PRACTICAL ELECTRONICS

NOVEMBER 1990 • £1.50

SCIENCE AND TECHNOLOGY

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NICAD CHARGING ADAPTOR
Plugging you into non-stop listening

LASERS
Telling tales of technology riding on a light-beam

BASIC ELECTRONICS
Understanding opamps, the universal tools of the analogue world

Anyone can win with our READER LOYALTY BONUS

See page 39

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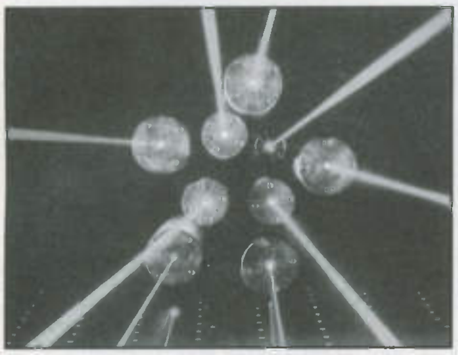

NEXT MONTH

BY POPULAR REQUEST!

"Set it free", was the cry after we showed you how to control a robot car tethered to a computer. And, "Set *us* free", was another cry after we presented you with some embedded microcontroller projects : "show us how to program our own 8748s!" Well, we're slaves to your command and two of our designers have lately been chained firmly to their irons. The pains of their toil will be brought before you next month, satisfying both calls for freedom. A masterful stroke! And there's more freedom for pedallers: part two of the Bike Computer with construction and alternative microcontroller use details. We've the usual liberal selection of unfettered features too, and the 1990 Annual Index.

PLUS

A BUMPER BONUS: GREENWELD'S 132 PAGE CATALOGUE!

★ UNSHACKLE YOUR DESIRES WITH OUR DECEMBER 1990 ISSUE

★ ON RELEASE FROM FRIDAY NOVEMBER 2ND

PE LIBERATES TECHNOLOGY FURTHER - BE PART OF IT!

★ ★ ★

PRACTICAL ELECTRONICS

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EASIER VCR

Recent research by Ferguson has indicated that as many as 28% of users either never set the video to record or find it difficult to do so. Ferguson recognise that ease of use and ease of programming are critically important factors for new users and replacement purchasers alike and has introduced a couple of video recorders which should help to overcome the problems experienced by so many people.

The new Videostar FV41R and the FV42L feature Instant Help Programming (IHP), a full on-screen programming function with 'Instant Help' pages.

IHP is unique to Ferguson and makes life easy by guiding users step by step through the programming process. Whatever stage the user is at, a simple press of a button will give instant access to one of several instant help pages, providing a comprehensive on-screen facility.

A useful facility is the 8-event over one year timer. Events can be recorded in any order, and a daily/weekly repeat facility allows the allocation of events to regular times. A particularly unusual extra feature is the ability to switch on the television set a pre-determined time. Another useful feature is the Go To function enabling the tape to be automatically wound to a specific counter number.

And, very relevant to the increasing availability of channels, is the 40 programme frequency synthesis tuner, enabling the channel number to be directly keyed in quickly and easily.

The information received about these VCRs does not specifically mention the number of events that can be pre-programmed for non-repeat recording. The remote control handset can handle four events, so it is likely that the VCR handles the same number. This is another area to which Ferguson should possibly give attention: four events are not enough when people go on two weeks holiday and perhaps want to record many more short events which are within the limits of the tape length. Perhaps an automatic tape changing facility would be useful too.

These two new machines should now be **in your local high street shops**, at around £329 for the standard play FV41R, and £349 for the 8-hour long play FV42L.

SUPER BRIGHT LEDS

Panasonic's new low cost ultra-bright Galium-Arsenide leds have become available through Trident Microsystems. The leds have been designed for bright ambient light applications and use high efficiency chips, providing two candellas at a forward current of 20mA. They feature a 5mm diameter lens made from a water-clear material, which focuses the light forward into a very narrow viewing cone.

Applications include outdoor display or information boards, or emergency signalling in any equipment where bright red graphics are required. The forward voltage drop is typically 1.8V.

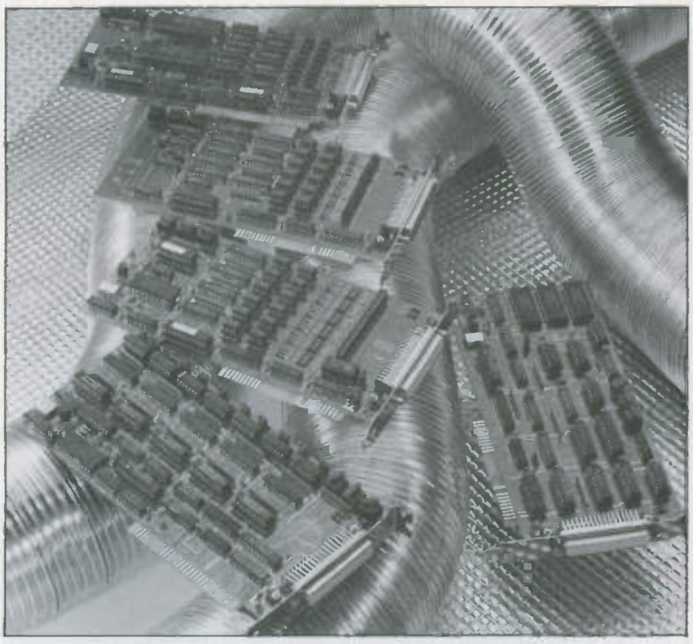
For further information contact John Turney, Trident Microsystems Ltd, Trident House, 55 Ormside Way, Redhill, Surrey, RH12 2LS. Tel 0737 765900.

Our browse through recently received literature

Multi Sources have introduced themselves to us sending through data on some of their products. For over two years they have been **marketing DC Metrology products** manufactured by Measurements International Ltd, utilising National Research Council of Canada's innovative technology. In addition Multi Sources are manufacturers of **pulse sources and generators**. The data received covers some of those products, including low cost high performance pulse generators, an automated potentiometer system, a four terminal scanner, and an automated dc voltage calibration system. These products are unlikely to be of interest to the average hobbyist, but PE readers in the test and development sectors of the trade should find benefit from asking for more information from **Multi Sources**, Unit 2, Stable Yard, Downs Barn, Milton Keynes, Bucks, MK14 7RZ. Tel: 0908 666042.

Harrison Electronics has sent through a 6-page list of surplus components for sale. Since it is dated July 1990 it is reasonable to suppose that the company **specialise in surplus components** and issue lists on a regular basis. This particular issue is devoted mainly to integrated circuits, from cmos **4000 to all varieties of 74ttl**. Also included are linear ics, microprocessors, diodes, transistors, triacs, regulators and crystals. If you are looking for a quantity source of surplus parts at reasonable prices, give Harrisons a call, note though that there is a minimum order charge of £25 plus vat. **Harrison Electronics**, Century Way, March, Cambs, PE15 8QW. Tel: 0345 51289.

Gem-Tech have sent in their interesting new catalogue. It is aimed at anyone who loves electronics and wants to build simple and useful projects, and to learn from doing so. To back up the kits are a range of other items, including a good selection of books to teach you more about electronics. There is also a cross-section of the essential tools which any enthusiast is likely to need, from screwdrivers and soldering irons, to meters and other important test gear. To round off nicely, printed circuit board making materials are available too, plus an excellent CAD pcb design software package. There are some valuable discounts on offer this month. **Gem-Tech**, Unit J, 8 Finucane Drive, Orpington, Kent, BR5 4ED.



PC-BUS EXPANSION BOARDS

Arcom has developed a new range of control and monitoring I/O expansion boards for IBM-compatible PCs. The range offers unprecedented levels of system integrity and ease-of-use, say Arcom.

The fundamental limitations of existing PCbus devices has been addressed by Arcom's range, which use an evolution of the PC I/O scheme. The limitations addressed include the difficulty of finding free PC I/O address space for expansion boards, inadequate specifications for industrial tasks, and the lack of a coherent and well-defined signal conditioning scheme to make connection to the real world.

The new I/O boards can be fitted and proven operational in minutes, tested and maintained with ease.

For more information contact Anthony Winter, Arcom Control Systems Ltd, Units 8-10 Clifton Road, Cambridge, CB1 4WH. Tel 0223 411200.

DYNAMIC DUO

Two new low cost analogue multimeters from Alpha are ideal for a host of general purpose applications. Both measure ac and dc voltage, direct current, resistance, dBs, and have a diode and battery test function. Pivot and jewel screw mechanism with a mirror scale are features of the analogue displays, which have both fuse and diode input protection.

Model AM1001 is the smaller of the two, measuring just 100 x 65 x 32mm and weighing only 110gms. Both ac and dc voltage can be measured to 500V and direct current to 250mA. AM2001 measures 1000V on both ac and dc plus direct current to 10A. One drawback of the AM1001 for some hobbyist experimenters is that its dc sensitivity is only 10k ohms per volt, placing more load on some circuits than may be desirable. The other meter, though, the AM2001, has a better sensitivity of 20k ohms per volts.

Both models are fully guaranteed and supplied ready for use with test leads, battery, spare fuse and instruction manual. The prices are £9.95 and £19.95 respectively, plus vat.

For more information contact Alpha Electronics Ltd, Unit 5, Linstock Trading Estate, Wigan Road, Atherton, Manchester, M29 0QA. Tel: 0942 873434.

If you are organising any event to do with electronics, big or small, drop us a line,

Please note : Some events listed here may be trade or restricted category only. Also, we cannot guarantee information accuracy, so check details with the organisers before setting out.

Oct 18-19. Direct to Home Broadcast by Satellite. IEEIE conference – registration £105 per day. IBA Conference Hall, Brompton Road, London SW3. 071-836 3357.

Nov 6-8. Total Solutions. NEC Birmingham. 0799 26699.

Nov 27. Installation and Maintenance of Security Equipment. IEEIE symposium. National Motorcycle Museum, Solihull. 071-836 3357.

1991

Mar 19-21. Nepcon Europe and Electronics International (formerly British Electronics Week). NEC, Birmingham. 0799 26699.

April 17-18. Laboratory Manchester. Windsor Hall, G-Mex Centre, Manchester. 0799 26699.

May 15-16. Laboratory Scotland. Scottish Exhibition Centre, Glasgow. 0799 26699.

IEE FARADAY LECTURES 1990-91

Presented by the Universities of Bath and Sussex.

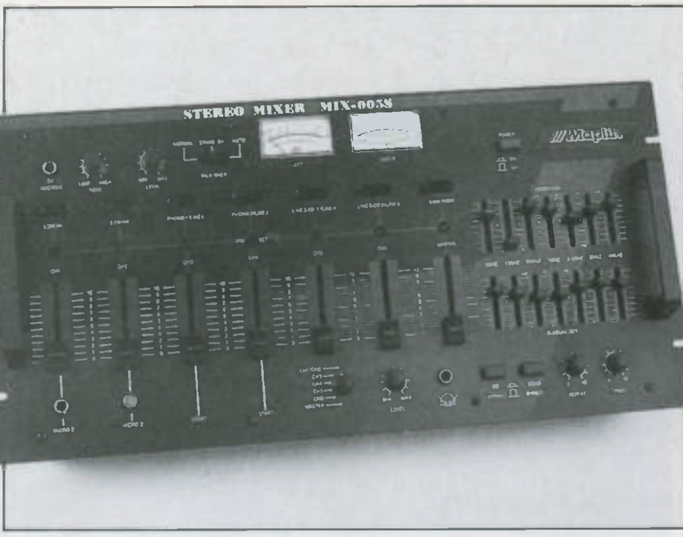
1990: Oct 17 Brighton. Oct 30 Edinburgh. Nov 7 Liverpool. Nov 13 Middlesborough. Nov 21 Manchester. Nov 27 Reading. Dec 4 Coventry. Dec 12 Ipswich.

1991: Jan 15 Exeter. Jan 22 Swansea. Jan 29 Southampton. Feb 5-7 London. Feb 12 Hanley, Stoke-on-Trent. Feb 27 Nottingham. Mar 6 Sheffield. Mar 13-14 Bath.

For free tickets and further information contact (enclosing SAE) The Faraday Officer, IEE, Michael Faraday House, Six Hills Way, Stevenage, Herts, SG1 2AY.

MICROPROCESSOR TRAINING COURSES

In conjunction with Colchester Institute, Flight Electronics is offering a range of intensive four-day microprocessor courses. Contact: Suzanne Kittow, Flight Electronics Ltd, Flight House, Ascupart Street, Southampton SO1 1LU. Tel: 0703 22721.



MIXING WITH THE BEST

Primarily intended for use in disco applications, Maplin's professional audio mixing desk should surely raise the roof and the amp levels! The boldly coloured (red and black) stereo mixer has six main input channels, each with preset level and slide fader controls.

Channels one and two are mic inputs with switches to select low or high levels. Chans three and four, and turntable/line level inputs are switch selectable. A special feature on these channels is the provision of auto (turntable) start outputs. Channels five and six are cd/line level inputs, which are also switch selectable.

Additional to the six main input channels is a DJ mic input with tone, level and talkover. A headphone monitor output with level control is provided and a rotary switch allows selection of the input channel to be monitored. Alternatively the master output may be monitored.

Two seven band (left and right) equalisers are provided to enable the master output to be equalised to suit room acoustics. The mixer also has a bucket brigade (BBD) echo circuit that can produce effects ranging from rapid 'slapbacks' to reverb and discrete echoes.

Obviously this is just the job to get that disco swinging!

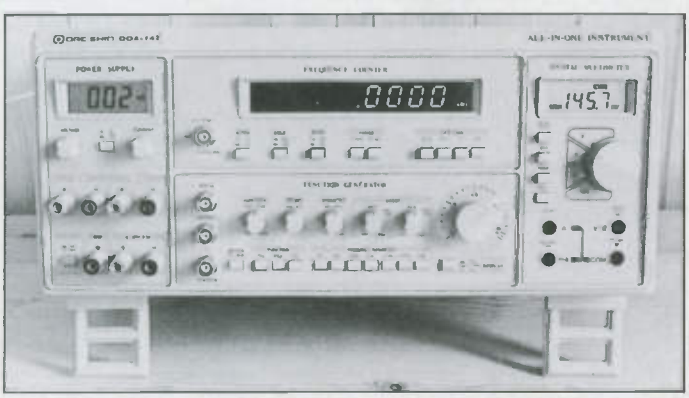
For further information contact any of Maplin's nationwide shops, or their head office at PO Box 3, Rayleigh, Essex, SS6 8LR. Tel 0702 554161.

FOUR IN ONE

A single instrument with four separate test and measuring systems is another new unit from Alpha. Their DOS 141 combines a DMM, function generator, frequency counter and power supply into an easy to use compact instrument.

As you will see from the photo, the instrument is full of functions _ too many to list here. Judging from Alpha's data it is obviously a high accuracy unit offering many applications in R&D, production and education. It is also ideal for the serious hobbyist who is prepared to spend the necessary £395 plus vat.

For further information contact Alpha Electronics Ltd, Unit 5, Linstock Trading Estate, Wigan Road, Atherton, Manchester, M29 0QA. Tel: 0942 873434.

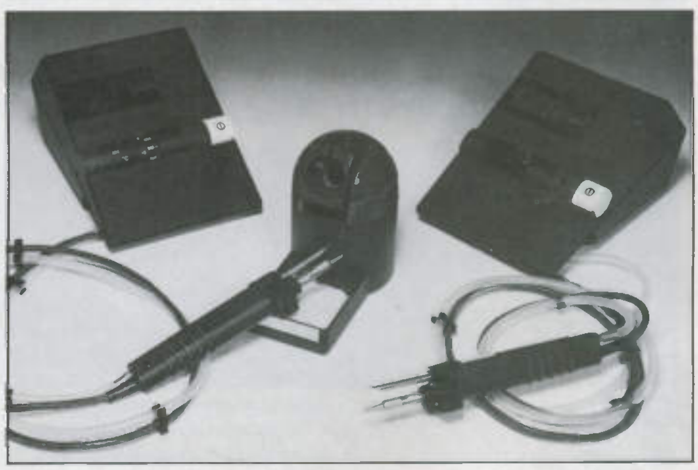


KOMPACT PAGING

Tele-Nova tell us that when they launched their first start-up radio paging system, Kompact, they were overwhelmed by the sheer number of small to medium sized companies who had now recognised that on-site radio paging systems were affordable.

The original Kompact comprises a central decoder and four receivers that simply plug into a mains socket. Now a new model, the Kompact Plus, has been launched. It is an updated system incorporating lightweight pagers as small as credit cards with a simple to use keyboard control that enables operators to contact ket members of staff anywhere on site. Four receivers and a console can be installed and ready for use at £70 per quarter. The system can be expanded to support up to 100 pagers. It can be linked to monitor machinery and interfaced to most telephone systems.

For further information contact Paul Lester, Tele-Nova, 111 Endwell Road, London SE4 2LY. Tel: 081 692 9816.

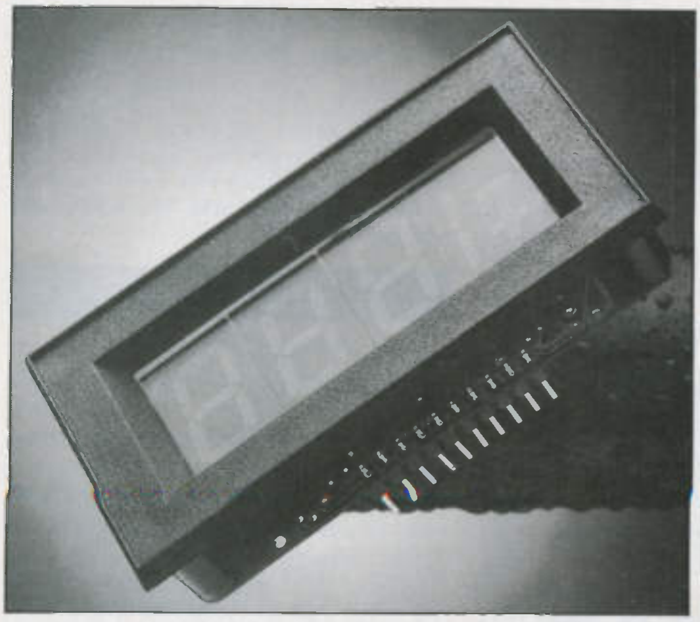


DEFUMIGATING IRON

The fumes from soldering irons really grime up your Editor's glasses after a hard day's work. If yours are too, or you're fed up with the aroma, how about asking Greenwood/Oryx for details of their new iron? The Skylab is a soldering iron that has been designed to also extract fumes directly from the area of the tip itself, reducing the possibility of gasses escaping into the atmosphere. Featuring a lightweight ergonomic design, the iron incorporates the heating element within the tip. The extraction pipe is unobtrusively integrated into the tool itself and can be adjusted or replaced in seconds if required. However, you do also need a standard fume extraction system to which to connect the pipe.

For further information contact Greenwood/Oryx, Portman Road, Reading, Berks, RG3 1NE. Tel: 0734 595843.

NEWS



MULTI-TURN LEDS

There is a new high efficiency three and half digit led digital panel meter module which features optional scaling for its 199.99mV range.

The MDM350 has auto-zero, auto-polarity and over-range indication, and the assembly has single-ended, differential or floating measurements, together with a digital display hold and high stability bandgap reference. A multi-turn scale feature is provided for readouts in engineering units.

The bezel, which fits a 68 x 33mm cut out, is supplied with an antiglare filter and mounting hardware. Supply voltage is 5Vdc at 120mA and the operating temperature is rated at 0°C to 50°C. Temperature coefficient is 50ppm/°C and the error specification is quoted at 0.05%rdg x 32.5mm

For more information contact John Leather, Martel Instruments Ltd, Tanfield Lea Industrial Estate, Stanley, Co Durham, DH9 9QX. Tel 0207 290266.

CONTROLS UNDER CONTROL

Here's a neat idea to get rid of that jumble of remote controls cluttering up your home:

The One For All remote control has just carried off a prestigious Product of Year Award from the Television and Radio Industries Club. It apparently can replace all the remote controls you currently have - and even the ones you don't have!

It is unique from other types of universal remote control because it does not have to 'learn' from the originals, so even if the originals are missing or broken, this control can still be used as a replacement. It is pre-programmed with all the information it needs for every type of home entertainment product you can think of, say the manufacturers, Celtel. You simply select the appropriate 3-digit code from the memory for each of your products. All the features of the original remotes are then instantly at your fingertips.

One For All will control up to 15 different products at any one time and offers many unique features and benefits to the user. At £79.95 the price compares favourably with the other alternatives on the market.

For more information contact Ruth Repton, Celtel Ltd, PO Box 135, Basingstoke, Hants, RG25 2HZ. Tel 0256 64324.

Newsworthy news of your new product could be on these pages – send us details and preferably a photograph

CHIP COUNT

74F1766 DRAM CONTROLLER

The new Burst Mode DRAM Controller (BMDC) type 74F1766 from Philips is a high performance memory timing generator designed to support Page, Nibble or Static Column modes of operation in addition to the normal DRAM access cycles. It performs memory access/refresh arbitration, refresh and memory access timing, RAS interleaving, CAS byte decoding and controls up to four banks of DRAM.

The device generates DRAM timing and so requires a companion address multiplexer like, for example, the 74F1762 Memory Address Multiplexer (already available from Philips) for row and column generation. This provides the flexibility of using the controller with any size of DRAM array by simply choosing an appropriate address multiplexer.

Output drives are designed for incident wave switching for maximum speed of operation so maximising the data rate in and out of the DRAM.

EMBEDDED MICROCONTROLLER 87C552

Philips' new 87C552 microcontroller is the most highly integrated 8-bit type to become available. It is 80C51 based and intended for real time embedded control applications. It incorporates a 10-bit analog to digital converter plus 8K bytes of eprom.

The 87C552 is fully software compatible with the 80C51 and thus provides the user with a migration path across the entire family. In addition to the above features, the microcontroller provides two PWM outputs, two standard counter/timers of the 80C51, an additional timer with four capture registers and three 16-bit compare registers, a watchdog timer, a full-duplex UART and a series IIC interface. The on-chip 8-channel successive approximation a/d converter has a conversion time of 50µs and a resolution of 10 bits.

TLC3204X ANALOGUE FAMILY

Texas Instruments' TLC3204X family of analogue interface circuits (AIC) is designed to provide an interface between a digital signal processor (DSP), such as the TMS320C25, and real world analogue signals. Since it was first released, the family has expanded to provide new options.

The AIC consists of two basic parts, a transmit and a receive section for two-way communication between analogue and digital. All devices in the family have a series of common features: switched capacitor filter (SCF), input anti-aliasing filter and output reconstruction filter; 14-bit dynamic range ADC and DAC with sampling rate variable up top 19.2 kHz; standard modem samplings can be easily programmed; input stage featuring programmable gain to maximise signal to noise ratio; serial port for direct interface to DSP with just six lines.

The TLC32040/42 were the original designs and have a bandpass anti-aliasing filter and a passband of 300Hz-3.4kHz. The difference is in the TLC32042 whose bandpass filter has a less sharp cut off at low frequencies. At 170Hz it is only 2dB down compared to 25dB for the TLC32040. These lower frequencies are important to preserve the quality of speech in some applications. The TL32044/45 are designed for voice band applications with a passband of 150Hz-3.65kHz.

The AIC family is built upon a flexible internal structure, developed mainly for voiceband applications. In high-speed modems for example, as data rates get into the range of 2400 to 9600 baud the cost of a dedicated custom chip solution tends to rise rapidly. A more flexible solution is to use a DSP and an analogue interface.

SOURCE DATA

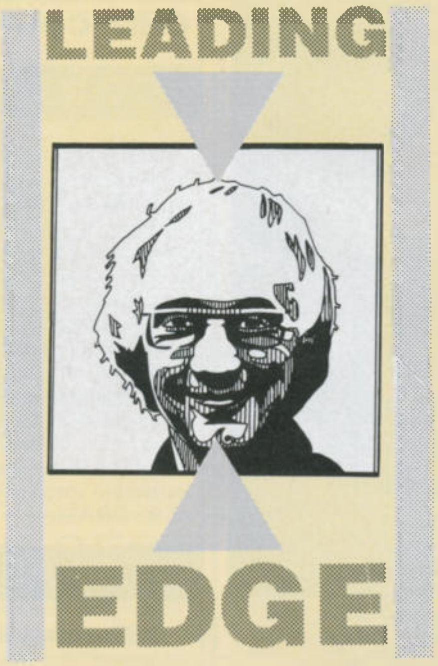
Philips Components Ltd, Mullard House, Torrington Place, London WC1E 7HD. Tel 071-636 0394.

Texas Instruments Ltd, Manton Lane, Bedford, MK41 7PA. Tel 0234 270111.

ELECTRONIC YELLOW PAGES

BY BARRY FOX
Winner of the UK Technology Press Award

Despite BT's market research and EYP upgrading it still seems easier to thumb the printed book than the keyboard.



It hardly seems possible but, after spending nearly three years back to the drawing board, British Telecom's new version of its Electronic Yellow Pages syste as bad as the first version.

In theory EYP lets anyone with a home or business computer search through a database of two million businesses in the UK. For someone in John O'Groats hunting for a business in Land's End, the effort of penetrating EYP might perhaps be worthwhile. But for most people it will still be far easier, and cheaper, to browse through BT's printed Yellow Pages books.

The clear picture I get is of BT's computer boffins dictating "They'll use it our way or not at all".

I first ran across EYP in January 1987 when BT's Yellow Pages division in Reading connected modems to its Vax computers so that anyone with a personal computer or viewdata terminal could program it to access database by telephone. Up to 64 callers could connect at the same time.

BT's publicity made the idea sound attractive; all the user had to do is enter a keyword for a trade or service and let the computer search through its memory and display a selected list of names and addresses.

The first EYP database was a test which covered only the London area plus Reading, Guildford and Watford. Even this restricted database was absurdly incomplete. Only firms which paid for display advertisements in the Yellow Pages book were entitled to a free entry in EYP. After a year only 40% of those entitled to a free entry had filled in the form to claim it. The first time round, only 29% of display advertisers bothered. Firms which had only simple text entries in the Yellow Pages book could not go on the electronic database even if they wanted to.

OBSTACLE COURSE

Although people accessing EYP did not pay a search charge, they had to pay British Telecom for the phone call, to Reading. At the rates of the day, anyone in London using EYP during peak business hours had to pay 4.4 pence per 22.5 seconds on line, equivalent to 12p per minute (plus vat).

To connect with EYP, the caller had to understand enough about computers to load and configure communications software for teletype or videotex transmission mode, match the transmission speed or baud rate with the EYP modem telephone number and then choose the right data, stop and parity bit parameters. Although computer buffs would find this easy, everyday users need to beg or buy advice.

Once connected, the caller faced an obstacle course through the incomplete database. Strings of numbers appeared on screen, from which the caller had to select options and then enter key words. Often these were rejected. Because the EYP system was based on viewdata software which uses 24 line pages, anyone attempting to print out the results of the EYP search onto paper got a string of blank or only partly used sheets.

As a test, I tried using EYP to search for a London dealer who sold pumps for a pond. Not counting the time spent setting up the computer parameters, it took 10 minutes and 20 sheets of paper to achieve nothing. For example, I could not stop EYP offering me the London region Ponders End.

By comparison, it took exactly one minute to take the printed Yellow Pages book off a shelf, look up "pond", follow one cross reference go straight to a firm advertising pumps for ponds.

BT's £0.5m campaign of full page newspaper advertisements, posters and radio commercials for EYP attracted nearly 40,000 potential users, which was around 25% of the estimated number of computer owners in the catchment area. But after a year BT admitted that there was a hard core of only 2,000 regulars left. The others had given up. BT then paid market researchers to phone the drop-outs. The researchers admitted that they heard again and again how users found the system incomprehensible, unfriendly and unusable.

CRITICAL TRIALS

When I phoned, Paul Fry business development manager for EYP, he put on a brave face.

"It was only a trial. We wanted to find out what people wanted by offering them something and then asking what they thought of it. We now know that what people want is wider scope and a more powerful search - although I don't think they realise that this will entail more effort learning how to set up the search parameters".

The EYP system invited callers to leave a message on the computer saying what they thought of the system. Fry told me that he was encouraged by the fact that out of 3,000 messages left, fan mail outnumbered hate mail by 3:1. But as leaving a message was as awkward as searching, it seems likely that many people gave up on EYP before learning how to leave a critical message.

Soon after, EYP's computer mailed me a personalised circular letter.

"I am pleased to say that there has been a great deal of interest shown in EYP" wrote Mike Rowley, Head of EYP "and the response has generally been very favourable".

"We don't see the current system as long term EYP", said Fry when I asked him what on earth was happening. "We are already designing EYP II, a second generation system to take criticism into account". His plan was to launch a revamped system late in 1988.

ENHANCED SERVICE

Now, two years late, EYPII is finally ready and BT is sending a circular letter to those who tried EYPI, urging them now to try the new "enhanced national service". This, says BT, provides a database of 2 million businesses, available at any time.

The new service is cheaper to use, because it uses one national dial up number (0345 444 444) which is charged at local call rate from anywhere in the UK. Connection is easier, because the EYP modems now automatically intelligently set themselves to match any data speed (up to 240 baud) and all the length and parity settings used for electronic mail communication.

Continued on page 43. ➡

PRACTICAL
ELECTRONICS

ON YOUR MICRO-BIKE

At the beginning of this year's promising Spring while continuing my cyclic exploration of the Thames Estuary, I chanced upon another cyclist of like-mindedness. We exchanged pleasantries about the technology of our respective machines, the prime cause of my interest being the computer he had on his handlebars.

It measured about two-by-two inches and was less than an inch thick. Its top surface was almost entirely taken up with a liquid crystal display, plus a couple of touch keys. He said it had been a present from a relative in France, and although not knowing the exact cost, thought it was around £35-£40. One key controlled the display of three journey factors: speed, distance, and elapsed time. The second key simply switched the unit on and off, which caused all the trip data to be lost: its memory was volatile.

My imagination was set into high gear by this unit and I began considering the best way of making one. To achieve such miniaturisation the manufacturers would have incorporated everything on to one chip: software, lcd, microprocessor, the lot. This, regrettably, is where the hobbyist constructor is unable to compete. There's no way in which the size of his unit could be achieved without having the backing of industrial facilities. I thus gave thought to what techniques could be used by the readers for whom I would also be designing my micro-cyclo.

Obviously, it had to be microprocessor controlled, the lcd had to be readily available, and the unit had to have appeal to a readership with a wide range of capabilities. For a while, I was severely tempted to make the unit as small as I could. This would have required the use of an embedded microcontroller, a device which embodies the microprocessor itself, plus eprom, memory and interface circuitry. The problem here is that such devices, like the 8748 for example, need special programmers - a factor which deterred some readers from building two recent PE projects. I also decided to give readers the opportunity to build a general purpose controller as well. Consequently, I opted to design the unit around a well established microprocessor, the 6502, plus standard peripheral chips.

The big advantage of the 6502 is that it is a device that has been around for a number of years and many readers have computers which use it, or variations on it, and so are more likely to be familiar with its coding language, and to have the facilities for programming it. The 6502 is very much still part of the mainstream scene, despite the proliferation of more sophisticated processors. It has also been upgraded by the manufacturers. The cmos version which I use here, the 65C02, has a lot more command calls available on it than the original device, but is essentially pin and code compatible. Another advantage of the 65C02 is that it consumes less power, making it better suited to battery use. And, unlike the original, it doesn't need external pull-up resistors.

To use the main control board on its own as a microcontroller for other applications, all you really need to do is change the eprom contents! But as a bike computer, the complete unit does far more than the one that inspired me.

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ISSN 0032-6372

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The aim of this exciting computing and leisure project is three-fold:

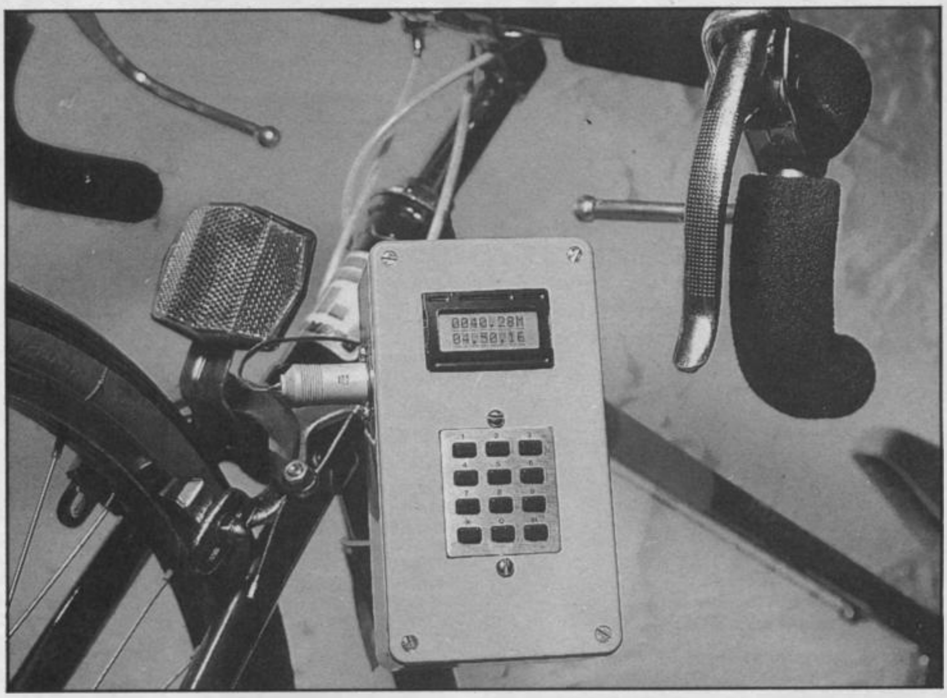
* To enable you to build a micro-controlled unit that will tell you all the essential details about your journey on a push-bike or other wheeled vehicle.

* To use the main circuit board as an independent microcontroller under command from eprom data of your own choosing.

* To show those of you who have had no experience of microprocessors that at their simpler levels they are easy to use and that you need have no fear of experimenting with them.

In its complete form, the project consists of the cmos versions of a 6502 microprocessor and 6522 VIA interface input-output controller, an eprom or eeprom containing the instruction codes for the microprocessor, a 2K non-volatile memory chip, a power-saving circuit, a push-button function selector, and a 16-digit alphanumeric lcd display. The block diagram is shown in Fig.1.

The bike computer keeps track of eight parameters during the course of your journeys:



BIKE COMPUTER

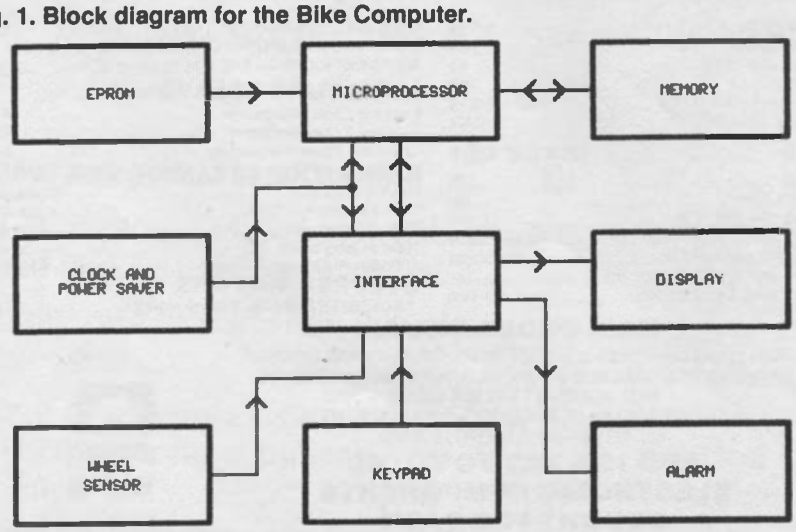
Monitor your pedal power with John Becker's micro-cyclo – and gain a general-purpose 6502 micro-controller as well.

* current speed
* distance travelled since start of trip
* peak speed reached during trip
* average speed during trip
* elapsed time since start of trip in hours, minutes and seconds
* elapsed time since start of trip expressed as decimal hours
* total revolutions of the wheel since start of trip
* total distance travelled since computer was first installed.

All distances and speeds are shown in miles and kilometres according to the switch function selected. You may instantly switch between the two measurement systems.

All functions may be reset to zero at any time, except for the total distance travelled since the computer was first installed. The latter parameter is reset to zero when the eprom is programmed.

Fig. 1. Block diagram for the Bike Computer.



The computer may be used with any wheeled vehicle and with wheels of any diameter. The data for a given diameter is set into the eprom during initial programming.

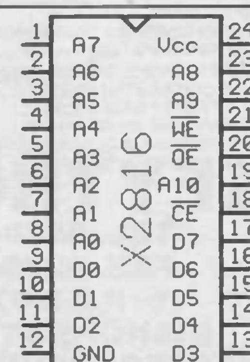
A ninth option is also provided :

* to use the bike computer as a security alarm controller triggered by unauthorised use of the bike. Resetting of the alarm requires a code number to be correctly entered on the keypad.

PROGRAMMED EPROMS

In order to complete the project you will need a fully programmed eprom or eeprom. To program it yourself you will need an eprom or eeprom programmer capable of handling 2Kbyte devices (16384 bits arranged as 2048 words x 8 bits) having the pin configuration shown in Fig.2. Alternatively, you may care to take advantage of a friend of mine who has kindly agreed to supply pre-programmed chips. Details later.

Fig. 2. 2816 eeprom pin-outs



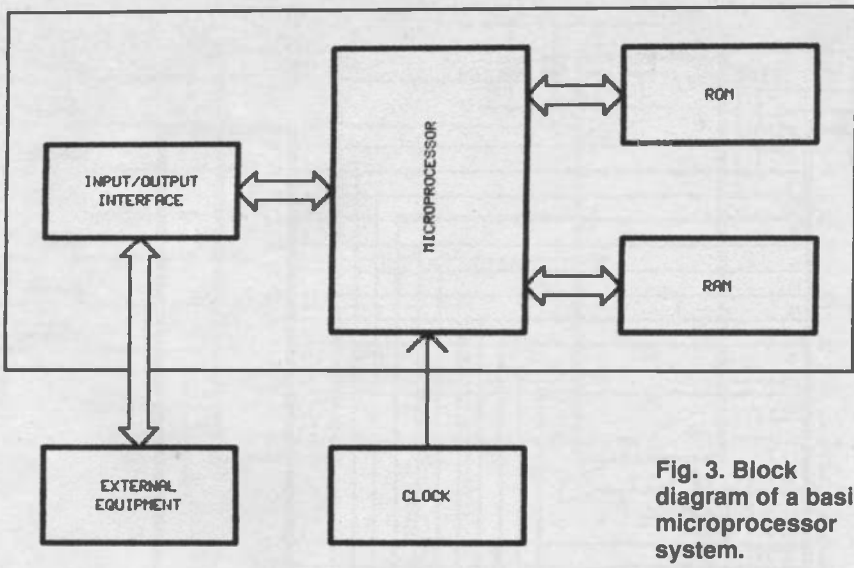


Fig. 3. Block diagram of a basic microprocessor system.

MICROCONTROLLER

There is a minimum of four hardware sections required for any microprocessor controlled system, as shown in Fig.3. The microprocessor is the heart of the system and it has been designed and manufactured to perform a number of arithmetic or logical functions in response to specific binary code instructions.

The instructions are stored in a non-volatile memory which usually takes the form of an eprom (electronically programmable read only memory) or an eeprom (electrically erasable read only memory). It is also possible to use a battery-backed rom to store the data, though not with the same degree of data security. In use, eproms and eeproms are identical in purpose; the main difference between them is that the former can only be reprogrammed following erasure by exposing it to ultra-violet light, whereas the latter can be erased or reprogrammed simply by changing the logic level on one pin. At least one random access memory (ram) is required with the system. This allows for the temporary storage of data by the microprocessor during its processing operations, and for storing data which may have been derived as the result of calculations or from external sources. More than one ram can be used to increase the memory capacity. The ram is usually of the volatile type, that is, it loses its data when the power is switched off. Alternatively, a lithium battery-backed ram may be used which can retain its data for at least ten years without external power.

An eeprom may be used for secondary ram storage providing the number of changes to its data are likely to be few - an eeprom typically has a life time of 100,000 data changes. Since the internal requirements of a microprocessor may produce this number of changes in less than a second, an eeprom cannot be used as the primary ram.

The fourth hardware block required is the input-output block, allowing data to be exchanged between the system and the outside world.

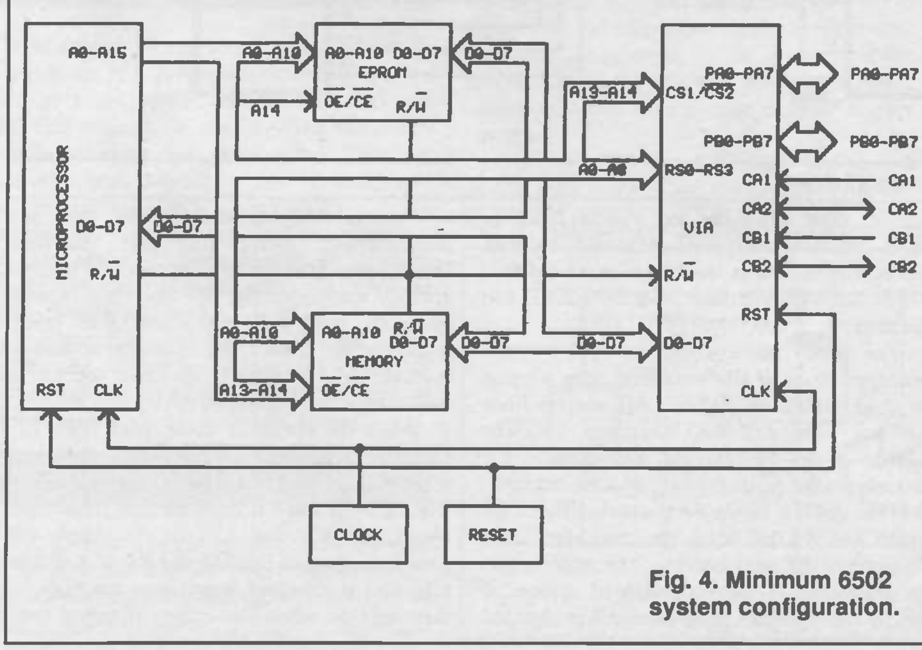


Fig. 4. Minimum 6502 system configuration.

BLOCK EXPANSION

The block diagram of Fig.3 is expanded in Fig.4 to show the typical interconnections between a microprocessor of the 6502 type and its three associated hardware blocks.

The 6502 has eight data lines which have the joint function of inputting and outputting data to and from rom, ram and the interface device. There are 16 address lines originating from the 6502 which are responsible for selecting which rom, ram or interface device is to be accessed and at which address within it. The devices are arranged so that each address can be treated as unique, ensuring that data conflict between the devices is avoided. Whether the devices are to be written to or read from is controlled by the R/$\overline{W}$ line. Other lines allow for the microprocessor to be interrupted during processing, or reset.

A separate clock generator sends the necessary timing pulses to the microprocessor triggering it to perform each instruction and internal operation. The clock pulses are usually produced at a crystal controlled frequency of at least 1MHz to ensure consistent high speed timing. However, they do not need to be so fast or so accurate and less precise and slower clocking rates can sometimes be used (although not in the Bike Computer).

MICROCONTROLLER CIRCUIT

Fig. 5 shows the actual interconnection details of the four parts of the microcontroller as required for the Bike Computer. For this application you will see that not all of the address lines are used, and that four inverters, IC5a-d, have appeared.

IC5b and its associated circuitry form the clock pulse generator running at 1MHz, as determined by the crystal's natural frequency. This clock frequency is routed direct to VIA chip IC3, and indirectly to IC1, for reasons we shall see presently.

Between them, IC5c, IC5d plus R1 and C1 control the initial resetting of the system when it is first switched on. At switch on, C1 will be completely empty of charge, consequently the outputs of IC5c and IC5d will respectively be high and low, so holding at reset the microprocessor IC1 via its pin 40 and the VIA (versatile interface adaptor) chip via its pin 34.

C1 begins to charge up via R1. As soon as the charge has risen sufficiently, IC5c and IC5d invert their output states, removing the reset level from IC1 and IC3. This condition will remain for as long the power is switched on.

INITIALISATION

As soon as its reset pin has gone high, the microprocessor becomes active. The first thing it does is to look at the eprom, IC2, to get its first instruction. That instruction is always located at the very last two addresses within the eprom, and it takes the form of another address to which the processor must then jump.

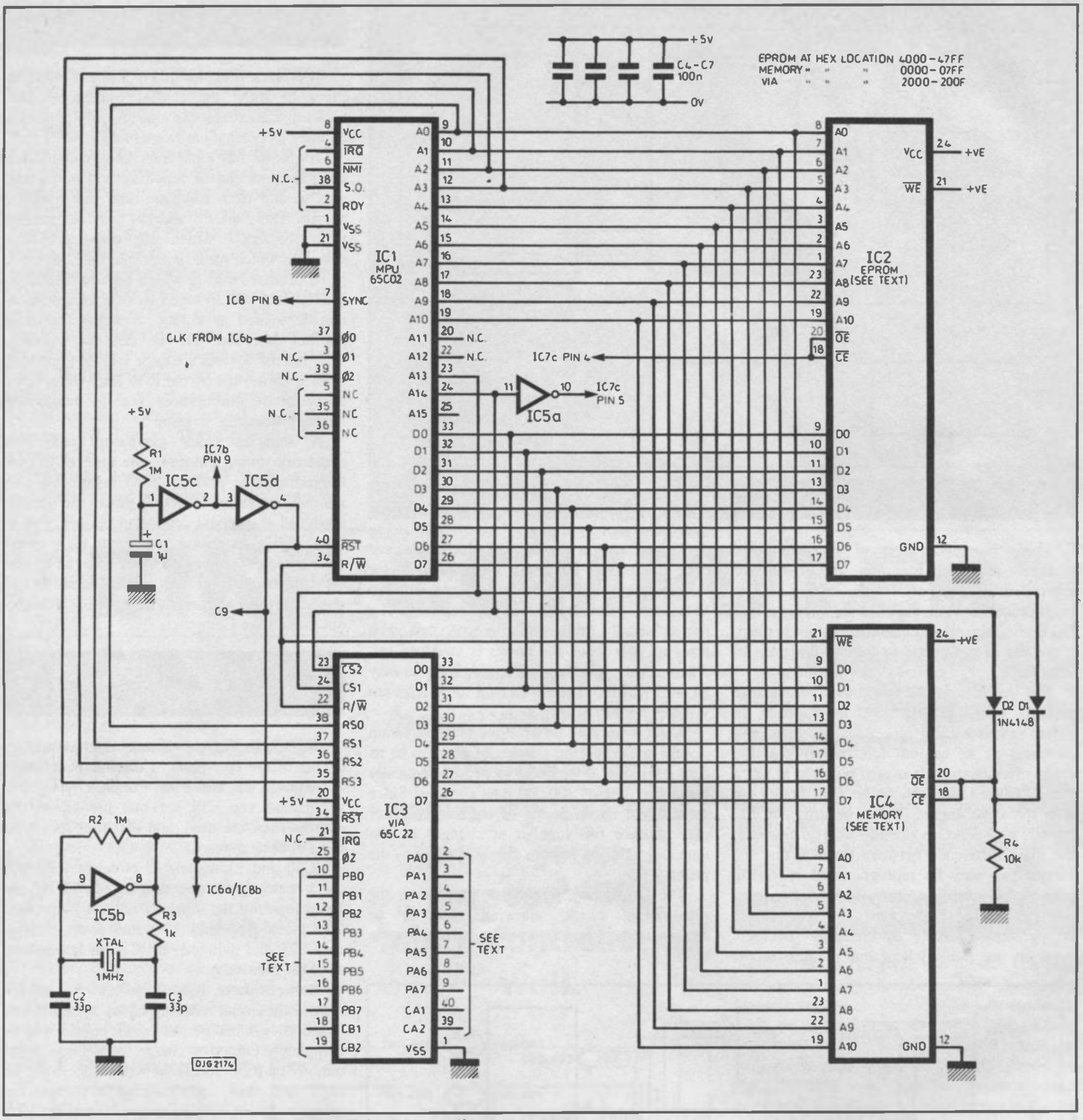


Fig. 5. Main circuit diagram for the bike microcontroller.

When designing a microprocessor-based system, the designer must always consider how the microprocessor is going to know where the eprom is located in order to get its first instruction byte. What the microprocessor does is to send all its 16 address lines high. It then reads the data on its data lines at that moment and takes that information as the next address to which it should jump. Obviously, we can't have all the various additional chips of any circuit all responding to all the address lines being high; only the eprom must respond. It is necessary to put the eprom at what the system will regard as the top-most address block and to inhibit any other devices lower down the address table while the top address block is being called. In the system presented here I've placed the eprom at the block (hex) &4000-47FF, the VIA interface at &2000-27FF and the memory at &0000-07FF.

The first address looked at by the microprocessor, if all the address lines were to be used, would be &FFFF. All address lines are not used and the maximum effective address is &47FF. Having read &47FF, the processor then reads the next address below it, &47FE. &47FF holds the most significant bit (msb) and &47FE holds the least significant bit (lsb) of the next address. The address can be anywhere in the programmed system at which the designer/programmer has decided to start his program. Purely for my programming convenience my software instructions start in the eprom at address &4560. Consequently, the top two eprom addresses hold &60 (lsb) and &45 (msb) respectively. (Had I, for example, wished to start directly at &4000, the two top codes would have been &00 and &40.)

While the eprom is being read, VIA IC3 and Memory IC4 are inhibited by processor address lines A13 and A14: IC4 is only active while its $\overline{OE}$ and $\overline{CE}$ lines are low. Therefore, by routing A14 and A15 via the simple OR gate consisting of D1, D2 and R4, IC4 will be inhibited if either of these lines are high, as they will be when the eprom is being read.

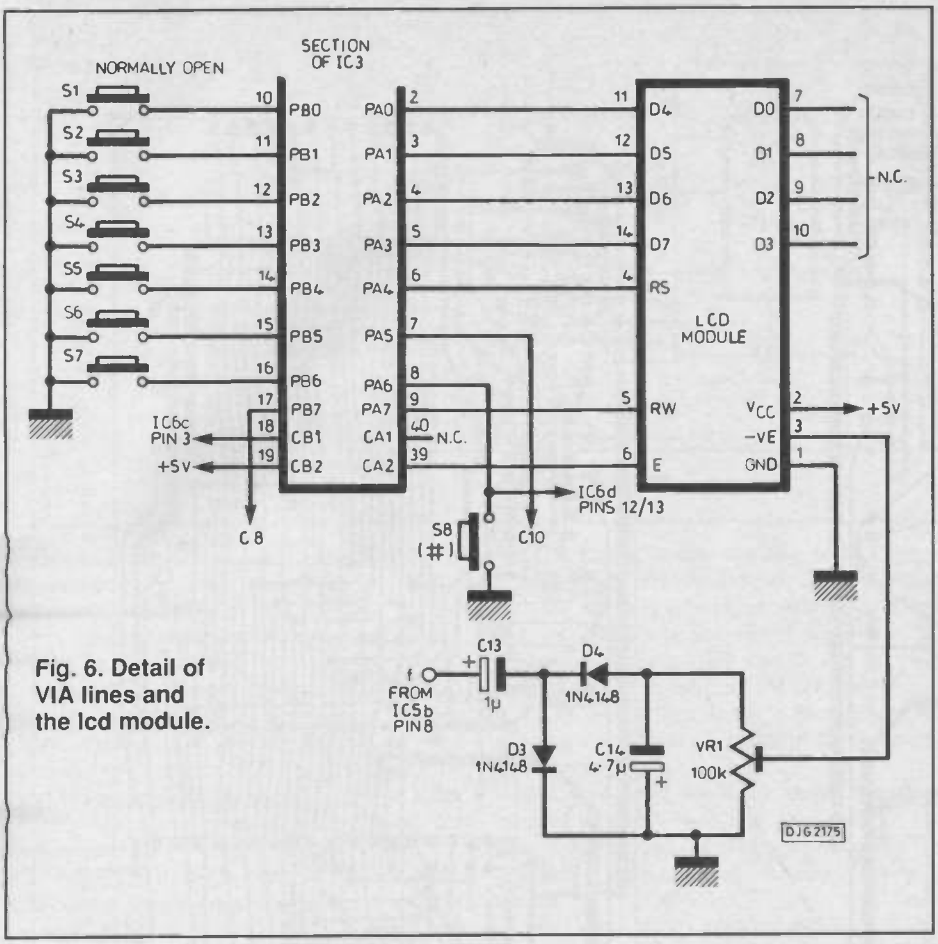


Fig. 6. Detail of VIA lines and the lcd module.

IC3 is only active if its CS1 input is high and at the same that its $\overline{CS2}$ pin is low.

While either IC3 or IC4 are being accessed, the eprom needs to be inhibited. This is achieved by taking its $\overline{OE}$ and $\overline{CE}$ lines high when address line A14 is low, using inverter IC5a to invert the logic. Although in Fig. 5 you will see that IC5a and the eprom lines $\overline{OE}$ and $\overline{CE}$ apparently connect to IC7, that routing can be ignored for the moment. Just imagine that the two points in question in Fig. 5 are joined.

VIA CHIP IC3

The routing of data to and from the outside world is via IC3. It has two input-output ports, each of 8 lines (bits), labelled PA0-PA7 and PB0-PB7 respectively, any of which can at any time be set as an input or an output. There are four other lines that can be used for real-world communicating, CA1-2 and CB1-2. The functions of all 20 lines, and other internal functions of the VIA, are controlled by the status of the internal registers, which in turn are accessed via lines RS0-RS3.

It is the microprocessor which controls the reading and writing functions of all these lines and registers, in accordance with the instructions present at each address within the eprom.

BIKE MONITORING

As a bike computer, the microcontroller circuit here needs to do five principal things: monitor a wheel rotation detector; keep track of time; perform calculations based on rotation and time; monitor several switches; send data to the lcd display.

Fig. 6 shows detail of the VIA lines which carry the data from the wheel detector and function selector switch, and send display data to the lcd.

The figure also shows the simple negative-voltage generator around C13, C14, D3, D4 and VR3 which feeds to the lcd module. The clock source is taken directly from the output of the clock generator IC5b.

Lines PB0-PB6 and PA6 are internally held high within IC3. When any of switches S1-S8 are pressed, the corresponding line is taken low, the event is registered by the system and the program causes the necessary action to be taken, usually resulting in a change of data display function.

PA0-PA4, PA7 and CA2 send data to and control the actions of the lcd module. PA5 and PB7 are associated with the power-saving circuit described later.

Monitoring of the bike's wheel rotation is performed by line CB1 which is connected to the circuit in Fig.7.

ROTATION DETECTOR

A Hall effect sensor is used to monitor the wheel's rotation. The sensor is a device which produces an output voltage which varies in level depending on the magnetic field close to it. In this instance the sensor is mounted on the one of the bike's front forks, facing the spokes. A magnet is fixed to a plate spanning between two spokes. Each time the wheel revolves and the magnet passes the sensor, IC10, the output voltage at its pin 2 fluctuates. (IC10 is incorrectly labelled as IC7 in Fig. 7 and 10.) Opamp IC9 amplifies the voltage change by an amount governed by R10 and R11. The amplified output feeds to the Schmitt trigger circuit around IC6c which changes its output logic state when a sufficiently strong voltage change is detected. The resulting output pulse is sent direct to the VIA on its CB1 line.

VR2 presets the sensitivity of the sensor by varying the threshold at which IC6c responds. C12 governs the attack and decay rates of the triggering, thus restricting the effects of minor voltage changes, and setting a minimum pulse length.

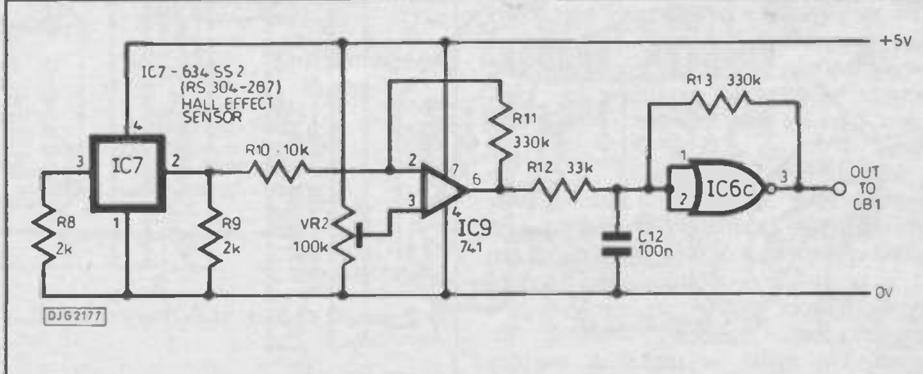
An internal shift register within VIA IC3 is triggered by each pulse. The register is read by the system at regular intervals, and then reset.

CLOCKED SAMPLING

The system has to be able to not only register pulses from the wheel sensor, but also to relate them against a precise timing factor. A combination of software programming and VIA internal timing have been used so that the wheel register count, subsequent calculations, and sending of data to update the lcd screen are performed once a second.

The VIA has an internal timer which can be set, under software control, to produce output pulses at a rate related to the crystal clock frequency. At a 1MHz clock speed, the minimum VIA pulse rate is eight pulses per second. This is divided by eight under eprom program control resulting in a pulse rate of 1Hz, which is a nice easy figure to work with

Fig. 7. Hall sensor and Schmitt trigger circuit.



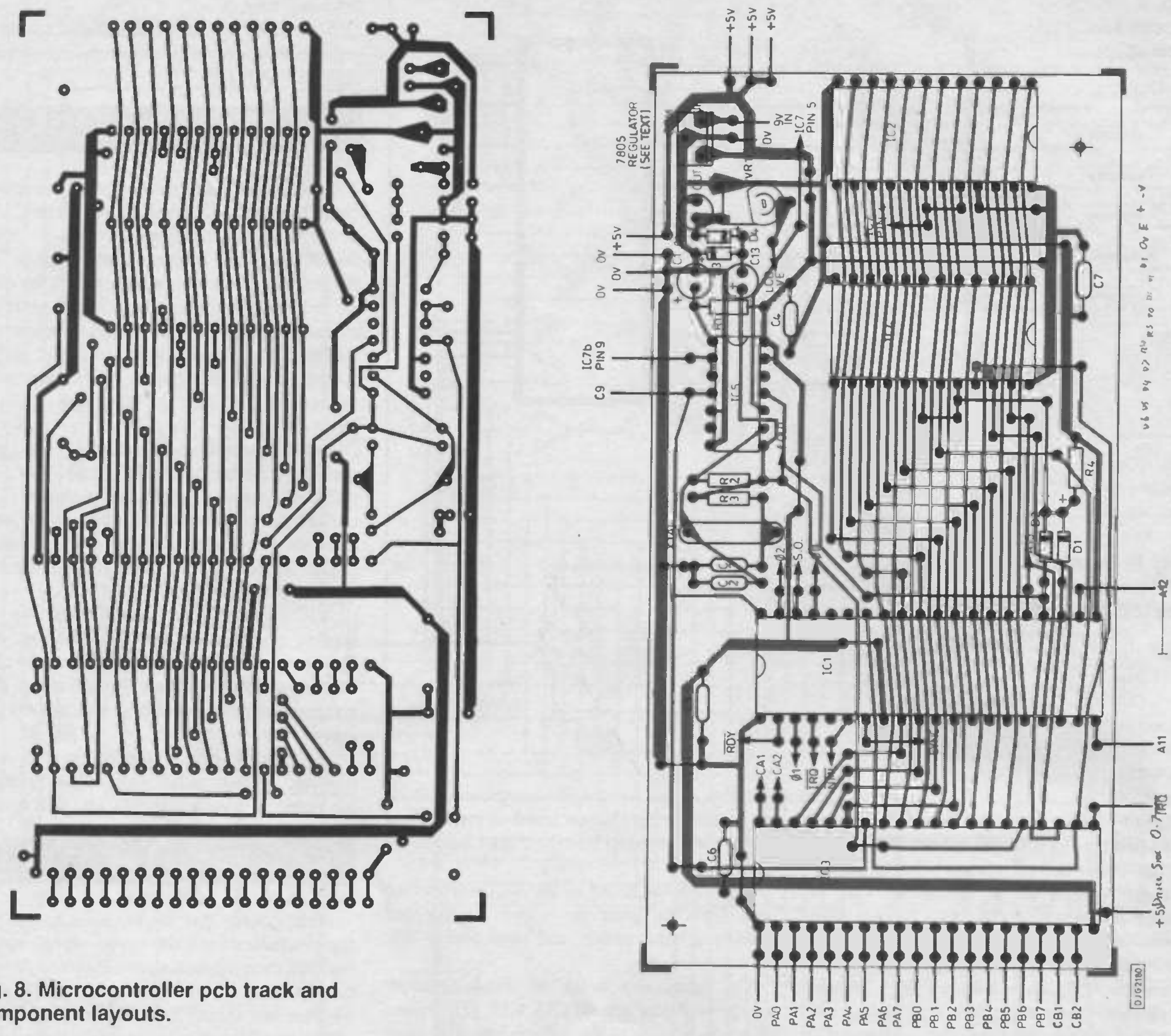


Fig. 8. Microcontroller pcb track and component layouts.

for subsequent calculations.

Under many circumstances I would feed such pulses directly to the microprocessor on one of the data lines. However, I use the pulses here to control the power saving circuit.

POWER SAVING

The memory and eprom chips can, in effect, be almost completely turned off when their use is not immediately needed. In this state they consume considerably less power than when active. Since we only need to sample the bike data at one second intervals, there is no point in consuming any more power than we need between the sampling points.

Ideally, we don't really need the microprocessor to be active during these periods either. The 6502 processor, though, cannot be turned off as such. But what we can do is to stop its controlling clock, and so prevent it from endlessly cycling through a program loop, repeatedly accessing the eprom. The timing of the clock stopping

COMPONENTS

MAIN UNIT

RESISTORS

R1, R2	1M (2 off)
R3	1k
R4	10k

All 0.25W 5% carbon film

CAPACITORS

C1	1µ 16V elect
C2, C3	33p polystyrene (2 off)
C4-C7	100n polyester (4 off)

SEMICONDUCTORS

D1, D2	1N4148 (2 off)
IC1	65C02 cmos microprocessor
IC2	2816 eeprom or 27C16 cmos eprom
IC3	65C22 VIA
IC4	MK48T02 lithium battery-backed cmos ram
IC5	4584 cmos Scmitt hex-inverter

MISCELLANEOUS

DIL sockets: 40-pin (2 off), 24-pin (2 off), 14-pin. Printed circuit board.

SENSOR, POWER SAVER AND DISPLAY

RESISTORS

R5-R7	100k (3 off)
R8, R9	2k (2 off)
R10, R14	10k (2 off)
R11, R13	330k (2 off)
R12	33k

All 0.25W 5% carbon film

POTENTIOMETER

VR1	100k skeleton preset

CAPACITORS

C8, C9	1n polystyrene (2 off)
C10, C11, C12	100n polyester (3 off)
C13	1µ 16V elect
C14	4.7µ 16V elect

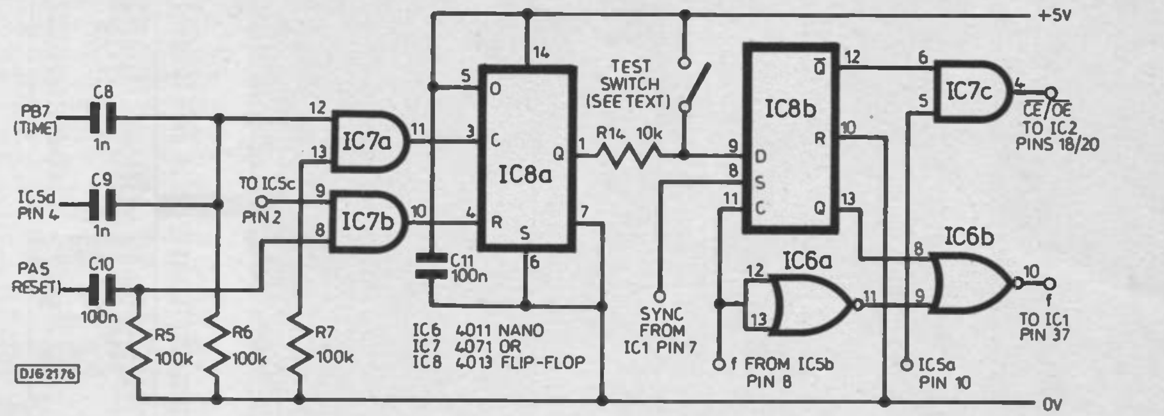
SEMICONDUCTORS

D3, D4	1N4148 (2 off)
IC6	4011 cmos quad-NAND
IC7	4071 cmos quad-OR
IC8	4013 cmos dual flip-flop
IC9	741 opamp
IC10	634SS2 Hall effect sensor

MISCELLANEOUS

DIL sockets: 8-pin, 14-pin (4 off), LCD module LCM570 or similar, 12-switch telephone keypad, bar magnet, printed circuit board, plastic box 120 x 65 x 40mm.

Fig. 9. Power saver circuit.



needs to be accurately synchronised with the processor's internal activities to avoid erroneous functioning. This requires the use of a moderately complicated sync control circuit, as shown in Fig. 9.

Each 8Hz timing pulse from IC3 goes through the OR gate IC7a to trigger the flip-flop IC8b. This in turn sets the Data input of a second flip-flop IC8b under trigger control on pin 11, direct from the clock oscillator IC5b. IC8b's Set input is under control from the microprocessor's Sync output, pin 7. Consequently, IC8b can only be triggered under the correct combination of sync, clock and data settings. When triggered, IC8b's $\overline{Q}$ output goes high allowing the AND gate IC6b to pass the clock pulses (coming through IC6a) to the microprocessor's clock input.

In this condition, IC8b's $\overline{Q}$ output has no affect on the OR gate IC7c, which can continue to pass the A14 address line logic levels from IC5a to the $\overline{OE}$ and $\overline{CE}$ pins of the eprom.

With clock signals available, the microprocessor reads and actions as much of the software program as fast as it can - until the software tells it to send a Stop pulse back to IC8 etc. The Stop command comes along to the VIA IC3, and out along its PA5 line to C10 in Fig. 9.

Via OR gate IC7b, the resulting pulse triggers IC8a, which inverts the Data signal on IC8b, so allowing the next correct combination of clock and sync signals to trigger the flip-flop to its opposite logic state. IC6b then closes, stopping clock pulses from reaching the microprocessor. IC8's $\overline{Q}$ output then forces a high level, via IC7c, on the $\overline{OE}$ and $\overline{CE}$ inputs of the eprom, so turning it off.

Since the processor is no longer operating, memory chip IC4 will also remain in an off condition. This state of affairs remains until the next 8Hz pulse is received, whereupon the cycle restarts.

We cannot totally turn off the VIA in this circuit (though we could in other circumstances) because we need it to continue performing two activities: using its internal timer to generate the 8Hz clock, and to continue monitoring the bike wheel rotation sensor.

The power saving circuit has also had to allow for the circuit initialisation process at power switch-on, hence the OR gates IC7a/b. IC8a is held reset by IC5c until C1 has charged up, at which point a pulse is generated across C9 providing the first clock pulse to trigger IC8a and so start the system.

MAIN CHIPS

Only the cmos versions of the microprocessor and VIA chips should be used. These are coded 65C02 and 65C22 respectively and are made by several manufacturers with various prefix and suffix codes. Either an eeprom or a normal eprom may be used for IC2 but a cmos eprom may be preferable because of its lower power consumption. The memory chip is a lithium battery-backed device allowing for data retention even after power switch-off. A normal volatile ram of the same pin configuration may be used if you don't mind losing the total-miles-covered storage facility. The lcd module used in the original is an LCM570 16-character alphanumeric display arranged as two rows each of eight characters. There are other types available, including low cost ones on the surplus market. Fuller details of the LCM570 were covered in PE May-Jun 90.

Friend Malcolm Harvey has kindly agreed to supply pre-programmed eproms for a limited period at £18.00 including post and vat. Send a cheque or postal order made payable to him, c/o Unit P, 8 Finucane Drive, Orpington, Kent, BR5 4ED. Ensure you state the diameter of the wheel with which the unit will be used. Either he or I will be pleased to advise you of component sources if you have difficulty finding a supplier for any of them.

Continued on page 38.

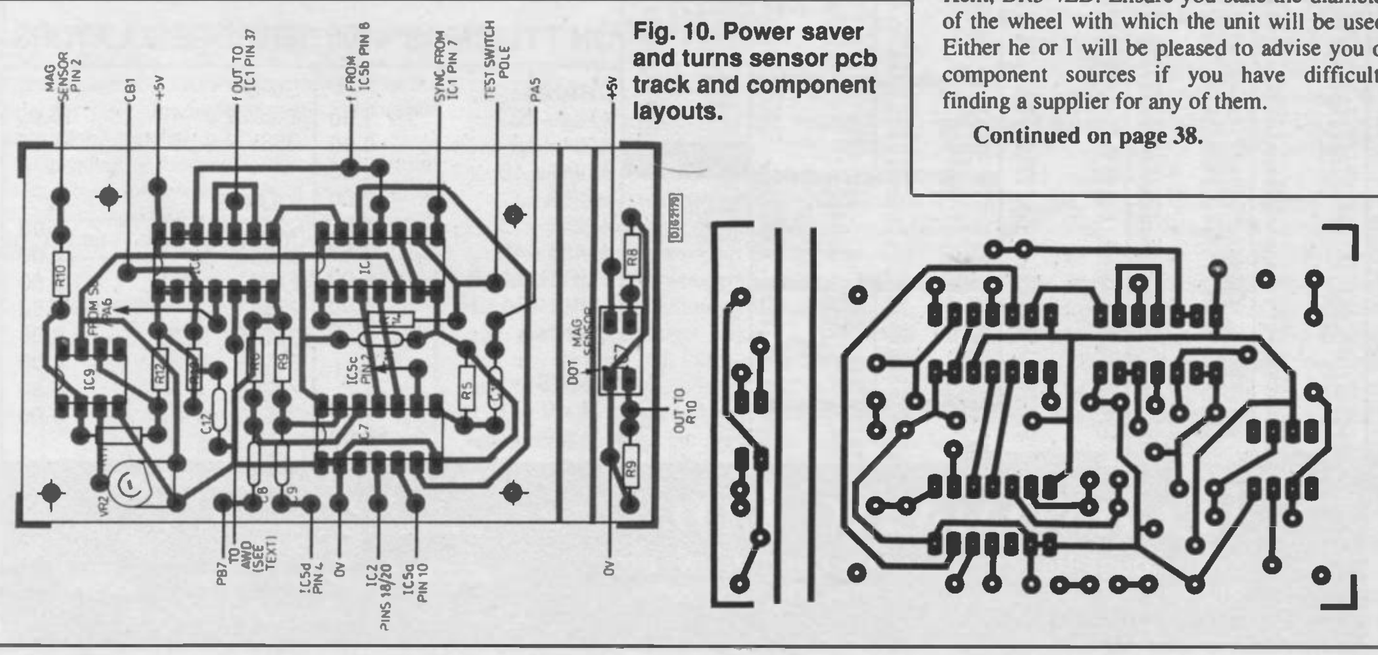


Fig. 10. Power saver and turns sensor pcb track and component layouts.

TTL'S

74 SERIES	
7400	0.16
7401	0.30
7402	0.16
7403	0.18
7404	0.23
7405	0.14
7406	0.30
7407	0.30
7408	0.23
7409	0.30
7410	0.13
7411	0.30
7412	0.30
7413	0.27
7414	0.28
7416	0.33
7417	0.30
7420	0.20
7421	0.60
7422	0.36
7423	0.36
7425	0.13
7426	0.20
7427	0.18
7428	0.43
7430	0.22
7432	0.27
7433	0.30
7437	0.24
7438	0.40
7440	0.40
7441	0.90
7442A	0.70
7443A	1.00
7444	1.10
7445	0.70
7446A	1.00
7447A	1.00
7448	1.00
7450	0.36
7451	0.15
7453	0.36
7454	0.36
7460	0.55
7470	0.27
7472	0.30
7473	0.23
7474	0.40
7475	0.30
7476	0.23
7480	0.65
7481	1.80
7483A	1.05
7484A	1.25
7485	0.70
7486	0.26
7489	2.10
7490	0.33
7491	0.70
7492A	0.42
7493A	0.55
7494	1.10
7495A	0.60
7496	0.80
7497	2.90
74100	1.90
74107	0.30
74109	0.75
74110	0.75
74111	0.55
74116	0.82
74118	1.10
74119	1.70
74120	1.00
74121	0.66
74122	0.70
74123	0.18
74125	0.37
74126	0.42
74128	0.55
74132	0.75
74136	0.70
74141	0.90
74142	2.50
74144	2.70
74143	2.70
74145	1.10
74147	1.70
74148	1.40
74150	1.75
74151A	0.38
74153	0.80
74154	1.40
74155	0.80
74156	0.90
74157	0.43
74159	2.25
74160	0.47
74161	0.80
74162	1.10
74163	0.80
74164	0.48
74165	1.10
74166	1.40
74167	4.00
74170	2.00
74172	4.20
74173	1.40
74174	0.58
74175	0.53
74176	1.00
74178	1.50
74179	1.50
74180	1.00
74181	3.40
74182	1.82
74184	2.50
74185A	2.50
74190	1.30
74191	1.30
74192	1.10
74193	1.03
74194	1.10
74195	0.80
74196	1.30
74197	1.10
74198	2.20
74199	2.20
74221	1.10
74251	1.00
74259	1.50
74265	0.80
74273	2.00
74276	1.43
74278	1.70
74279	0.73
74283	0.68
74285	3.20
74290	0.90
74293	0.90
74298	1.22
74351	2.00
74365A	0.80
74366A	0.80
74367A	0.80
74368A	0.70
74376	1.60
74390	1.10
74393	1.20
74490	1.40

74LS SERIES

74LS00	0.10
74LS01	0.10
74LS02	0.10
74LS03	0.10
74LS04	0.10
74LS05	0.10
74LS08	0.10
74LS09	0.12
74LS10	0.10
74LS11	0.10
74LS12	0.10
74LS13	0.18
74LS14	0.22
74LS15	0.12
74LS20	0.12
74LS21	0.12
74LS22	0.12
74LS24	0.33
74LS26	0.12
74LS27	0.12
74LS28	0.12
74LS30	0.12
74LS32	0.13
74LS33	0.13
74LS37	0.14
74LS38	0.13
74LS40	0.13
74LS42	0.23
74LS47	0.50
74LS48	0.46
74LS51	0.11
74LS54	0.11
74LS55	0.13
74LS73A	0.14
74LS74A	0.18
74LS75	0.21
74LS76A	0.24
74LS78	0.42
74LS83A	0.37
74LS85	0.24
74LS86	0.22
74LS90	0.24
74LS91	0.50
74LS92	0.29
74LS93	0.24
74LS95B	0.75
74LS96	0.46
74LS107	0.25
74LS109	0.25
74LS112	0.25
74LS113	0.25
74LS114	0.25
74LS122	0.33
74LS123	0.33
74LS124	1.40
74LS125	0.30
74LS126	0.28
74LS132	0.28
74LS133	0.28
74LS136	0.28
74LS138	0.26
74LS139	0.26
74LS145	0.62
74LS147	0.86
74LS148	0.72
74LS151	0.25
74LS152	2.00
74LS153	0.28
74LS154	0.76
74LS155	0.34
74LS156	0.34
74LS157	0.20
74LS158	0.25
74LS160A	0.40
74LS161A	0.40
74LS162A	0.40
74LS163A	0.40
74LS164	0.34
74LS165A	0.48
74LS166A	1.50
74LS168	0.58
74LS169	0.53
74LS170	0.66
74LS173A	0.60
74LS174	0.28
74LS175	0.30
74LS181	1.48
74LS183	1.58
74LS190	0.44
74LS191	0.41
74LS192	0.39
74LS193	0.39
74LS194A	0.43
74LS195A	0.43
74LS196	0.43
74LS197	0.40
74LS221	0.43
74LS240	0.43
74LS241	0.40
74LS242	0.41
74LS243	0.48
74LS244	0.38
74LS245	0.38
74LS247	0.38
74LS248	0.36
74LS249	0.68
74LS251	0.62
74LS253	0.34
74LS256	0.50
74LS257A	0.34
74LS258A	0.36
74LS259	0.48
74LS260	0.28
74LS261	1.20
74LS266	0.20
74LS273	0.42
74LS275	1.25
74LS279	0.31
74LS280	0.86
74LS283	0.49
74LS290	0.24
74LS292	14.00
74LS293	0.26
74LS295	0.38
74LS297	14.00
74LS298	0.83
74LS299	1.18
74LS231	5.62
74LS323	1.78
74LS324	2.20
74LS348	1.18
74LS352	0.78
74LS353	1.88
74LS356	2.10
74LS363	1.38
74LS364	1.36
74LS365	0.24
74LS366	0.28
74LS367	0.28
74LS368	0.28
74LS373	0.42
74LS374	0.42
74LS375	0.4
74LS377	0.70
74LS378	0.62
74LS379	0.86
74LS381	4.50
74LS390	0.39
74LS393	0.34
74LS395A	1.00
74LS399	0.66

74LS445	1.50
74LS465	2.78
74LS467	2.78
74LS540	0.93
74LS541	0.76
74LS608	7.00
74LS610	21.56
74LS612	21.56
74LS624	2.10
74LS626	2.18
74LS628	2.18
74LS629	0.93
74LS640	0.84
74LS640-1	3.00
74LS641	0.86
74LS642	0.82
74LS642-2	3.00
74LS643	0.84
74LS643-1	2.48
74LS644	0.84
74LS645	0.86
74LS645-1	1.28
74LS668	0.83
74LS669	0.56
74LS670	0.60
74LS682	1.71
74LS684	1.71
74LS687	2.42
74LS688	1.70
74C923	4.33
74C925	9.28

4000 SERIES

4000	0.10
4001	0.10
4002	0.11
4006	0.31
4007	0.11
4008	0.32
4009	0.18
4010	0.18
4011	0.11
4012	0.11
4013	0.17
4014	0.29
4015	0.32
4016	0.16
4017	0.26
4018	0.27
4019	0.25
4020	0.30
4021	0.33
4022	0.33
4023	0.11
4024	0.22
4025	0.11
4026	0.58
4027	0.16
4028	0.26
4029	0.31
4030	0.15
4031	0.86
4032	0.49
4033	0.57
4034	0.73
4035	0.39
4036	1.76
4037	0.72
4038	0.43
4039	1.76
4040	0.27
4041	0.33
4042	0.27
4043	0.33
4044	0.33
4045	0.69
4046	0.39
4047	0.42
4048	0.24
4049	0.16
4050	0.18
4051	0.35
4052	0.32
4053	0.32
4054	0.50
4055	0.49
4056	0.49
4059	3.44
4060	0.37
4063	0.45
4066	0.16
4068	0.11
4069	0.11
4070	0.11
4071	0.11
4072	0.11
4073	0.11
4075	0.11
4076	0.39
4077	0.11
4078	0.11
4081	0.10
4082	0.11
4085	0.33
4086	0.30
4089	0.72
4093	0.16
4094	0.41
4095	0.55
4096	0.86
4097	1.23
4098	0.47
4099	0.39
4501	0.24
4502	0.33
4503	0.27
4504	0.52
4505	1.76
4506	0.55
4507/4030	0.35
4508	0.64
4510	0.29
4511	0.27
4512	0.35
4513	0.77
4514	0.62
4515	0.62
4516	0.33
4518	0.96
4519	0.33
4520	0.25
4521	0.33
4522	0.82
4526	0.40
4527	0.35
4528	0.38
4529	0.35
4531	0.62
4532	0.58
4534	0.45
4536	2.61
4538	1.36
4539	0.57
4541	0.63
4543	0.63
4551	0.62
4553	0.78
	1.36

LINEAR ICs

4555	0.26
4556	0.33
4557	1.36
4560	1.08
4566	1.53
4568	2.48
4569	1.70
4572	0.30
4583	0.57
4584	0.27
4585	0.37
4724	1.28
14411	7.50
14412	7.50
14416	3.00
14419	2.60
14490	4.20
14495	4.50
14500	6.50
14599	2.00
22100	3.50
22101	7.00
22102	7.00
40014	0.48
40085	1.20
40097	0.36
40098	0.40
40100	1.12
40101	0.74
40102	1.04
40103	1.12
40104	0.85
40105	1.36
40106	0.32
40107	0.47
40108	2.56
40109	0.68
40110	1.60
40114	1.76
40147	1.76
40163	0.50
40173	1.20
40174	0.44
40175	0.52
40192	0.45
40193	0.45
40194	0.55
40244	1.34
40245	1.34
40257	0.80
40373	1.08
40374	1.08
80C95	0.75
80C97	0.75

NEW LOW PRICES ON TTL/ CMOS 4000 SERIES REGULATOR

ZIF sockets	
24 pin	5.50
28 pin	7.00
40 pin	8.00

TTL & ECL	
10116	70p
10231	350p

ADC0808	11.90
AM7910DC	15.00
AN103	2.00
AY3-8910	4.50
AY3-8010	4.50
AY3-8912	5.00
CA3019A	1.00
CA3028A	1.10
CA3046	1.07
CA3059	2.22
CA3060	3.50
CA3080E	0.95
CA3086	0.60
CA3089E	2.50
CA3090AQ	3.75
CA3130E	1.00
CA3130T	1.20
CA3140E	0.45
CA3140T	1.00
CA3146	2.25
CA3160E	1.50
CA3161E	2.00
CA3162E	6.00
CA3189E	2.70
CA3240E	1.45
D7002	6.00
DAC1408-8	3.00
DAC0800	3.00
DAC0808	3.00
DG308	2.32
HA1366W	1.90
ICL7106	6.85
ICL7611	1.90
ICL7650	4.38
ICL7660	2.30
ICL8038	5.56
ICM7555	0.90
ICM7556	1.30
LC7120	3.00
LC7130	3.00
LC7137	3.50
LF347	0.88
LF351	0.33
LF355	1.52
LF356N	0.64
LF357	1.50
LM10CLH	8.51
LM301A	0.20
LM307N	0.45
LM308CN	0.75
LM311P	0.30
LM318N	1.25
LM319N	1.50
LM324N	0.35
LM334Z	1.15
LM335Z	1.30
LM336	1.60
LM339	0.40
LM348	0.60
LM349CH	3.50
LM358P	0.32
LM377	2.00
LM380N-8	1.50
LM380N	0.90
LM381N	3.00
LM382	2.00
LM384	3.25
LM386N-1	1.20
LM387	2.40
LM391	2.65
LM392N	1.10
LM393	0.35
LM394CH	4.50
LM709	0.48
LM710	1.00
LM711	1.00
LM723	0.50
LM725CN	4.00
LM733	0.65
LM741	0.20
LM747	0.70
LM748	0.30
LM1011	4.80
LM1014	1.50
LM1801	3.00

LM1830	2.50
LM1871	3.00
LM1872	3.00
LM1886	6.00
LM1889	4.50
LM2917	3.00
LM3302	0.90
LM3900	0.80
LM3909N	1.00
LM3911	1.80
LM3914	3.50
LM3915	3.40
LM3916	3.40
LM13600	1.50
M51513L	2.30
M51516L	4.50
MB3712	2.00
MC1310	1.50
MC1413	0.75
MC1458	0.45
MC1495L	3.00
MC1496	0.70
MC3340	2.00
MC3401	0.70
MC3403	0.65
MF10CN	4.00
MK50240	9.00
ML920	5.00
ML922	4.00
MM6221A	3.00
NE531	1.20
NE555	0.10
NE556	0.30
NE564	1.79
NE565	1.00
NE566	1.00
NE567V	2.00
NE570	2.85
NE571	3.00
NE592	0.70
NE5532P	1.50
NE5533P	1.80
NE5534P	1.20
NE5534AP	1.50
OP07EA	3.50
PLL02A	5.00
RC4136	0.80
RC4151	2.00
RC4195	1.50
RC4558	0.75
S50240	9.00
SL490	2.70
SN76033N	3.00
SN76660	1.20
SPO256AL	7.00
TA7130	1.40
TA7204	1.50
TA7205	0.90
TA7222	1.50
TA7310	1.50
TBA231	1.20
TBA800	0.80
TBA810S	0.90
TBA820	0.80
TBA820M	0.75
TBA920	2.00
TBA950	2.25
TC9109	5.00
TCA940	1.75
TDA1010	2.25
TDA1024	1.10
TDA1170S	3.00
TDA2002	3.25
TDA2003	1.90

TDA2004	2.40
TDA2006	3.20
TDA2020	3.20
TDA2030	2.50
TDA3810	7.50
TDA7000	3.50
TEA1002	7.00
TL061CP	0.40
TL062	0.60
TL064	0.38
TL071	0.30
TL074	0.85
TL081	0.35
TL082	0.40
TL083	0.75
TL084	0.86
TL094	2.00
UA759	3.20
UA2240	1.30
UCN5801A	6.00
ULN2003A	0.75
ULN2004A	0.75
ULN2068	2.90
ULN2802	1.90
ULN2803	1.80
ULN2804	1.90
UPC575	2.75
UPC592H	2.00
UPC1156H	3.00
UPC1185H	5.00
XR210	4.00
XR2206	4.00
XR2207	3.75
XR2211	5.75
XR2216	6.75
XR2240	1.50
ZN404	1.00
ZN414	0.80
ZN419P	1.75
ZN423E	1.30
ZN424E	1.30
ZN425EB	4.20
ZN426EB	3.00
ZN427EB	8.00
ZN428EB	4.50
ZN429EB	2.25
ZN447E	9.00
ZN448	7.50
ZN449E	3.00
ZN450E	7.50
ZN459CP	3.00
ZN1034E	2.00
ZN1040	6.60
ZNA134H	23.00
ZNA234E	9.50

CPU's

1802CE	8.50
2650A	10.50
6502	3.50
65C02-2MHz	9.00
6502A	6.50
6502B	8.00
6800	2.50
6802	3.00
6809	6.50
6809E	10.00

VOLTAGE REGULATORS

1A FIXED VOLTAGE PLASTIC TO220

+VE			-VE	
5V	7805	0.33	7905	0.33
6V	7806	0.33	7906	0.50
8V	7808	0.33	7908	0.50
12V	7812	0.33	7912	0.38
15V	7815	0.33	7915	0.38
18V	7818	0.33	7918	0.38
24V	7824	0.33	7924	0.38

1A FIXED VOLTAGE PLASTIC TO92

5V	78L05	0.26	15V	78L15	0.26
6V	78L06	0.28	5V	79L05	0.45
8V	78L08	0.28	12V	79L12	0.43
12V	78L12	0.26	15V	79L15	0.50

OTHER REGULATORS			
LM309K	1.40	ICL7660	2.50
LM323K	2.50	SG3524	3.00
78HO5KC		TL494	3.00
5A 5V	5.75	TL497	2.25
78H12	7.50	78S40	2.50
		RC4195	1.50

VARIABLE REGULATORS			
LM305AH	2.50	LM723N	0.50
LM317T	1.20	78HGKC	6.50
LM317K	2.40	78GUIC	2.25
LM337T	2.25	79HGKC	6.75
LM350T	4.00	79GUIC	2.50
LM396K	15.00	79MGT2C	1.40

OPTO ISOLATORS			
ILD74	1.30	TIL112	0.70
ILO74	2.20	TIL113	0.70
MCT26	1.00	TIL116	0.70
MCS2400	1.90	6N137	3.60
MOC3020	1.50	6N139	1.75
TIL111	0.70		

DISPLAYS			
FND357	1.00	MAN6610	2.00
FND500 TIL730	1.00	NSB5881	5.70
FND507 TIL729	1.00	TIL311	6.50
MAN74 DL704	1.00	TIL729	1.00
MAN71 DL707	1.00	TIL730	1.00
MAN3640	1.75	MAN8910	1.50
MAN4640	2.00		

DISPLAY DRIVERS			
9368	4.50	ULN2003	0.90
9370	4.50	ULN2004	0.90
9374	3.50	ULN2068	2.90
LM3914	3.50	ULN2802	1.90
LM3915	3.50	ULN2803	1.80
LM3916	3.50	ULN2804	1.90
UDN6118	3.20	75491	0.70
UDN6184	3.20	75492	0.70

OTHERS			
2N5777	0.50	ORP12	1.20
BPX25	1.80	ORP60	1.20
BPX25	2.80	ORP61	1.20
OCP71	1.80	SFH205	1.00

·ATTENTION· ALL PRICES ARE SUBJECT TO CHANGE WITHOUT NOTICE

SCRS	
1A 50V	70p
5A 400V	50p
8A 600V	140p
16A 100V	200p
C106D	45p
MCR10	36p
T1C44	36p
2N3525	130p
2N4444	140p
2N5060/4	40p

ZENERS	
2 7V 33V	
400MW	9p
1W	15p

TRIACS	
Plastic	
3A 400V	60p
8A 400V	70p
6A 500V	90p
8A 400V	75p
8A 500V	95p
12A500V	105p
16A500V	130p
T2800D	130p
T12800D	50p
T1226D	70p

DISCRETE DISPLAYS LEDS	
125"	
RED TIL209	0.12
GREEN	
TIL211	0.15
YELLOW TIL212	0.20
Rect LEDs (R G Y)	
	0.30
CXB (B) Colour	1.00
10 LED	
Bargraph	
Red	2.25
Green	2.25
0 2"	
TIL220	0.15
TIL220	0.18
TIL226	0.22
TIL32	0.55
TIL78	0.55
TIL31B	1.20
TIL81	1.20
TIL100	0.75

CPU's

68B09	10.00
68B09E	12.00
8035	3.50
8039	3.50
80C39	4.50
8080A	9.00
8085A	3.00
80C85A	9.00
8086	9.00
8087-5	63.00
8087-8	£90
80287-8	£142
80287-10	£158
8088	7.50
8741	12.00
8748	12.00
Z80	2.50
Z80A	1.25
Z80B	3.60
70008	7.50
(Z80 CMOS)	

SUPPORT DEVICES

2651	12.00
3242	8.00
3245	8.00
6520	3.50
6522	3.00
6522A	4.60
6532	4.80
6551A	4.80
6821	2.50
68B21	2.80
6840	3.75
68B40	6.00
6850	1.80
68B50	3.00
6852	2.50
6854	6.50
68B54	8.00
6875	5.00
8154	8.50
8155	4.15
8156	3.80
8205	2.00
8212	2.40
8216	1.60
8224	P.O.A
8226	4.25
8228	5.50
8243	2.60
8250	8.54
8251A	3.25
8253C-5	3.38
8255AC-5	3.20
8256	8.00
8257C-5	4.00
8259C-5	4.00
8275	29.00
8279C-5	4.80
8282	3.00
8283	4.00
8284	4.60
8287	3.80
8288D	21.50
8755A	POA
16450N	15.00
TMS4500	14.00
TMS9901	7.44
TMS9902	8.08
Z80P10	2.50
Z80AP10	2.75
Z80CTC	2.50
Z80ACTC	1.75
Z80DART	2.50
Z80ADART	7.00
Z80DMA	7.00
Z80ADMA	7.50
Z80AS10-0129	7.00
Z80BP10	5.00
Z80BCTC	5.00
Z80BDART	9.00

RAMs

2016-150	4.00
2101	4.00
2107B	5.00
2111A-35	4.00
2114	1.50
2114-3	2.50
2147	4.00
4116-15	2.00
4116020	1.50
4164-15 (TI)	3.00
4164-15	1.50
4416-15	3.00
4532-20	2.50
41256-15	3.00
5101 5501	4.00
5514 5114	4.00
5516	4.00
5517	4.00
50256-15	4.00
6116LP-3	3.00
6264LP-15	2.60
6810	2.00
74S189	1.80
74S201	3.50
74S289	2.25
93415	6.00
93425	6.00

ROMS PROMS

28L22	4.00
24S10	2.50
18SO30	2.00
18SAO30	2.00
74S188	1.80
74S287	2.25
74S288	1.80
74S387	2.25
82S23	1.50
82S123	1.50
82S129	1.50

NEW LOW PRICES ON TTL & CMOS 4000 SERIES & REGULATORS

CRT CONTROLER

CRT5027	18.00
CRT6545	9.00
EF9364	8.00
EF9365	25.00
EF9366	25.00
EF9367	36.00
EF6369	12.00
MC6845	6.50
MC6845SP	6.50
MC6847	6.50
SFF96364	8.00
TMS9918	15.00

CRYSTALS

32 768kHz	1.00
1 00 MHz	2.70
1 8432 MHz	2.25
2 00 MHz	2.25
2 45760 HMz (S)	2.00
2 5 MHz	2.50
3 12 MHz	1.75
3 276 MHz	1.50
3 5795 MHz	1.00
4 00 MHz	1.40
4 194 MHz	1.50
4 43 MHz	1.00
4 608 MHz	2.50
4 9152 MHz	2.00
5 000 MHz	1.50
5 068	1.75
6 00 MHz	1.40
6 144 MHz	1.40
7 00 MHz	1.50
7 168 MHz	1.75
8 00 MHz	1.50
8 867 MHz	1.75
10 00 MHz	1.75
10 50 MHz	2.50
10 70 MHz	1.50
11 00 MHz	3.00
12 00 MHz	1.50
14 00 MHz	1.75
14 318 MHz	1.60
14 318 MHz	2.50
15 00 MHz	2.00
16 00 MHz	2.00
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18 00 MHz	1.70
18 432 MHz	1.50
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75110	0.90
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75113	1.20
75114	1.40
45115	1.40
75121	1.40
75122	1.40
75122	1.20
75150P	1.20
75154	1.20
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75452	0.50
75453	0.70
75454	0.70
75480	1.50
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75492	0.65
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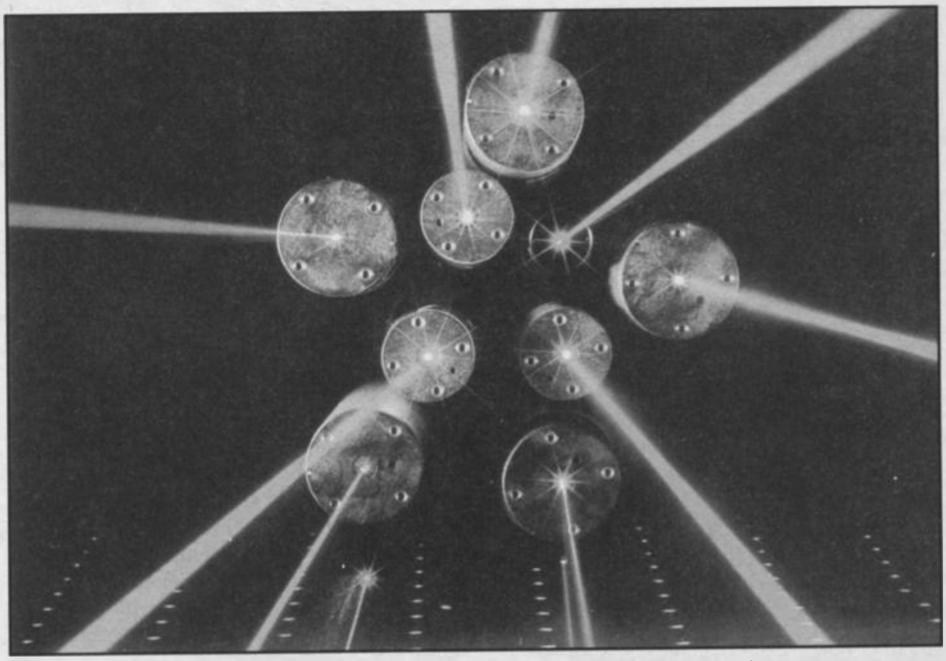
Lasers which once existed only in the minds of science fiction writers, are now so commonplace around us, in holograms, eye surgery, printing, etc, that people have ceased to wonder what the letters stand for.

Laser stands for *Light Amplification by Stimulated Emission of Radiation* and since one is dealing with light what better way to amplify the signals than with mirrors. So with the semiconductor laser at least, one need not be ashamed to admit that it is all done with mirrors.

Lasers operate in the spectrum between the ultraviolet and infrared (0.1μm to 1000μm) as shown in Fig.1. The advantage of operating higher in the frequency spectrum is that a higher transmission bandwidth is obtained and in the optical range the signals are also immune to electrical noise.

A feel for the attainable bandwidths can be obtained by comparing a radio signal transmitting at 10^8Hz with a laser operating at 10^{14}Hz. The maximum bandwidths obtainable from each are 10^8 and 10^{14} respectively showing that the bandwidth of the laser is six times greater than the radio in this example. With the larger bandwidth it is possible to transmit at a higher speed and so it is possible to transmit about thirty volumes of the *Encyclopaedia Britannica* in one second. The biggest application of lasers is in communications using optical fibres and the bandwidth is a compromise between distance and number of repeaters. This aspect will be dealt with under optical fibres.



Photograph kindly supplied by laser manufacturers Spindler and Hoyer.

LASERS

Part One. Mike Sanders coherently shines light on the science fiction devices that have become common-place realities.

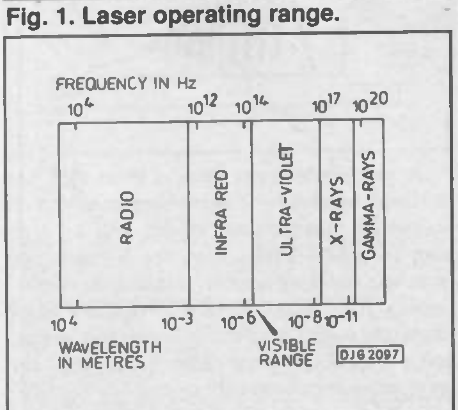
The main features of lasers are the stimulated emission and the amplification. In order to sustain the lasing, optical feedback is employed using mirrors. This is similar to using feedback in electronic amplifiers.

PROPERTIES OF LASERS

Lasers have a high brightness since the beam diverges very little. They can also be focused to a small size of the order of a wavelength of the particular laser, for making small holes, cuts, marks, etc in materials.

Depending on the type of laser, low power in the range of microwatts to high power in the range of kilowatts can be obtained. In addition, pulsed lasers can provide high instantaneous energy in the region of terawatts or hundreds of joules per pulse.

Fig. 1. Laser operating range.



Lasers display a high degree of chromaticity (pure colour) because of the small spread in wavelength and some of the lasers that will be discussed are helium-neon, ruby, carbon dioxide, dye, neodymium-YAG, neodymium-glass and semiconductor lasers. The ruby laser was invented in 1960, followed by the gas laser in 1961 and the semiconductor laser in 1962.

Lasers also have good coherence. Coherence is a complex subject but the simple explanation is to say that if the emission is all of the same frequency and travelling in parallel, in the same direction, and in phase, the radiation is coherent.

As an example of non-coherent radiation, the sun's rays may be considered. Random frequencies at random intervals are produced. Similarly with a spotlight whose beam spreads by about two degrees of arc. By contrast a laser diverges only a few seconds of arc and therefore the concentrated energy can be used for space communications.

There are two aspects of coherence, spatial and temporal coherence. Temporal coherence means that all the emission from the same source has a fixed phase relationship at a point in space at different times. Spatial coherence is when all the emissions have a fixed phase relationship at the same time but at different points in space. Two pure sinusoidal waveforms of the same frequency would be perfectly coherent.

One method of obtaining coherence using ordinary sources of light is to place a pinhole in front of the light. The hole acts as a diffraction grating and since only a small part of the emission is allowed through the hole, good spatial coherence is obtained. Another method is to place a diffraction grating (slits) far enough from the emitting source so that the slits are illuminated uniformly.

In comparison with ordinary sources, lasers have nearly perfect coherence but this can be improved even further as we shall see later, by altering the geometry of semiconductors, using injection locking etc. Researches are pursuing these and other avenues with almost manical commitment since, the purer the wavelength and the more coherent the emission, the wider the bandwidth that can be transmitted.

THEORY OF OPERATION

The theory of light states that light energy travels in discrete bundles called photons. Stimulating a photosensitive material with light will release electrons and the converse is

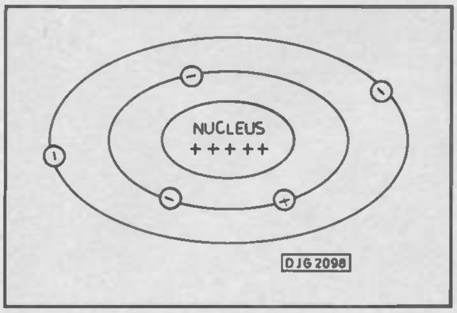


Fig. 2. Electron orbits.

also true, that is, stimulating the electrons in a laser will release light.

Three types of transitions involving photons are of interest in laser operations:

a) absorption
b) spontaneous emission
c) stimulated emission

When light of the correct wavelength falls on a photosensitive material, it is absorbed. The other two terms *spontaneous emission* and *stimulated emission* will become clear in the explanation below.

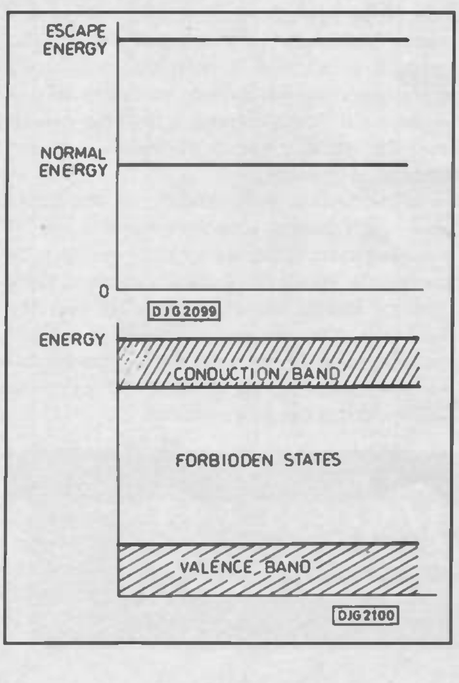
But to begin at the beginning, all material is composed of atoms consisting of a nucleus with a positive charge, and one or more electrons with a negative charge, in one or more orbits around the nucleus, as in Fig.2.

TWO LEVEL SYSTEM

When energy is supplied to a material, say by heating it, the electrons revolve in larger orbits from the nucleus until they escape from the material, if sufficient energy has been applied. This is illustrated in the energy level diagram of Fig.3.

In solids, atoms are packed tightly together and therefore energy levels exist more in the shape of energy bands (Fig.4). The number of electrons in the valence band would depend on the group of the periodic table to which the element belongs.

Figs. 3 and 4. Energy levels and bands.



At a temperature of absolute zero, all the electrons would be in the valence band and in order for the material to conduct heat or electricity some of the electrons must be raised into the conduction band.

In between the valence and conduction bands, there are forbidden states where the electrons are not allowed to reside. The gap between the valence and conduction bands depends on the construction of the material and can be altered by chemically doping the material since this alters the physical bonds.

When an electron drops across the energy gap, light is emitted with a wavelength equal to the distance between the valence and conduction bands. For optical fibre communications wavelengths around 0.85µm, 1.3µm and 1.55µm are of interest because of certain features in glass fibre which we shall examine under Optical Fibres.

The emission from light emitting diodes is spontaneous, ie the electrons are excited and light is emitted whereas the emission from lasers is stimulated. This means that in lasers the electrons are pumped to a higher level and then allowed to engage in an avalanche effect. Rather like carrying a rock to the top of a hill. Not only is the potential energy of the rock raised but it will also dislodge other rocks on the way down.

There are more electrons in orbits closer to the nucleus than there are in orbits further away from the nucleus. This can be compared to the earth's atmosphere which is rarer the further one gets away from the earth.

The stable distribution of electrons is often displayed by the exponential graph of Fig.5, which shows more electrons at a lower energy levels. The number of electrons in the energy levels is related by the following equation:

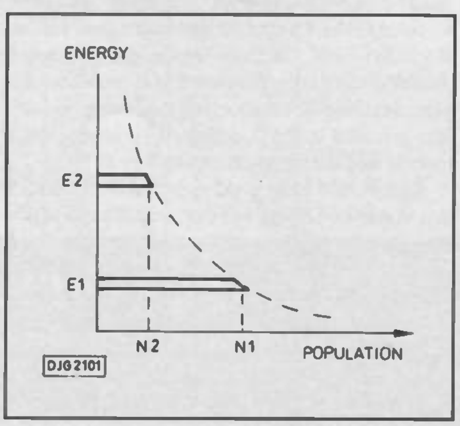
$$\frac{N1}{N2} = \exp - \frac{(E2 - E1)}{KT}$$

where

K is Boltzmann's constant
T is the absolute temperature
N1 is the number of electrons at energy level E1
N2 is the number of electrons at energy level E2

This is the position at thermal equilibrium. In order to provide lasing, the electrons need to be supplied with energy so that more electrons are raised to the higher energy level in the outer orbit. This process is called

Fig. 5. Electron distribution.



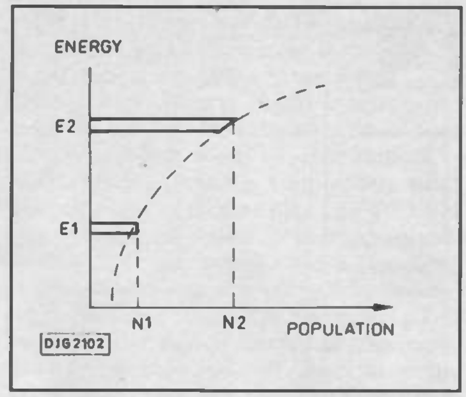


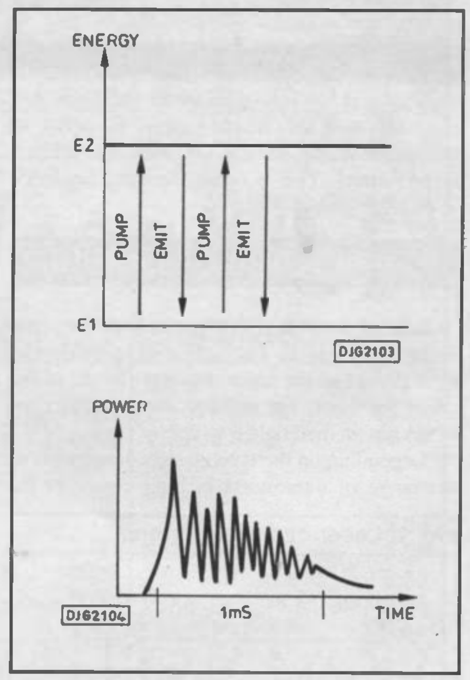
Fig. 6. Inverting the population.

population inversion and the exponential graph now looks like that of Fig.6 with more electrons at the higher level.

A system with two energy levels is called a two level system and the transition from one energy level to the other takes place at the edges of the band. The ammonia maser and the laser diode are examples of two level systems.

Two level systems are pulsed systems since they go through a continuous pump-emit, pump-emit cycle, (Fig.7). The power output from a ruby laser is like that shown in Fig.8. The build up and depletion of the population leads to the spikes and the gradual decline in height of the spikes is because the output power of the flash lamps decline. The spikes are unevenly spaced.

Figs. 7 and 8. Pulsed system, and ruby laser output pulse.



In multimode lasers there is more than one mode of operation, ie wavefront peaks as in microwave transmission. Modes will be dealt with later. Multimodes allow the lasing to hop from one mode to another, resulting in random pulsing. If the mode can be restricted to a single mode, the output is as in Fig.9 with less spiking and a gradual dying out of the oscillations. The oscillations are also evenly spaced.

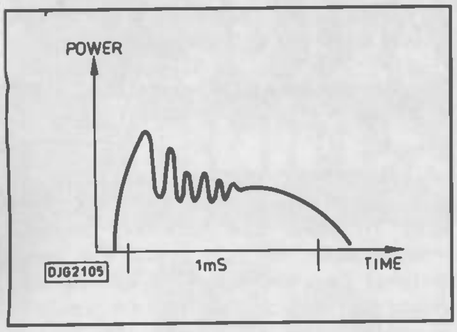


Fig. 9. Single mode pulsed output.

THREE AND FOUR LEVEL SYSTEMS

The ruby laser can also operate as a three level system, as can a dye laser. In a three level system electrons are pumped to a much higher level E2, Fig.10. If electrons will stay at level E2 for a few milliseconds, it is called a metastable state.

If they do not stay there, then spontaneous emission takes place. But assuming they do stay there for a little while, continuous pumping can take place between levels E1 and E2. The electrons then drop to an intermediate level E3 without emitting light. Lasing then follows as they drop back to E1.

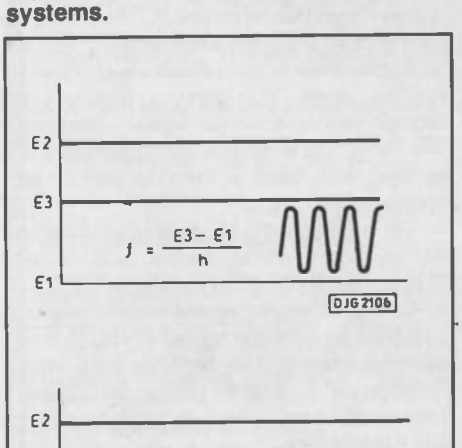
Just as pumping is continuous, lasing is also continuous as the electrons drop back to E1. The frequency that is emitted is proportionate to the distance between E2 and E1:

$$f = \frac{E3 - E1}{h}$$

where h is Planck's constant.

The pumping energy for such lasers is quite high since the whole population of the lasant needs to be inverted.

Figs. 10 and 11. Three and four level systems.



In a four level system, the electrons are pumped to level E2 as before where they stay for a while before dropping to level E3 in Fig.11. This is followed by lasing between levels E3 and E4 and then a transition back to E1 without radiation.

The advantage of a four level system is that less pump energy is required compared to a three level system since the whole lasant population does not have to be inverted and therefore continuous wave operation is simpler. The frequency of radiation is given by:

$$f = \frac{E3 - E4}{h}$$

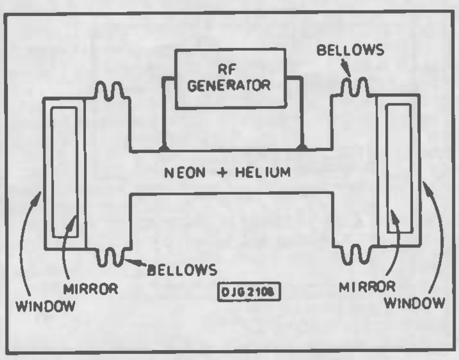
Typical lasers employing four level systems are neodymium-YAG, helium-neon, ion and carbon dioxide. The excitation in gas lasers is by electric discharge, and by optical methods in solid lasers.

Energy transfer by collision with other ions, atoms and molecules is one of the main methods of achieving population inversion in metal vapour, carbon-dioxide and helium-neon lasers.

TYPES OF LASERS

Lasers come in all shapes and sizes from low power to high power, continuous wave and pulsed. A variety of materials can be used in liquid, solid and gas form. The excitation of these ranges from electric discharge to physical collision. Some of the commonly used materials and their methods of excitation, power outputs and frequency range will be dealt with briefly.

Fig. 12. Helium-Neon lasers.



HELIUM-NEON LASERS

The most common of all the visible lasers is the helium-neon which emits at two wavelengths in the red part of the spectrum. The popular wavelength is 0.6328µm with power outputs from 0.5mW to 50mW continuous wave.

Most helium-neon (He-Ne) lasers are constructed as narrow tubes with only about 2mm diameter. The original helium-neon laser tube was 1.5cm in internal diameter and 1 metre long (Fig.12). An electrical glow discharge of about 50mW is produced by means of a voltage of about 2kV. But several kilovolts are required to get the discharge started. Alternatively, excitation is by RF methods.

This is a low gain laser and therefore about 99% feedback is required to keep it lasing. Mirrors are mounted at each end to amplify the light by bouncing it back and forth. The mirrors are adjustable so that they can be moved both towards each other as well as parallel to each other.

One mirror is also made less opaque so that it can transmit. The original device used internal mirrors which were difficult to adjust in the low pressure gas. Today external spherical mirrors are used which are several layers of dielectric substrate.

Helium and neon are chosen because they have similar energy levels so population inversion can be achieved by transferring energy from helium to neon, neon being the lasant. The atoms that engage in the lasing are not ionised and therefore this is a neutral gas laser.

The helium-neon laser is a fairly reliable, low cost laser and is used for image and pattern recognition and in reading bar codes. It is also used in the construction industry for tunnelling and constructing sewers.

A major application of this laser is in recording and playing back holograms. It is used to measure displacement using interference fringes and to locate the edges of materials in industrial processes. In factories, the helium-neon laser is used to detect flaws on a surface and measure the roughness; this is called non-destructive testing. It is also used in alignment, ranging and flow measurements. The helium-neon laser is used to guide high power lasers to work areas and align them onto the material.

CARBON DIOXIDE LASERS

In general gas lasers can provide continuous wave operation at room temperature without the cooling required for other lasers. Also, because gases do not have the physical deformities that solids do, their emissions are closer to a single frequencies, ie, they are said to be monochromatic.

Pure carbon dioxide lases quite weakly, therefore it is common to introduce nitrogen and helium or helium and neon in small quantities. The wavelength is 10.6µm and the power output is from a few watts to several kilowatts, continuous or pulsed.

Molecular vibrations provide the lasing action rather than electronic transitions. Hydrogen fluoride and carbon monoxide also use molecular vibrations in order to supply the lasing action. Carbon monoxide lasers can supply from a few watts to several kilowatts, continuous or pulsed.

Molecular vibrations provide the lasing action action rather than electronic transitions. Hydrogen fluoride and carbon monoxide also use molecular vibrations in order to supply the lasing action. Carbon monoxide lasers can supply from a few watts to about 15kW but they are only about 10% efficient.

Carbon monoxide lasers are much more

efficient, about 40% efficient but they are not only toxic but corrosive as well and therefore not employed in high power applications.

Industrial processes employing carbon dioxide lasers include cutting, welding, heat treating, scribing, marking and hole piercing. Materials that can be worked by carbon dioxide lasers are wood, paper, glass, most metals, ceramics, cloth and plastic.

Laser	Wavelength (μm)	Power(W)
Argon	0.5145 to 0.488	0.005 to 20
Krypton	0.6471	0.005 to 6
Xenon	0.995 to 0.5395	200 (pulsed)

Fig. 13. Comparison of ion lasers.

ION LASERS

Ionised gas is the lasant and these are usually four level systems. An electrical discharge is started in a plasma of the gas and the output is from a few milliwatts to several watts. Gases that are commonly used are argon, krypton and xenon. Typical power outputs and wavelengths emitted are shown in Fig.13.

The lasers can be tuned to wavelengths other than those shown in Fig.13 but those shown are the most common operating ranges. In addition the xenon laser can provide a higher output than the other two by operating it in a pulsed mode.

The argon laser was used by astronauts to measure the distance from the moon to the earth, and it is also used in eye surgery. The xenon laser is used for processing materials particularly is removing thin sheets of metal. Both argon and krypton lasers are used in spectroscopy, particularly Raman spectroscopy.

DYE LASERS

An organic dye is used as the lasant. A typical dye such as xanthene (rhodamine 6G) which is an organic dye could be used and pumped by nitrogen or argon lasers. An output of about 10mW could be obtained with a hundred pulses per second.

A wide bandwidth is obtained, typically 10^{-13} Hz, encompassing hundreds of lines in the spectrum. Therefore it is possible to scan the visible spectrum merely by changing the dye, which can be made automatic. With this automatic facility, it is not surprising that it can be used to detect pollution and in photochemistry.

METAL VAPOUR LASERS

A process called cataphoresis is used where, for instance, cadmium is evaporated at an anode and condensed at the cathode. In this process about one gram of cadmium is used up in a thousand hours. The power is only in the range 50mW to 100mW and the current is also low so that air cooling is sufficient.

Such lasers are used in photochemistry, spectroscopy and laser light shows.

AMMONIA MASER

The ammonia maser *(Microwave Amplification by Stimulated Emission of Radiation)* was invented in 1954. The researchers were attempting to construct an amplifier but instead the device oscillated. Unable to stabilise it, the scientists accepted it as an oscillator and attempted to check its oscillating frequency range. To their amazement it could not be tuned to any other frequency apart from its frequency of oscillation.

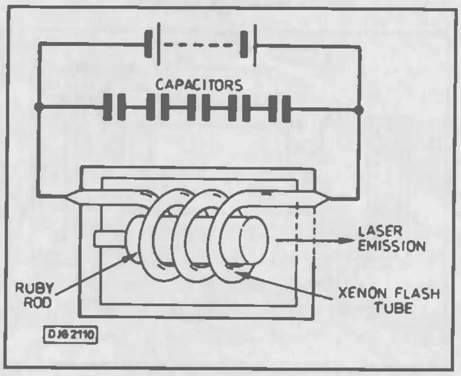
It was then decided to use the ammonia maser as a clock since it is accurate to one second in 10,000 years. By comparison, the best clocks of the day were accurate to only one second in ten years. For time keeping the ammonia maser has been replaced by rubidium and caesium which are even more accurate.

The other use for the maser was in reception of satellite signals. Although these have now been replaced by parametric amplifiers the maser was the best available technology in those first exciting days of satellite experiments.

In order to reduce the noise in the detectors and front end amplifiers the maser was operated at -271.5°C (1.5K) which is not far off absolute zero (-273°C). This is achieved by immersing the devices in helium and at absolute zero all molecular vibration stops.

All this may seem excessive effort but when one is trying to detect a signal as low as 10^{-13} watts, in the presence of noise, extreme measures are required. Masers cannot handle powers above 10^{-5}, therefore they are ideal for these low level applications. Masers also have an edge over travelling wave tubes and klystrons since they have very little inherent noise.

Fig. 14. Ruby laser.



RUBY LASER

In 1960 Maiman constructed and operated the first laser made from a crystal of ruby. The ruby laser uses sapphire (Al_2O_3) as the host and triply ionised chromium ions (Cr^{3+}) as the lasant. The chromium replaces about 0.05% of the aluminium atoms.

The wavelength is 0.6943μm in the red part of the spectrum and because of the poor thermal properties of sapphire the output has to be pulsed. Nevertheless several joules of energy can be provided for piercing holes, drilling diamonds, spot welding, space probes and pulsed holograms.

Ruby is easy to cut into the required shape, usually a rod 1cm in diameter and 10cm long, (Fig.14). The ends are silvered in order to amplify the light with one end partially transmitting to provide an output path for the pulses.

A number of capacitors of about 100μF with a potential of a few kV is discharged into a flash tube. The flash tube containing zenon is wrapped around the ruby crystal. The energy absorbed from the flash tube into the ruby crystal provides enough energy for population inversion.

NEODYMIUM-GLASS LASERS

Glass is used as the host substance and triply ionised neodymium, Nd^{3+}, as the lasant. The output wavelength is 1.06μm but the bandwidth is much wider than the output from the neodymium-YAG laser. This results in several modes of oscillation and when these are locked together, a bandwidth as wide as 10^{12}Hz can be obtained with a pulse as narrow as 10^{-12} sec. Pumping is by gas discharge lamps.

But glass has a low thermal conductivity, therefore the duty cycle must be kept low, around one pulse per second. However, reasonably high energies can be obtained, around 100 joules per pulse. This makes the laser practical for hole piercing and welding.

NEODYMIUM-YAG LASERS

Once again triply ionised neodymium Nd^{3+} is used as the lasant. The host is yttrium-aluminium-garnet (YAG) which is also used as synthetic diamonds. The chemical formula of YAG is $Y_3Al_5O_{12}$. From 1% to 2% of the metal ions are replaced by neodymium.

The output is 1.06μm and can be operated pulsed or continuously from a few watts continuous up to 1kW pulsed. It is a four level system therefore population inversion is obtained with a low threshold energy.

The laser can be pulsed with a high repetition rate but above 2000 pulses per second, the average power starts to decline. Continuous wave lasers can be Q switched (Q switching will be dealt with later) in order to provide high energy pulses.

The neodymium-YAG laser is used for spot welding, seam welding, cutting, piercing holes in gemstones and exciting dye lasers.

One of the biggest application of lasers is in communications using optical fibres, therefore the semiconductor laser has been under intense development in order to provide higher power from small chips as well as purer frequencies and single modes.

The development of the semiconductor laser will be dealt with in the next part as well as methods of producing short, high peak power pulses. Such techniques for pulsed lasers include mode locking, Q switching and cavity dumping.

Next month we shall look at semi-conductor lasers.

PE

Part 11: Owen Bishop examines the most vital of all active building blocks in the analogue world – the opamp.

BASIC ELECTRONICS

Operational amplifiers were originally developed for use in computers. These were not digital computers - the sort we are all familiar with nowadays - but analogue computers. The main difference between the two types of computer is that they have different ways of representing numbers while they are processing them. In a digital computer, a numerical value is represented by a set of high and low logic levels, each corresponding to one digit of the number, expressed in binary. The high and low levels are represented by voltages; usually 0V (or close to 0V) represents logic low, while +5V (or close to it) represents logic high. The essential feature is that there are only two voltage levels recognised in the computer circuits.

In an analogue computer too, a numerical value is represented by a *voltage*. Here the voltage can take not just one of two values but *any value* within a given range. the number is represented on a suitable *voltage* scale. For example if the scale is 1V to 100, the number 135 is represented by 1.35V and 341 is represented by 3.41V. The scale would be different for much larger or much smaller numbers. In the computer, these voltages are added, subtracted, multiplied or divided, according to mathematical operations that have to be performed. It is easy to see that amplifiers must play an important part in such a computer. To multiply a number by 25, for example, we use an amplifier with a gain of 25. We feed the voltage representing the number into the amplifier; the output voltage represents the number multiplied by 25. Division is performed by an amplifier with a gain of less than unity. As we shall show later, amplifiers can also be used for addition and subtraction. Since these amplifiers are used to perform mathematical operations, they are called operational amplifiers.

FUNCTIONS

The original operational amplifiers were made from discrete components but, nowadays, they are available very cheaply as integrated circuits. Although analogue computers are still used for specialist purposes, on the whole they have given way to digital computers. In spite of the decline of analogue computers, operational amplifiers or 'opamps', as they have come to be called, remain with us as one of the more important elements of electronic circuitry. Often their function is to perform some kind of mathematical operation, even though the circuit that they form part of would hardly be dignified by the name of 'computer'. A common use for opamps is in measuring devices, such as testmeters, electronic thermometers, and electronic kitchen scales. Even though the display and much of the operation of the device may be digital, the early stages of the circuit often uses one or more opamps. They take the voltage from the transducer, perform a few simple mathematical operations on it - perhaps correcting for errors inherent in the transducer - and then present the result to the digital circuit for further processing. Opamps are so simple to use that they have found applications in many other fields too, including audio circuits.

FEATURES

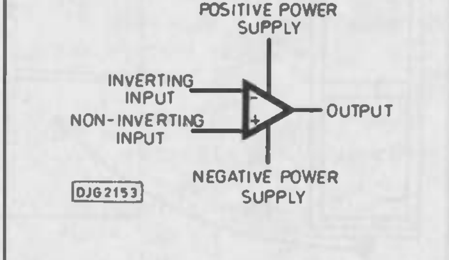
Fig.1 shows the symbol used for an opamp in a circuit diagram, and illustrates its essential features. The opamp has two input terminals, known as the inverting input and non-inverting input. The save space, we shall refer to these as (-) and (+), respectively, from now on. The opamp has one output terminal.

An opamp normally operates on a dual power supply. This has three power rails:

Positive rail
Ground rail, taken to be 0V
Negative rail

The positive and negative rails are equally positive of and negative of the ground rail. For example, in Investigation 1 (below) the voltages of the three rails are +3V, 0V and -3V respectively. The power supply terminals of an opamp are connected to the positive and negative rail. There is no power connection to the 0V rail, though in some circuits we may wire one of the input terminals to 0V to obtain a 0V input level. The voltages of the power rails represent the maximum voltages positive and negative, that can be applied to the input terminals. Similarly the output voltage always lies between these two extremes. In many types of opamp, the output voltage is restricted to a narrower range and never rises as high as the positive rail or as low as the negative rail. *(Regrettably! Ed).*

Fig. 1. Main features of an opamp.



An important characteristic of the opamp is that the input terminals have very high input impedance. In the case of the popular 741 opamp, which has bipolar junction transistors at its inputs, the impedance is about 2MΩ. Some other types of opamp have field effect transistors at their inputs, and the impedance is often as high as $10^{12}\Omega$ (1 Teraohm). With such a high input impedance, the amplifier draws virtually no current from the circuit to which it is connected. In particular, this means that voltages in the circuit are unaffected by having the amplifier connected there. Conversely, the output of the amplifier is only a few tens of ohms. In other words, it can supply a relatively large current without any significant fall in its output voltage. The twin characteristics of high input impedance and low output impedance are ideal for an amplifier and are of course essential in amplifiers that are to perform mathematical operations precisely.

The output voltage depends on the *difference* between the input voltages at (+) and (-). The bigger the difference, the bigger the output (except that it can not exceed the power rail voltages). As might be expected, the (+) and (-) inputs work in the opposite sense. Output swings positive if (+) is positive of (-); it swings negative if (-) is positive of (+).

To say that (+) is positive of (-) does not necessarily mean that the (+) input is at a positive voltage. For example, if the (+) input is -1.5V and the (-) input is -2.5V, the (+) input is positive compared with the (-) input, so the output swings positive.

Opamps are able to respond rapidly to changes of input voltage. Most can amplify oscillating signals with a frequency of several megahertz. Yet they also respond to dc signals, ie to steady input voltages.

Another feature of the opamp is its very high gain. The gain of the 741 opamp, for example, is 200 000. Other types have gains as high as a million. However, we very rarely make use of this high gain. Instead, we use external components to set the gain of the amplifier circuit to the required level, which is seldom more than a few thousand.

PRACTICAL OPAMPS

Opamp ics may be packaged in metal cans similar to those used for certain transistors, but most often they are in the familiar dil (dual-in-line) package as shown in Fig.2. Although there are dozens of different opamps available, most of them follow the standard pin-out shown in this drawing. Pins 1, 5 and 8 are used for connecting external components used to compensate for various amplifier errors, though this is required only in the most critical applications. The types of compensation provided and the method of

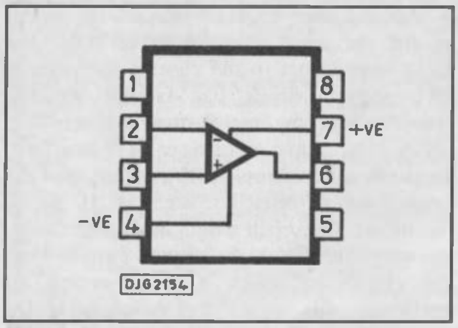


Fig. 2. Typical opamp ic.

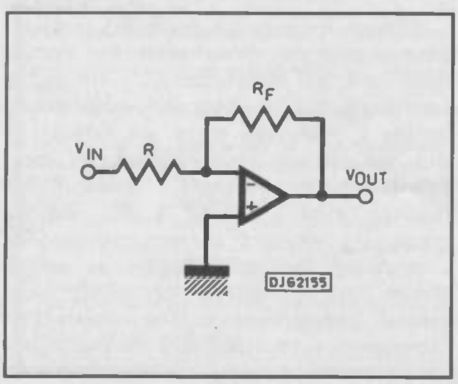
achieving it varies with the type of amplifier. Compensation is required only in the most critical applications and, with most opamps, these terminals may be left unconnected.

Opamps are also available in larger packages, often two, three or four separate amplifiers to a package, sharing common power supply terminals.

There are several families of opamps, mostly distinguished by the type of transistor used. The most successful opamp was the 741, based on bipolar junction transistors. Although this was the industry standard as a general-purpose amplifier and is still in use, it has the disadvantage that its output voltage range is limited. It can not swing freely in either direction as far as the supply voltages. It requires a minimum supply voltage of +5V and -5V, which restricts its use in certain areas. There are many other opamps in the same family offering (at suitable prices) various refinements on the 741. They may have greater precision, faster action, higher gain, lower noise, higher slew rate (the ability of the output to swing very rapidly), or greater output current (power opamps).

Another major family of opamps is based on mosfet technology, of which the CA3130 and CA3140 are popular examples. These have the advantage that the inputs have exceedingly high input impedance. They require less power than the bipolar opamps and their output voltage is usually able to swing very close to that of the supply rails in both directions. Many of them are able to operate with low supply voltages. The ICL7611, for example, operates on voltages as low as +1V and requires an operating current of only 10µA.

Fig. 3. Opamp wired as an inverting amplifier.



USING OPAMPS

As a first example, we investigate the use of an opamp as an inverting amplifier. Fig.3 shows the essential connections. The function of the circuit is to take an input voltage, Vin and produce a corresponding output voltage Vout. Vout is to be greater (ie, amplified) than Vin but the opposite polarity (ie, inverted). The circuit requires two resistors, the input resistor R and the *feedback* resistor Rf. As this is an inverting amplifier, Vin goes to (-) via resistor R. The other input, (+), is held at 0V by a wired connection to the 0V rail. The feedback resistor connects the output terminal to the (-); it feeds back the output voltage to the inverting input. We will see how this circuit behaves by trying it out on the breadboard.

Investigation 1 - Inverting amplifier

The circuit of Fig.4 is powered by a 6V battery, which is tapped between cell B and cell C. The voltages at the tap is taken to be 0V, and the rails are at +3V and -3V respectively. In Fig.4 we have given actual values to the resistors of Fig.3. Note that the feedback resistor has a higher resistance than the input resistor.

Vin is to be a low voltage, since we are to attempt to amplify it. We obtain this by using a potential divider consisting of R3 and R4. We studied potential dividers in Part 2 (Feb 90). Can you calculate what the voltage at Vin will be when the flying lead at the top of the divider is connected to +3V?

Vout is measured by a voltmeter and, as this is an inverting amplifier, we expect Vout to be negative. Unless you are using a meter with automatic polarity, connect the positive terminal of the meter to the 0V rail and the negative terminal to the output of the amplifier.

Set up the circuit (Fig.5); connect the power; connect the flying lead to +3V. Measure and record Vout. Calculate the gain of the circuit.

Repeat with the flying lead connected to +1.5V (between cell A and cell B). What is the gain?

Repeat with a negative voltage input, connecting the flying lead to -3V and then -1.5V (between cell C and cell D).

Replace R2 with a 180k resistor and repeat the above. What is the gain of the circuit now?

Fig. 4. Investigation: Inverting amplifier.

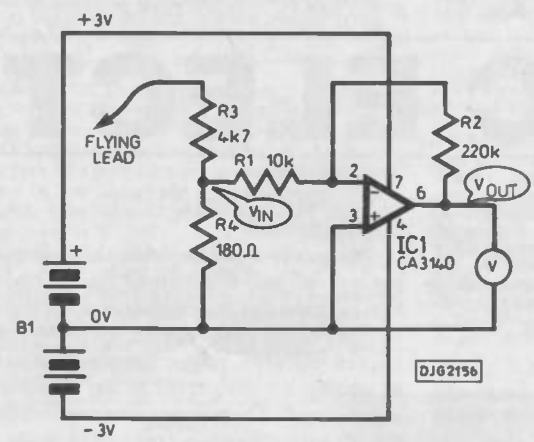
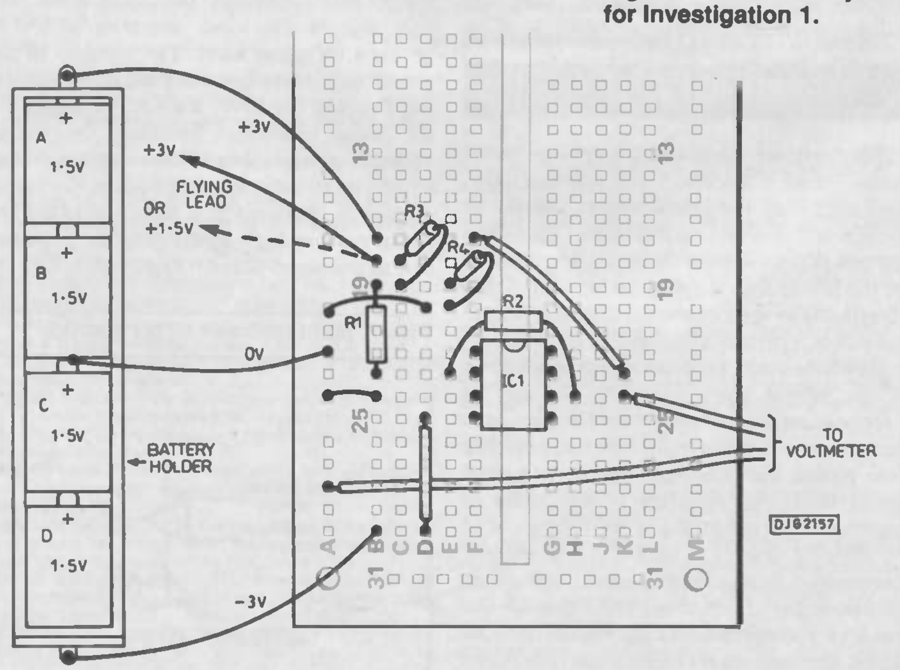
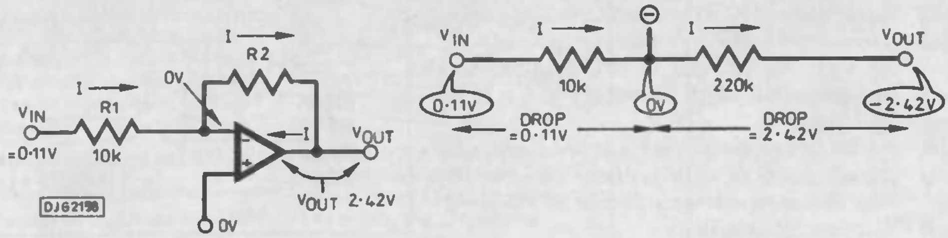


Fig. 5. Breadboard layout for Investigation 1.





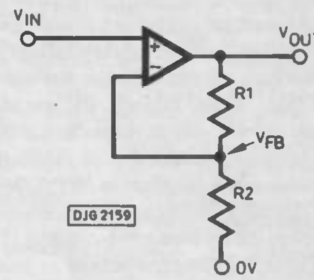


Fig. 6. Voltages in an inverting amplifier. Fig. 7. (far right) non-inverting amplifier.

FEEDBACK AND GAIN

In the inverting amplifier of Investigation 1, we feed back the output voltage to the *inverting* input (-). A positive-going input results in negative going output, which is fed back to the input and opposes the positive-going input. We call this ***negative feedback***. Under such circumstances there will be a point at which the tendency for output to increase is balanced by the effect of negative feedback. In this condition the circuit is stable. The exact point at which this occurs can be found if we remember this rule, which applies to all opamp circuits with negative feedback:

Output changes until (+) and (-) are at the same voltage.

Let us see how this works in an example taken from the investigation. This rule and Ohm's Law (volt/amps=ohms) are all that we need to discover what happens. Suppose that Vin is 0.11V. (+) is at 0V and, if the rule above is true, (-) is also at 0V. This means that there is a voltage drop of 0.11V across R1. Ohm's Law tells us that the current through R1 is 0.11/10000 = 0.000011A = 11µA. We have said earlier that the input terminals draw virtually no current as this current (or almost all of it) must flow on through R2. If the current through R2 is 11µA, the voltage drop across R2 must be 0.000011 x 220000 = 2.42V. The (-) end of R2 is at 0V, so the other end (the end wired to the output terminal) must be at -2.42V. If the output voltage falls to -2.42V (which is what happens in the investigation) the current flowing along R1 continues along R2 and enters the output terminal of the opamp. The circuit is stable under these conditions.

Exercise: Work out what should happen if (a) Vin is 0.04V, R1 is 10k and R2 is 220k; (b) Vin is 0.15V, R1 is 20k and R2 is 180k.

Now we will look at the more general case. If the input voltage is Vin, the current I through R1 is given by:

$$I = \frac{Vin}{R1}$$

If the output voltage is -Vout, the current I though R2 is:

$$I = \frac{-Vout}{R2}$$

Since the current is the same through both resistors, we have:

$$\frac{Vin}{R1} = \frac{-Vout}{R2}$$

From this equation we can calculate the gain of the circuit:

$$Gain = \frac{Vout}{Vin} = \frac{-R2}{R1}$$

Thus the gain of the circuit is determined simply by the ratio of the input and feedback resistors. It does not depend on the gain of the opamp itself. If we use high precision resistors, the gain of the circuit can be determined very precisely.

INPUT IMPEDANCE

There is one problem with the inverting amplifier. Although the input impedance of the opamp is very high, and we have considered this to be a big advantage, the input impedance of the *circuit* is far less. Since the (-) end of R1 is always held at 0V, the input impedance of the circuit is the resistance of R1 - only 10k. We have thrown away one of the opamp's useful features. Whether this matter or not depends upon the application, but it is a point to be kept in mind.

VIRTUAL EARTH

A useful concept arises from the study of the inverting amplifier. Since (+) is held at 0V (ground or earth voltage), and since the amplifier always operates to keep (-) at the same voltage as (+), (-) is always at 0V too. It acts as a *virtual earth.* Whatever current flows through R1, it always seems to 'disappear' into the amplifier, just as if R1 had been connected directly to the 0V line. Actually, it does not disappear, but flows on through R2, but the effect is the same. We shall return to this concept later.

NON-INVERTING AMPLIFIER

As Fig.7 shows, the input to this circuit goes directly to the (+) input. The input impedance of the circuit is as high as that of the opamp input. Once again, we have negative feedback to (-) but, in this circuit, the feedback voltage is taken from a potential divider, R1/R2. This is negative feedback, so the rule quoted above applies. As Vin varies, the output varies so as to keep both (+) and (-) at the same voltage. The feedback voltage, Vfb (see Fig.7), is always equal to Vin.

The usual equation for a potential divider applies, so we can say that:

$$Vfb = Vout \times \frac{R2}{R1+R2}$$

So:

$$Vout = Vfb \times \frac{R1+R2}{R1} = Vin(1 + R2/R1)$$

The gain of the circuit is:

$$Gain = \frac{Vout}{Vin} = 1 + R2/R1$$

You may remember from Part 2 that, if appreciable current is drawn from the divider, the voltage is less than that calculated by using the values of the resistors. In this case the amount of current flowing to (-) is negligible, so the gain of the amplifier is precisely determined by the resistor values.

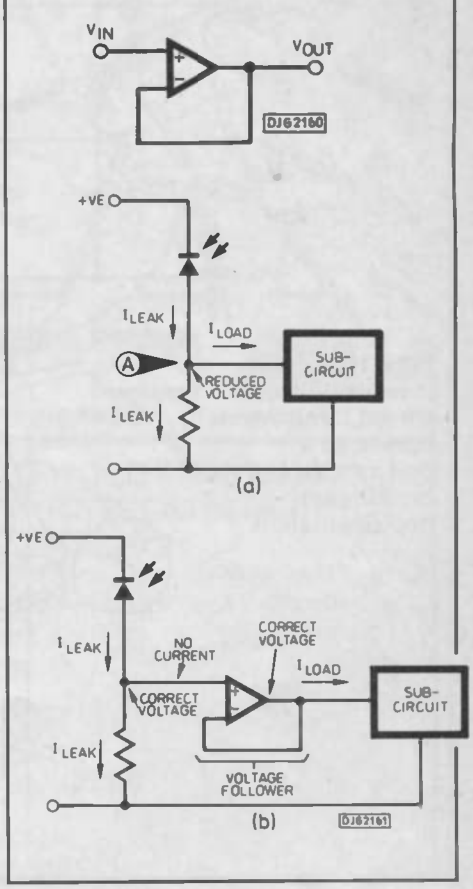
Investigation 2 - Non-inverting amplifier

Try breadboarding the amplifier of Fig.7, and check that the gain is as quoted above.

VOLTAGE FOLLOWER

A variant on the non-inverting amplifier is shown in Fig.8. Here Vout is fed directly back to (-). Applying the rule, we find that Vout is equal to Vin. An amplifier that does not amplify may seem to be of little use, but it has an important application - impedance-matching. For example, if we have a photodiode in series with a resistor as in Fig.9, the voltage at A depends on the size

Fig. 8. Voltage follower and (Fig. 9a/b) using it for impedance matching.



of the leakage current and is proportional to the amount of light falling on the photodiode. If point A is connected to a sub-circuit with low input impedance (Fig. 9a), a relatively high proportion of the leakage current goes to the sub-circuit. Less current flows through the resistor and, consequently, the voltage across it is reduced. A voltage follower connected as in Fig.9b takes no appreciable current, so there is no fall in voltage. Yet the amplifier can supply a current of several milliamps to the following sub-circuit.

The voltage follower is similar in function to the common-collector circuit, or emitter-follower, described in Part 7, July 90. the Vin whereas, with the emitter-follower, there is a constant voltage difference of about 0.6V due to the forward voltage drop of the base-emitter junction.

COMPARATOR

The opamp is essentially a difference amplifier, with very high gain. Without feedback, even a small difference in voltage at its inputs causes the output to swing as far positive or negative as it can. This is no use for measuring a voltage; feedback is essential to limit the gain to a known level. But if we want simply to compare two voltages, to know which is the greater, all we need to do is to apply these voltages to the two inputs, without feedback, and watch which way the output swings.

Investigation 3 - A comparator

Fig.10 shows the opamp wired to compare two voltages. One voltage comes from a potential divider consisting of a thermister R1 (see Part 3, March 90) in series with a fixed resistor R2. The voltage at point A rises as the temperature of R1 increases. The second voltage comes from another potential divider, consisting of VR1. We set VR1 to produce a standard voltage against which the voltage at A is to be compared.

Set up the circuit as in Fig.11 and connect the battery. Although we do not make use of the 0V line in comparator, we still refer to the power lines as +3V and -3V.

1. Turn VR1 anti-clockwise to supply a -3V input to (1). What happens to the led? Explain this.

2. Turn VR1 clockwise to give a +3V input to (1). What happens to the led?

3. Turn VR1 so that the led comes on, then turn VR1 so that it just goes out. Now grip R1 between finger and thumb; what happens? Remove you finger and thumb; what happens?

4. Add an input resistor R4 and feedback resistor R5, as in Fig.12. What do you notice about the feedback in this circuit? Repeat step 3. If the led does not go out when R1 cools, try cooling it further by touching a cube of ice against it. Does the behaviour of the circuit remind you of a circuit that we have described in an earlier issue?

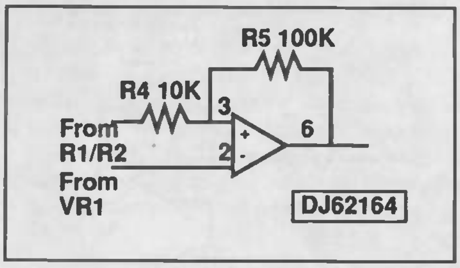


Fig. 12. Modifying the circuit of Fig. 10.

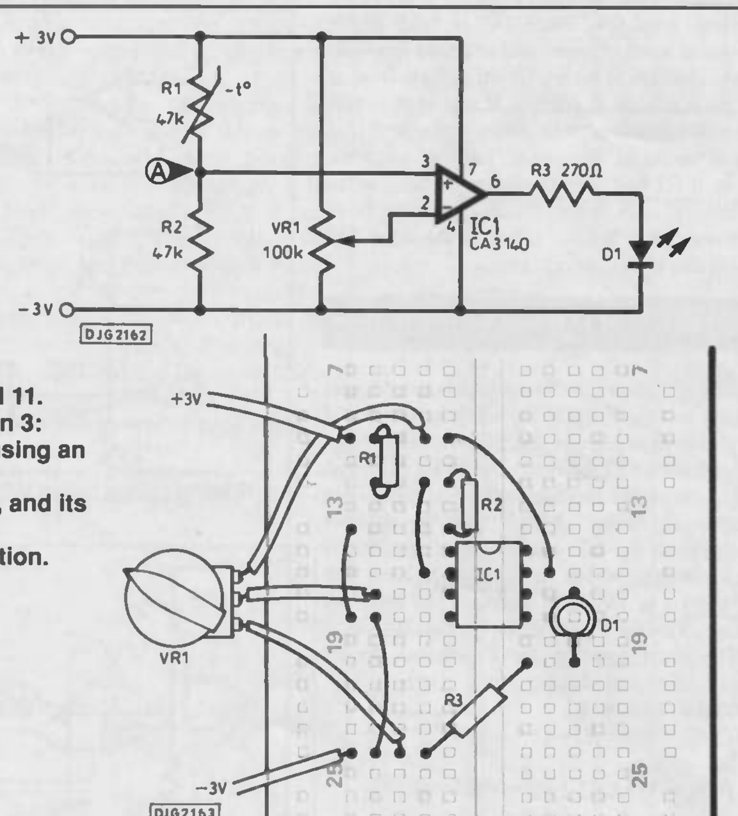
ADDER

The circuit for performing addition makes use of the concept of virtual earth, discussed above. In Fig.13 there are three input voltages, representing values that are to be added together. A current flows along each resistor, toward the virtual earth at the (-) input. The currents are I1 = V1/R, I2 = V2/R and I3 = V3/R. These three currents flow on through the feedback resistor, which has the same value as the input resistors. The voltage drop across R is:

$$
\begin{aligned}
Vout &= -(I1 + I2 + I3) \times R \\
&= -\left(\frac{V2}{R} + \frac{V2}{R} + \frac{V3}{R}\right) \times R \\
&= -(V1 + V2 + V3)
\end{aligned}
$$

In other words, the output voltage is the inverse of the sum of the input voltages. The circuit has added the input voltages.

We shall investigate this further next month. In the meantime, a brief discussion of the investigations so far.



Figs. 10 and 11. Investigation 3: Circuit for using an opamp as a comparator, and its breadboard implementation.

DISCUSSION

Investigation 1:

Vin = 3 x R4/(R3+R4) = 3 x 180/4880 = 0.11V. With the flying lead at +3V, Vout is -2.42V. (The result varies slightly, depending on the values of your resistors). Gain = -2.42/0.11 = -22.

With the lead at +1.5V, Vin = 1.5 x 180/4880 = 0.055V. Vout is -1.21V. Gain = -1.21/0.055 = -22.

With lead at -1.5V, Vin = -0.055V, Vout = 1.21V, gain = -22.

With the lead at -3V, Vin = -0.11V, Vout = 2.42V, gain = -22.

Using a feedback resistor of 180k, gives a gain of -18.

Exercise: (a) current is 0.04/10000 = 0.000004A = 4μA; Vout = 0.000004 x 220000 = 0.88V; gain is 0.88/0.04 = 22

(b) current is 0.15/20000 = 0.0000075A = 7.5uA; Vout = 0.0000075 x 180 = 1.35V; gain = 1.35/0.15 = 9.

Investigation 3:

1. The led comes on, so Vout must be high (almost +3V); this is because (-) is negative of (+).

2. The led goes out, so Vout must be low (close to -3V); this is because (-) is positive of (+).

3. The led is just off because (-) is slightly positive of (+). Warming R1 reduces its resistance, causing the voltage at A to rise; this makes (+) slightly positive of (-), making Vout high and turning on the led. Allowing R1 to cool reverses the above and turns the led off.

4. When R1 is warmed and Vout goes high, the increased output voltage is fed back; this is *positive* feedback, pulling up the voltage at A even further. Allowing R1 to cool does not bring the voltage at A down far enough to be make (+) negative of (-). We must increase the resistance of R1 considerably (ie, by using ice to cool it) before the voltage at A falls below (-) and the led is turned off. The action of this circuit is the same as the *Schmitt trigger* circuit described in Part 7, July 90.

PE

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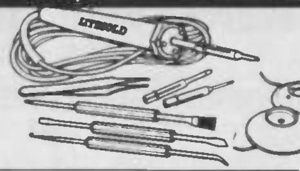

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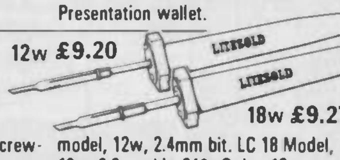

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2	A	4	7.01	2.20
3	M	6	12.08	2.36
4	P	8	12.87	2.42
6	S	12	15.62	2.64
8		16	18.59	3.08
10		20	25.02	3.52
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1500	40.40		4.18
2000	60.41		5.11
3000	102.72		6.32
4000	133.35		O/A
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1	A	2	7.91	2.20
2	M	4	12.81	2.75
3	P	6	14.82	2.75
4	S	8	20.30	3.24
6		12	25.81	3.24
8		16	36.52	3.57
10		20	43.34	4.07
12		24	51.87	4.29

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1		2	6.19	1.98
2	A	4	10.01	2.20
3	M	6	11.60	2.42
4	P	8	13.84	2.53
5	S	10	17.72	2.64
6		12	19.41	2.91
8		16	25.74	3.02
10		20	29.94	3.24
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2	M	4	13.17	2.53
3	P	6	19.05	2.64
4	S	8	21.72	2.75
5		10	27.46	3.19
6		12	31.32	3.41
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2	A	4	21.05	2.91
3	M	6	25.49	3.02
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FARADAY

One of the greatest scientists of all time. This statement has been used about Faraday on a number of occasions. He laid the foundations of much of today's electrical and electronic science as well as making some major discoveries in chemistry and other areas of science. He discovered electromagnetic induction, formulated the basic relationships between electricity and magnetism upon which people like Maxwell and Hertz were to build. In turn their discoveries lead on to the first wireless transmissions in the late nineteenth century.

YOUNG FARADAY

Michael Faraday was born on 22nd September 1791 in the south of London. He was the son of a blacksmith who had moved down to the south from Yorkshire some years before in search of work. He had a very rudimentary education and this meant that his research in later years was more practical in nature than theoretical. In fact he very much admired people like Maxwell who were able to look at theories mathematically.

In 1805 the family moved to North London and at about the same time when Faraday was just 14 years old he started work with a bookseller. Here he learned the arts of book binding, but far more important he had access to a very wide range of books which he would not have been able to see anywhere else. The young Faraday read them avidly and soon he began to develop a keen interest in science and the latest developments which were taking place.

As the years passed Faraday's interest in science grew and when he was 21 he decided to give up his job in the book trade in preference for a new career in science. Having heard of Humphrey Davy of the Royal Institution, he applied for a job there and was accepted. Here he took on a wide variety of duties and even accompanied Davy on his lecturing tours around Europe. Faraday made the most of this experience and learned a great amount from Davy's lectures. This kindled his interest still further.

Michael Faraday as portrayed in 1852. By courtesy of the Institute of Electrical Engineers.

FIRST DISCOVERIES

Faraday was not content to let his opportunities pass him by. He soon started on some of his own research at the Royal Institution. Initially, he spent a lot of his time developing a form of stainless steel, and then in 1820 he discovered a new compound involving carbon, iodine and hydrogen.

However, at this time discoveries were being made in the new science associated with electricity. The magnetic field around a wire carrying current had just been detected and news of this greatly interested Faraday. He set about investigating this discovery repeating many of the experiments himself. He also proved that a wire carrying a current in a magnetic field was deflected. However, he wanted to find out whether a current could be induced in a wire in any way. He tried many experiments but they were all unsuccessful, possibly in some instances because his measuring equipment was not sensitive enough.

Faraday contributed much to electromagnetic research in the 19th century, making the momentous discovery that current could be induced into a wire.

Although Faraday pursued his work on the idea of electromagnetic induction from time to time he also worked on several ideas related to chemistry. In fact he managed to become the first person to isolate benzene.

Faraday was achieving a great deal of success. With this came recognition, and in 1824 he was elected to the Royal Society. Then a year later he was made director of a laboratory at the Royal Institute where he worked. He also started to lecture and he was able to captivate his audiences with up-to-the-minute science and intriguing demonstrations as well as by his engaging style of lecturing.

FURTHER WORK

In spite all of these successes the idea of electromagnetic induction was never far from his mind. He kept working at it intermittently over a number of years. Then in 1831 he undertook a new series of experiments and on 29th August he succeeded. He set up his famous experiment which consisted of two coils wound on a soft iron torroidal core. The first coil was connected to a battery while the second one was connected to a very makeshift galvanometer. He noted in his experiment log book that the meter needle deflected when the battery was connected or disconnected, but that when a steady current was flowing then nothing happened.

Faraday announced his momentous discovery to The Royal Society later that year. However, very soon Faraday heard that Joseph Henry in America had performed some very similar experiments and might actually have made the discovery first. The news had actually taken some months to reach him because of the slow speed of communications in those days.

Faraday was still pursuing his work into other topics as well. He put forward the idea of magnetic lines of force. In keeping with his method of working this was very much a practical visualisation from the lines made by iron filings when placed near a magnet. He was also working on some ideas of electrolysis. The names he used are still those we have today: cathode, anode, ion, cation and anion.

HEALTH

The rate at which Faraday worked took its toll. After his discovery of electromagnetic induction he fell ill and only slowly recovered. It was not until after 1840 that he started work again. This time he set about investigating the polarisation of light. Using some "heavy glass" he had discovered some years before, he managed to rotate the polarisation of light when a magnetic field was present. This effect was named after him as the Faraday Effect. He also tried to find an equivalent effect using an electric field, but to no avail. It took another 30 years before this effect was discovered by Kerr.

RETIREMENT

Faraday continued to work for a while but the effect of his illness was still apparent at times. His powers of reasoning were not as good as they had been and he suffered from loss of memory. Realising that he could not keep up his original pace of work he began to retire from his many commitments from about 1860. He was granted a place to live at Hampton Court where he spent his last years with his wife. Faraday still spent some time on his researches but he made no more major discoveries and he died on 25th August 1867 at the age of 75.

PE

HOME-BASE

Gadget-mad Ian Burley is automating his shopping; could probably keep watchful record of his CT2 rabbiting; though he can't see a future for back-seat viewers.

SHOPPING ON-LINE

It's taken the best part of four years to be realised, but by the time this is published, the first of an initial batch of 5,000 Keyline teleshopping terminals should be in the hands of eager new owners.

We last covered news on the progress of Keyline back in June. For those of you who still aren't sure what I'm on about, briefly, Keyline is a new concept in armchair or teleshopping. You're virtually given a terminal, though there is a monthly standing charge. The device itself uses sophisticated artificial intelligence techniques to decipher plain English command phrases the user types in and convert them into legitimate shopping orders. Connection is via the phone and all purchases are done by credit card transactions. Participating companies offering goods or services will have special order processing computers to handle Keyline traffic. Keyline hopes to make the bulk of its money through taking a cut of the purchase transaction value from the service provider.

Originally, all Keyline terminals were to have unique user identity information embedded in them. However, along came the smart card and now Keyline has announced that it has adopted a smart card type manufactured by Gemplus Card International, part of the SGS-Thomson group. The card in question includes a microprocessor, 2K bytes of eeprom and the MCOS (Multi-application Chip Operating System). Incidentally, Gemplus makes the smart cards required for use with Sky TV satellite receivers, for which over 1,500,000 smart cards have already been produced from the Gemplus factory in Livingstone, Scotland. Every registered Keyline user will have their own unique smart card containing their name and address, credit card details and Keyline ID. It will be possible for Keyline users to use each others' terminals simply by using their own cards. There are also plans for public access Keyline terminals, so while the personal Keyline terminal is eminently portable you won't necessarily have to take it everywhere with you.

Eventually, it's planned that Keyline accounts will be linked to their owner's bank accounts so that credits can be downloaded into the smart card for later use. This could be the first definitive example of electronic cash in the UK.

The current Keyline status is that STC is building an initial 5,000 terminals, though sadly these will not have the smart card facility as implementation of this technology would have forced the project to miss its end of 1990 targets. By way of recompense, Keyline is offering any users signed up for the initial batch of terminals six months usage without a standing charge. After six months users will have the option of returning their terminals and getting their deposit money back or continuing but with the standing charge from then on.

At this year's Ideal Homes Exhibition alone, 2,500 requests for priority order forms were taken on the Keyline stand. At the same exhibition, the *Daily Mail* awarded Keyline its Blue Riband Award for technical innovation. The signs so far are good, but what will you be able to do with your Keyline terminal in the early days? Seven companies are expected to be ready to do business with Keyline users by the end of this year; the National & Provincial Building Society, National Westminster Bank, Littlewoods mail order catalogue, Kays of Worcester mail order, Sun Alliance insurance, Ladbrokes betting and the associated Hilton Hotel group. The first thing which is apparent from the list is that Keyline is by no means restricted to tele-"shopping" specifically. Betting, insurance quotations and claims, hotel booking, building society and bank account management are just some of the extra uses. Online games, electronic mail and access to public information services are just a few more mooted applications. Addenbrookes Hospital in Cambridge has even been experimenting with Keyline terminals as a way of keeping in touch with mothers in their post-natal clinic.

Putting my money where my mouth is I've already ordered my Keyline Terminal. Success is not guaranteed for Keyline supremo Chris Curry, co-founder of Acorn Computers of BBC Micro fame. It will be interesting to see what news I will have to report on Keyline in a year's time - by that time it will have hopefully signed up hundreds of thousands of users, or probably failed.

TALK TO YOUR WATCH!

Last month we featured a picture from the Summer Consumer Electronics Show in Chicago of a futuristic wrist watch called a ChatterBox. From the picture, sectionally reproduced below, you may have deduced that this is a watch you can talk to - and it will play back a digitised recording of what you've said. The rather imposing black watch, which would dwarf even my chunky wrist, has a built in microphone and dual function selector switch/miniature speaker. Up to 15 seconds of sound can be digitised to an internal chip memory though the play back can be speeded up or slowed down in order to introduce fun sound effects. Although not shown at CES this time, the company behind the watch, Santa Clara California based Chatter Box Inc., is promising optional clip-on modules like an fm radio, voice pitch changer and a sound effects generator. The basic watch, which should be ready in time for the American Christmas market will sell for between $30 and $40, or about £16-£21 before taxes, which sounds like a bargain to me, especially after seeing the incredible chip integration inside first hand. Oh yes, a five function lcd quartz watch can be found right in the middle of the thing if you look hard enough!

CORNERING THE RADIO

Respected hifi manufacturer, Bose, has introduced a new multi-zone audio system designed to serve several rooms around your house simultaneously. This is nothing new - Bang & Olufsen, for example, has offered such a system for several years, but that relied on infra-red remote controller technology which isn't very good at reaching control receptors hidden away around corners. High frequency sonic controllers popular in the seventies can reach around corners but have a limited range and they annoy the pets! Remarkably, Bose has turned to any obvious solution which hardly anybody else uses - radio remote control. Bose UK claims it is the first company to be officially licensed by the Department of Trade and Industry to sell a radio frequency remote controller for hifi use according to the 1984 Telecommunications Act. For radio buffs, the frequency used is 27.465 MHz. The system, lavishly called the Lifestyle Music System, is a slimline cd player and am/fm tuner with thirty presets.

Designed to work with Bose Acoustimass active speakers (power amplifiers are contained in the speaker units rather than the music centre), up to two simultaneous programmes can be played - one for the tuner and another for the cd. On top of that you can have several sets of speakers in different rooms, each set to different volumes, as required, using additional remote controls. As the main remote control uses radio transmissions there's no need to point the device and you can be up to 20 metres from the music centre - in the garden, the bath, garage, wherever! Not being a hifi expert, I can only rely on reliable reports that the system is very impressive, both to use and listen to. A starter system costs a few pence shy of £2,000, which I'm told is reasonably good value, especially compared to the competition like B&O. Bose has never been exactly conventional with its characteristically recognisable speaker systems, but perhaps this time the company is on the verge of setting trend to be followed by others?

HAVE VIDEO – WILL TRAVEL

Hitachi has been showing how it has applied its television and video technology to that most hostile of viewing and listening environments; the inside of a car. A while ago the company installed a state of the art VHS-C hifi video player and tuner complete with Dolby Surround multi-speaker audio into a Lotus Esprit Turbo for the benefit of entertaining journalists (I missed out, unfortunately). The two-seater Lotus isn't really a very good place to install all this hi-tech, and lately the system has been demonstrated in a much larger Renault Espace people mover. The driver or passengers view tv or videos on the move via a high quality 5 inch tft (thin film transistor) active matrix colour monitor. In fact British law only permits passengers to watch tv in-car. A remote control is provided for video/tv selection and speaker balancing. 240 watts of power amp complements the Pro Logic Dolby Surround processor. The stereo tv tuner uses a four aerial "diversity" system for optimal signal strength. The video player unit is removable for use out of the car. I can't see much of a future for bored back-seat passengers if the Hitachi system catches on.

TELEPOINT SIX MONTHS ON

The first Telepoint CT-2 cordless telephone networks went live over six months ago. On my travels around the country, I have seen plenty of evidence that the public base stations which users require to use their tiny phones away from home are now becoming commonplace. Next time you're at a motorway service station for example, look out for up to four one-metre long vertical antennas strategically positioned near the car park. Little Chef restaurants seem to bristle with them these days. Zone Phone sponsors the ITV London weather bulletin, Call Point and Phonepoint logos have been spotted at various sporting events and BYPS, with its catchy Rabbit logo is beginning to catch the eye even after its late arrival on the scene.

I haven't seen much sign of any users yet, however. Potential users I have spoken to have all been put off by either the lack of an incoming call facility away from home or, incredibly, by the price. At usually just less than £200, the phones are initially very attractive - being incredibly small and light and around half the price of their cellular counterparts. Unfortunately the home base station which you need to use the phone as a conventional cordless unit at home still costs another £200. Call costs are attractive in London where there is a premium rate on cellular calls within the M25 boundary, but elsewhere in the country cellular costs are reasonably close to telepoint tariffs.

None of the telepoint dealers I spoke to six months ago have seen much business from the new phones, although one dealer claimed to have discovered a niche market where office workers were using the phones with a base station as a high quality mobile phone around the office.

I suppose the biggest indictment of the poor start the telepoint services have acheived so far is that I haven't been tempted to buy one yet - and I'm gadget mad! I will buy one though - as soon as the combined phone and personal base station price breaks below the £200 barrier. PE

Ian Burley is the Deputy Editor of BT Micronet, an on-line computer and technology magazine published on Prestel by British Telecom.

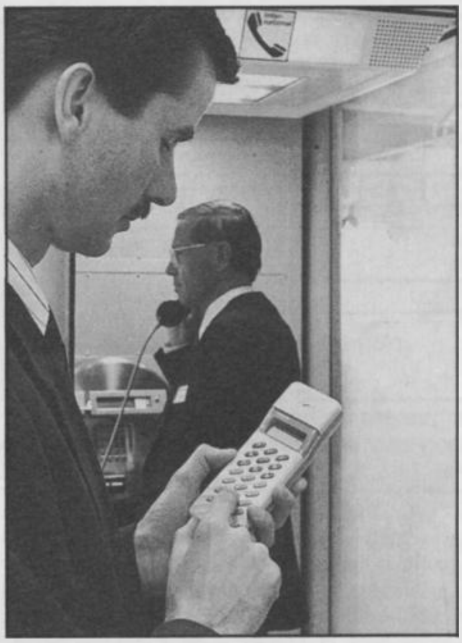
WHY DIGITAL PHONES?

Tom Ivall examines the benefits to be gained from the incoming digital public mobile telephone systems.

All the new public mobile telephone systems are to be digital in operation. The radio signals transmitted and received by the hand-portables or carphones are carrier frequencies modulated by digital codes. The speech signal to be transmitted is analogue-to-digital converted, then encoded into a stream of binary digits. Typically these '1' and '0' bits modulate the carrier frequency by a form of frequency shift keying (fsk). Logic 1 shifts the carrier frequency a predetermined amount in one direction; logic 0 shifts it equally in the opposite direction.

CT2

One of these new digital systems, called CT-2 (cordless telephone 2), was pioneered in Britain. In hand-portable form it's intended for three kinds of use: as a cordless phone for the home; as a business/workplace cordless phone; and as an outdoor mobile phone restricted to working near base stations set up in public places. The last-mentioned is of course the telepoint service already running in the UK (see Ian Burley's Home Base reports in the June and July 1990 issues).



Digital Telepoint CT-2 handset made by Siemens and due to enter full service in 1991.

In their mode of operation the digital systems can be divided into two groups: cordless and cellular. Quite possibly hybrids could be formed from these.

Not yet in operation but due to arrive some time in the 1990s are a pan-European cellular digital system called GSM (Groupe Special Mobile); a harmonised cordless phone standard for all Europe known as DECT (Digital European Cordless Telecommunications); a low-priced, mass-market cellular digital service for Britain called PCN (Personal Communications Network); and a pan-european PCN scheme named DCS 1800 (Digital Cellular System on 1800 MHz).

Public digital systems are also on the way in Canada, the USA and Japan. The ultimate in digital technology, little more than a dream at the moment, is a global scheme known as UMTS (Universal Mobile Telecommunications System). This would probably evolve from the PCN mass-market idea and would integrate all pre-existing technologies - cellular, cordless, paging and so on. It would enable anyone owning a suitable handset or carphone to travel with it and use it throughout the world.

DIGITAL BENEFITS

All the cellular public phone services now in operation are analogue systems. The carrier frequency in each channel is frequency modulated (see Mike Sanders' article in PE August 90 for fuller details). These analogue systems are well established and well tried, so why change them? It seems almost perverse to abandon analogue baseband signals when the digitised version of a speech waveform needs so much more bandwidth to transmit.

A major problem with the existing analogue cellular systems (AMPS, TACS, NMT etc) is their limited capacity. Congestion is already occurring and customers are complaining about difficulties in making calls. In the UK, the extended TACS system operated by Cellnet and Vodafone will probably reach saturation at about two million subscribers.

The limited capacity is a result of these systems' relatively low efficiency in the use of spectrum space. Efficiency in all engineering is an output : input ratio. Here, it's the ratio:

$$\frac{\text{communications achieved}}{\text{spectrum space used}}$$

The 'communications' is measured in erlangs (units of telephone traffic intensity, where one erlang is one permanently engaged circuit). 'Spectrum space' is measured not just in frequency bandwidth but in geographical space and time as well. This is because efficient usage of the radio spectrum depends on re-using the same radio frequencies at different places or at different times. Fig.1 illustrates this concept that spectrum space has the three dimensions of frequency bandwidth, space and time. So the above efficiency ratio in more precise form becomes:

$$\frac{\text{traffic intensity}}{\text{bandwidth x space x time}}$$

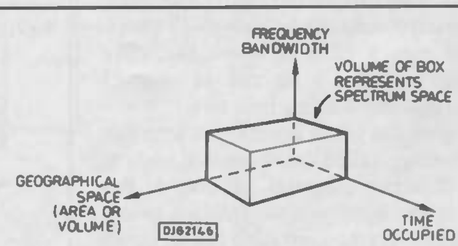
In practical units this boils down to a widely used formula in the telecoms field: erlangs per MHz per sq km. (This includes the 'time' dimension because an erlang is a circuit engaged over unit time.)

In the analogue cellular systems the spectrum space efficiency is low basically because of co-channel interference between cells. The overall frequency allocation for the system is fixed by international regulations, and as each channel within it must have a certain minimum bandwidth there is a limited, fixed number of channels. So to cope with thousands of simultaneous calls, all these available channels have to be re-used many times over.

The capacity of a system can be increased by making the cells smaller in coverage area and packing them closer together. But the closer they are, the worse the co-channel interference becomes. Then, this co-channel interference can only be kept reasonably low by reducing the transmitter powers.

Of course there is a practical limit to this process. If you took it to the extreme you would end up with the very low power and few metres range typical of the cordless phone in the home. So it's co-channel interference which fundamentally sets a limit on the spectrum space efficiency of cellular systems - a low value of erlangs/MHz/km^2 in the analogue case.

Fig. 1. Spectrum space available to radio systems has three dimensions: bandwidth, space and time.



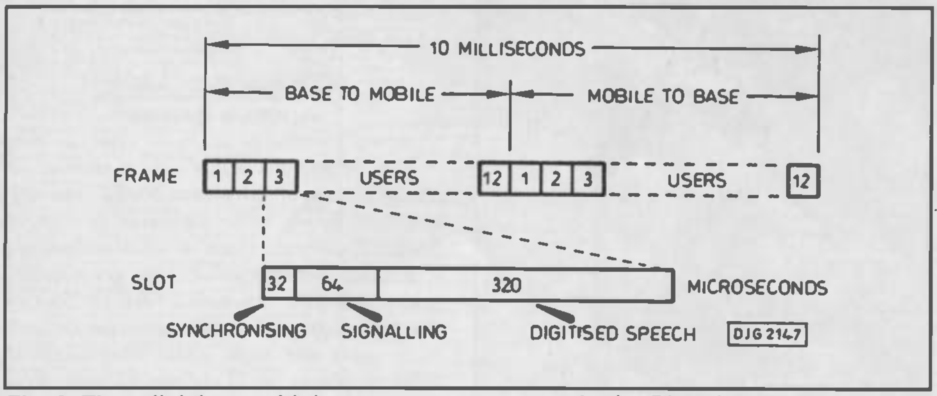


Fig. 2. Time division multiple access arrangement in the Digital European Cordless Telecommunications system. Each carrier frequency is shared on a time-division basis by 12 speech channels.

HIGHER NETWORK DENSITY

Digital signals provide better efficiency because, for a given quality of telephony, they allow much higher levels of co-channel interference. Thus, for a given transmitter power, more cells can be packed into a given area, thereby increasing the communications achieved for the same spectrum spaced used. So the value of the erlangs/MHz/km^2 measure of efficiency increases.

Engineers working on the GSM digital system, for example, reckon that it will give up to a three-fold improvement in spectrum space efficiency over the NMT system taken as a reference analogue system.

The reason for this superiority of digital transmission is inherent in the nature of digital signals generally. With analogue telephony the quality of the speech communication depends on how accurately the speech waveforms are maintained throughout the system. Co-channel interference disturbs or blots out these waveforms at the receiver.

With digital telephony this does not occur, at least in the same direct manner. The co-channel interference can certainly disturb the digital fsk waveform transmitted. But because this waveform is a binary coded version of the speech the disturbance doesn't affect the speech quality so much. In binary coded speech it is the mere presence or absence of 1 or 0 bits in a sequence that affects the accuracy, not the condition of the waveforms delineating these bits.

However, the bit streams sent over the air in the new digital systems are not simple codes like pcm. As Mike Sanders pointed out, straight pcm with its 64-kbit/s bit rate, would require an excessive bandwidth for each speech channel. So the speech coders adopted are designed to reduce this. Both CT-2 and DECT use adaptive differential pulse code modulation, reducing the bit rate to 32 kbit/s. And GSM uses a form of linear predictive coding that produces a bit rate of only 13 kbit/s (and possibly 8 kbit/s later on).

In addition the GSM system has a further layer of coding, called convolutional coding, for error reduction purposes. Of course, this also makes the system more tolerant to co-channel interference by reducing the bit errors caused by this interference.

Apart from the capacity problem in cellular telephony, there are three other influences behind the decision to go digital in cellular and cordless systems generally. First, the whole of telecommunications is moving towards digital technology, in both transmission and signalling. The climax of this process will be the integrated services digital network (ISDN) which is now building up. Since public mobile telephones are connected into the fixed network, there will be engineering, operational and economic advantages in using its new technology.

Secondly, the size, cost and power consumption of vlsi digital signal processing electronics are falling rapidly. This makes the digital technology extremely attractive for producing much smaller, lighter and cheaper handsets than the analogue equivalents. Finally, because the digital methods of signal processing and signalling are programmed by software, a digital mobile system is easier and less costly to change if it has to be modified or enhanced in the future.

TIME DIVISION PRINCIPLE

All the new digital mobile systems use time division as the basic principle for multiplexing the digitised speech signals. As Mike Sanders explained, this takes the form of time-division multiple access (tdma) in the GSM cellular system. The DECT scheme, which is micro-cellular and operates within buildings, also uses tdma but in a different way.

Its carrier frequencies are in a band - not yet fully decided - in the region of 1700 MHz. Each carrier is shared by 12 speech channels on the time division principle shown in Fig.2. Time is divided into 10ms frames, and each of these is subdivided into 417μs slots for the 12 users as shown. Each slot contains a burst of data consisting of digitised speech together with synchronising and signalling data.

In both DECT and CT-2 the handset transmits and receives speech signals on the same, single carrier frequency. To achieve this the radio channel transmits and receives alternatively in very short bursts of bits. Appropriately this is called 'ping-pong' - or, more formally, time division duplex - transmission. As shown in Fig.3, the CT-2 bursts are each 1 ms long and contain data at a rate of 72 kbit/s. This data rate has to be just over twice the basic speech coding rate of 32 kbit/s to allow speaking and listening to be virtually simultaneous.

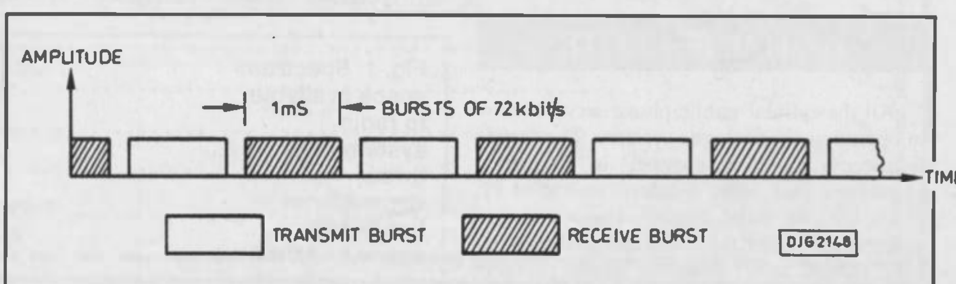
The GSM system works in the 900MHz mobile radio band. Carrier frequencies are 200 kHz apart and each carrier takes eight speech channels. As in CT-2, the carriers are modulated by a form of fsk called Gaussian minimum shift keying which occupies less frequency spectrum than ordinary fsk. Here the transmit and receive signals are separated not in time but in frequency, by a spacing of 45 MHz.

Fig.4 shows the time division in the tdma system. Time is divided into blocks of 26 frames. Each frame of 4.62 ms is then subdivided into eight slots. Each slot, lasting for 577 μs, contains 156 bits of data made up of digitised speech, a guard period, control and tail bits and a sequence of 26 bits which the receiver uses to overcome multipath transmission effects.

In the predictive and convolutional speech order, every 20 ms of speech produces 456 bits and this number is conveyed by four of the slots shown in Fig.4. Overall the data rate transmitted by radio is 271 kbit/s.

The digital system to be used for the PCNs is still being worked out in detail but broadly it will follow the well-established GSM technology, as an outcome of international agreement. In Europe all such international agreements are now made through an organisation called ETSI (European Telecommunication Standards Institute). In 1988 this body replaced the old CEPT (Conference Europeenne des Administrations des Postes et des Telecommunications) originally set up by the telecoms authorities of 26 countries. GSM began as a CEPT group

Fig. 3. The 'ping-pong' time division duplex principle used in CT2 cordless telephony. A single radio frequency carries both transmit and receive digital signals in alternate short bursts of bits.



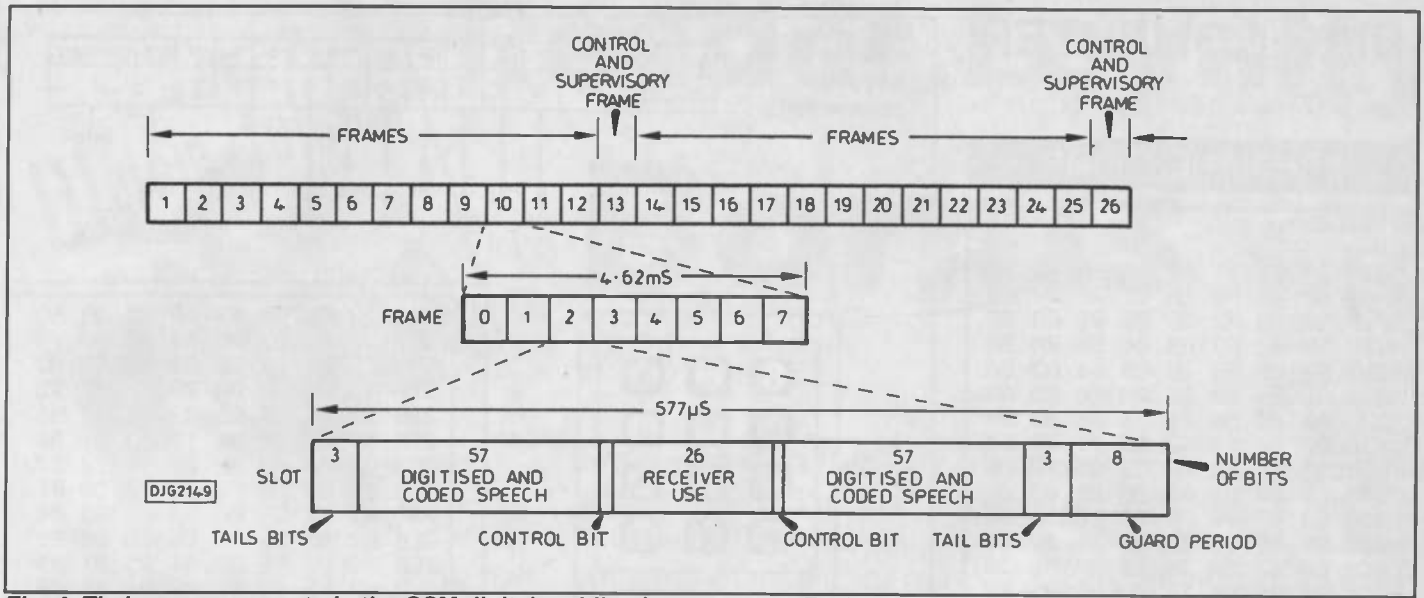


Fig. 4. Timing arrangements in the GSM digital mobile phone system. Each radio frequency carries eight speech channels. Duplex working is by frequency division rather than the time division of CT2 and DECT.

and is now within ETSI. New frequency allocations for these digital services have to be made by world-wide agreements through the International Telecommunication Union.

PING-PONG SYNTHESISER

An example of the novel circuitry needed for time division techniques is shown in Fig.5. In the 'ping-pong' duplex transmission system (Fig.3) the handset contains a frequency synthesiser which has to switch repeatedly between two frequencies: the transmitter frequency, at about 800 MHz, and the heterodyne receiver's local oscillator, which differs by about 10 MHz (to give a 10MHz IF). The problem is to maintain a frequency accuracy of 1-2 kHz at these abrupt transitions. It means that phase errors at the transitions must be kept extremely small.

Fig.5 is actually the outline of a frequency synthesiser used in the Ferranti telepoint handset. Much of the circuitry is integrated in a cmos gate-array chip. Basically it is a conventional phase-locked synthesiser, with a flip-flop phase comparator working on pulses from the reference oscillator and programmable frequency divider. The error signal from the comparator adjusts the radio frequency generated by the voltage-controlled oscillator (vco). But the circuit also includes a technique for making an extremely fine, individual phase correction at every frequency transition.

This technique uses the two capacitors, which are alternately switched across the opamp in synchronism with the frequency transitions. The different voltages on these shift the vco frequency. Also, the phase comparator is enabled by a switched voltage level. Broadly, the phase correction works by making tiny changes to the division ratio of the programmable divider. These give slight time shifts, as small as 16 picoseconds, to the divider's output pulses. In principle the correction method is analogous to that of a vernier on a mechanical measuring instrument, by which readings can be made to a small fraction of a main scale division. PE

One of the prototype digital phones from Microtel, a consortium led by British Aerospace.

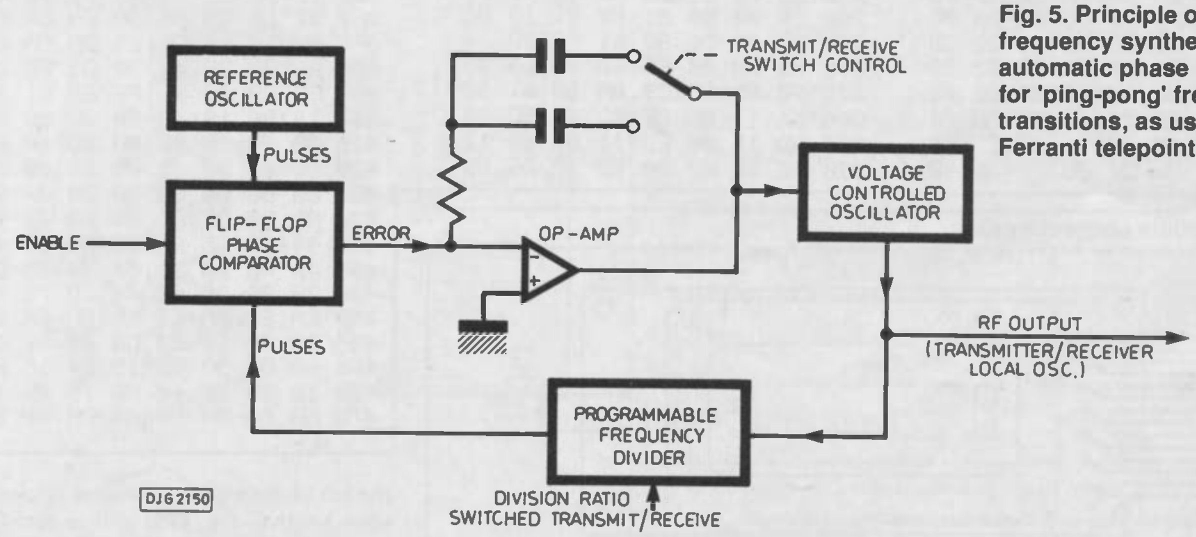
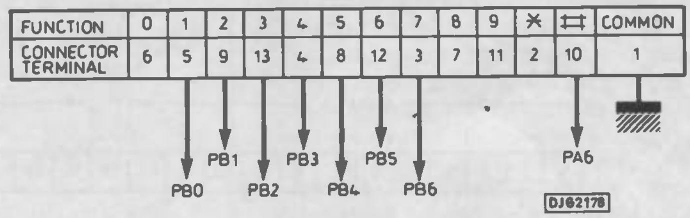


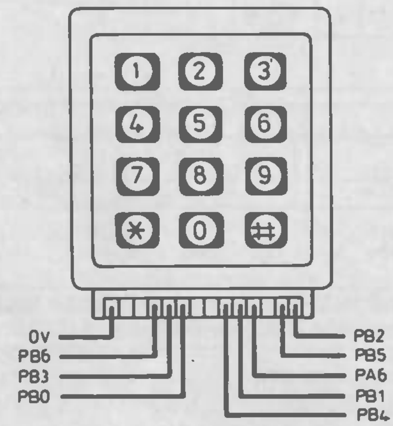
Fig. 5. Principle of vlsi frequency synthesiser, with automatic phase correction for 'ping-pong' frequency transitions, as used in the Ferranti telepoint handset.

BIKE COMPUTER

Continued from Page 17

Fig. 11. Keypad connections.





EPROM HEX DUMP

```
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008 C9 7F F0 1A C9 3E D0 0D
010 A9 00 A2 03 95 00 E8 E0
018 F0 90 F9 A9 04 EA EA EA
020 EA EA EA 20 00 44 A2 00
028 AD 0A 20 8E 0A 20 85 00
030 A2 08 86 01 18 46 00 90
038 07 20 58 40 C6 01 D0 F4
040 A5 FF F0 08 C9 03 F0 04
048 C9 07 D0 03 20 A0 43 4C
050 80 40 00 00 00 00 00 00
058 A9 09 85 1A A5 1A A8 B9
060 00 47 AA B9 20 47 A8 20
068 00 42 C6 1A D0 EE A5 69
070 29 0F AA F8 18 B5 30 69
078 01 95 30 D8 60 00 00 00
080 EE FF 06 AD FF 06 C9 08
088 B0 03 4C 70 41 A9 00 8D
090 FF 06 A9 03 85 1A A4 1A
098 B9 10 47 AA B9 30 47 A8
0A0 20 00 42 C6 1A D0 EF F8
0A8 38 A9 00 65 69 85 69 C9
0B0 60 90 14 A9 00 85 69 65
0B8 68 85 68 C9 60 90 08 A9
0C0 00 85 68 65 67 85 67 D8
0C8 A9 00 AA 85 03 95 50 95
0D0 A0 E8 E0 0A 90 F7 AA B5
0D8 30 A8 A2 A9 20 00 42 E6
0E0 03 A6 03 E0 0A 90 F0 A5
0E8 A8 C5 17 90 16 F0 02 B0
0F0 06 A5 A9 C5 18 90 0C A5
0F8 A8 85 17 A5 A9 85 18 A9
100 01 85 19 A5 69 29 0F AA
108 A9 00 95 30 A5 FF D0 09
110 20 70 46 20 E8 44 4C 4F
118 41 C9 01 D0 12 A5 19 F0
120 06 20 79 46 20 E8 44 A0
128 29 20 90 43 4C 4F 41 C9
130 03 D0 09 20 70 46 20 F4
138 44 4C 4F 41 C9 04 D0 0F
140 A5 19 90 0B 20 79 46 20
148 F4 44 A0 B9 20 90 43 20
150 40 46 20 A0 43 4C 70 41
158 00 00 00 00 00 00 00 00
160 00 00 00 00 00 00 00 00
168 00 00 00 00 00 00 00 00
170 AD 01 20 85 03 09 20 8D
178 01 20 EA EA EA A5 03 8D
180 01 20 4C 00 40 00 00 00
188 AD 00 20 29 7F A8 AD 01
190 20 29 40 D0 16 A9 01 8D
198 10 07 A2 07 86 FF A5 49
1A0 8D 11 07 A9 00 8D 12 07
1A8 4C D0 41 AD 10 07 D0 01
1B0 60 C0 7F EA D0 0B A5 49
1B8 F8 38 ED 11 07 C9 03 90
1C0 0D A2 00 8E 01 20 CA EA
1C8 8E 03 20 20 90 46 D8 60
1D0 A2 01 86 1B EA 20 40 46
1D8 A0 00 8C 16 07 B9 E8 47
1E0 A2 10 20 98 44 EE 16 07
1E8 AC 16 07 C0 08 D0 0A A9
1F0 C0 A2 00 20 98 44 AC 16
1F8 07 C0 10 90 E0 60 00 00
200 F8 84 05 A0 09 18 B5 00
208 65 05 95 00 90 08 CA B5
210 00 69 00 88 D0 F4 D8 60
218 00 00 00 00 00 00 00 00
220 F8 84 05 A0 09 38 B5 00
228 E5 05 95 00 CA B5 00 E9
230 00 88 D0 F6 D8 60 00 00
238 00 00 00 00 00 00 00 A9
240 00 AA 95 90 95 E0 E8 E0
248 0A 90 F7 85 C6 85 D6 A0
250 03 A2 00 BD 05 06 D0 08
258 E8 88 88 E0 03 90 F4 60
260 C9 0A B0 01 88 8C 10 06
268 8E 00 06 A0 01 A2 00 B5
270 75 D0 08 E8 88 88 E0 03
278 90 F5 60 C9 0A B0 01 88
280 8C 11 06 8E 02 06 D8 38
288 AD 10 06 ED 11 06 8D 12
290 06 38 A9 04 ED 12 06 8D
298 13 06 18 69 E0 85 0A AC
2A0 00 06 A2 00 B9 05 06 95
2A8 C7 E8 C8 E0 03 90 F5 AC
2B0 02 06 A2 00 B9 75 00 95
2B8 D7 E8 C8 E0 03 90 F5 A5
2C0 D7 C9 0A 90 13 A0 04 84
2C8 03 A0 03 A2 00 18 76 D7
2D0 E8 88 D0 FA C6 03 D0 F1
2D8 A5 C7 C9 0A B0 0D A0 04
2E0 A2 03 18 36 C6 CA D0 FB
2E8 88 D0 F5 A9 04 85 07 A9
2F0 99 8D 05 06 A9 04 85 09
2F8 A5 09 18 69 C5 AA A4 09
300 B9 D5 00 85 05 F8 20 25
308 42 C6 09 D0 EB A6 0A A0
310 01 20 00 42 CE 05 06 A5
318 C6 F0 D9 A9 05 85 09 18
320 A5 09 69 C4 AA A4 09 B9
328 D4 00 A8 20 00 42 C6 09
330 D0 ED A6 0A A9 01 85 05
338 F8 20 25 42 E6 0A A0 04
340 18 A2 03 36 C6 CA D0 FB
348 88 D0 F5 C6 07 D0 A0 A2
350 0A A0 09 B5 E0 C9 0A B0
358 05 CA D0 F7 F0 10 29 F0
360 4A 4A 4A 4A CA 95 E0 E8
368 B5 E0 29 0F 95 E0 A0 00
370 A2 00 B9 E0 00 0A 0A 0A
378 0A 18 C8 79 E0 00 95 95
380 E8 C8 C0 0A 90 EC 60 00
388 00 00 00 00 00 00 00 00
390 A2 09 B9 00 00 9D 00 06
398 88 CA D0 F6 4C 3F 42 00
3A0 A6 FF 8A 0A 85 1C AA BD
3A8 70 47 85 15 BD 80 47 85
3B0 0B BD 90 47 20 30 44 A2
3B8 10 A4 1C B9 A0 47 20 98
3C0 44 A4 1C B9 B0 47 20 98
3C8 44 A6 1C E8 BD 70 47 85
3D0 15 BD 80 47 85 0B BD 90
3D8 47 20 30 44 A2 10 A4 1C
3E0 C8 B9 A0 47 20 98 44 A4
3E8 1C C8 B9 B0 47 20 98 44
3F0 60 EA EA EA EA EA EA EA
3F8 EA EA EA EA EA EA EA EA
400 A2 00 38 4A 90 03 E8 D0
408 FA C9 00 86 FF A2 01 86
410 1B 86 19 60 00 00 00 00
418 00 00 00 00 00 00 00 00
420 00 00 00 00 00 00 00 00
428 00 00 00 00 00 00 00 00
430 A2 00 85 0C 09 80 20 98
438 44 A6 15 A0 00 B5 00 4A
440 4A 4A 4A 20 61 44 B5 00
448 29 0F 20 61 44 20 78 44
450 EA EA EA EA EA EA EA EA
458 EA EA E8 C8 C0 03 90 DD
460 60 09 30 86 15 84 16 A2
468 10 20 98 44 A6 15 A4 16
470 60 00 AA AA AA AA AA AA
```
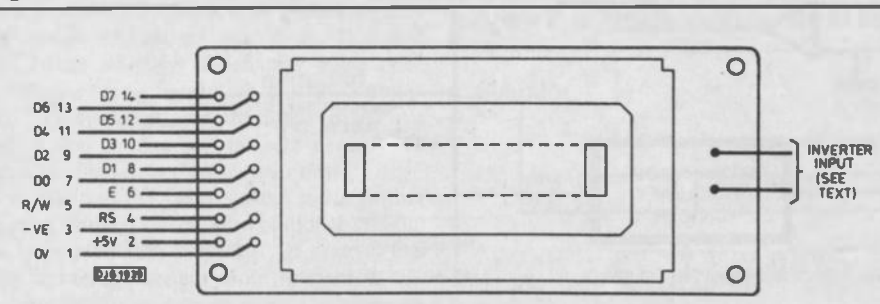

Fig. 12. lcd module connections.



The hex dump will be continued next month, when we shall also look at it in detail, and describe the construction.

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IN–SITU NICAD RECHARGER

Dave May's adaptor lets you recharge your nicads without interrupting your listening!

Using nicad rechargeable nickel-cadmium secondary cells can save a lot of money, compared to using throw-away primary cells or batteries, whether of the zinc-carbon variety or the more expensive but longer lasting alkaline types. So much so, that as a result "trannies", Walkman type personal stereos, radio-cassettes etc, probably get a good deal more use. Normally one has to remove the cells when exhausted and transfer them to a charger unit for the recommended recharging period, and then replace them in the battery compartment. The unit described here enables you to recharge your nicads "in–situ".

Why should you want to recharge them without taking them out of the trannie, or whatever? Here are just a few reasons:

1) To save time and trouble
2) To save wear and tear on the battery cover and contacts
3) To ensure that all the cells receive the same amount of charge
4) So that you can use the set whilst recharging the batteries.

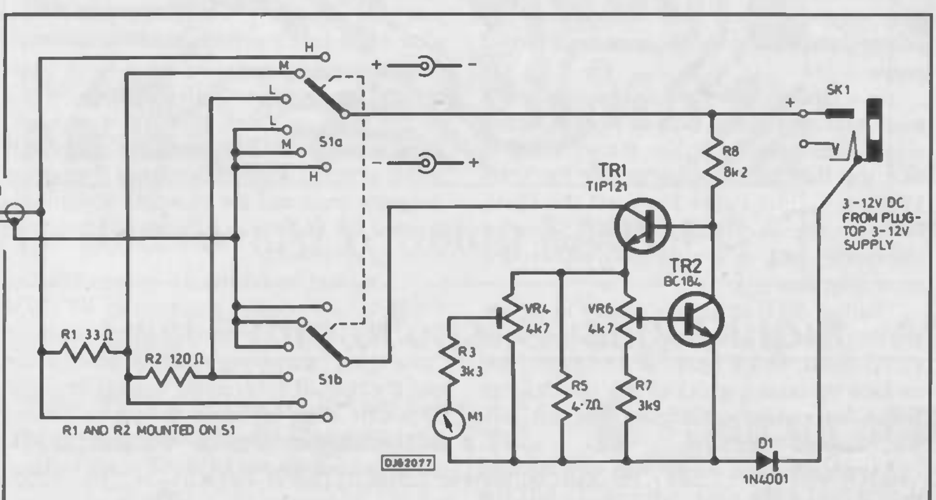
Of these, reason three is particularly important. With many of the nicad rechargers available, you cannot be sure that all cells will receive the same amount of charge. Unless you mark the cells and religiously rotate them around the charging positions, this can lead in time to one cell being repeatedly charged less than the others and finishing up at the end of the charge period with a lower and lower useful life than the rest. Thus recharging is needed more and more often. Some attractively priced nicad chargers are in fact just not suitable for some recharging applications. For instance, my Sanyo personal stereo uses three AA cells, whilst a charger for up to four AA cells I was given can only charge cells in pairs. All of these and the other problems as well are swept away by the handy little unit described below.

HOW IT WORKS

Fig.1 shows the circuit of the unit. It is powered from a 3V to 12V 300mA unregulated power supply of the sort manufactured for a silly price in the Far East and sold at a modestly reasonable price from many UK outlets. This simply plugs into the in–situ charger, with reverse polarity protection provided by the 1N4001 power diode. At the other end, a lead terminated in a "spider" plug with 2.1 and 2.5mm power plugs and 2.5 and 3.5mm jack plugs will plug into the external power socket of just about any battery operated whatsit. It's the bit in between that makes it useful.

Switch S1 provides a choice of three different values of series resistance to set the charging current, and also enables the output plug polarity to be set to centre contact positive, or negative, as needed. The charging current is indicated on the meter, which monitors the voltage drop across the 4.7ohm resistor. The npn darlington transistor is normally saturated by the base current through the 8k2 resistor, so that the available values of series limiting resistor are 4R7, 4R7 + 33R, and 4R7 +33R + 120R. In the event of excessive demand current, for example a short circuit at the output plug, the voltage drop across the 3k9 resistor turns on the BC184, reducing the base current to the darlington and limiting the current to a safe value.

Fig. 1. Circuit Diagram of the in–situ nicad recharger



CONSTRUCTION

Fig.2 shows the layout and the all important breaks in the track. Take my advice and use a proper track cutting tool. A twist drill bit can be used but the twist of the flutes puts a front rake on the cutting edge and this tends to tear the copper back as it cuts: it can also leave an almost invisible whisker of copper shorting to the adjacent track. The proper tool has straight flutes and no front rake, so it does a neater job. It is not expensive and should last a lifetime. I find it pays to check with an eyeglass that each cut is complete, a moment or two spent doing this can save much longer in fault-finding when the completed circuit doesn't work.

The circuit board can most conveniently be connected to the switch and the meter with a short length of colour coded ribbon cable. The meter used is one of the very cheap indicators mass produced in the Far East and used as vu meters, power meters, vswr meters etc. Full scale deflection differs somewhat from make to make but is in the range of 120 to 250 µA. The scale is designed to provide extra resolution at low current, becoming more cramped at the top end. This type of indicator is widely available on the surplus market and good value at a pound or two. Fig.3 shows the meter scale used on the prototype: it can be photocopied if you don't want to cut up your copy of PE (*none of our readers are vandals! Ed.*) and used to rescale your meter. An alternative version may be used, with the intermediate scale calibration marks being filled in to suit the particular meter being used, while setting up as described below.

Fig. 2. Component layout for the circuit.

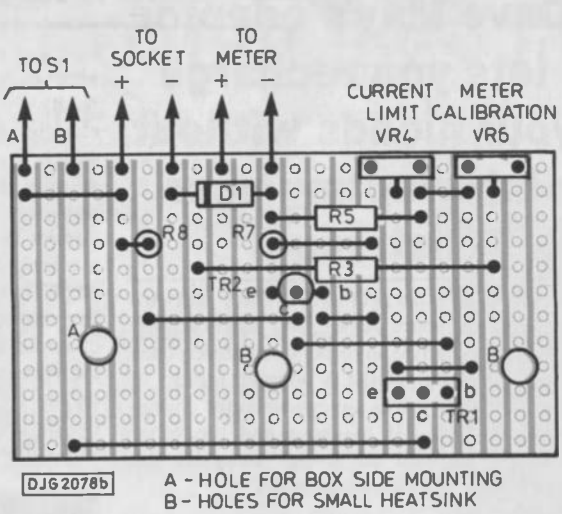
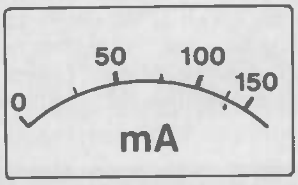


Fig. 3. This meter scale can be photocopy reduced/enlarged to suit your meter.



COMPONENTS

RESISTORS

R1	33R
R2	120R
R3	3k3
R4 R6	4k7 min skel vert preset (2 off)
R5	4R7
R7	3k9
R8	8k2

All 0.25W 25% carbon

SEMICONDUCTORS

D1	1N4001
TR1	TIP121 (with pcb vertical mounting heatsink)
TR2	BC184

MISCELLANEOUS

S1	2 pole 6 way rotary switch, with pointer knob to suit
Sk1	2.1mm power socket (input)
Pl1	Universal plug (e.g. FK08J Maplin)
M1	Meter (see text)
Box	Small plastic (to suit)

SETTING UP

Set the wiper of the BC 184's 4k7 pot to of the TIP121 darlington. Connect the power supply, set to 6V, to the adaptor's input. Short circuit the adaptor's output spider plug via an ammeter - digital or analogue - set to, say, the 1 amp range. Adjust the 4k7 pot for a short circuit current of 180mA. Now adjust S1 and the output voltage of the power supply so that the ammeter reads 150mA or less. Adjust the other 4k7 pot so that the reading on the adaptor's meter agrees with that on the external ammeter. The adaptor is now set up.

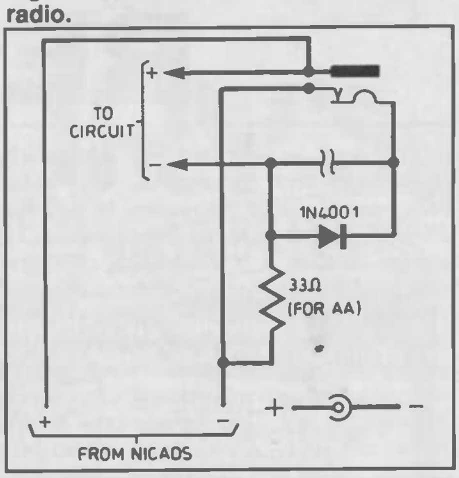
SETTING UP

If you only intend to use the adaptor with a single piece of equipment, omit the wiring on one side of S1, so that the adaptor can only produce the required polarity output. Only the very simplest modification to the equipment to be recharged is necessary: simply connect a shorting link or suitable resistor across the outer break contacts of the equipment's external dc power socket. Set S1 to L (low), the power supply output voltage to 3V and plug in. Now wind up the power supply volts and/or adjust S1 to set the desired charging current - 50mA to AA cells, 150mA for commercial C and D cells - or as directed by the manufacturer.

If you intend to use the adaptor with several different items of equipment, some having centre positive and others centre negative power sockets, then S1 should be fully wired as shown. In principle, the same simple link across the power socket outer is all that is necessary in each equipment, but the inclusion of a reverse polarity connection diode as in Fig.4 is most strongly recommended: remember that off load the unregulated power supply will provide an output of 18V or more - you wouldn't want to accidentally connect that back to front to the equipment, especially if it had inadvertently been left switched on! True, this involves cutting a track as shown, but better safe than sorry.

If you measure and note the current normally taken by the radio set or whatever, say 20mA, then by setting the current indicated by the meter to 20mA more than the required charging current, you can use the radio at the same time as charging the batteries. Alternatively, the charging period can be extended instead. PE

Fig. 4. Modification to typical portable radio.



LEADING EDGE

➡ Continued from page 8.

But the search procedures are still unfriendly, muddled and time consuming. Callers first get a message on screen asking them to type a code word to identify the type of computer they are using, referred to as either Prestel or VT100 microcomputer. Illogically the caller must key VTI to signify VT100. Absurdly, the system rejects the very similar and logical instruction VT1, wasting valuable call time by transmitting the full display page of text again before each rejection.

After that, the system wastes more valuable call time on painting pretty viewdata designs on screen before asking further questions. For no apparent reason, control key strokes must be preceded by an unseen question mark. While this is happening, any printer connected to the PC spews out wasted pages.

As a random and genuine practical test, I tried hunting for any firm in North London which sells security grilles for windows. It took less than half a minute to take the North London Yellow Pages book off the shelf, look up the section labelled "Security Services" and spot a display advert for security grilles.

Dialling EYP and trying to key in similar words, produced screenfulls of options but no useful result. I tried again, several times, and on each occasion got locked into search loops which led nowhere. Escaping was difficult, which wasted more time.

I couldn't work out how to step through the fields of the search menu, to tell the wretched thing what service or goods I was looking for and in what area of the country. It just kept eating my mistakes, repeating the same futile search patterns based on incorrect instructions (eg searching for a town name entered as goods) and laboriously throwing up the same questions over and over again. Even at the fastest line speed available (2400 baud, which is eight times faster than many domestic modems) the viewdata screenloads wasted far too much expensive telephone time for no reward.

To try and be fair on the system I dialled the Help Line number given out by BT (0734 506506) to ask for advice. I got only an "intelligent" answering machine which asked me a string of infuriating market research questions. I left my name and phone number urging someone from EYP to phone me back. By the end of the week I'd still heard nothing. PE

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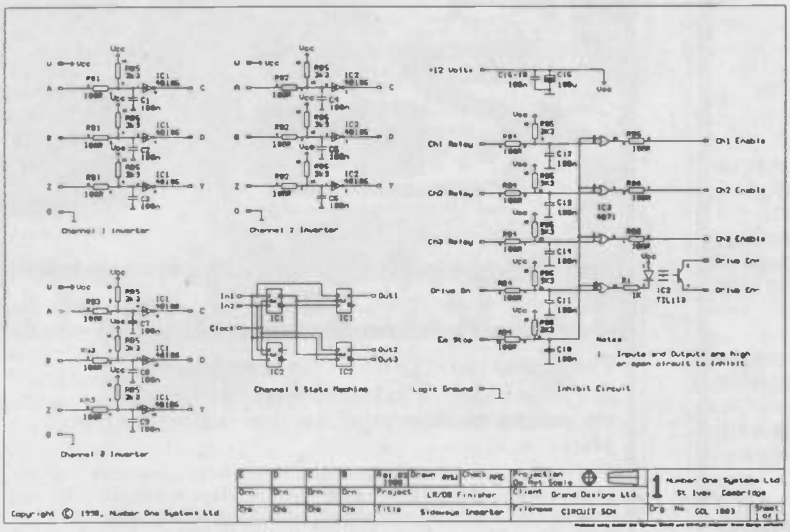

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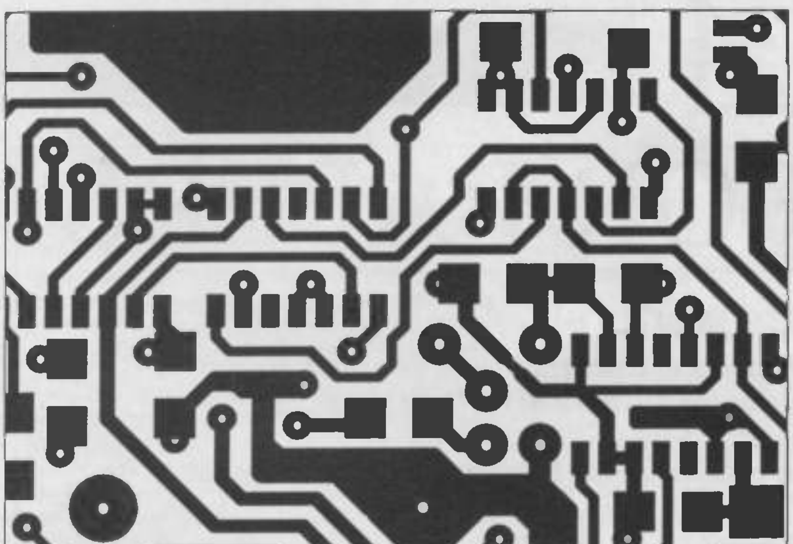

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Your Ed looks at some of the new books recently received.

Simple Short Wave Receiver Construction. R.A.Penfold. Babani BP275. £3.95. ISBN 0-85934-220-4.
One of life's pleasures, however experienced you are at electronics, is putting together a few components and finding that you can listen to transmissions from far off distant places. In this book Robert Penfold shares his enthusiasm for radio construction with you, showing how easy it can be to build your own receiver. He takes a look at the basics of short wave radio and then describes several practical projects to enthral you. His crystal set uses principles which date back into history but which with the aid of modern components shows how simply a receiver can be built. Moving a stage up from crystal sets, he then looks at tuned radio frequency receivers (TRFs), and describes two circuits illustrating their theory. Finally, an amateur bands receiver is presented which uses the direct conversion techniques. I am sure that anyone with an interest in the mysteries of radio will gain pleasure and knowledge from this book. How about following it up, Robert, with a book covering long wave receivers capable of picking up transmissions below the 'normal' broadcast wavelengths? That's a subject which seems to be much under-covered.

Digital Electronics Projects for Beginners. Owen Bishop. PC Publishing. £5.95. ISBN 1-870775-08-2.
With a background encompassing education as well as electronics, Owen Bishop is in an ideal position to show newcomers how to understand the exciting world of electronics and to have fun while doing so. In this book he presents 12 digital circuits that are ideal material for any beginner or early starter to cut his or her teeth on, exploring and implementing basic logic. The projects include: logic probes, movie show, progressive timer, intruder detector, capacitance meter, combination door sentry, digital die, Christmas decoration, weekly reminder, remote-control switch, metronome, and an anemometer. Each project has a circuit diagram and a drawing of the layout on stripboard making it very easy to follow the construction. Written assembly and testing details are thoroughly given, and there is an appendix giving you additional important constructional information of a more general nature. I am also pleased to see that in addition to the regularly used digital chips, some of the newer HC devices have been used as well. This is certainly a very useful and interesting book.

Getting the Most from Your PC's Hard Disk. J.W.Penfold. Babani BP280. £3.95. ISBN 0-85934-225-5.
To the uninitiated, the use of a hard disk drive on a computer might seem to be no different to using a floppy disc. Up to a point this is true, though in order to make full and better use of the hard disk, there are various procedural changes one should make. One most important aspect that should be considered is that of backing-up your files against the possibility of data loss. This book gives advice on security matters such as this, and on ways in which your files can be arranged in sub-directories, making your applications much easier to configure. A further benefit to be gained from this book is through the advice on installing your own hard disk drive on computers which do not already have the facility. You are given basic information on how a disk is fitted, and how to format and prepare it for use. Those who already have a hard disk will probably find the information on interleave factors and installing DOS to be of good use.

Fault Diagnosis of Digital Circuits. V.N.Yarmolik. Wiley. £29.95. ISBN 0-471-92680-9.
This book is a comprehensive and up-to-date treatise which emphasises the use of on-line testing techniques for digital devices used in computers. It is divided into two parts, one dealing with topics of general interest including reliability, fault modelling and testing schemes; the other highlights recent developments and focuses on various methods of compact testing. This is very much a book for the specialist electronics engineer who also has a thorough grasp of mathematics. Regrettably it will not be of use to the average hobbyist who wishes to automate the debugging of general project assemblies.

Power Control Circuits Manual. R.M.Marston. Heinemann Newnes. £12.95. ISBN 0-434-91216-6.
This book is specifically aimed at the practical design engineer and technician as well as the amateur experimenter and electronics student. It deals with its subject in an easy-to-read, down to earth and non-mathematical but very comprehensive manner. Split into eight distinct chapters, it explains the basic principles of electrical-electronic power control, shows a variety of practical control techniques. It includes switch and relay circuits, cmos switches and selectors; ac power control and dc motor control circuits; audio power control and dc power supply circuits. In nearly 200 pages the book appears to be a mine of information on virtually any aspect of power control about which you need to know more. It is full of graphs and circuits, and mostly uses solid state devices which are reasonably priced and readily available. This is undoubtedly a highly useful reference book to have in the workshop.

Electronic Engineering Semiconductors and Devices (Second Edition). John Allison. McGraw-Hill. £12.95. ISBN 0-07-084194-2.
Aimed at the serious electronics enthusiast upwards, this book describes the operation and characteristics of modern active electronic components in a precise manner which will be easily understood even though a modicum of mathematical knowledge is required as well. In this second edition, the author describes the electronic conduction processes in semiconductors, insulators, metals and respective junctions, relating them to the operating characteristics of a wide variety of electronic engineering devices. The text is based in the main on a series of lecture courses given to university electronic and electrical engineering undergraduates.

Analog Electronics. Ian Hickman. Heinemann Newnes. £30.00. ISBN 0-434-90723-5.
There is a neat quotation at the start of this book: *"Digital is easy. Analog... that's professional"*. Yes, indeed, once you've grasped the fundamentals of Boolean logic, what more is there to digital electronics?! Analog electronics, on the other hand, needs the application of far more theory and mathematics in order to persuade it to function as required. In this book, Ian Hickman sets out to present readers with a wide variety of practical information about concepts and techniques which should enable them to feel at home with analog design without fear about its deeper mysteries. The book includes many examples from his large collection of circuits (built up over thirty years in commercial, professional and defence electronics) selected for their usefulness in a wide range of applications. They are practical analog circuits, complete with component values in many instances, culled from dozens of magazines (including PE), books and journals. The book includes the latest developments and techniques as well. Its aim is to take readers 'inside' electronic circuits so that they can see what makes them tick, showing how and why exactly they do what they do. The wealth of information can be applied to readers' own design problems, offering viable solutions which might not normally be self-evident. One useful chapter is that called Tricks of the Trade, offering numerous routes to alternative solutions. This book is an excellent key to a greater understanding of what analog electronics can do, and how you can make it do it.

PUBLISHERS' ADDRESSES

McGraw-Hill Book Company (UK) Ltd
Shoppenhangers Road, Maidenhead, Berks, SL6 2QL. Tel 0628 23432.

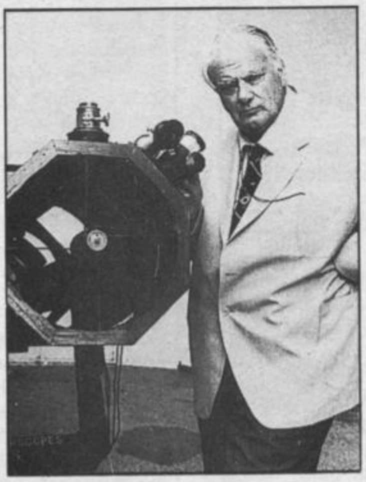
PC Publishing
4 Brook Street, Tonbridge, Kent, TN9 2PJ. Tel 0732 770893.

John Wiley and Sons Ltd
Baffins Lane, Chichester, West Sussex, PO19 1UD. Tel 0243 779777.

Bernard Babani (Publishing) Ltd
The Grampians, Shepherds Bush Road, London W6 7NF. Tel 081-603 2581.

Heinemann Professional Publishing
Halley Court, Jordan Hill, Oxford, OX2 8EJ. Tel : 0865 311366.

SPACE WATCH



BY DR PATRICK MOORE CBE

Amateur astronomers can explore the mysteries of the universe as valuably as NASA, ESA and Ulysses.

At the time when these notes are being written, the launch of the Ulysses probe is scheduled for October 5 (I hope to be at Cape Canaveral to see it go). Ulysses is a new kind of space-craft, designed to study the pole of the Sun. For obvious reasons, the solar poles are inaccessible to Earth-based instruments, and any space-craft to study them must be sent well out of the ecliptic plane. With Ulysses, this will be done by a pass of Jupiter, so that the initial path will take it outward. The solar poles are of immense interest, and we hope that Ulysses will provide us with our first real information about conditions there.

There is news of other probes, too. Magellan has begun its survey of the surface of Venus, while Galileo is still on its tortuous path to Jupiter. Unfortunately, there are problems with the whole space programme. Hipparcos, the astrometric satellite, has cost much more than expected, because it was put into the wrong orbit and this has added to the difficulties of the ground stations, while, of course, the trouble with the Hubble Space Telescope has led to a great financial burden as well as the scientific problems. Things are not helped by the money used in dealing with the political crisis in the Gulf. The end result is that NASA may have to cancel some of its projects, and ESA, the European Space Agency, could also be affected; missions in danger are SOHO, CLUSTER, and (sadly) the Huygens probe, to be carried to Saturn's satellite Titan by the Cassini space-craft. Let us hope that none of these cancellations actually have to be made.

THE BRITISH ASTRONOMICAL ASSOCIATION

This month is the centenary of one of the most famous astronomical societies in the world - the British Astronomical Association. It was founded in October 1890, and its first meeting was held on the 24th of that month, in London, under the presidency of Captain W. Noble. Ever since then it has had an observational record second to none, and its members include professional as well as amateur astronomers.

Modern technology is so sophisticated that one may well ask "What is the use of amateur astronomy?" The answer is that amateurs can carry out work which professionals do not want to do, have no time to do, or frankly cannot do - there are many professionals who could not distinguish between the Great Bear and Orion, so that they would be very likely to miss the sudden appearance of, say, a bright nova. Amateurs have a great record for discoveries of novae and comets; they monitor the planets and some kinds of variable stars; they make important observations of phenomena ranging from aurorae to meteors - in fact, they are kept very busy, and it may be fair to say that astronomy is still the one science in which amateurs can make valuable contributions. Certainly their work is warmly welcomed by professionals.

The BAA has monthly meetings in London as well as functions in other parts of Britain. Its main Centenary Meeting this year will be exactly one hundred years after that first gathering; a Coat of Arms will be presented, and there will be special stamps issued by the Post Office. Let us hope that the next hundred years of the Association will be as fruitful as the first.

Patrick Mooré shows off the original artwork of one of the new stamps highlighting the pioneering role played by British astronomers.

THE OCTOBER SKY

Autumn is upon us, and Summer Time in Britain ends on October 28. Of the planets, Mercury is more or less out of view, though it may just be glimpsed in the east before dawn during the first week of the month; Venus is now almost gone, though it too can be seen very low in the east just before sunrise. Saturn, very low in Sagittarius, sets early. This leaves us with the brilliant Mars and Jupiter both of which are well on view. Jupiter, in Gemini (the Twins) rises before midnight, and is then excellently placed for the rest of the night; a small telescope will show its main belt and also the four main satellites. Mars, in Taurus (the Bull) is rather north of the red star Aldebaran, and is much the brighter of the two; it is in fact brighter than any star in the sky apart from Sirius, though at the moment it cannot rival Jupiter. By the end of October Mars has an apparent diameter of 17 seconds of arc, and the main dark markings on its surface can be seen with a modest telescope - unless they are veiled by a Martian dust-storm, which is always a possibility.

The Moon is full on October 4, at Last Quarter (half) on the 11th, new on the 18th, and at First Quarter (half) on the 26th. There are no solar or lunar eclipses this month.

The Orionid meteors, associated with Halley's Comet, are active from about October 16 to 27, with a maximum on the 22nd; the Moon will not be obtrusive, so that this is a good chance to see one of the year's richest showers. Levy's Comet has now moved into the far south, but it is interesting to note that Encke's Comet, which has a period of only 3.3 years, comes to perihelion this month. It will be in the region of Leo, so that it does not rise long before the Sun, and it is faint - but observers with larger telescopes will be looking out for it. It has a long history; the first observation of it was made by the French astronomer Pierre Mechain as long ago as 1786.

The 'Summer Triangle' (Vega, Deneb and Altair) is now dropping in the west; the Square of Pegasus dominates the southern aspect, while Orion rises by midnight, preceded by some members of his retinus - notably Aldebaran and the Pleiades cluster. However, perhaps the principal interest among the stars this month is provided by Mira, the variable star in Cetus (the Whale), which lies well below the line of stars marking Andromeda. Mira reaches its maximum on October 1 or thereabouts; the exact date cannot be given, because, like all stars of its type, Mira is not perfectly regular. the mean period is 331 days. At some maxima Mira may not exceed magnitude 3, but at others it has been known to become brighter than the Pole Star - so if you look in the south and see a bright, red, unfamiliar star, you may be sure that it is Mira. It is a vast red giant, swelling and shrinking as it changes its output of energy.

TRACK FEEDBACK

LENGTHY CALLING

Dear Sirs,

I am looking for someone to make (one-off, initially) a micro voice recorder similar to those featured by some of your advertisers, except that it must be small enough to go into a 1 x 0.5 inch (cross-section) picture frame. It must be powered by small solar/light cells around the 16 x 12 inch frame and be capable of running spoken verse for one to two minutes with a speaker approximately thimble-sized. Only a very low level output is required. Should the device prove successful, many more would be wanted.

D.H. Adams, Jesmond, Newcastle upon Tyne.

Would any enterprising reader care to take up the challenge? Ed.

SCOPE UPGRADING

Dear Mr Becker,

I have been given a Cossor 339A oscilloscope in working order but very dirty looking. I am cleaning it up and will service it.

At the same time I propose replacing most of the components with modern ones where possible. For example, using 0.6W metal film resistors to replace the old 0.25W and 0.5W carbon types. I also propose to change a number of capacitors, where necessary using them in series, ie, two 450V types in place of the existing 750V rated ones. Is there any contradiction in doing this?

Incidentally, I recently took out a subscription to PE -best wishes!

Albert C. Hemes, Bromsgrove, Worcs.

I can't think of any reason why what you propose should be problematic, other than the possibility that the leads of some modern components may not be long enough to span across the tag boards (if the scope predates the use of pcbs). If this is the case, extra lengths of stout wire can be soldered to the components to make up for the shortage. You may find that you can still buy electrolytics having a working voltage at the rating you need without having to resort to series coupling. This would avoid you having to double the capacitance of the two capacitors in order to maintain the same value. Remember that the total capacitance of several capacitors in series is calculated as :

$1/CT = (1/C1) + (1/C2) + (1/C3)$ ... etc

One company who stock high voltage capacitors is Electromail, tel 0536 204555.

I am pleased to welcome you as a subscription member -you're part of an ever-increasing group of fans, which is swelling even more since started running our special subscriptions offers (see page 10 of this and other recent issues). Ed.

UFO DETECTING

Dear Sir,

I have been trying to find a circuit diagram for a Magnetic Field Distortion Meter, but as yet I have not been able to find one or anyone who can supply a kit.

The purpose for which the meter will be used is to detect UFOs on our sky watch.

Has any such meter or circuit ever been published in PE? I would be very grateful for any help you could give me.

J.W. Moore, Worksop, Notts.

I can't see anything suitable listed in the PE Master Index going back as far as 1975. Your best chance is to go down to your local library and find out which is nearest reference library that holds books on UFOs as well as those on electronics, and then to do some browsing.

You could also ask your library if they know of the addresses for any organisations involved in UFO hunting. There must be many around country.

In order to detect for the presence of magnetic fields you need a device such as a Hall effect sensor, or perhaps a variation on the metal detector principle. As to whether such things can be modified to perform the task you want done, I can't advise. Perhaps other readers might know? Ed.

AERIAL PLOT

Dear Ed,

I would like to suggest that one of your authors should produce some features regarding antennas and aerials for radio, tv and cb. It would also be interesting to read an article that would allow me to build a plotter for an IBM PC.

A.D. Mathison, West Germany.

Mr Mathison gave many examples of the type of function he would like covered on aerials and related devices. We shall certainly give active thought to implementing his suggestions. Ed. PE

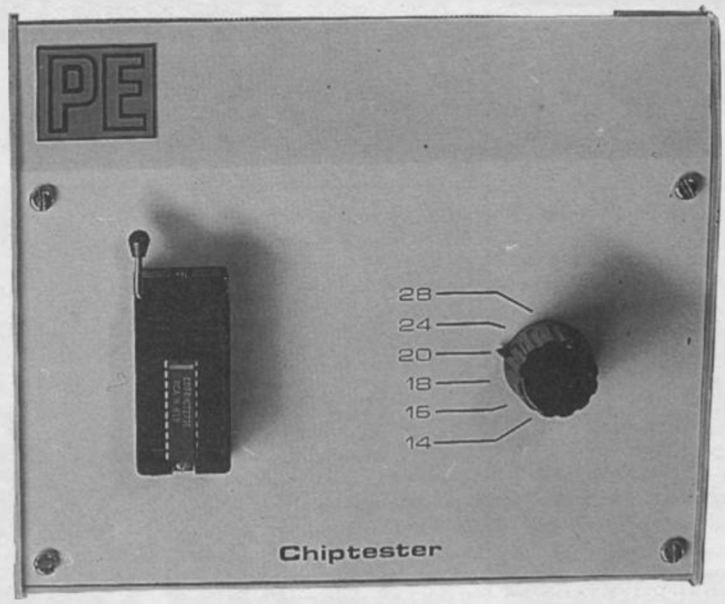
From the circuit description details of last month we now give you information on using this versatile chiptester.

1. LOAD DEVICE FROM DISC

Usually, this is the first operation of a test. Press 1 on the keyboard and the program will ask for the device type to be entered.

Normally, the devices are stored under the "root" number, ie SN74LS00 will be stored as 7400. The logical function of all the variations, eg SN7400, 74S100, 74S00, 74ALMS00, etc is the same in each case and thus valuable disc space is saved by only having one entry, 7400, for all similar types.

Note: There are one or two exceptions to this rule and they are usually where the pin configuration is different between the devices with the same root number, 74H01 is one example. It does not matter what you call devices yourself and you can construct files with alphanumeric labels up to 10 characters long.



PE CHIPTESTER

Part Two.

This excellent test unit has extensive check and compare facilities, and you can add more to its chip library, as Dave Raynor explains.

One would normally, therefore, enter 7400 at this point. However, in order to demonstrate another facility, type in 74LS00 <RETURN>. The program will search the whole disc looking for the 74LS00 and of course not find it!

The message 'Type number not found' will be given and the program will ask if you wish to search for a similar number. Answer Y for this, now enter part of the core number, 740 <RETURN>.

Notice that the disc library is now in memory and the program has selected a number of devices with similar type numbers to choose from, among them will be 7400, the device required. Enter 7400 <RETURN> and the program will load in the complete device specification file and return to the main menu.

2. EDIT TEST PARAMETERS

At this stage one could go directly to 3. (Test Device) and a rapid test will be performed. However, the test parameters may be modified to display the test voltages as pin colours or as waveforms or to enable loop tests to be conducted. So press 2 to discover how the Edit Test Parameters program works.

The green words on the right show the current state of the type of tests to be carried out. At the moment everything is turned off. Notice the red help prompt at the bottom of the screen, this is a common feature in many parts of the program - always look here if you are not sure what to enter.

Let's decide to display some waveforms: answer Y to the first question.

Now we have the option of entering the pin numbers of which we wish to display the waveforms. Notice from the prompt that we could enter 0 (zero), meaning "don't display traces, but show me the voltage levels on the pins of the chip socket display". (There are two types of voltage display. One is by blue or red colours on each chip pin, the other is by waveform traces. This will become clearer after testing a chip).

For each pin number to be displayed, one must enter the number followed by a <RETURN>. Two consecutive <RETURNS>s with no number in between will complete the entry line.

Alternatively, we can enter A <RETURN> for a display of all the pins of the device selected (except supply pins).

Let's select A this time.

Now we have the option of selecting a conditional loop test. This is useful if you have an intermittent fault and you wish to continue looping through the test until the device either goes on fault, or performs correctly.

Press Y to accept this test.

Answer No to "Loop until pass".

Your green codes should now read:

YES
ALL
YES
loop until fail.... YES

If not, you may answer N to the prompt "is this OK" and go through the menu again. When it's right, answer Y to get back to the main menu.

3. TEST DEVICE

Now you will need a working 74LS00 chip.

Press 3 from the keyboard and the Test Device Program will be run.

On the far right of the screen is a representation of the chip socket with the ic shown in the correct position and orientation. Beneath the socket display is a panel showing the chip type and it's size. There is also a space for special messages and the cursor position which is not activated at the present point. Please note that the chip socket operating lever may in fact be found on the opposite side to that shown on the screen.

If you are concerned about inserting and removing sensitive chips with the power on, note that at this stage all pins of the socket, except the selected supply pin, are powered down. They will not be powered down again until the main menu is re-entered.

Follow the instructions given on the main screen.

Note: The zero insertion force socket will accept chips when the operating lever is in a raised position. When the lever is lowered the spring contacts squeeze onto the chip pins, holding the chip in position.

CURSOR OPERATION

After a few cycles have been traced out, press the spacebar as suggested by the prompt at the bottom of the screen. Testing will be suspended while you inspect the display. If you now use the left and/or right cursor keys the cursor will appear and you will be able to position it wherever you desire. When there are more than 14 or 15 traces on the screen, this becomes very useful as it allows the eye to follow down from one trace to another.

At the bottom right of the screen there is shown the present cursor position. If, as with the present test of the 7400, there is no clock cycle being used, the display will show the true test number, ie the test under the cursor corresponds with the test number called for in the device specification file. However, if clock cycles are in use then some of the tests in the device specification can generate from 1 to 1024 clock cycles. In this case the cursor will show the number of cycles and tests carried out to the point where the cursor is positioned.

While the trace is frozen let's have a look at what else is displayed.

COMPONENTS

CAPACITORS

C1	100 µF 6.3V radial electrolytic 0.2 inch lead pitch
C2, C3	10n disc ceramic 25V 0.2 inch lead pitch. (2 off)

SEMICONDUCTORS

IC1	6522 versatile interface adaptor
IC2	SN74LS02 quad 2-input NOR

SWITCH

S1	pcb mounted rotary 2p 6w

CONNECTORS

J1	40-pin ic socket
J2	28-pin low profile ic socket (3 off, see text)
J3	28-pin universal zif socket
J4	2-row ribbon transition connector 20-way (mini IDC dil)
J5	2-row ribbon transition connector 34-way
J6	ribbon cable socket (IDC) 20-way (with strain relief clip)
J7	ribbon cable socket (IDC) 34-way (with strain relief clip)

MISCELLANEOUS

Printed circuit board
1 metre 20-way ribbon cable
1 metre 34-way ribbon cable
500mA anti-surge fuse 20mm
20mm pcb mounting fuse clips (2 off)
Case 170mm x 143mm x 55.5mm
Collet knob, pointer type. 21mm for 6mm spindle
Adhesive ribbon cable clip 20-way
Adhesive ribbon cable 34-way
ICs 7400 and 7414 to be used as demonstration devices in the testing.

SOCKET DISPLAY

On the socket display the colours represent the logic levels on the individual pins, red for +5V, blue for 0V. These colours will change as the device is being tested. The direction of the arrows indicates whether the pin is an input or output pin. If the test parameters have specified waveforms to be displayed, but no pin numbers are specified, then only this socket display will be used.

WAVEFORM TRACE DISPLAY

On the trace display the waveforms themselves indicate the logic levels and the colours are used to show whether a pin is an input or output pin. The white traces are from the output pins. These are the pins being measured and compared against the specification in the device file. If the logic level on a particular pin does not match the device file the trace will turn blue, while still showing the logic level measured. This allows the precise fault on a chip to be located if desired. Note, however, that a fault on an input pin waveforms displayed (red) are the intended stimulus waveforms - not the measured waveforms, and thus may be used as a known reference when investigating a faulty ic.

PRINT-OUT OF WAVEFORM DISPLAY

Don't do it now, but note that if you press P on the keyboard whilst the display is frozen, then a print-out of the screen will be sent to the printer port. The program "DUMP" on the disc is used for this and if you don't have an Epson compatible printer you may swap this program for your own routine.

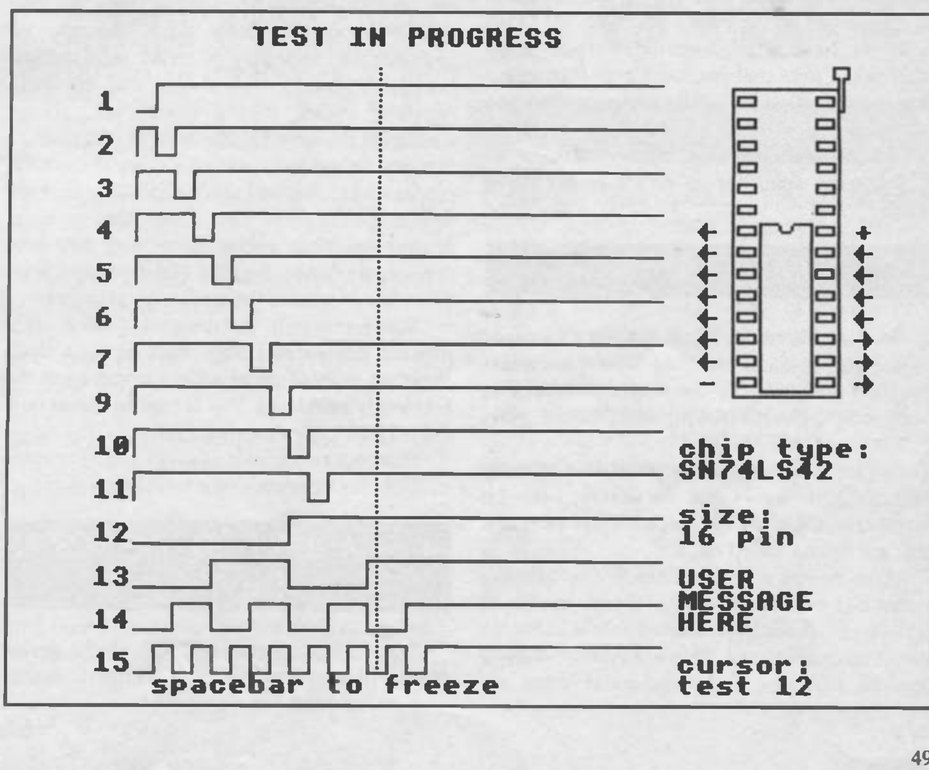
Press <RETURN> to recommence the tests again and notice that after the eighth cycle the display at the top of the screen will change so as to display the looping count value.

The test parameters we set up at step 2 required the device to be continually tested until it failed - since we have a working 7400 in the socket the test will continue looping forever. After several looping cycles have been traced, press the spacebar to freeze the display again.

Notice how the four sections of the ic are being tested simultaneously. On careful inspection you will see that although the first four tests cover all the possibilities of input conditions, there are four further tests that change the output state of each section of the ic individually, thus checking for internally shorted sections. When constructing your own device files keep this possibility in mind.

Now to make our device fail!

Fig. 9. Typical screen display created by Chiptester.



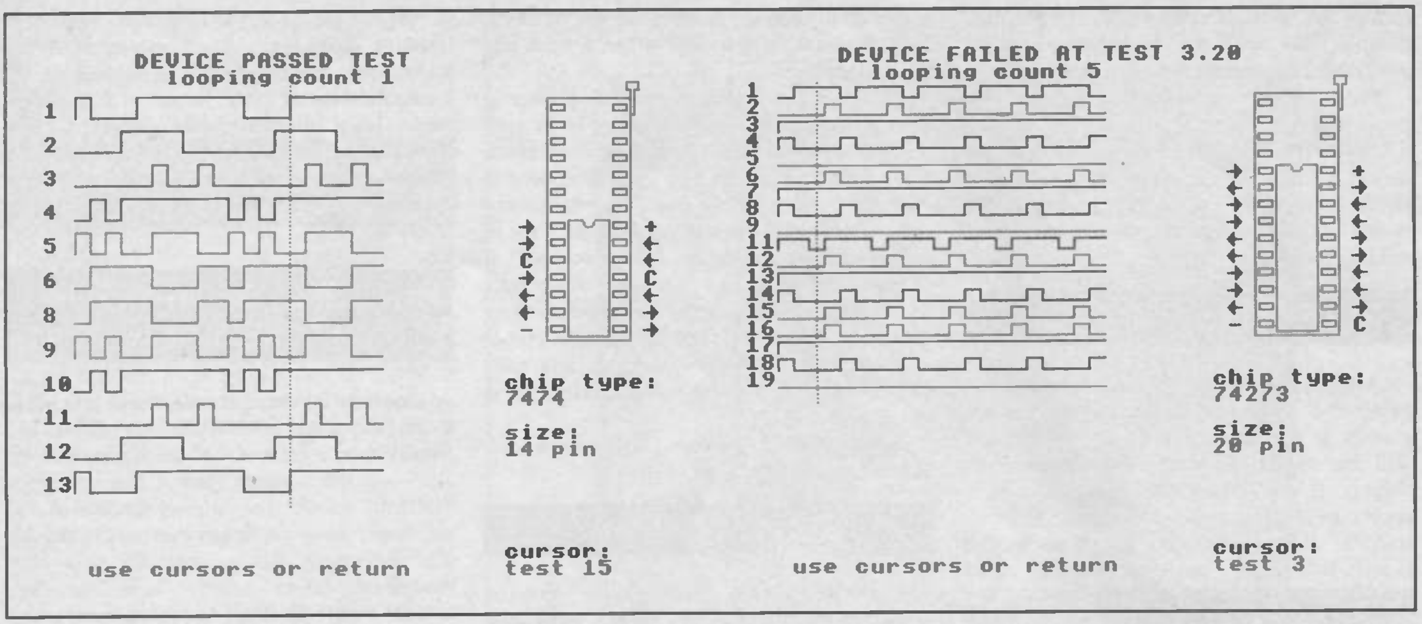


Fig. 10. Further typical Chiptester screen displays.

DEVICE FAILED MESSAGE

Press <RETURN> to recommence testing and take a small screwdriver and short together pins 8 & 9 of the ic. The ic will now fail at test 1 or 7.

The display at the top of the screen will show a message similar to:

DEVICE FAILED AT TEST 7.23
looping count 3

This means that 23 cycles had been performed before the failure occurred. Test 7 was the test number being carried out at the time (test 7 of eight tests per loop in the case of 7400) and that three loops had been performed. Note that the test number given here is the true test number relating to the device specification file. This is not the same as that shown on the cursor display.

If you have a failed device and you "loop until pass", note that the loops will start again from Test 1 after each fail. The complete test of the device will not be performed until the device actually works.

Press the spacebar to return to the main menu.

FAST TESTS

To see how much faster the testing can be performed, re-enter the Edit Test Parameters program and turn off the waveform display, but keep the device looping until failure. Now action TEST DEVICE.

Notice that the display panel is now only recording the loops and on failure, (use the screwdriver again!) the display shows the test that the device failed on.

Also notice that the Chip Socket display panel has not displayed the signal directions and levels. If we have wanted to see these we could have selected YES for waveforms, but 0 for pin numbers to be displayed when we were in the Edit Test Parameters program.

CLOCK CYCLE DISPLAY

You will need a 7474 ic for this demonstration.

Select 7474 from the disc library (option 1) and edit the test parameters (option 2) to loop continuously, showing all waveforms. Test the device following option 3 and after one complete loop test stop the test by pressing the spacebar.

On the socket display on the right hand side of the screen you will see that pins 3 and 11 are designated as CLOCK pins by the use of the letter C.

On the waveform trace you will see that pins 3 and 11 change colour from red to blue occasionally. This is the part of the test when these pins are being used as clock pins. Notice that the "clock cycle" actually lasts for two Chiptester cycles. With some devices, eg counters, the clock may go on for many cycles, but the waveform will always end up doing complete cycles, thus a clock cycle always finishes at the same voltage level as it started.

Only on the last cycle of a clock test are the output states measured and compared against the device specification. This means that on some devices the white output traces may turn blue temporarily during the time that the output level is not as expected in the device specification.

Notice that only the designated clock input pins are allowed to change state during a clock cycle, all other input pins have to remain at the previously held level. This is true no matter how many clock cycles are specified.

Short out two ic pins again (8 and 9) or press <ESCAPE> to return to the main menu.

4. SEARCH FOR UNKNOWN DEVICE

This feature allows you to match the device library files against the measured performance of the unknown ic. The whole library is searched, and any device with a similar pin size is matched, so the test takes considerably longer than selecting from disc and testing directly.

It's a useful test if somebody has scratched the marking off the ic or if it's a "house" coded device.

Insert the 7400 in the test socket and select option 4. Notice that the program asks for the number of pins on the chip. This automatically rules out some of the devices and shortens the testing time. Be sure to set the Chiptester switch to the same number of pins as the device.

When the test is run the program will list any device number that corresponds logically to the chip in the socket. For the 7400 there are quite a number of them since Chiptester does not distinguish between the different open collector types and devices with varying current source/sink ability.

The search feature will not test chips which require an offset in the socket.

5. ENTER/EDIT TEST DATA

Part 1 - entering data:

This is the part of the package that allows you to construct test files for yourself (or edit existing ones). You can skip this section and also section 6 if you only want to test devices already on the disc file.

Note: It is assumed that the user of this section will be fully conversant with both the logical and electrical operation of ics. For many types of device you will need the manufacturer's data sheet to help you construct valid tests.

Select option 5 from the main menu.

If you have already loaded a file from the disc as described previously then you will receive this message.

ENTER NEW DATA (Y/N)

This option allows you to use the same program to EDIT the existing device file by answering N. On this occasion though, answer Y in order to enter new data.

PRIME INFORMATION ENTRY

This is the data entry page for capturing fundamental information about the device. If you pressed Y in answer to the "enter new data" question, then the chip socket display will be empty and the bottom right-hand display panel will be blank. If it's not then you are in the EDIT mode and the following description will not make proper sense so press escape and re-answer the question with Y.

The cursor will be flashing on the entry panel for the chip type number. The yellow dot marks the 10th character which is the maximum length for a type number. Note the prompt at the bottom of the screen.

We are going to use our 74LS00 again, so enter 7400 and <RETURN>.

The next line is asking for the offset in the socket, enter 0 or just press <RETURN>. (An offset is only used for ics with unusual supply pins, see earlier in the article for details).

Now enter the number of pins on the chip: 14 <RETURN>.

For the user message you could enter any message of your own, such as:

MY FIRST TRY <RETURN>

Note from the prompt that you may enter up to 30 characters, these will be split up into three lines of 10 characters each. The yellow dots indicate the 10th character of each line.

For the clock pin numbers, Enter 0 or just <RETURN> as the 7400 does not need clock cycle testing. If the device needed clock cycle testing we would have entered the number(s) of those pin(s) designated as clock input pins.

For the 7400 we have four output pins, 3,6,8, & 11, enter these using a <RETURN> between each number and an extra <RETURN> to finish ie:

3 <RETURN> 6 <RETURN> 8 <RETURN> 11 <RETURN><RETURN>

The right hand side of the display will now show you all the parameters you have just set up, including the chip position and the input/output relationship of the device pins.

If everything is correct then answer Y to the prompt, else go back and re-enter anything you would like to change. Note that you only need to press <RETURN> to keep items previously entered.

LOGICAL DATA ENTRY

This is the section that allows entry of the actual tests to be carried out on the device. Up to 28 tests are possible and if you have specified clock pins then some of these tests may be clocked for up to 1024 cycles. Each test will be entered as a new 'page' of this display.

The first page, "Test 1 of 1", only allows definition of input and output pin levels. Other pages will allow the exit of the test or the facility to skip back to edit, or view previous tests. Note that <ESCAPE> is inactive in this part of the program as you may only return to the main menu by completing the test file tidily. This is achieved by entering 28 in the skip line. (see under last Test below).

When entering logical events, enter the pin numbers that are at a high, or logic 1 level. All others are assumed to be low. Do not enter the supply pin number. Note that pin numbers may be entered in any order, but it is usually easier to enter them in numerical order, or in the order of a pre-written logical table.

This is a truth table for one section of our 7400:

Pin	1	2	3
Function	IN	IN	OUT
	H	H	L
	H	L	H=NAND Function
	L	H	H
	L	L	H

This is the same for all the other sections of the ic and as all the pins of the socket can be measured simultaneously we can test all the sections with just four tests. However, since we have 28 tests available we will add four more tests to check that the output pins will toggle independently.

This is what our eight tests will look like:

TEST FUNCTION TABLE

Pin	Function	Tests 1	2	3	4	5	6	7	8
1	IN	H	H	L	L	H	L	L	L
2	IN	H	L	H	L	H	L	L	L
3	OUT	L	H	H	H	L	H	H	H
4	IN	H	H	L	L	L	H	L	L
5	IN	H	L	H	L	L	H	L	L
6	OUT	L	H	H	H	H	L	H	H
7	GROUND								
8	OUT	L	H	H	H	H	H	L	H
9	IN	H	L	H	L	L	L	H	L
10	IN	H	H	L	L	L	L	H	L
11	OUT	L	H	H	H	H	H	H	L
12	IN	H	L	H	L	L	L	L	H
13	IN	H	H	L	L	L	L	L	H
14	SUPPLY								

So to enter "test 1" we enter "logic high input pins" with:

1 <RETURN> 2 <RETURN> 4 <RETURN> 5 <RETURN>

9 <RETURN> 10 <RETURN> 12 <RETURN> 13 <RETURN> <RETURN>

and "logic high output pins" with:

0 <RETURN>

since no output pins are high for this test.

Notice that our yellow pins have now turned blue to indicate that the display is now in a valid state for the test number displayed (test 1).

Look at the chip socket display: if this corresponds with our first column in the test function table then press Y to answer the prompt. Notice that the display page now changes to: "Test 2 of 2" and the display now has an extra line to allow exit from the tests by entering 28. We will see this used in test 8 (see Last Test below).

Also notice that the blue has turned yellow again. This is because the display is now not valid for test 2. However, the display is useful since it shows the previous test conditions and this allows you to check previous values easily as a comparison and memory jogger.

CLOCK CYCLE ENTRY

(Skip this section when practising with the 7400).

If we had specified a clock pin(s) in the prime information section, this second test would also have displayed another line asking for the clock count value. Note for reference that once a clock count has been entered for the current test page, then the input pin logic levels may not be changed and the values assumed for the input pin levels are those of the previous test. Only the defined clock pin(s) will change logic levels during a clock cycle(s). Note also that the value entered for the output pin levels will be tested only at the end of all the clock cycles called for, although the display will show the measured output waveforms during each of the clock cycles.

So now enter the second test from our function table:

Input Pins 1 <RETURN> 4 <RETURN> 10 <RETURN> 13 <RETURN><RETURN>

Output Pins 3 <RETURN> 6 <RETURN> 8 <RETURN> 11 <RETURN><RETURN>

Skip etc. <RETURN>

Check the display against our function table and if all is well, answer Y to the prompt.

ERROR CHECKING

You may have noticed by now that the program has a certain amount of error checking built into the entry routines. Some of these allow re-entry of individual numbers and some require the re-entry of the whole line. If you make too many mistakes in one line the the program may give up and pass on to the next line anyway, so always check the display before passing on to the next test.

Now enter more of the tests in our function table, up to and including test 7.

Last Test, Exit From Data Entry

Enter test 8 like this:

Input Pins 12 <RETURN> 13 <RETURN><RETURN>

Output Pins 3 <RETURN> 6 <RETURN> 8 <RETURN><RETURN>

Skip etc.: 28 <RETURN>

After checking the display, press Y in answer to the prompt and you will return to the main menu. This is because 28 was entered in the 'skip' line.

The test files are all held in memory so you can now use options 2 and 3 to test the device and check that your specification works. If it needs editing then you may use option 5 again to re-enter the editor.

CHECKING DEVICE FILES

It is of course necessary to have a device to test and we will assume that it is also a working one!

Plug in the ic and use option 2 to set the display to show all the waveforms. Now use option 3 to test the device and when the test is complete, check the waveforms against the Test Function Table.

If you have made a mistake in entering the tests or interpreting the device data sheet then Chiptester will fail the device at the first place a fault is discovered. Check the displayed waveforms looking for the blue marked section(s) of the output traces. At this point the trace will show the measured value of the output pin in question and the value in the file is thus the inverse of this and should therefore be changed. One should study the display and discover the cause of error before making a note of the test number and using option 5 to edit the test files.

Note that there may be further errors, but Chiptester will not warn you of this until the first error is corrected.

When you are satisfied that the test files are correct you will want to save them to disc. See option 6 below for this.

5. ENTER/EDIT DATA

PART 2 EDITING DATA:

In order to edit the test data answer N to "ENTER NEW DATA".

If the Prime information is correct then answer Y to the prompt to gain entry to the Logical Data pages.

Notice that the display now shows "test 1 of 8" and the blue colour indicates that the information is valid for this test. By answering the prompt with Y each test may be quickly flipped through and checked if desired.

Note that for longer tests you may get to any particular entry quickly by answering N to the prompt then <RETURN> for each entry and using the skip function to skip directly to the particular test that you are interested in. This is possible because <RETURN> without any entry value will leave the previous values for that line intact.

Note also that one must be careful to avoid accidentally editing past the end of the file (test 8 in our example), as the effect is to create a longer file. Naturally, any accidental extension may be converted into a valid test by repeating the last test or any valid data, but it is not possible to shorten a file by using the edit facility.

When the required test is arrived at, answer N to the prompt to enter the edit facility for that test. Notice that the display colour changes to yellow to indicate non-valid data, but this time the display shows the data for the current test rather than the previous test. Having changed the data for the test in question, one may either enter 28 for the skip number (thus leaving the edit session) or press <RETURN> to move on to the next test page.

When editing, always enter values into the line requiring change, as just pressing <RETURN> will leave the previous entry intact. If there are no pins at a logical high value then enter 0 <RETURN> to clear out the previous values.

Values that need to stay the same need not be re-entered as a <RETURN> will leave the previous entries intact.

EDITING CLOCK CYCLES

Be very careful when editing data files that contain clock cycles. Every clock cycle test must be immediately preceded by a non-clock test in order to set the state of the input pins for the clock cycle. In normal entry this is ensured by the software, but during editing it is possible to defeat the conditional entry and thereby set up a clock cycle that has another clock cycle test immediately preceding it. The input conditions are not guaranteed under these circumstances and so the test will be invalid.

6. SAVE DATA TO DISC

Once the test data has been verified option 6 may be used to save the file to disc.

The program will offer the type number currently assigned (7400 in our case) and if this is to be changed, one may do so by answering the prompt with N.

In our example we'll leave it set to 7400 and answer Y to the prompt. The disc will now be searched and in our case it is found that a 7400 already exists on file and we will be given the option of overwriting the existing file with the new data in memory. It is left to your discretion as to whether it is desirable to overwrite the existing file! Note that if we answer N, then the way to leave this section is to use <ESCAPE>.

Altering the contents of a type on disc file:

Use option 1, 5 and 6 as above to overwrite the existing file.

Altering the type number of a disc file:

It is sometimes useful to keep the data on disc file intact, but to change the type number that is assigned to it. It is not possible to do this within the main program, but there is a utility file on the disc which will do this for you.

From Basic, CHAIN"U.ALTRDEV" and follow the instructions. After use, program control will be passed back to Chiptester.

This is most useful for discarding a rubbish file accidentally saved to disc - usually done while demonstrating Chiptester! Use a type number that you will want to use next and then after entering the correct data for this type, use option 6 to overwrite the rubbish file.

Since every device record is 349 bytes long it is possible to edit the files using DISC DOCTOR or a similar product, should the need ever arise. See the appendix for details of the record structure.

Starting a brand new set of files:

In order to comply with all versions of DFS it is necessary to start with one entry in a file already on disc. So if you wish to start a new disc, say with a new range of ics, the following procedure should be adopted:

1. Backup the master disc to your new freshly formatted disc.
2. Put away your master disc!
3. Delete the old DATA file on your backup.
4. Use option 5 to enter the data for the first new device and from the main menu press BREAK to enter Basic.
5. CHAIN the utility U. STRTFLE and follow the instructions given.

A new DATA file will now be created containing just the one entry.

Note that it is possible to start a file without using instruction 4 above, but your new file will contain a dummy entry which may be overwritten at a later date as described using U. ALTRDEV as above.

Options 7 and 8 do not require our demonstration device in order to be described.

7. LIST DEVICES ON DISC

This facility allows you to list by type number all the devices on the disc in drive 0.

The following options are selectable.

a) list to screen
b) list to printer and screen
c) list in the order found in the DATA file
d) sort the file into alphanumeric order before listing
e) if sorted, the file may be dumped to other disc surfaces. This can only be done with systems addressing more than one drive.

When listing files longer than 60 ics to the screen, the computer will pause between batches. Press <SHIFT> to display subsequent pages.

8: BATCH TEST

This facility is very similar to option 3 except that no waveform display is provided and that the test procedure may be repeated without returning to the main menu.

The facility is provided in order to give a very speedy operation when testing batches of the same chip. Once set up, all that is required is

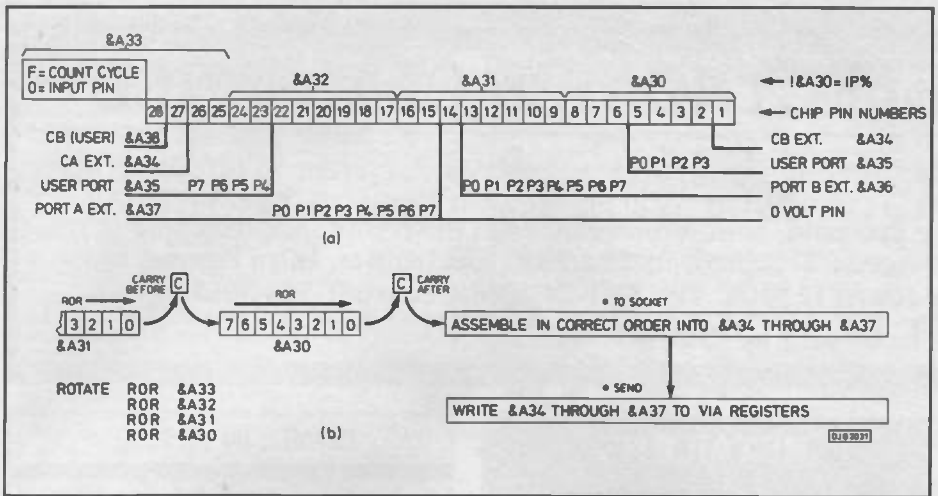


Fig. 10. (a) Socket pin to computer variable assignments. (b) Changing the word !& A30 into bytes to be sent to the socket pins.

the exchange of the chip in the socket and the press of one key on the computer.

Except for the selected power supply pin (which, if desired, may be altered by turning the front panel switch between tests), the chip socket is powered down whilst the instructions are displayed.

Exit to the main menu by pressing <ESCAPE>.

SOFTWARE WRITING

The following section discusses some software details for those who might like to experiment with writing their own programs.

In the computer, the word location !&A30 is used to store the value taken from the universal zif socket or to set the VIAs to the required output levels. As can be seen from the upper part of Fig.10a the four bytes of the word are arranged logically with the least significant bit representing pin one of the socket.

The lower part of Fig. 10a illustrates the actual socket pin connections with the ports of the VIAs. Because it's not practical to have all the VIA ports line up logically with the socket pins some conversion has to be done when writing to or reading from the socket, and this is done while the word !&A30 is converted into bytes.

Fig. 10b shows the method used to slide the word !&A30 into the various bytes waiting to be sent to the socket pins. The Rotate Right (ROR) command is used on each of the four bytes of the word in turn with the result that all the bits are moved down by one and the least significant bit (corresponding to pin 1) ends up in the Carry bit where it can be tested and assembled into the correct position of the byte waiting to be sent to the VIA register concerned with that pin. On successive cycles of ROR instructions the remaining pins of the socket are appropriately handled.

The following example program is used to send the five pre-assembled bytes to the VIA registers and serves to illustrate all the variables and commands needed. Naturally, similar subroutines will be needed to set the directions of the VIA pins and to read in the values from the chip under test, and these may be found on the software disc using the same variable names as used below.

SOFTWARE

The author, David Rayner, has kindly offered to supply readers with a copy of his software disc for the nominal price of £6. This includes postage in the UK, but overseas readers should add an extra £1 to cover the additional postage. Please write to him at 10 Hardys Field, Kingsclere, Newbury, Berks. RG15 8EU. A listing of the software is available from the PE Editorial Office. Please enclose a large stamped addressed envelope.

ADDRESSES AND VARIABLES:

Variables

USER PCR CB	cbuser	= &A38
EXT CA & CB	cabext	= &A34
USER VIA	portu	= &A35
EXT VIA PA	porta	= &A37
EXT VIA PB	portb	= &A36

Operating System call addresses

O.S. call	osbyte	= &FFF4
Internal page	rdsheila	= &96
	wrtsheila	= &97
External page	rdfred	= &92
	wrtfred	= &93

VIA Registers

PCR external	PCRext	= &0C
PCR internal	PCRuser	= &6C
User (base)	Uadd	= &60
Ext. A (base)	Aadd	= &01
Ext. B (base)	Badd	= &00

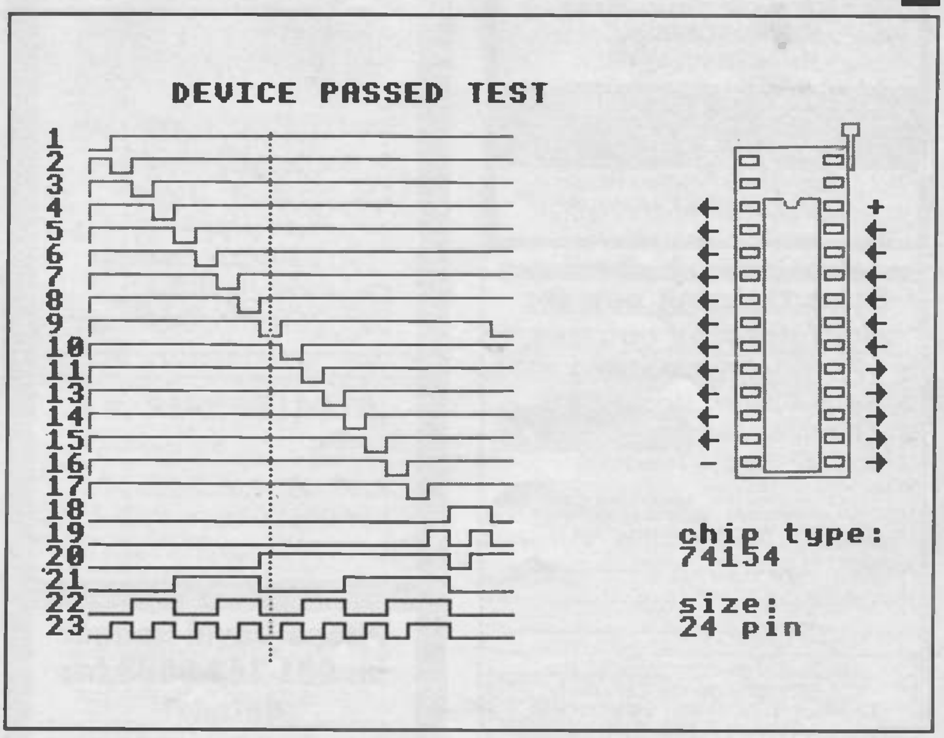
Main machine code subroutines on disc.

.direction	Sets skt. pin directions
.toskt	Disassembles !&A30
.fromskt	Assembles !&A30
.send	Send disassembled word
.read	Read back VIA registers

Code for sending data to socket

```
.send    LDY  cbuser
         LDX  #PCRuser
         LDA  #wrtsheila
         JSR  osbyte
         LDY  cabext
         LDX  #PCRext
         LDA  #wrtfred
         JSR  osbyte
         LDY  portu
         LDX  #Uadd+0
         LDA  #wrtsheila
         JSR  osbyte
         LDY  porta
         LDX  #Aadd+0
         LDA  #wrtfred
         JSR  osbyte
         LDY  portb
         LDX  #Badd+0
         LDA  #wrtfred
         JSR  osbyte
         RTS
```

PE



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INDUSTRY NOTEBOOK

ST CECILIA ELECTRONICA

By Tom Ivall

Subjectivity governs our appreciation of music, live or recorded - we hear what we want to hear.

I recently heard a group of pop musicians enthusing on the radio about their discovery of "acoustic" music and musical instruments. Apparently this was a mind-blowing experience for them. It was some kind of revelation, a cleansing of the doors of perception. In my ignorance I had thought that all music was acoustic, in the original Greek sense of that word. But obviously I was behind the times. They were concerned with different ways of generating the sound waves, rather than with hearing.

Of course, their discussion was perfectly understandable against the background of most people's experience of music - pop, classical or whatever - which is predominantly electro-acoustic. Apart from recording, reproduction and broadcasting, even at live pop concerts the audience hears the voices and instruments mainly through the colouring of transducers, filters and loudspeakers. Sound synthesisers and musique concrete processors can only be made audible by electro-acoustics.

Some very good loudspeakers have been designed but as far as I know the ideal piston has not yet been produced. You are always listening to a diaphragm or cone of some thin material being vibrated into its own natural resonances by a form of electric motor - not to mention the effects of the enclosure.

PURE ENJOYMENT

Attending a live concert, opera or recital is a very special experience. There's a sense of occasion and excitement. Although the same performers may be doing the same programme tomorrow, this particular evening is unique. As an interaction between the musicians and this particular audience, it will never happen again. The excitement is increased by our anticipation of the unexpected or risky. It could be an evanescent moment of great beauty and emotion, or it could be a painfully embarrassing wrong note.

Much of this is ironed out by the technical perfection of recording. Accuracy is achieved at the expense of artistic spontaneity and interpretation.

Musical purists of a certain kind tend to sneer at the trappings of the live performance, which they see as a distraction. They say the sound itself is all that matters. A good recording, which you can listen to at home, is all you need. This attitude is one example of the polarisation that the very existence of recording seems to have created.

There are musicians who absolutely refuse to do live performances, only recordings. Others go to exactly the opposite extreme. In his BBC Reith Lecture on the symphony, the composer Alexander Goehr mentioned that certain conductors have the habit of attempting live imitation of their records in the concert hall. And that orchestra managers will only appoint conductors who already have good connections with major recording companies.

ILLUSORY

Of course, we all know that a recording is not what an audience hears in a concert hall. It's a highly artificial concoction resulting from multiple microphone placings, balancing, revisions, patching to replace wrong notes and so on. Some musicians, according to Goehr, see in this "a vain pursuit of the definitive version." It is a trap which "leads to concentration on tiny details at the expense of the overall line of a performance. It is a kind of surrender to the possibilities of the medium itself, which allows for almost infinite division of the music into fragments which are then glued together by the editor."

Nevertheless, says Goehr, even though we know that recorded music is synthetic and constitutes an illusion, our experience of it influences our taste.

You get even more synthetic with electronically generated or processed music. Here I don't think there's much point in having live performances. I well remember going to an evening of electronic music in a conventional concert hall. We all sat like idiots gazing at an ugly heap of racks, boxes and cables for several hours. One attempt to mitigate this kind of uneasy experience is 'space music'. Four loudspeakers are placed in the corners of the hall and play back four different parts arranged by the composer in a contrapuntal relationship, or perhaps a contra-locational relationship. I haven't heard this, but it's reported to be a pleasant musical experience, possibly a bit like having several orchestras in different positions around a hall, as was popular in the baroque music period.

SUBJECTIVE

Electronic engineers working on the recording, reproduction and broadcasting of music have always been dogged by the problem of subjectivity. Even after the application of the most precise, thorough and foolproof engineering their products are still finally submitted to the vagaries of subjective assessment. They would really like to have an objective measure of sound quality - perhaps a figure of merit obtained from measurements of electrical and acoustical variables - which would be independent of personal preferences but at the same time correlated with subjective experience.

A big problem with subjective assessment of sound quality - apart from variations between listeners depending on circadian rhythm, degree of tiredness etc - is that hearing is not just a passive registering of impressions. It's an active process of attention and even *in*tention. To some extent you hear what you want to hear.

An engineer may listen for a particular type of distortion and suppress the emotional or intellectual effect of the artistic material. A musician may listen for features of musical performance and not be aware of quite obtrusive distortion. Whereas an engineer carries in his head a distinct a priori concept of frequency, which he may regard as the primary characteristic of sound, it's possible for a musician to say: "I cannot accept the distinction between tone colour and pitch as it is generally stated. I find that tone makes itself noticed through colour, one dimension of which is pitch." This was the composer Arnold Schoenberg writing in his *Harmonielehre*.

Although many audio engineers have great musical sensitivity I doubt whether the aesthetics and the technology can ever be merged in a synergetic way. Perhaps it's better that they remain separate. But the permanent tension between them, like that between morality and expediency, will always be interesting to watch - and hear.

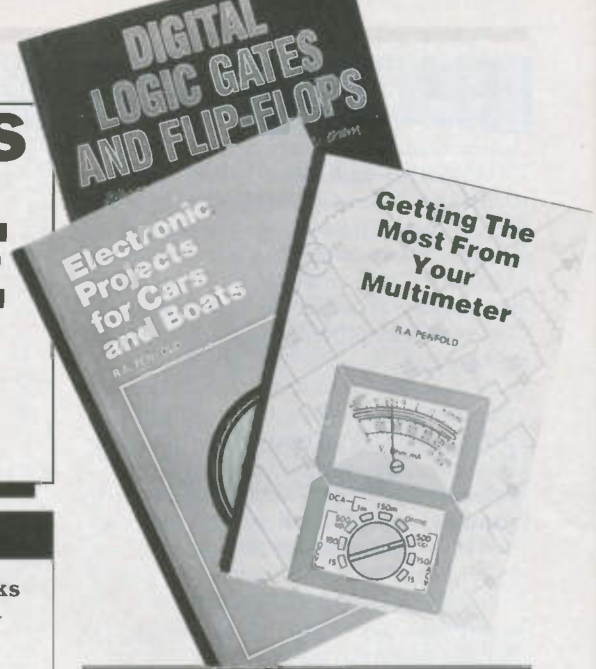
(The festival day of St Cecilia, Patroness of Music, is November 22nd).

PE

PRACTICAL ELECTRONICS

BOOK SERVICE

Here is your Editor's choice of books he thinks will be of interest to electronics and computer enthusiasts



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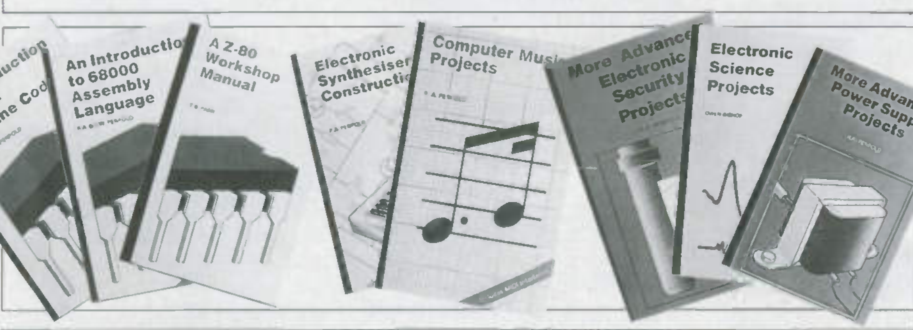

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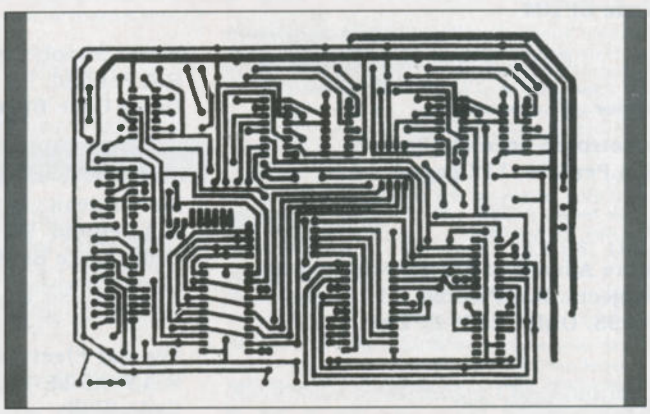

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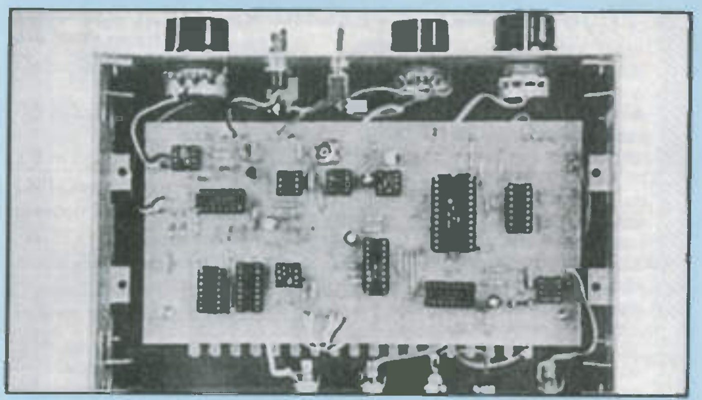

NICE AND EASY DOES IT

Building the projects published in PE is a lot easier than some of you perhaps might think. Especially when you use one of our professionally made printed circuit boards.

It's almost like painting by numbers. All the pcbs are fully drilled, and basically all you need to do is slot in the components and carefully solder them to the pcb track pads. Their places are shown in the drawings published with the project.

IDENTITIES

Component identities are usually clearly marked on them. Even if they are colour coded, like some resistors and capacitors, their values are easily worked out from component colour code charts. From time to time we publish these charts, but it you don't already have one, send a 9in x 4in stamped and self-addressed envelope to the Editorial office asking for one.

TOOLS

For many projects you only need a few simple tools - Soldering iron between 15W and 25W, with a bevelled tip. Damp sponge for keeping the tip clean. Good multicore solder of 18swg or 22swg grade. Fine nose pliers for wire shaping. Adjustable spanner or heavy pliers for tightening nuts. Miniature screwdriver for adjusting preset controls. Small wire cutters for trimming component leads. Drill and selection of bits for drilling holes in boxes. Strong magnifying glass for checking joins in close up. It's also preferable to have a multimeter for setting and checking voltages. There are some very good low cost ones available through many of our advertisers, but get one that is rated at a minimum of 20,000 ohms per volt. Many projects do not require you to have a meter, but if you are serious about electronics, you really should have one.

ASSEMBLING THE PCB

Authors will sometimes offer their own advice on the order of assembly, but as a general guide, it is usually easier to assemble parts in order of size. Start though with the integrated circuit sockets. Please use them where possible, they make life much easier than if you solder the ics themselves - with sockets you can just lift out an ic if you want.

Then insert and solder in order of resistors, diodes, presets, small capacitors, other capacitors, and finally transistors. Clip off the excess component wires before soldering, then make sure the solder covers the pads and the wires. Now use a magnifying glass, ideally one that you can hold to your eye, and take a good look at the joints, checking that they are satisfactorily soldered, and that no solder has spread between the pcb tracks and other joins. Be really thorough with visual checking since errors like this are the most likely reason for a circuit not working first time.

SOLDERING

Bring the tip of the iron into contact with the component lead and the pcb solder pad, then bring the end of the solder into contact with all three, feeding it in as it melts. Once sufficient solder has melted to fully surround the pad and the lead, remove the solder, and then the iron. Now allow the join to cool before touching it, otherwise the solder may set unsatisfactorily. If it does move, just reheat the join once more.

WIRING

Connecting the pcb to the various panel controls is the final assembly stage. Do this just as methodically, following the published wiring diagram. You can connect the wires to the pcb in one of three ways. The best is to insert terminal pins into the connecting holes on the pcb, and then solder wires direct to them. Or, pass the end of the wire through the pcb hole, soldering it on the other side. Alternatively, the wire can be carefully soldered direct to the pcb tracking. In all cases first strip the plastic covering off the wire, twist the strands together, and apply solder to them to keep them secure.

TESTING

Now you are ready to test and use the project as described by the author. Components can occasionally fail, but these days it is extremely uncommon, and if you have followed the instructions, been careful with your joins, and bought the parts from a good supplier, you will have the enormous satisfaction of having built an interesting and working unit. It really can be easy if you do it with care.

CHOOSE ONE NOW!

The PE PCB Service list shows all the pcbs available through PE. Look down the list and see which title takes your fancy - there must be at least one that will interest you! You will probably already have the relevant issue of PE, but even if you don't we can still help you.

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We can usually supply copies of back issues of PE up to three years old. These are £1.75 each including postage (£2.25 for overseas readers). If we no longer have the issue needed, we will be pleased to send a photocopy of the article for the project that you want to build. These are £1.00 each per issue, including postage (£1.50 to overseas readers).

OBTAINING PARTS

Some projects are available from advertising suppliers as complete kits. Otherwise, all the components listed in the text will be available from suppliers who specialise in individual components.

Occasionally a specific part may only be available from a particular supplier, if so the source will be given in the parts list. Otherwise there should be no difficulty in buying the parts. We have many good suppliers advertising in PE so have a look through their adverts - that's why they're here! Even though a part may not be listed in the adverts, a phone call or two should find a supplier who will be pleased to help. Like us, they too are in the business of encouraging you to enjoy electronics!

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