and control to be exercised over the interface. The six registers in the 6821 share addresses 4004-4007, while the four registers of the 6850 share addresses 4008-4009.

The 6821 Peripheral Interface Adapter (PIA) provides the system with a parallel connection to the outside world. The 6821 is a programmable device which gives the user the ability to set it up from a program to suit the particular application. This allows the 16 I/O lines to be used in whatever manner is appropriate to the application, e.g. one can be used for turning on a lamp (i.e. an output), while another may be used for detecting the tripping of a switch (i.e. an input). In addition, there are four control lines provided to allow the micro and the outside world to be synchronised.

The 6850 Asynchronous Communications Interface Adapter (ACIA) is the serial I/O equivalent of the 6821. This allows data to be converted from parallel form (as held in the memory and transferred on the data bus) into serial form as required in such applications as modems.

CONTROL SIGNALS

The final set of signals which pass around the system are for timing and control purposes. For example, because the data bus is bidirectional, an address in the RAM area could either mean that there is data on the bus to be written to that location, or that the data already in the location should be put onto the data bus. One of the signals (R/W), therefore, indicates whether the current address and data values refer to a read or a write operation.

Other signals on the control bus (which is not a bus in the true sense of the word) include signals to provide timing, reset the system, etc. It is also worth noting that in some cases, control signals may originate from outside the system shown in Fig. 7—for example, interrupt requests and I/O "handshake" signals. However, we will be looking much more closely at these control signals when we study the 6800 CPU in detail next month.

NEXT MONTH: Having established some of the basic principles of micro systems, we move on to look in detail at the workings of the 6800.
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PREAMPLIFIER MODULES

All modules are supplied with in line connectors but require potentiometers, switches etc. If used with our power amps they are powered from the appropriate Power Supply.

<table>
<thead>
<tr>
<th>Type</th>
<th>Application</th>
<th>Functions</th>
<th>Price</th>
</tr>
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<tbody>
<tr>
<td>HY6</td>
<td>Mono PreAmp</td>
<td>Full HiFi facilities</td>
<td>£8.45</td>
</tr>
<tr>
<td>HY66</td>
<td>Stereo Pre-Amp</td>
<td>Full HiFi facilities</td>
<td>£11.95</td>
</tr>
<tr>
<td>HY73</td>
<td>Guitar Pre-Amp</td>
<td>Two Guitars plus Microphone</td>
<td>£12.45</td>
</tr>
<tr>
<td>HY78</td>
<td>Stereo Pre-Amp</td>
<td>As HY66 less tone controls</td>
<td>£10.95</td>
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<tr>
<td>HY79</td>
<td>HY78 Guitar Pre-Amp</td>
<td>Special Effects Pre-Amp as HY73</td>
<td>£18.95</td>
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</tbody>
</table>

MOUNTING BOARDS: For base of construction we recommend the B6 for HY6. B66 for HY66-78 £1.45

MOSFET MODULES

Ideal for Disco’s, public address and applications with complex loads (line transformers etc.) Integral Heatsink

<table>
<thead>
<tr>
<th>Type</th>
<th>Output Power</th>
<th>Load Impedance</th>
<th>Price</th>
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<tr>
<td>MOS128</td>
<td>60</td>
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<td>£34.45</td>
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<tr>
<td>MOS248</td>
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<tr>
<td>MOS364</td>
<td>180</td>
<td>4</td>
<td>£64.45</td>
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BIPOLAR MODULES

Ideal for Hi Fi, Full load protection

<table>
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<th>Type</th>
<th>Output Power</th>
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<tr>
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<tr>
<td>HY60</td>
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<tr>
<td>HY6060</td>
<td>30+30</td>
<td>4</td>
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</tr>
<tr>
<td>HY124</td>
<td>60</td>
<td>If</td>
<td>£17.45</td>
</tr>
<tr>
<td>HY128</td>
<td>60</td>
<td>8</td>
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<tr>
<td>HY244</td>
<td>120</td>
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<tr>
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Distortion less than 0.01%

POWER SUPPLY UNIT

<table>
<thead>
<tr>
<th>Type</th>
<th>For Use With</th>
<th>Price</th>
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<tbody>
<tr>
<td>PSU050</td>
<td>PRE AMP</td>
<td>£6.45</td>
</tr>
<tr>
<td>PSU012</td>
<td>1 or 2 HY30</td>
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<tr>
<td>PSU022</td>
<td>1 HY124</td>
<td>£20.45</td>
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<td>PSU032</td>
<td>1 MOS128</td>
<td>£21.45</td>
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<td>PSU084</td>
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</tr>
<tr>
<td>PSU084</td>
<td>1 MOS364</td>
<td>£26.45</td>
</tr>
</tbody>
</table>

All the above are for 240v operation.

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Practical Electronics October 1985
A Cleveland GP won the first Robat contest held as part of the European Personal Robotics Conference in London in July. Although the device of Dr John Marr failed in the aim of playing a game of robot table tennis it had potential according to the organiser, John Billingsley, and won Dr Marr a trip to San Francisco in September to take part in the U.S. finals of the competition.

...resembled an anglepoise lamp which used a chip vision system...

Known as Zillian, Dr Marr's device resembled an anglepoise lamp which used a chip vision system similar to the Snap system. The bat managed to make contact with the ball and made a hitting movement but was not able to control the direction the ball took after that. The bat also required some assistance in locating the ball by use of a joystick.

To help with his expenses in getting to the States, Dr Marr received £500 donated by Joe Bosworth, the founder of RB Robot.

In second place came John Knight and David Lowery of Fareham, Sussex, with Kung Fu, which combined a vision system of which Bard would have been proud and the combined power of a Dragon and Accorn Atom. Movement was provided by a spring, the bat being halted by a magnetic clutch.

Knight and Lowery represented Britain in the European finals in Brussels in August with the help of £100 from the Institute of Mechanical Engineers.

There were two other entries which lacked the precision of the others but contained the same amount of enthusiasm for the idea.

This was the first public showing of the devices, development of which began soon after the contest was announced by Billingsley at the beginning of last year. An earlier workshop was held to assess progress and swap ideas.

The competition has attracted a lot of interest from throughout the world but to date working devices are thin on the ground. Billingsley said that ATT in the States had been working on the idea but with the help of a Puma and Vax which he thought was overdoing it a little.

...Robat was already ahead of the Micromouse...

He added that the signs for the future were encouraging. Robat was already ahead of the Micromouse contest, which he also organised, at the same stage.

His major problem is now finding a venue for future contests. Anyone organising an exhibition in May or June next year, who would like to offer space for the Robat and Micromouse contests should contact Billingsley at Portsmouth Polytechnic.

Four new robots arms were unveiled at the Education, Training and Development Exhibition held at the NEC in the summer.

The most unusual was the HS3 Tracer Robotic System from LJ Electronics. It is based on the concept of an X Y plotter but instead of a pen it has a small gripper which moves up and down to pick and place.

At a cost of about £600 it comes with a p.c.b. assembler kit and, in case you should want to use it as a plotter, a pen carrier and three coloured pens are also supplied. It is described as a robotic table rather than an arm.

The drives for the X and Y axes are stepper motors while d.c. motors power the up and down movement and the gripper. The company says the table was developed to be used with a vision system.

It was felt that a system suitable for a normal arm was unnecessarily complicated. Restricted the area of operation and the vision system, which will be supplied in the future, can be simple.

Max-1 marks the entry of Flight Electronics into the robot market. At a price of £399 plus VAT it resembles a larger version of the Ogre with a similar robust construction.

Max-1 has three axes, wrist, shoulder and elbow, plus a gripper all powered by d.c. motors with optical feedback. The drive transmission to the three axes is by metal worm gears with the gripper using a lead-screw.

With the arm fully extended Max-1 is said to be able to lift 4lbs. It is to go on sale in the autumn when more details will be available.

Another machine with an autumn launch is the latest in the ever increasing range from Cybernetic Applications. In keeping with the names of its other products, this one is called Naia, a water nymph, as it is hydraulically powered, using water.

...cylinders are made of see-through acrylic...

It has five axes plus a gripper with the axes powered by different kinds of hydraulic piston. The gripper is pneumatically powered. All the cylinders are made of see-through acrylic so that students can see how they work.

Control is possible using all the normal micros, including C64, Apple, IBM PC and BBC B. It is also intended to have a model controller as do the rest of the company's arms. A price has yet to be fixed but it will be less than £1,000.

Finally, anyone with £8,250 plus VAT might be interested in the latest arm from TecQuipment, the MA3000. It does not have the sophistication of its smaller companion, the MA2000, but is larger and more rugged and is intended for colleges which would normally be looking at the Puma to do a similar job. It has a reach of 750mm, can lift 2kg with an accuracy of 3mm. Powered by d.c. motors, with potentiometers, it has nine speeds, five axes plus a pneumatic gripper and is controlled by a BBC B.

If you have an old ZX-81 gathering dust in a cupboard and you are wondering what to do with it there is a kit supplied by Maplin Electronic Supplies for £50 which will allow you to turn it into a simple line follower. The kit contains the electronics on three p.c.b.s, two d.c. motors and an infra-red sensor for line following.

Known as Trundle it was developed as a school project and was featured on 4 Computer Buffs on Channel Four.

Practical Electronics October 1985
all in your

NOVEMBER issue!

PRACTICAL ELECTRONICS
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REVIEWS...
* 21 YEARS of ELECTRONICS
* DISCO LIGHTS CONTROL
  commodore
  * USER PORT EXPANDER

8 EXTRA PAGES

Thanks to our READERS!

NOVEMBER ISSUE ON SALE, OCTOBER 4
The idea for this power supply came about as a result of the author occasionally connecting a new circuit to the bench power supply, switching on, and then discovering that the output voltage was too high. It had been left at the 25V or thereabouts required for the previous session, whereas the new circuit required 5V or 9V. It is surprising just how many semiconductors can be instantly destroyed by this occurrence. What is needed to combat this problem is a supply that always starts at zero volts when it is switched on, with the user then having to set the required output potential before using the unit. With this system it is obviously impossible to damage components at switch-on due to an excessive output voltage.

Using a very simple system this power supply provides zero volts at switch-on. The output voltage is controlled in a novel way, with a set of touch contacts being used to increase the output voltage and a second set being used to decrease it. A built-in meter indicates the output voltage so that the desired potential can easily be set. This may seem to be a rather gimmicky way of doing things, but it does in fact provide good results with low output noise and good regulation, and is a perfectly practical approach.

The supply has a maximum output current of 1A, and current limiting protects the unit against output short circuits and other overloads. The output voltage range is from 0V to 20V, but the full 1A output can only be supplied at output potentials of around 17V or less. This voltage range and current rating is adequate when developing and testing the majority of circuits, including such things as 5V logic circuits, 9V battery powered projects, and 12V car projects. Measured at an output potential of 10V, the regulation is better than 1% and the output noise is under one millivolt peak to peak at all output currents.

**SYSTEM OPERATION**

The first requirement is to derive an unregulated d. c. supply from the mains supply. A regulator circuit fed from this supply is then used to reduce the output potential to the required figure and to provide accurate stabilisation. The unregulated voltage under full load must be a few volts more than the required maximum output voltage. The extra voltage is needed to compensate for losses through the regulator even at maximum output voltage. Also, there is likely to be a substantial amount of ripple on the unregulated supply, and the voltage at the bottom of the ripple waveform must be sufficient to maintain the maximum output voltage after the voltage drop through the regulator has been taken into account.

A transformer is used to step-down the mains voltage to a more suitable level, and the transformer also provides isolation from the dangerous mains supply. A rectifier provides full wave rectification of the transformer’s a.c. output to produce a pulsating d. c. supply. This is reasonably smoothed by a high value capacitor. However,
at high load currents the ripple content will still be at least a few hundred millivolts peak to peak, and the electronic smoothing provided by the regulator circuit is essential if a low noise level on the output is to be achieved.

In order to obtain a well regulated output voltage a highly stable reference voltage is needed. The basic action of the circuit is to stabilise the output at the same potential as the reference source, and we therefore require a reference voltage that is adjustable over a range of about 5V to 20V. In a conventional power supply unit this voltage is provided by a potentiometer fed from a simple Zener stabiliser circuit. In this case we are using a charge on a capacitor as the reference source. Operating one set of touch pads feeds a current into the capacitor from the positive supply rail and increases the charge voltage (and therefore the output voltage as well). Touching another set of contacts gradually discharges the capacitor into the negative supply rail, causing the charge potential and output voltage to fall.

**SWITCH-ON**

At switch-on the charge on the capacitor is zero, and the initial output from the power supply is consequently zero volts as well. Although the circuit may seem to lack a voltage regulator, the voltage across the capacitor is in fact very stable, and is totally unaffected by noise on the unregulated supply, or any voltage variations on this supply caused by loading or fluctuations in the mains voltage. In the long term the charge on the capacitor will leak away, mainly due to slight imperfections in the capacitor itself, but provided a good quality component is used the charge voltage will not change significantly for an hour or more. This supply could not be recommended for applications that require a highly stable supply to be maintained for many hours at a time, but few amateur users will require this feature.

The reference voltage is fed to one input of an error correction amplifier. The output of this amplifier drives a buffer stage which enables high output currents to be accommodated. The other input of the error amplifier is fed from the output. The purpose of the amplifier is to compare the output voltage with the reference voltage, and make any correction necessary to balance the two signals. This is really just a simple negative feedback system.

It is important for any bench power supply to have protection against damage due to the inevitable short circuits and general overloads on the output. The most common form of overload protection, and the one incorporated in this design, is current limiting. The current limiting circuit at the output monitors the output current, and has no effect if the current is less than one amp. If the output current significantly exceeds this figure a transistor is switched on and pulls the output of the error amplifier lower in potential. This prevents any significant rise in the output current, and even with a short circuit on the output little more than one amp flows since the transistor is then switched on so hard that it pulls the output voltage down to practically zero. Note that the current limiter circuit is included within the negative feedback loop so that the feedback compensates for any small voltage variations caused by this circuit during normal operation. Of course, when the current limiter comes into action it overrides the feedback action by "crowbarring" the output of the error correction amplifier.

**CIRCUIT OPERATION**

The full circuit diagram of the Touch Controlled Power Supply is shown in Fig. 2.

T1 is the mains transformer and the mains supply connects to its primary winding via an on/off switch, S1. The output of T1 is rectified by D1 and D2 which make up a conventional push-pull type fullwave rectifier circuit. C1 is the smoothing capacitor.

C2 is the charge storage capacitor. In order to set the output voltage accurately it is necessary to have quite slow charge/discharge rates, but on the other hand the rates must not be so slow that it takes a long time to make large changes in the output voltage. R1 and R2 are used to limit the charge and discharge rates respectively to a suitable compromise, and it takes typically about seven seconds to take the output voltage from zero to 20V. The precise time taken depends on exact component values, and also on the skin resistance between the touch contacts (usually about 1 megohm or so). S1c is used to discharge C2 when the unit is switched off, thus ensuring that no residual charge remains when the unit is switched on again. R4 provides current limiting to protect S1c against sparking at the contacts and eventual failure.

---

**SPECIFICATION**

<table>
<thead>
<tr>
<th>Input</th>
<th>Mains 240V a.c.</th>
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</thead>
<tbody>
<tr>
<td>Output voltage</td>
<td>0 to 20V regulated</td>
</tr>
<tr>
<td>Output current</td>
<td>1A max.</td>
</tr>
<tr>
<td>Regulation</td>
<td>1% at 10V</td>
</tr>
<tr>
<td>Noise</td>
<td>1mV pk-to-pk</td>
</tr>
<tr>
<td>Control</td>
<td>Touch plates</td>
</tr>
<tr>
<td>Indication</td>
<td>Neon, meter</td>
</tr>
</tbody>
</table>

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Practical Electronics  October 1985
IC1 is the error correction amplifier and this is just an operational amplifier used in the non-inverting mode. Protection resistor R3 couples the voltage on C2 to the non-inverting input of IC1. The output of the power supply connects directly to the inverting input of IC1 giving 100% negative feedback and the required overall unity voltage gain. IC1 is a type which has an output stage capable of providing output voltages almost right down to the negative supply potential. This is important as it enables IC1 to function properly without having to provide it with dual supply rails. IC1 also has a PMOS input stage, and again, this is important in this application. The PMOS input stage gives IC1 an input impedance of around 1·5 million megohms. This ensures that it does not significantly discharge C2 even over a long period of time.

TR2 is an emitter follower buffer stage. The TIP122 is in fact a power Darlington device which has a current gain of several thousand times. It is thus easily capable of producing an output current of up to one amp from the drive current of a few milliamps available from IC1.

**OVERLOAD PROTECTION**

The parallel resistance of R5 and R6 (0·6 ohms) is in series with the positive output of the supply, and the output current therefore flows through these components. This generates a voltage across them, and this voltage is proportional to the output current. At output currents of up to 1A the voltage developed across R5 and R6 is 0·6V or less, which is inadequate to bias TR1 into conduction. However, at slightly higher currents this voltage becomes large enough to bias TR1 into conduction. TR1 then diverts some of the output current from IC1 to earth through the load, pulling its output voltage lower in the process. However hard TR1 conducts it is not possible for it to reduce the output voltage of IC1 to zero, and on the face of it a short circuit across the output could still cause a massive current to flow. In practice this cannot happen as there is a voltage drop of about 1V or so through TR2, and this enables TR1 to pull the output potential down to a level that prevents more than about 1·2A from flowing even with a short circuit on the output.

C3 provides final smoothing of the output and also aids good stability. R7, VR1, and ME1 form a simple voltmeter circuit which is used to monitor the output potential of the unit. VR1 is adjusted to give the meter a full scale value of 20V. A separate earth socket (SK3) is provided so that either output of the unit can be earthed, but neither output need be earthed. In practice it is advisable to earth one or other of the outputs unless a floating supply is essential. Apart from the improved safety this also helps to minimise breakthrough of radio frequency signals from the mains supply to the output.

**CONSTRUCTION**

Start construction by fitting the components to the p.c.b. following the component layout of Fig. 3. C2 must be a carbonate capacitor or some other high quality plastic foil type, and should not be an electrolytic or even a tantalum bead capacitor. Only a good quality plastic foil type will have a sufficiently low leakage level to give good results in this circuit. It must also be a miniature printed circuit mounting type if it is to fit onto the board without difficulty.

As IC1 has a MOS input stage it requires the usual MOS antistatic handling precautions. It should be fitted in an 8-pin d.i.l. integrated circuit holder, but it should be left in the protective packaging and should not be plugged into circuit until the unit is in all other respects finished. Fit pins to the board at the points where off-board connections will eventually be made.

**COMPONENTS . . .**

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<th>Resistors</th>
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<tbody>
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<tr>
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<tr>
<td>R4</td>
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<tr>
<td>R5, R6</td>
</tr>
<tr>
<td>R7</td>
</tr>
<tr>
<td>VR1</td>
</tr>
<tr>
<td>All 1/2 W carbon 5% unless noted</td>
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<table>
<thead>
<tr>
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<tbody>
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</tr>
<tr>
<td>C2</td>
</tr>
<tr>
<td>C3</td>
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<table>
<thead>
<tr>
<th>Semiconductors</th>
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</thead>
<tbody>
<tr>
<td>D1, D2</td>
</tr>
<tr>
<td>TR1</td>
</tr>
</tbody>
</table>

| TR2          | BFY51 silicon npn |
| IC1          | CA3140E MOS op.amp |

<table>
<thead>
<tr>
<th>Miscellaneous</th>
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</thead>
<tbody>
<tr>
<td>ME1</td>
</tr>
<tr>
<td>SK1, 3</td>
</tr>
<tr>
<td>T1</td>
</tr>
<tr>
<td>LP1</td>
</tr>
<tr>
<td>S1</td>
</tr>
</tbody>
</table>

Metal instrument case about; 200 x 150 x 100mm; Printed circuit board PE PCB Service-100; Control knob; Touch contacts; Mains lead and plug; 8-pin d.i.l. i.c. holder; Plastic power transistor insulating kit; Soldertag, grommets, wire, pins, etc.
A metal instrument case having approximate outside dimensions of 200 by 150 by 100 millimetres is about ideal for this project. It is not essential to use the specified type, but the case must be of all metal construction, and it must have sufficient internal height to accommodate the mains transformer.

The front panel and internal layouts of the prototype can be seen from the photographs and it is advisable to keep to these general arrangements. The mains transformer is mounted on the chassis or base panel, and a solder tag is fitted on one of the mounting bolts to provide a chassis connection point for the mains earth lead. The mains transformer fitted to the prototype is a type having twin 17V, 2A windings which are connected in series to act as a 17V-0-17V winding. The unit should work well using similar transformers, such as an 18V-0-18V type rated at about 1-6A, or a twin 20V component rated at 1A or more and suitably connected. Do not use a transformer having a rating of more than 20V as this could produce an excessive unloaded voltage.

TR2 and the printed circuit board are also mounted on the chassis or base panel. The printed circuit is mounted using three 6BA or M3 bolts, and spacers must be included to hold the connections on the underside of the board clear of the metal case. The chassis or case acts as a heatsink for TR2. As its heat-tail connects internally to the collector terminal it must be insulated from the chassis or base panel using the appropriate (plastic T06B) type of insulating kit. Use a continuity tester or a multimeter set to a high resistance range to ensure that TR2 is properly insulated.

Mounting ME1 might prove a little difficult as most panel meters require a main mounting hole some 38 millimetres in diameter. Probably the easiest way of making this is to use a fretsaw, but if one of these is not available a simple alternative is to drill a ring of small, closely spaced, holes just within the border of the required cutout. A needle file can then be used to join up the holes, after which a large half-round file is used to tidy up and enlarge the cutout as necessary. The meter itself can be used as a sort of template when marking the positions of the four small mounting holes.

Either proper touch pads can be obtained, or M4 panelhead screws can be pressed into service. In either case soldertags must be fitted under the mounting nuts to enable connections to be made to the contacts. It is obviously essential to insulate the contacts from the case, and this can be achieved by mounting small grommets on the front panel and then mounting the contacts in these. An alternative would be to mount the contacts on a piece of plastic sheet, and then glue this in place on the front panel. Cutouts for the contacts would, of course, have to be made in the front panel. Whatever method is adopted, mount the contacts as close together as possible, otherwise they will be inefficient and difficult to use.

A hole for the mains lead is made in the rear panel of the case and this should be fitted with a grommet to protect the cable. S1 is a 4-way 3-pole rotary switch having an adjustable end stop, and the latter is set for 2-way operation.

The unit is completed by adding all the hard-wiring, and this is all detailed in Fig. 4. As the mains supply is involved, take great care when wiring up the unit, and thoroughly check for errors.

**ADJUSTMENT AND USE**

Start with VR1 at about half maximum resistance and then switch on. If the unit is functioning properly there should be no significant deflection of the meter at this stage. By operating the "up" touch contacts it should be possible to build up the output voltage and obtain a strong deflection on ME1. By operating the "down" contacts it should be possible to take the output voltage back down to about zero again.

In order to calibrate the output voltmeter, a multimeter set to a suitable d.c. voltage range should be connected across the output of the unit and the output voltage is then set as accurately as possible at 20V. VR1 is then adjusted to give precisely full scale deflection on ME1. Ideally the scale plate of ME1 should be carefully removed so that the 0 to 50 scale can be replaced with a more convenient 0 to 20 one, using rub-on transfers. Meter movements are very delicate and great care must be taken if a new scale is fitted to ME1.

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**Fig. 4. Wiring diagram of the Touch Controlled PSU**

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Practical Electronics  October 1985  31
The classic and much-used syndrum sound is a falling pitch effect, usually over a high- to middle-frequency range. Most syndrums are actually capable of producing a range of sounds, but the basic effect is the same with only the frequency range and duration being variable. This syndrum design takes things a step further and in addition to the standard syndrum effect a modulated falling pitch sound can be generated. In other words, instead of a straightforward fall in pitch the tone can be made to vary up and down, with an overall fall in pitch.

This enables some interesting sounds to be generated, and the unit is certainly much more versatile in this respect than an ordinary syndrum. Three modulation waveforms are available, and both the modulation depth and frequency are adjustable. The pitch, sweep range, and decay time are also variable, giving a large degree of control over the sound produced. The output amplitude is about 3V peak-to-peak from a low source impedance, and the unit should readily drive any power amplifier or mixer.

SYSTEM OPERATION

The block diagram of Fig. 1 shows the general make-up of the unit and helps to explain the manner in which it functions. With any unit of this type it is of more than academic importance to understand the way it functions, as there are a number of controls to set up properly in order to obtain the desired sound, and it can be difficult to master this unless you have a reasonable idea of what's what.

A VCO (Voltage Controlled Oscillator) produces the basic signal, but in order to give a reasonable drum sound some envelope shaping is required. The output of the VCO is therefore processed by a VCA (Voltage Controlled Amplifier), which is fed with a high control voltage almost immediately the unit is triggered, and then this voltage decays over a period which is adjustable from around only 200ms or so to about four seconds. This gives the fast attack common to all drum sounds, plus either a short, dull sound, or a long, rich sound, as required.

The envelope shaper which provides the control voltage is a very simple type, but is perfectly adequate for this application. The principal method of triggering the unit is to strike the case with a drumstick, or to simply tap it by hand. A pick-up mounted on the case produces a short burst of signal which is amplified and fed to a time constant circuit. This rectifies the signal and smooths it to produce the d.c. control voltage needed by the VCA. The attack time is fixed and quite short while the decay time can be adjusted over the range specified previously. A buffer stage matches the high output impedance of the time constant circuit to the low input impedance at the control input of the VCA.

Fig. 1. The block diagram for the Modulated Syndrum
A falling control voltage is needed for the VCO in order to produce the falling pitch effect, and the obvious source for this voltage is the envelope generator. It is necessary to have control of the basic pitch of the VCO plus the sweep range so that the desired effects can be generated, and the output of the envelope shaper is therefore fed to the control input of the VCO by way of a level control and a mixer. The output level potentiometer acts as the sweep range control. Another input of the mixer is fed with an adjustable bias voltage, and it is this that sets the basic pitch of the VCO.

The modulation is applied merely by coupling the output of a low frequency oscillator into a third input of the mixer. A buffer amplifier is needed to match the high output impedance of the oscillator to the relatively low input impedance of the mixer, and a level control is included to enable the modulation depth to be adjusted.

Although the unit was designed primarily for manual triggering, a trigger input is included so that the unit can be controlled by a computer or other digital control circuit.

**CIRCUIT OPERATION**

The full circuit diagram of the unit is shown in Fig. 2. The VCO is built around the two transconductance operational amplifiers of IC1, and the configuration is similar to a conventional dual operational amplifier triangular/squarewave oscillator. IC1a acts as the Miller integrator and IC1b is the Schmitt Trigger.

The advantage of using a transconductance operational amplifier as the integrator is that it enables the operating frequency to be voltage-controlled by way of the amplifier bias input. In fact it is the bias current that determines the operating frequency, but the inclusion of R4 in series with this input gives a current flow that is roughly proportional to the applied voltage, and the oscillator is effectively a voltage controlled type.

Each transconductance amplifier of the LM13600N has a Darlington pair emitter-follower output stage, and discrete output buffers are consequently unnecessary; resistors R5 and R7 provide the output loads. The output from IC1a is a triangular wave and IC1b provides a squarewave output. In this application the triangular waveform with its much lower harmonic content seems to give by far the better sounds, and it is therefore this output signal that it utilized. A wide frequency range is available, and the full audio range can in fact be covered by the VCO.

The VCA is based on another transconductance amplifier, IC2. Only one section of IC2 is used, and the second amplifier and output buffer are just ignored. IC2 operates in the standard VCA configuration, but to avoid the need for dual supply rails, R1, R2 and C2 are used to provide a centre tap on the supply. This is also used to bias the VCO circuit. Although C2 may seem to have an un-
usually high value, this is in fact essential in order to prevent a significant breakthrough from the VCO to the output of the VCA when the latter is cut off. Again, the VCA is really current-rather than voltage-controlled, but series resistor R12 provides the conversion from current to voltage operation.

MIC1 is the pick-up which can be either a ceramic resonator or a crystal microphone insert. IC4b is an inverting amplifier with a voltage gain of 20dB which also ensures that MIC1 feeds into a reasonably high input impedance of 100k. The non-inverting input of IC4b is biased to the negative supply rail so that the output signal is half-wave rectified. This gives a series of positive output pulses which are fed to the time constant circuit.

If a trigger pulse is fed to JK1 then IC4b acts as a non-inverting amplifier and supplies a single, but longer, pulse to the time constant circuit. Its effect is much the same though. A pulse duration of anything from about 5ms to 50ms is suitable. Note that the LM358N device used for IC4 is a type which is capable of producing output voltages right down to the negative supply potential, and that the circuit relies on this property for correct operation. Alternatives such as the 1458C are not suitable for the IC4 position.

C5 is the smoothing capacitor, and this rapidly charges from the low source impedance of IC4b when the unit is triggered. However, D1 prevents C5 from discharging through the output stage of IC4b, and the only discharge path is through the relatively high resistance of R17 and VR4. This gives the required fast attack and slow decay times, with the decay period being variable by means of VR4. IC4a is the buffer stage which ensures that the VCO and VCA do not significantly load C5.

MIXER

The mixer circuit is really a passive type and IC3 is just a buffer amplifier. Although a summing mode mixer might seem to be a better choice it would not be suitable here as it provides an unwanted signal inversion. IC3 is another type which can provide output voltages right down to the negative supply potential, and again most alternatives (such as the 741C and LF351) are unsuitable.

IC5b acts as the low frequency oscillator, and this is a standard operational amplifier astable circuit. In this case it is not the squarewave signal at the output of IC5b that is required, but the roughly triangular signal across timing capacitor C6. This is not a high quality triangular waveform as C6 charges and discharges exponentially, rather than linearly, through R24 and frequency control VR5. The somewhat rounded waveform is perfectly satisfactory for the present application though. The signal across C6 is at a high impedance, but IC5a provides the necessary buffering. VR1 is the modulation depth control and S1 enables the modulation to be switched out altogether when it is not required.

The normal waveform across C6 can be changed by switching either D2 or D3 into the charge/discharge path. Switching D2 into circuit bypasses VR5 and R24 during the charge half-cycle, giving a very short charge time. This results in a sawtooth output waveform of the type having a fast attack and a ramp on the trailing edge. When D3 is switched into circuit it has a similar effect, but it is the discharge half-cycle that is affected. This gives a sawtooth waveform, but of the type having a ramp on the leading edge and a fast decay time.

CONSTRUCTION

With the exception of the controls, sockets, and battery, all the components fit onto the printed circuit board, as shown in Fig. 3. The only MOS device is IC3 and the usual antistatic precautions should therefore be taken when dealing with this component. Some component retailers now supply the LM13700N instead of the LM13600N, and either type is suitable for IC1 and IC2 in this circuit.
Fig. 3. Component layout on the printed circuit board. This board is available from the PE PCB Service, order code PE-005

Fig. 4. Positioning of the controls. The lettered leads from the controls should be terminated at the identical locations on the p.c.b. Note that JK2 is fixed to the rear panel

The completed Modulated Syndrum with top panel removed showing interwiring and location of the p.c.b. The MIC insert is glued to the base of the case, right of the circuit board
Do not overlook the two link wires, one near to R1 and the other just below IC5. It is advisable to use the types of capacitor specified in the components list, as other types, although perfectly suitable from the electrical point of view, might not fit onto the board properly. At this stage, only pins are fitted to the board at the points where connections to off-board components will eventually be made.

The case needs to be a reasonably tough type, and a plastic Verocase with metal front and rear panels is used as the housing for the prototype. This measures about 205 x 140 x 40 millimetres, and will readily accommodate all the components. All the controls plus JK1 are mounted on the front panel—JK2 is fitted on the rear panel. S1 is ganged with VR1, but obviously a separate switch could be used here if preferred. Similarly, S3 is a set of make contacts on JK1, which has d.p.d.t. contacts (a socket with s.p.s.t. contacts is unlikely to be obtainable), and the unit is automatically switched on and off as the plug is inserted into JK1 and removed. Again, a separate switch could be used here, but it might then be difficult to find space for all the controls on the front panel.

CIRCUIT BOARD

The printed circuit board is mounted on the base panel of the case using M3 or 6BA fixings, with R5, R7, R13 etc. towards the front of the unit. MIC1, whether a ceramic resonator or a crystal microphone insert, is glued to the base panel of the case using any good quality household adhesive. Most inserts and resonators either have solder tags or flying leads, but one type of resonator does not. With this type leads must be carefully soldered direct to the inner (silver coloured) and the outer (copper coloured) contacts, and the component must obviously be mounted with this side facing upwards. Do not leave the soldering iron in place any longer than is absolutely necessary when making these connections, and be careful not to accidentally short-circuit the two contacts with excess solder.

To complete the unit the hard-wiring is added. This is illustrated in Fig. 4 in conjunction with Fig. 3 (e.g. point "A" in Fig. 3 is connected to point "A" in Fig. 4"). Provided the leads to MIC1 are kept quite short it is not necessary to use screened cable here.

If the unit is to be triggered manually using a drumstick it is advisable to use some self-adhesive plastic or foam rubber material to protect the case over the area where it will be struck. It does not matter where on the case the unit is struck since the vibrations will always be transmitted through the case to MIC1 so that proper triggering is obtained.

IN USE

The output from JK1 is coupled to the amplifier, mixer, or whatever via an ordinary screened jack lead. As explained previously, the unit is automatically switched on when the plug is inserted into JK1, and switched off again when it is removed. When initially testing the unit it might be more convenient to plug a pair of headphones into JK1, preferably a medium or high impedance type.

Tapping the unit should produce some sort of output, and a little experimentation with the controls should soon reveal whether or not everything is working properly, and should give an idea of the range of sounds that is available. The unit should be touch-sensitive, with the sweep range and volume being to some extent dependent on how hard the unit is struck. Some picks-ups are more sensitive than others, and if the unit seems to be grossly oversensitive making R18 lower in value should cure the problem. A higher value for R18 will give increased sensitivity.

The trigger input is ideal for use with MOS and CMOS outputs which provide a logic 0 output voltage of virtually zero volts. TTL outputs could in theory provide a logic 0 potential that would prevent the VCA from fully cutting off, although this problem does not seem to occur in practice.

Note that when using the sawtooth modulation waveforms the modulation frequency will be about double that obtained when using the triangular waveform. Also, the two sawtooth waveforms will sound little different when the modulation frequency is fairly high, but the difference should be quite apparent at low frequencies.

A wide range of frequency, sweep range, and modulation is available, and it is well worthwhile spending some time familiarising yourself with the effects that can be obtained, and noting the control settings that give the best effects (there should be plenty of these).

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BOOK REVIEWS

A PRACTICAL INTRODUCTION TO THE NEW LOGIC SYMBOLS

Author  Ian Kampel
Price  £11.50 hardcover
Size  223 x 142mm. 150 pages
Publisher  Butterworths
ISBN  0 408 01461 X

Few engineers will welcome a title that threatens to impose yet another new standard upon them. However, the new logic symbols explained in Ian Kampel's work are already in use in some areas—notably VLSI design—and it seems likely that all the major technological countries will change to this new symbolism in the near future. The standard for symbols on which the book is based is the International Electrotechnical Commission Publication 617; the relevant British Standard is BS3939 Section 21. As the author comments in his introduction, this new language exists, and "It is also a language which has a real incentive for people to learn it: in due course their career may depend upon it!"

The essence of the new logic symbols is the embodiment of a "systems", or top-down approach. A single symbol can be used to represent what previously would have been given as a complex circuit diagram; but that symbol itself may be further broken down into the equivalent of block-diagram form, or even into individual gates or i.e.s.

An instructional book on such a subject is obviously welcome, and A Practical Introduction to the New Logic Symbols clearly defines the terms used before going on to give examples. The approach reflects the "language" itself, progressing from simple definitions to increasingly complex symbols. In this way, each chapter builds on its predecessor, so that the book has to be read sequentially, rather than as a reference work. This requirement reflects the way the new symbols themselves work; it is not a question of a simple "new-for-old" swap, but the adoption of a new method of thinking—a new grammar. Every engineer, and engineering student, needs at least to be aware of this new standard, and this book meets that need more than adequately.

D.A.B.
**PROJECT 1**

**Safe Power Supply Unit**

This is a 9V+9V d.c. unit designed for use with the Teach-In '86 series (see above). It is the first of nine related projects, each relevant to that month's Teach-In notes. This unit is not essential for Teach-In participants, but it will nevertheless always be a useful tool in its own right.

**Soldering Buyer's Guide**

Soldering is a very much underestimated art in the world of the electronics enthusiast, and its true importance is not fully appreciated. It is really a simple task, when you know how, and the combined skill and patience involved can often lead to the correct solution, or at least the shortest possible road to a solution. This guide shows you how — it also features a wide range of currently available tools and equipment.

**MARCO TRADING**

<table>
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<tr>
<td>74LS</td>
<td>Universal charger to charge 1.9, 2V, 3V</td>
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<tr>
<td>7415</td>
<td>N.C.</td>
<td>£3.00</td>
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  - BF 265, 0.25W, 2.5A, 60V.

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- **2N3058**

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  - 30mm, 8Ω.

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**FUSES**

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  - 3mm, 10A, 250V.

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**The Sky This Month**

Bright planets are fairly well represented this month. Venus is brilliant in the eastern sky before dawn, and on 21 September it passes close to Regulus in Leo—a good opportunity for amateur photographers!

Jupiter is an evening object and, with a magnitude of -2.3, is far brighter than any other star or planet apart from Venus; but it is well south of the celestial equator, and by the end of the month it sets around midnight. Saturn is also an evening object in the south-west after sunset. The rings are wide open, so that the planet is a beautiful sight even in a modest telescope.

Mercury and Mars are close together in the early part of September; again in the morning sky, but they will not be particularly easy to make out. Mars incidentally, is three magnitudes fainter than Mercury.

The minimum separation between the two is 46 seconds of arc. It is surprisingly seldom that one planet occults another; the last occasion was on 3 January 1818, when Venus passed in front of Jupiter, and the next will not be until 22 November 2065, when the same thing will happen.

Halley’s Comet is still faint, and perhaps the main interest this month will centre upon Comet Giacobini-Zinner, which will be by-passed by the American probe ICE (International Cometary Explorer). Giacobini-Zinner, with its period of 6.6 years, can sometimes reach the fringe of naked-eye visibility.

It will not do so this year, but as the magnitude will reach 8 or so it will be a reasonably conspicuous telescopic object. Positions for September will be as follows:

<table>
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<tr>
<td>22</td>
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<td>27</td>
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At the end of the month the comet will cross the celestial equator, and by December the declination will be -38°, so that British observers will lose sight of it; the magnitude will have faded to about 11. Photographers would be well advised to practise upon Giacobini-Zinner in preparation for Halley.

During September evenings the “Summer Triangle” of Vega, Deneb and Altair is still very much in evidence, with Ursa Major at its lowest in the north and the W of Cassiopeia not far from the zenith.

Pegasus, the Flying Horse, dominates the southern aspect, with its four main stars making up the famous “Square”. It is difficult to understand why Alpheratz, one of the four, has been transferred to the neighbouring constellation of Andromeda.

Andromeda is, of course, celebrated because of the presence of Messier 31, the nearest of the large spiral systems at a distance of 2.2 million light-years. It too can be used as a convenient “photographic rehearsal” for Halley’s Comet.

Low in the south, look for Fomalhaut in Piscis Australis (the Southern Fish) which is of the first magnitude and is one of our nearer stellar neighbours; it was also found by IRAS to be associated with an infra-red excess indicating cool, possibly planet-forming material. In the east the Pleiades have come into view, soon to be followed by the orange-red Aldebaran, the so-called “Eye of the Bull”. By the early hours of the morning Orion has come back into view, led by the red supergiant Betelgeux and the glittering white Rigel, at least 60,000 times more luminous than our Sun.
that it never sets over the British Isles. Mu Cephei lies not far from a triangle of fairly dim stars of which one is Delta Cephei, the prototype short-period variable.

Mu is itself variable; the magnitude range is from about 3-6 to 5-5, so that the star is always visible with the naked eye, but it is far from conspicuous, and when it is near minimum the colour is hard to discern without binoculars or a telescope. Yet when any optical aid is used, Mu Cephei lives up to Herschel's nickname.

How far away is it, and how luminous is it? Clearly it is a red supergiant—a star which has used up its main store of hydrogen "fuel" and is approaching senility; but its distance has never been well determined. One estimate gave around 1500 light-years, in which case the star would have something like 50,000 times the luminosity of the Sun—as against a mere 15,000 Sun-power for Betelgeux.

** STELLAR HEAVYWEIGHT **

New studies of it have now been carried out at the high-altitude Pic du Midi Observatory, in the French Pyrenees. Using the 2-metre reflector there, N. Mauron has examined Mu Cephei in the light of sodium, and has announced that the star is surrounded by a vast envelope with an apparent diameter of as much as one minute of arc.

He also finds that Mu Cephei is much further away, and much more luminous, than has been previously believed. The power is now given as about 100,000 times that of the Sun, outclassing even such cosmic searchlights as Deneb and Canopus.

According to Mauron, the circumstellar "cloud" is shining because sodium atoms are scattering light in the outer part of a violent stellar "wind". We have become used to talking about the solar wind—a stream of atomic particles being sent out by the Sun constantly in all directions and which, incidentally, has a marked effect upon some types of comet-tails, driving them outward; but we have heard less of the much stronger "winds" produced by very massive stars. And if the new data are correct, Mu Cephei is very massive indeed, and is the equal of 20 Suns. This is not a record, but it puts Mu Cephei very much into the class of stellar heavyweights.

Moreover, the star itself is huge. The diameter has been estimated as over 800,000,000 miles, which is comparable with the size of Jupiter's orbit round the Sun. Again this may not be a record but it dwarfs Betelgeux, whose diameter is no more than 250,000,000 miles at most!

** DECEPTIVE APPEARANCES **

In astronomy, as in so many other subjects, appearances can be very deceptive. Looking at Betelgeux and at Mu Cephei, it seems that Betelgeux is much the more impressive of the two, it is in fact one of the brightest stars in the sky. But in reality things are very different. If Mu Cephei were as close to us as Betelgeux, it would cast perceptible shadows, and if it were as near as Alpha Centauri at a mere 4-3 light years, it would appear almost as a second sun.

If you have a pair of binoculars, I suggest that you go out on the next clear night and locate Mu Cephei. You cannot fail to recognize it; its hue is so striking that there is no fear of mistake. It may seem like a tiny, glowing point, but we have to realize that it is one of the most remarkable stars we know.

What will happen to it eventually? It is squandering its reserves of energy; it will not last for nearly as long as the Sun before disaster overtakes it. It may collapse into a neutron star, or even produce a black hole. But this will not happen for tens of thousands of years at least, so that there is plenty of time for us to look at and admire the "Garnet Star".

---

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39
Faced with the problem of providing a realistic sounding ringing telephone for an amateur dramatics group, the usual answer is to use a sound effect recorded on tape. However, this has disadvantages, namely: it must be exactly set up on the tape deck so that it can be started precisely on cue; it does not 'resonate' after the phone has been answered, something you do not notice until you try it; and what if you run out of sound effect before the actor answers the phone?

**REAL PHONE**

These problems can be overcome by using a real phone which can be answered by the actors on stage.

A surplus phone can be picked up at an 'electrical junk' shop for a few pounds these days. The circuit provides all the timing to produce the familiar 'ring ring .. pause .. ring ring' effect of a real telephone. All the operator has to do is hold a button down! The circuit is based around three CMOS i.c.s and its operation is reasonably straightforward.

Looking first of all at the phone end, the bell mechanics consist of two coils and a pivoted hammer which alternately strikes one of two bells. To make the phone ring it is necessary to pulse each coil in turn, to pull the hammer back and forth. The coils come wired in series and are designed to run from about 48 volts.

However, the bell will work satisfactorily on a 24V supply, and if we alternately switch 12V across each coil independently, this has the same effect. This is achieved by TR1 and TR2; being a complementary pair, a pulse input to both their bases switches them alternately. Note that to achieve the correct magnetic polarities the coils must be wired up as shown - if the circuit does not work first go, try reversing one pair of the coil connections. D1 and D2 protect the circuit from induced voltage spikes.

IC2c and IC2d are wired as a 25Hz oscillator which drives the coils via TR1 and TR2. This would make the bells ring continuously, so it is gated on and off at the correct times via IC1b, by the rest of the circuit.

The output of the 1Hz oscillator also goes to one input of IC1b; the other input is from the inverted counter output, Q of IC3b. When and only when both inputs of IC1b go high, the bell ringing oscillator is activated. This will occur during the '0' and '1' counts of IC3a and IC3b. In between these counts, when the oscillator output goes low, and during the '2' count when the Q output of the counter is low, the bells will pause. Thus we achieve the required 'ring ring .. pause' sequence.

The 1Hz control oscillator is gated on and off by a pushbutton marked 'Ring', via IC2b. This button also resets the counters to zero via negative edge detector C2 and R3, and IC1c, when initially pressed. If required, the button could be routed through the receiver cradle switch in the phone, so that it stopped ringing as soon as the receiver was picked up.

G. Durant, North Yorks.
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IVAX Review

PHIL DANE

In the past the design of robots has followed the basic form of the human arm but recently there has been a distinct trend for assembly machines to be of a more rational concept. It has become obvious, through experience, that it is both difficult and impractical for machines to successfully emulate the discrete and complex movements of humans.

SCARA

An increasingly common rationalisation of robot design is that of the SCARA (Selective Compliance Assembly Robot Arm). This type of robot arm (Fig. 1) consists of a horizontal jointed arm with a gripper which has both vertical and rotational movement. The arm is set to a predetermined height which means that the only change in potential energy occurs when the gripper is being raised or lowered. This is not so with a conventional anthropomorphic arm.

Noting this trend towards the use of SCARAs in industry, Powertran have developed a bench top machine which may be used in education or training and incorporates all the features of its industrial counterpart.

IVAX

The new SCARA from Powertran has been named IVAX and is said to be more sophisticated than some other designs as it employs four servo controlled axes rather than three. The extra axis provides controlled vertical movement using a rack and pinion drive. This allows the arm to be tolerant to small variations in the height of the workstation otherwise each station would require discrete height adjustments.

IVAX has been designed with a total concept in mind, to enable complete emulation of many industrial applications, with work stations which may be expanded or re-configured as and when required. Also its open frame design means that many of the moving parts including the optical encoders may be viewed whilst the machine is in operation, a facility very useful to students and trainees.

MECHANICS

The three rotational axes of the IVAX are illustrated in Fig. 2. They all use the same type of d.c. motor with integral gearbox, optical disc read by two slotted opto switches (giving phase/quad) and precision 30 to 1 secondary gearbox. Axes 0 and 1 also make use of constant torque springs which eliminate the effect of backlash in the secondary gearbox.

Axis 3 in addition drives through a 1 to 1 toothed belt which is shown in Fig. 2d. The gripper (see photo) has parallel jaws and is self centring. It has 'vee' grooves in both the horizontal and vertical planes to ensure positive gripping action. The gripper is actuated through a pneumatic circuit controlled by a three-way valve, and for those establishments without a separate compressed air facility the IVAX has its own tiny compressor which is 'whisper' quiet.

SPECIFICATION

Description
D.c. servo powered SCARA robot arm with independent input/output. Microprocessor controlled. Command entry from hand-held teach pendant or external computer via parallel interface.

Configuration
Arm with two rotational axes of motion in horizontal plane. Gripper with vertical and rotational position and on/off control.

Drive
D.c. servo motors driven from Pulse Width Modulated amplifiers. Pneumatic gripper.

Feedback
Open frame optical encoders providing continuous positional feedback on all four numerically controlled axes.

Control
Resident Z80A microprocessor or additionally external computer via parallel interface.

Resolution
1:3240 on all rotational axes (5 minutes of arc). Better than 0.2 millimetres on vertical axis.

Operating Envelope
Partial toroid; external radius 280mm, internal radius 108mm, depth 40mm.

Speeds
Rotational speeds to 60 deg/sec in steps of 0-25 deg/sec.

Movement
Rotational axes 270 deg
Vertical linear axis 40mm
Gripper opening 15mm

Work Cell Interface
16 inputs: Switch to ground or 5 volt digital.
16 Outputs: Open-collector sinking 30 milliamps.

Other Features
Optional EEPROM non-volatile storage provided for 3 programable sequences of 32 steps.
Optional large capacity RAM for storage of 15 programable sequences.
The electronic control system makes use of complex circuitry which is illustrated in the schematic diagram of Fig. 3.

The heart of the IVAX controller is the Z80A microprocessor running at 4MHz. The controller monitors the inputs, controls the axes of IVAX (speed and acceleration), has sequence control, monitors for errors in the closed loop system, updates the EEPROM (if fitted), communicates with the host computer and receives information from the teach pendant. The controller is also capable of executing commands from the host computer and teach pendant. On board RAM can either be 2K or 8K bytes, enabling a storage of 3 to 15 sequences respectively (a sequence is 32 steps). An optional non-volatile storage (2K) can be fitted in the form of EEPROM. This option enables up to 3 sequences to be stored so that the system can be switched off, or during mains failure the program stored in EEPROM will not be corrupted.

For educational courses in maintenance, testing and fault finding on microelectronics systems, test points have been provided so that all areas of interest can be monitored. An added facility of the system is that the IVAX firmware includes setting up tests which demonstrate the correct functioning of all circuit elements.

An EEPROM is an electrically erasable and programmable read only memory for use where permanent storage is required but also offering the ease of changing the data stored if required.

An expansion port is fitted which allows the electronics to control a further four axes and numerous other input/output devices. Half of the Z80A input/output address map, together with all necessary signals, is available for further control. Numerical control of each of the robot’s four axes is achieved through independent closed loop systems to give reliability, accuracy and repeatability. Optical
encoders are used with pulse width modulated amplifiers for d.c. servo drives to give a resolution on the major axes of better than 5 minutes of arc.

A watchdog circuit is incorporated into the system to protect the robot from abuse. The firmware monitors the robot’s operation every 5ms. If stalled, for example, by a person holding the robot’s arm, the firmware will halt the robot, reducing the axis error to zero and thus protecting the robot from damage; however, the robot’s position is still maintained. The inputs and outputs are continuously displayed on the control unit by light emitting diodes (L.E.D’s). The outputs can be individually or simultaneously programmed through single host computer commands.

**HOST COMPUTER (BBC ‘B’ OR APPLE IIE)**

Although the IVAX can be controlled by using the teach pendant, its full potential can only be realised using a host computer, which will allow the digital inputs to be monitored and the outputs to be controlled. The host computer also enables programs to be written for the IVAX in which decisions can be made on the basis of the digital input status. As IVAX is capable of off-line programming and conditional sequence control, it is possible to write programs on the host computer which can be down-loaded to IVAX to allow the host to be used elsewhere.

**PROGRAMMING**

The supplied software consists of procedures and functions so that the IVAX can be controlled entirely using BASIC commands from a host computer such as the BBC. The co-ordinates for the commands are simple cartesian x,y,z co-ordinates with an angle (in degrees) for the gripper orientation. With the x,y and z dimensions being in millimetres the writing of off-line programs becomes a simple matter.

Consider the following brief example (Program 1): In this program the robot moves to a start position, picks up a workpiece, moves to a position where a tolerance testing gauge is fitted, inserts the workpiece into this gauge, tests for the workpiece being within tolerance (input 2 low) and switches output 3 on for ‘GO’ and off for ‘NOGO’.

As can be seen the procedure name implies the function the robot is performing thus making programs very simple to follow. Many other simple to use procedures exist. Impressive examples of which include being able to program speed and acceleration of an axis with just a single command for each. Speed can be set to any number in the range 1 to 255 with 255 being the maximum speed of 60 degrees/second for the rotational axes.

User procedures also exist and are invaluable for writing programs, for example being able to record the present robot position and gripper state with just a single command.

The BASIC software gives complete access to the Z80A based controller and allows user programs to be simulated, run, or downloaded to the IVAX quickly and easily.

Any location of the IVAX controller memory can be read from or written to the host computer, thus providing a window on the operation of the Z80A based system.

Complete listing of the IVAX firmware is made available and provision has been made within the firmware for students to enhance and extend the operation of the IVAX. This not only makes the IVAX robotic system a learning device for engineers but also for system programmers using high or low level (machine) languages.

**SIMULATION**

As with its industrial counterparts IVAX comes complete with its own graphic simulation for the BBC so the principles of simulation
and off-line programming can be demonstrated. When condition sequencing has been written into the program the simulator stops at that point and enquires as to the state of the appropriate input.

THE WORKCELL

A typical workcell (see photo) consists of two input conveyors (with component feed rate control), measuring gauges, reject bins and an output conveyor. The robot picks components from the conveyors and presents them to the measuring devices, one checks for oversize, one for undersize, which give either a go/nogo signal to the inputs of IVAX. Reject components are placed in the appropriate bin and passed components are placed on the output conveyor.

The robot may also be programmed to:
1. Alternate between servicing each input conveyor if there is a component present on each (components are detected by a reflective opto switch).
2. Concentrate on one conveyor if there is a queue of components and may also stop the conveyor. (See flowchart Fig. 4.) Alternatively the robot is available with a CNC Mill and feed conveyor.

With the ability to analyse 16 inputs and set 16 outputs, IVAX can cope with an immense number of events and can take a tremendous variation of actions, provided all have been anticipated by the programmer.

With the system being so flexible in both hardware and software it makes an ideal tool for project work. The increasing use of robots in industry implies a need for the training of a substantial number of personnel of all levels, but especially technicians and engineers in the technology of robots.

Robot technology encompasses not just the mechanical engineer but also the electronic engineer. They must come together to work as a team to develop the automation of production. This calls on universities, colleges and training establishments to provide courses with hands-on experience to enable technicians to retrain in the new robot technology and Flexible Manufacturing Systems. This is the reason why Powertran Cybernetics Education Division has developed the SCARA IVAX robotic workcell.

Up until now the robots available for education and training have only been able to pick and place, with many of them no more than toys. The IVAX SCARA is different. It has been designed to simulate an industrial robot having conditional sequence control. The Powertran IVAX SCARA robot has taken the state of the art technology used on industrial FMS and scaled it down to perform actual production line techniques involving: measurement, palletising, decision making, assembly work and milling.

BUYERS NOTE:
The basic system comprises: a power supply unit, control unit, IVAX SCARA robot, teach pendant, software, manual and coursework.

If purchased in kit form a comprehensive construction booklet is provided.

This product can be obtained from:
Powertran Cybernetics Limited
(Education Division),
Portway Industrial Estate,
Andover,
Hampshire,
SP10 3PE.
(0264) 64455.
LAST month we looked at a robot interface with four conventional servo channels, plus an unconventional channel dubbed the TACACOOGA. This month we look at the construction of that interface. It is designed, where possible, to use the kind of cheaper components most likely to be found in the constructor's "junk" box. We also illustrate the ultra-simple gripper (Fig. 5).

MECHANICAL ADVANTAGE
Should you wish to use a more sophisticated gripper mechanism, in which the motor is geared down to drive the jaw, then the TACACOOGA may be used in reverse, but a single-pole changeover type limit switch is required.

Only two changes are necessary. One is to swap the gripper motor wires so that the automatic cut-off (stall current detect) operates when the gripper is closing instead of opening. The other change is to remove the link between A and B in LK2 and wire a microswitch so that it detects when the jaw is fully open, switching point B to point C (OV).

With this arrangement the Torque control preset might as well be set to maximum motor speed. The stall current cut-out feature will activate when the gripper bites onto the object it is to grasp. Note that even with VR10 set to maximum sensitivity your gripper might only pick up an egg safely if it is hard boiled. Part of the entertainment of experimental robotics is in the matching of electronics and mechanics to application.

In this slightly more conventional arrangement, I suppose the circuit name should be truncated to ACOCOC (Automatic Cut-Off On Closure). This configuration does assume a high reduction gearing between motor and jaw, so that when the motor is de-energised the jaw cannot roll back from the object in its grip. A worm drive is a typical arrangement for this purpose.

NEED A GEARWHEEL?
Listed below are some useful addresses for those who wish to procure modular mechanical and electrical components suitable for Experimenting With Robots. The common denominator with all these type building media is cost. Components are not particularly cheap, but they do offer the advantage of being re-usable, so that when the initial outlay is divided by the number of variants constructed each individual machine works out to be quite inexpensive. In addition to this, these modular systems are highly educational in a subject area of great importance to future industry.

MEDIUM: Fischer Technik
AVAILABILITY: Toy stores
SUPPLIER: Artur Fischer UK Ltd., 25 Newtown Rd., Marlow, Buckinghamshire SL7 1JY
(The complete range of Fischer Technik parts is surprisingly extensive, and includes many electronic modules. The little engineer appears courtesy of this company.

MEDIUM: Meccano
AVAILABILITY: Specialist model engineering shops
SUPPLIER: M. W. Models, 4 Greys Rd., Henley-on-Thames, Oxfordshire RG9 1RY. 0491 572436.
(This company seems to be the Meccano Mecca, providing a mail order service to UK and overseas customers from an amazing stock. Write to "Everything Meccano", or telephone for details.)

MEDIUM: Lego Technic
AVAILABILITY: High Street shops
SUPPLIER: Lego UK Ltd., Wrexham, Clwyd LL13 7TQ

REQUIRE A PULLEY?
Fig. 4. Component layout on the double-sided p.c.b. Note that the black "dots" represent through-board links. Use eyelets, or tinned copper wire to make these connections first. Last month's Components List requires correcting. The 100n capacitors are as follows: C9-12, C15-20, C23-25 (13 off). This board is available through the PE PCB Service, order code 004.
PAG

The gripper circuit may be used in yet another configuration, and this is called Pulse Activated Gripper. In this mode of operation the gripper motor is driven for a preset time period generated by IC13 triggered from the Enable E line. The time period is the same for each motor direction. The options link table should be referred to if the p.c.b. is used. Table 2 also indicates which components to omit or link out.

The PAG may work to your satisfaction with C17 at 100nF, but should a longer motor duration be required for a particular gripper design then C17 may be increased in value to suit. The pulse width generated by IC13 should be set to just long enough in duration to fully open, or fully close the jaw. No undue strain on the motor should result from the energisation period lasting a fraction of a second longer than the motor’s limits of travel.

With the circuit operating in this mode, the preset VR9 ought to be set to maximum torque, although altering its setting might allow you to null a slight difference in motor travel time between each direction of the jaw. Alternatively, the torque limiting facility might be utilised to advantage in the ‘close’ direction, to control the grip on fragile objects.

SPAG

A Symmetrical PAG (SPAG) can be built if the torque control aspect of the circuit is of no use, and still more components saved. Table 2 shows how VR9 can be lost, and if the link references are related to the circuit diagram in Fig. 3, it will be seen that IC12a operates as a straightforward linear amplifier, and IC12b becomes redundant.

EPUD

Although the experimenter may discover other ways to configure the gripper circuit, the Electromagnetic Pick-Up Driver is the last variation to be discussed here. By removing the components indicated in Table 1, the circuit becomes a simple solenoid driver for a robot capable of picking up ferrous objects. The Torque control facility remains intact, and allows greater freedom of choice of the solenoid rating. Since the solenoid might be an unspecified ‘junk box’ item, stripped from a relay, or even home spun, VR9 can be adjusted until the pick-up has adequate ‘attraction’ without overheating.

<table>
<thead>
<tr>
<th>MODE</th>
<th>FUNCTION</th>
<th>P.C.B.</th>
<th>LINKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TACACOOGA</td>
<td>Torque Adjustable</td>
<td>Fully populated</td>
<td>A – B</td>
</tr>
<tr>
<td></td>
<td>Closure, Automatic</td>
<td></td>
<td>D – E</td>
</tr>
<tr>
<td></td>
<td>Cut-Off On Opening</td>
<td></td>
<td>J – H</td>
</tr>
<tr>
<td></td>
<td>Gripper Actuator</td>
<td></td>
<td>M – N</td>
</tr>
<tr>
<td>ACOOGC</td>
<td>Automatic Cut-Off</td>
<td>Wire limit switch with n.o.</td>
<td>D – E</td>
</tr>
<tr>
<td></td>
<td>On Closure</td>
<td>contacts between link positions</td>
<td>J – H</td>
</tr>
<tr>
<td></td>
<td>B and C.</td>
<td>Board fully populated</td>
<td>M – N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change R27 to 68k</td>
<td></td>
</tr>
<tr>
<td>PAG</td>
<td>Pulse Actuated Gripper</td>
<td>Omit R29, R30, R31, R32, R34, D3, D4, D5, TR11, VR10, C15, C16</td>
<td>B – G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D – E</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>L – K</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M – N</td>
</tr>
<tr>
<td>SPAG</td>
<td>Symmetrical Pulse Actuated Gripper</td>
<td>Omit as PAG, plus VR9, C13 and D2. Short cut R28. Short out D1. Change R27 to 56k. Link VR9 (top) to VR9 wiper position</td>
<td>B – G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D – E</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>L – K</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M – N</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>B – G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M – P</td>
</tr>
</tbody>
</table>

Table 2. TACACOOGA options. All unmentioned links should be left open.

It is worth noting at this point that driving an op. amp. from TTL outputs in the way that IC11 drives IC12a will work reliably only if both the op. amp’s inputs are driven from the same piece of silicon, i.e. the same TTL chip. It appears at a glance that in the EPUD configuration R25 might just as well be connected directly to OV, but if it were, the driver circuit would probably become unstable.

CONSTRUCTION

Only one or two notes are necessary in connection with assembling the p.c.b. (Fig. 4). The first step is to decide how many channels are required initially, and therefore how much of the
PRactical Electronics October 1985

CROSS WIRING THESE DURING ANY EXCISE WILL MOST LIKELY LEAD TO THROUGH-BOARD LINKS. ALTHOUGH THE P.C.B. IS DOUBLE-SIDED, THROUGH THE GRIPPER CIRCUIT SHOULD BE USED IN; WHETHER IT IS TO BE USED AS THE P.C.B. IS TO BE POPULATED. THE NEXT STEP IS TO DECIDE WHICH MODE THE GRIPPER CIRCUIT SHOULD BE USED IN; WHETHER IT IS TO BE USED AS THE FULL TACACOOGA, AS A DERIVATIVE THEREOF, OR AS A STRAIGHTFORWARD MOTOR (OR ELECTROMAGNET) SWITCH.

When ready to proceed with construction, first insert the through-board links. Although the p.c.b. is double-sided, through-plating has been omitted to control its cost to the constructor. Eyelets or pieces of 22 s.w.g. tinned copper wire should be used for these links where they occur underneath i.c.s and other components, but elsewhere the use of solder pins will create an abundance of "easy clip-on" test points. The through-board links should be made before any components are inserted, of course, particularly those located beneath IC5-8 and IC13.

If the p.c.b. is drilled to 0.8mm for the i.c.s, you may find it necessary to open out to holes to 1mm for the passive components, or greater in the case of power components.

Sockets should at least be used for IC5-8, if not all d.i. components, including the addressing switches.

The three heatsinks are cut out of sheet alloy, and their dimensions are shown in Fig. 6. The two shared heatsinks require the use of mica washers and 4BA nylon nuts and screws to secure the transistors. Heatsink compound should be applied, and the transistors mounted loosely on the heatsink before inserting them in the p.c.b. If they are tightened to the heatsink whilst in situ, and then soldered, the transistors' leads will not be left under permanent stress.

The remaining components may be soldered in any order, and the i.c.s inserted in their sockets afterwards. During any subsequent experimentation with the board it must be borne in mind that there are three distinct OV systems on the p.c.b. which meet at a common "star" point. These are: Analogue Ground, Digital Ground, and a high current line for the motors, called Motor Ground. Cross wiring these during any excercise will most likely lead to unwanted voltage drops along certain tracks which in turn upset the digital logic, or the accuracy of the analogue circuits. This point is particularly important to remember if you intend building all, or part, of this interface on stripboard.

SOFTWARE

A program to demonstrate the complete interface, and written in BASIC for the standard ZX81, is shown in Listing 1. The program assumes that all the address decode switches are off (logic 1's), so that the interface is located at base address 65520.

10 LET L=65520
20 PRINT " ' WHICH CHANNEL: 0.1.2.3.4.7"
30 INPUT C
40 CLS
50 LET M=LET
60 PRINT " CHANNEL ' C"
70 IF C=4 THEN GOTO 200
100 PRINT " POSITION: 1 - 255?"
110 GOTO 230
200 PRINT " SELECT "
210 PRINT " ' 1) OPEN GRIPPER"
220 PRINT " ' 2) CLOSE GRIPPER"
230 INPUT P
240 POKE M.P
250 PRINT " '
260 GOTO 20
210 PRINT " ' 1) CLOSE GRIPPER"
220 PRINT " ' 2) OPEN GRIPPER"

NEXT MONTH: Give your robot shifty eyes!
THIS month BBC Micro Forum moves on to look at some of the less obvious elements of the analogue port. First under the microscope are the two pushbutton inputs nominally provided for joysticks.

JOYSTICK FIRE BUTTONS

One of the most popular uses for the analogue port (in the early days of owning a computer, at least) is for connecting the games joysticks. Most of us just plug them in without a second thought, and then get on with alien blasting, or whatever, until the early hours of the morning. It may be of interest, however, to look at just how the joysticks are usually connected up to the analogue port. As shown in Fig. 1, each joystick is, in fact, a pair of potentiometers wired between \( V_{ref} \) and ground. The fire buttons act by shorting the pushbutton inputs to ground. The figure shows the connection from the wiring side of the plug. With the four-channel ADC (described last month), there is clearly no problem catering for two independent joysticks.

The 'fire' or pushbutton inputs are internally connected to PB4 and PB5 on the system VIA. The levels on these inputs are normally at logic 1, but change to logic 0 when the corresponding button is pressed. The easiest way to read the state of the pushbuttons, however, is to use the BASIC ADVAL function. Using the following statement:

\[
X = \text{ADVAL}(0) \text{ AND } 3
\]

will give the following values for \( X \), depending on the button states as follows:

- \( X = 0 \): no buttons pressed
- \( X = 1 \): left button pressed
- \( X = 2 \): right button pressed
- \( X = 3 \): both buttons pressed

The left button is labelled button 0, and the right one button 1 on the connector drawing.

Clearly the fire buttons can be replaced by almost any other switch, or by any circuit which switches between two states. This can be a useful addition to the user port in applications which require more lines than those available.

LOW COST JOYSTICKS

Adding joysticks to the BBC Micro can be relatively expensive since analogue potentiometer types are required. Mr. A. Moran of Reading has suggested a simple way of interfacing the lower cost switch type of joystick via the user port. Usually, it is necessary to build some form of interface between the analogue port and this type of joystick, but his approach does away with that problem, and allows a lower cost solution to be produced. Indeed, if you don't already own one, you could even try building your own switch joystick using two 2-way centre-off switches, some rubber bands, and a pushbutton switch; any offers for a design?

The interface to the user port is shown in Fig. 2, where the connections are those for a Philips G700 joystick. The connections for other popular models such as the Atari, Competition Pro, Quickshot, etc., are all similar. If in doubt, a simple battery and bulb arrangement will allow the exact connection details to be determined. The pull-up resistors are to ensure good noise immunity. With the joystick connected in this way, the switches will return a logic 0 when closed. Listing 1 provides an interesting demonstration of the joystick at work. The relationship between the user port bit values, and the joystick movements, are given in Table 1. The program allows an asterisk to be moved around the screen, and produces a satisfying 'zap' when the fire button is pressed. The program also allows diagonal movement by testing each direction independently.

In passing, readers may already have noticed in last month's column that long lines in program listings have been broken for printing. This has been done manually (hence all of the mistakes are mine!), in an attempt to break each line at an identifiable point. This is to try to avoid the problems which can occur when an automatic line breaker is used, and I do try to break lines at obvious points like commas or where extra spaces will do little or no damage.

<table>
<thead>
<tr>
<th>User Port</th>
<th>Joystick Value</th>
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<tr>
<td>( \text{UP} )</td>
<td>1</td>
</tr>
<tr>
<td>( \text{DOWN} )</td>
<td>2</td>
</tr>
<tr>
<td>( \text{LEFT} )</td>
<td>3</td>
</tr>
<tr>
<td>( \text{RIGHT} )</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 1. Switch values
FIRE BUTTONS FROM ASSEMBLER

It will not always be the case that reading the fire buttons is something you will want to do from a Basic program. If speed is
of the essence, or if the buttons are to be read from a sixties ROM, machine code is really the only answer. In previous months we have looked at how to read the VIA registers directly. The operating system, however, includes powerful and flexible facilities which can be called from either Basic or machine code programs. One group of facilities available to the machine code programmer is provided by the OSBYTE calls. In order to use these it is simply a matter of taking a subroutine call to &FFFD. When the call is made, the CPU registers should be set up with the following states:

A selects the OSBYTE facility required
X may contain an OSBYTE parameter
Y may contain an OSBYTE parameter

Only some OSBYTE calls take parameters, but when they are required, they are passed in the X and Y registers. So far, so good, but how do we read the fire buttons? An OSBYTE call with A=80 and X=0 is the equivalent of the ADVAL(0) call in Basic. When the call is completed, the value in bits 0 and 1 of the X register (i.e. the two least significant bits) indicate the logic state of the fire buttons. A bit is set to 0 if the button is pressed, since the circuit is such that when a button is pressed, it connects the otherwise floating input to ground. As with all theory, however, we really need a practical example to see all of this at work.

LIGHT SENSOR

The simple interface shown in Fig. 3 detects light falling on the photo-Darlington transistor. In darkness or low light levels the transistor is virtually non-conducting, and hence the output is very close to +5 volts. When sufficient light falls on the lens of the transistor (which has a transparent case), it turns on and the output level falls to less than 1 volt.

The logic gates following the sensor output provide some simple signal processing. Gates (a) and (b) buffer the transistor output to indicate 'light' and 'dark', respectively, when the output is at logic 1. The remaining gates are arranged as a latch which allows any change to be remembered.

The latch is reset by a low level from the manual reset switch; this could easily be replaced by an input to pin 13 on gate (d) from a computer output line, e.g. the user port. The latch allows the circuit to remember any event which causes the transistor to switch until the computer has time to take note. Holding the reset switch in the reset position all the time disables the latching action. Depending on whether the 'light' or 'dark' input is fed to the latch (pin 8), the latch will remember either a dark or light event, e.g. a beam of light being broken, or a light being turned on, respectively.

INTRUDER ALARM

One of the natural applications for this type of interface (which will work just as well with the user port) is in intruder alarms. This is how the circuit of Fig. 3 is shown configured. The flip-flop is arranged so that when the beam of light falling on the transistor is broken, the latch output changes from 0 to 1, and stays there until the reset line is taken to 0. The 'dark' output is at 1 when the beam is broken, or reverts to 0 when the beam is restored. An advantage of this arrangement is that if either lead is cut, the line will float to an alarm level, hence defeating the attempt to silence the alarm!

In use, it is best to limit the field of view of the transistor by enclosing it in a case with a small aperture cut in one side. The curved surface of the transistor package acts as a lens to direct the light onto the base junction. The light source can be almost anything; daylight from a window or room lighting at night. If the alarm is set off continously, reduce the amount of stray light by using a small tube (painted matt black on the inside) over the aperture pointing at the light source.

Listing 2 is an example of an intruder alarm based on the circuit given. The software assumes that the latched output is connected to the right fire button (P81), and that the 'dark' output is connected to the left (P80). The program includes the

Listing 1. Joystick demo

10 REM Joystick Demo: Andrew Moran
20 REM -----------------------
30:
40 ENVELOPE 1.1,4,-4.12,10,20,20,
50 .0,0,-.5.100,100,
60:
70 REPEAT
80 01X:01Y: J=(255-7A650)
90 IF J=16 ROUND 1.1,50:1, J=16
100 IF J=16 SOUND 1.1,50:1: J=16
110 IF J=16 SOUND 1.1,50:1: J=16
120 IF J=16 SOUND 1.1,50:1: J=16
130 IF J=16 SOUND 1.1,50:1: J=16
140 PRINTTAB(01X,01Y)"" print Tab
150 PRINTTAB(01X,01Y)"
160 UNTIL FALSE

Listing 2. Light sensor demo

machre code technique described above for reading the fire button inputs. The alarm goes off when the light beam falling on the transistor is broken; simply press the reset button to silence it!

NEXT MONTH

BBC Micro Forum will be looking at a simple light pen for your micro.
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The NEW educational product range from Flight Electronics Ltd, all of which may also be used as low cost development systems for engineers working on low budgets.

**SPECIFICATION**

**AC ADAPTOR JACK:** 1/P DC +12V, 800mA

**POWER SW:** AC ADAPTOR

**BATTERY:** 1.5V x 4

**PULSE SW:** Two bounce-free pushbuttons

**LOGIC SW:** Eight logic level switches in DIP type

**DC O/P:** DC +5V, 750mA for user.

**B.023 BREADBOARD:** Solderless breadboard with 1580 interconnected tie points

**CLIP TERMINAL:** Logic probe clip terminal

**BATTERY HOLDER:** 1.5V x 4

**LED DISPLAY:** Eight LED buffered logic level indicators

**BNC JACKS:**

**SELECT SW:** Clock range selection

**LOW:** 10 - 40 Hz

**HIGH:** 1K - 20K Hz

**BANANA JACKS:**

**CLOCK ADJ:** Fine adj. of clock frequency

**Includes Logic Probe**

**2 MPF-1/B**

**PRECONDITION:**

**MICROPROCESSOR:** 16 bit CPU Intel 8088, 4.77 MHz version with an 8-bit data bus

**RAM MEMORY:** 4K standard RAM on two 2K byte RAM chips. Expandable to 24K by using three 8K byte RAM chips.

**ROM MEMORY:** 16K standard ROM on two 8K byte ROM chips. Expandable to 48K by using three 16K byte ROM chips.

**ROM memory contains program code for the monitor, line assembler and disassembler.**

**DISPLAY SCREEN:** 20 character x 2 line LCD display shows any two lines of a 20 character x 24 line logical screen.

**KEYBOARD:** 59-key, full-size QWERTY keyboard

**PRINTER INTERFACE:**

**PRINTER INTERFACE:** Centronics standard parallel interface with 16-pin connector.

**CASSETTE INTERFACE:** Can be used with any monaural cassette recorder.

**RECORDING SPEED:** 1000 - 2000 bits/second.

**BUS CONNECTOR:** 62-pin IBM

**3 MPF-1/55**

**ADVANCED INTERACTIVE MONITOR:**

**THE HEART OF THE MPF-1/55 SOFTWARE RESIDES IN 16K BYTES OF ROM.**

**DISASSEMBLER:** The built-in disassembler allows the user to keep the contents of the RAMs.

**8K ROM:** Sophisticated monitor expandable to 16K.

**INSTRUCTIONS:**

**INPUTS AND OUTPUTS:**

**AUDIO SPEAKER:**

**AUDIO CASSETTE INTERFACE:**

**1000 Baud**

**PARALLEL PRINTER INTERFACE:**

**CENTRONICS/EPSOM**

**VIDEO MONITOR INTERFACE:**

**COLOUR TV INTERFACE:**

**SYSTEM EXPANSION CONNECTOR:**

**50-pin connector to provide interface with RS-232C or ROM cartridges**

**KEYBOARD:** Standard calculator 49-key keyboard with 153 ASCII codes

**PROFESSIONAL DOCUMENTATION:**

**User's Manual and Monitor Source Code Listing Manual are standard.**

**4 MPF-1P**

**280 CPU high performance microprocessor with 158 instructions.**

**4K RAM:** Battery Back-up circuits provided for the user to keep the contents of the RAMs.

**8K ROM:** Sophisticated microprocessor instructions on both printer and video display.

**SCREEN EDITOR:**

**TEXT EDITOR:**

**TWO PASS ASSEMBLER:**

**PRINT DRIVER:**

**DEBUGGING FEATURES:**

**20 Digits. 14 segment green phosphorescent display.**

**49-key alphanumeric keyboard including editing and functional keys.**

**Audio cassette interface:** 165 baud average rate for data transfer between memory and cassette.

**Extension connectors:** all CPU buses usable for expansion.

**225° diameter speaker.**

**9V, 1.0A adaptor provided.**

**Three complete self-learning textbooks with instructions.**

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4. (9)  How to Build Your Own Solid State Oscilloscope £21.70
5. (5)  International Transistor Equivalents guide £32.75
6. (8)  How to Design and Make Your Own PCBs £28.95
7. (2)  Power Supply Projects £29.75
8. (-)  Radio Control for Beginners £19.95
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