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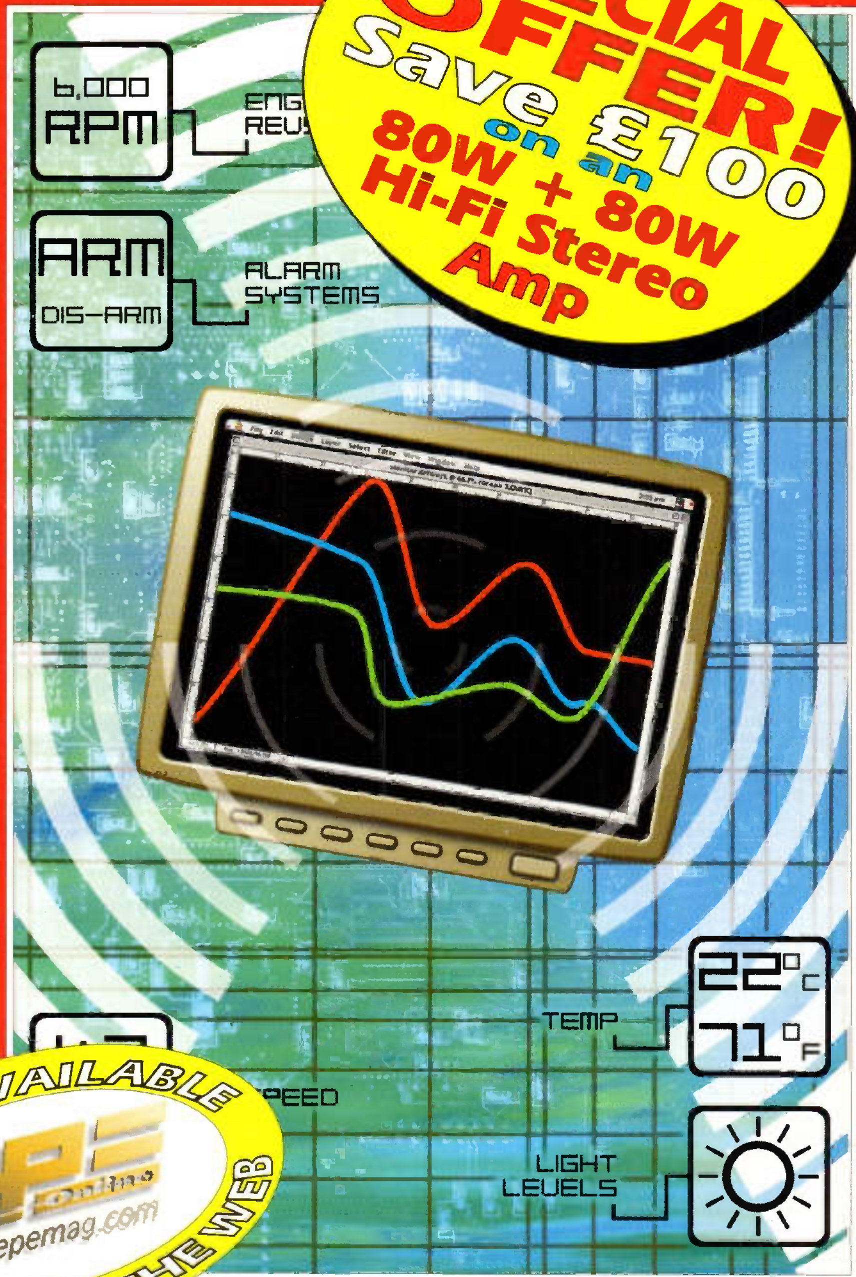

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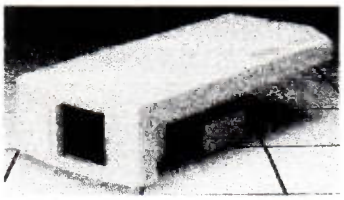

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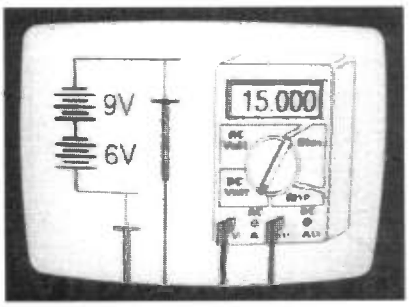

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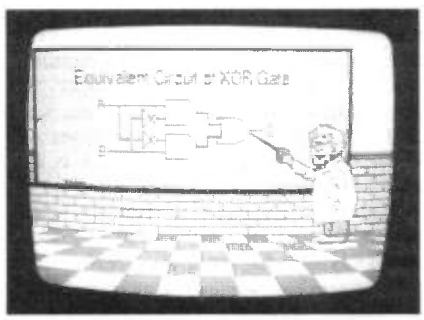

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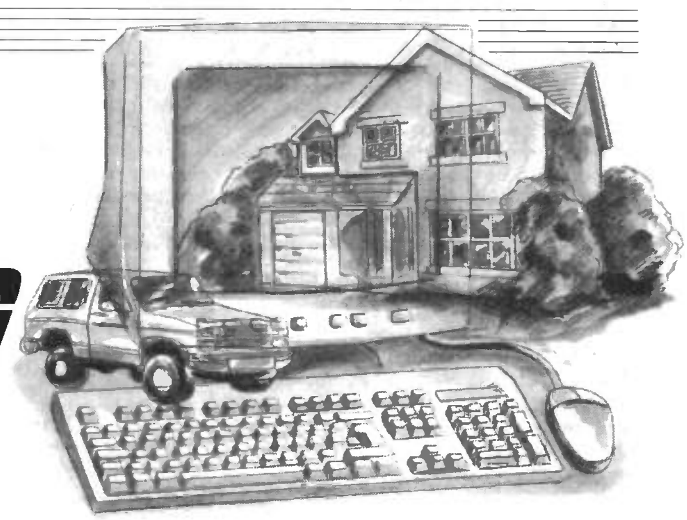


WIRELESS MONITORING SYSTEM

JAMES HUMPHRIS — Part One

Low cost radio-linked short-range data logging is now readily and simply available.

UNTIL recently, the lack of availability of low-cost data transmitters meant that the use of telecommunications within the home for hobbyists or for educational purposes was either too expensive or complicated to be practical.

Increases in the demand for such devices, along with improvements in the technology, mean that various companies are mass-producing telemetry equipment that is low cost and can legally be used in the domestic environment. This equipment usually consists of pairs of radio transmitter and receiver modules that are suited for short-range data transfer purposes.

This article describes a project that makes use of such modules in order to monitor domestic conditions or environments without the need for wires. The basic system is used with a.m. (amplitude modulated) modules, although the use of f.m. (frequency modulated) modules is discussed in Part 2.

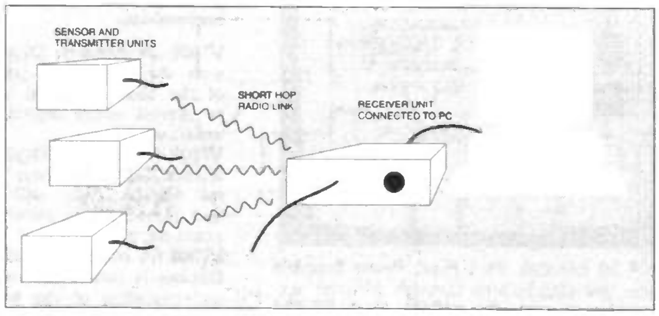


Fig.1. Block diagram of the Wireless Monitoring System.

The system is based around a PIC microcontroller and can be used to monitor the activity of virtually any number of different conditions within a small area, i.e. around a house or within a classroom or workshop. The beauty of this system is its incredible flexibility!

It has been designed to comply with Home Office regulation MPT1340 and does not need a licence for use in the UK.

A PC-compatible computer (running Windows 3.1, 95 or 98) is required to display the recorded data.

For compactness, surface mount devices are used for the Transmitter. The Receiver circuit board uses "standard" through-hole components.

WAVES NOT WIRES

Radio waves have several distinct advantages over lengths of wire. Typically, radio waves are far more robust; they cannot be cut or broken and do not degrade over time. Sensing devices linked by radio waves tend to be less physically intrusive and more independent. Keeping the actual sensor local to the transmitter virtually eliminates any noise or degradation in the signal being monitored.

Furthermore, any hard-wired sensing interface has a limited number of inputs that need to be manually configured every time a change is required in the system configuration. Using radio waves not only increases the number of sensors that can be used, but also provides the added flexibility of being able to be brought on and off line as required.

Damage caused by faults in an r.f. (radio frequency) system is limited to the transmitting device and sensor interface at which it occurs, rather than affecting the whole system. Sensors can also be placed upon mobile equipment such as robots or vehicles and provide continuous data over a short range without trailing wires.

This project consists of a minimum of two units, a single Transmitter and a Receiver connected to a local PC-compatible computer, as shown Fig.1. As many units as are required to perform the task can be added, and information logged by the PC. Every time an output change occurs in the sensor connected to a transmitter, a message is sent to a receiver connected to the PC. The latter can then analyse and process the information.

Due to the low power radio modules used, the emphasis here is not on the physical range of operation, but more to providing increased flexibility and fewer wires!

APPLICATIONS

The transmitters have been designed to make any hardware very simple and place all of the strain on the software running them. This means that by re-programming the devices, many types of data logging can be achieved.

For example, the PIC could be programmed to collect and store information regarding a sensor signal for a long period before transmitting this information at a later time. Useful, for example, to monitor temperatures and speeds in a vehicle, downloading the data once back at base.

Alternatively, it could be programmed to transmit a message only if a sensor output fell below or rose above a predetermined level. It is due to this wide range of configurations that a specific system is described here, but advice is given to readers who may wish to reprogram their own PICs.

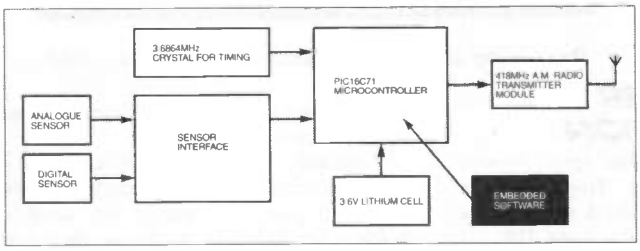


Fig.2. Transmitter block diagram.

A further advantage is that the PIC consumes a very low quiescent current. This means that the transmitter units can be battery powered and operate over very long periods without the need for any maintenance.

HOW IT WORKS

The block diagram of the transmitter unit's operation is shown in Fig.2. Two sensor interfaces provide one digital and one analogue channel. The output from the sensor interface is fed directly into the microcontroller that continuously monitors the inputs. When a change occurs in either of these levels, the radio transmitter is passed a serial message consisting of the digitised sensor information.

A single 3·6V Lithium cell is used to power the unit. It is thus completely independent in use and suffers no external interference from other equipment.

The receiver block diagram is shown in Fig.3. The radio receiver monitors all the activity on the specific radio channel to which it is tuned, and converts the presence or absence of the r.f. carrier to logic high or low respectively. This signal is monitored by the microcontroller, which determines the validity of the data stream.

If a valid data packet is detected, it is processed and re-modulated into the correct timing protocol for RS232 data. This signal is converted into RS232 levels by a line driver and is then passed on to the PC via a serial port.

Power is supplied to the receiver via a standard mains power adaptor, the output of which is regulated within the receiver to 5V. Two l.e.d.s are used to show the status of the r.f. and the RS232 channels. The modulation of the r.f. channel and RS232 line is performed entirely by the microcontroller in real time.

TRANSMITTER DESIGN

The Transmitter circuit diagram is shown in Fig.4. This design incorporates an on-board temperature sensor (R2) and tilt switch (S5), both of which can be monitored by the software.

Any change in the temperature of the air around R2, which is a negative-coefficient thermistor, causes a proportional change on the voltage at IC1 pin 2. This level is constantly digitised by an analogue-to-digital converter (ADC) inside the PIC (IC1). The PIC is an 8-bit processor and hence the converter has 256 discrete output levels.

When the output of the ADC changes, the PIC then transmits a message. In the configuration used, the minimum detectable temperature change is ±0·3°C. Each transmission lasts for 330ms which means that the maximum rate of change of temperature that is accurately measurable is one degree per second.

The output from the tilt switch S5 is fed directly to pin 1 of IC1, and is also continuously monitored for a change in state. When a high level is detected, continuous messages are transmitted.

The bit periods required for the communication across both the r.f. and RS232 channels are produced by timing routines within the PIC. This means that the hardware is kept simple, but the crystal frequency used must be a direct multiple of the frequency required. In this case, 3·6864MHz is chosen since when divided by 12288, it provides the 300-baud bit-rate used in the r.f. channel, and when divided by 384 provides the 9600-baud bit-rate required for RS232 communication.

Dual-in-line (d.i.l.) switches S1 to S3 can be used to allow software options to be chosen without needing to reprogram the PIC. However, the software provided does not make use of this feature and

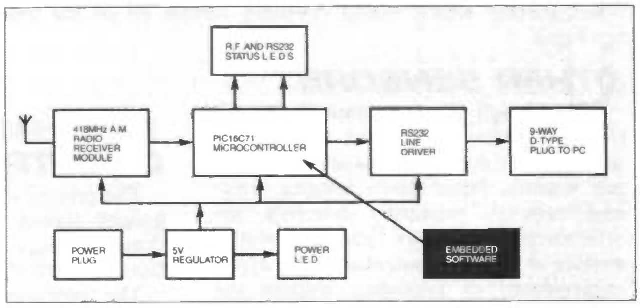


Fig.3. Block schematic diagram for the Receiver.

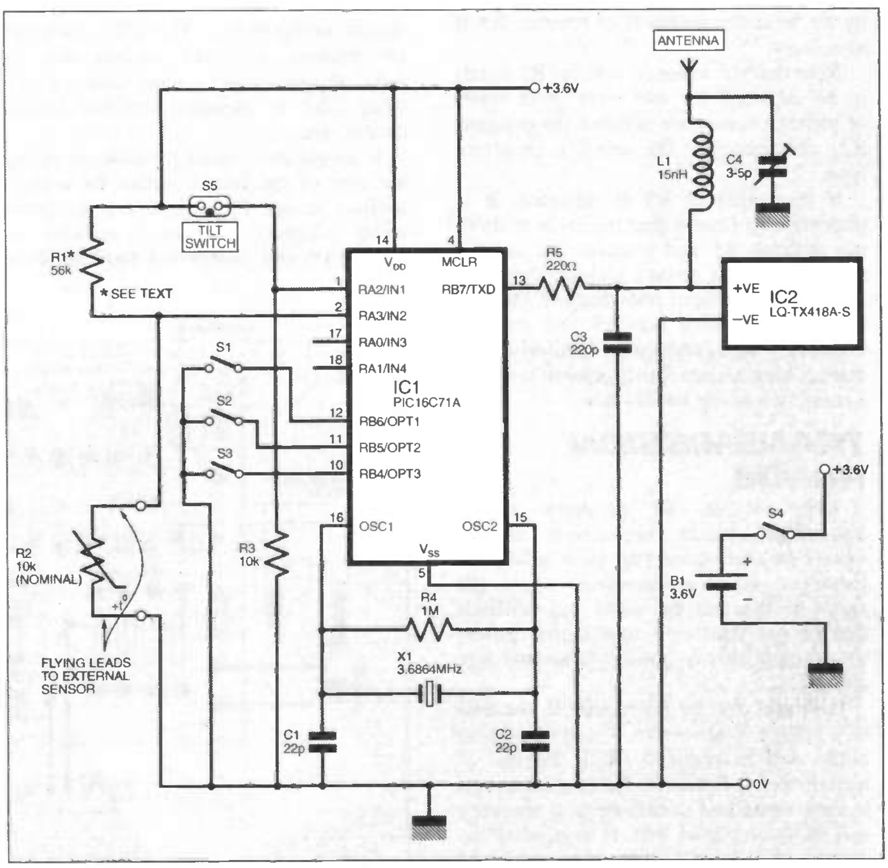


Fig.4. Complete circuit diagram for the Transmitter. Note that switches S1 to S4 are d.i.l. slide types.

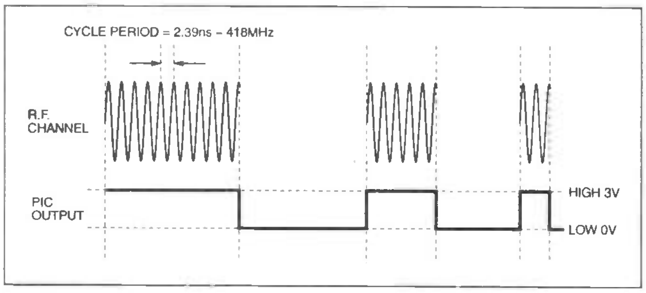
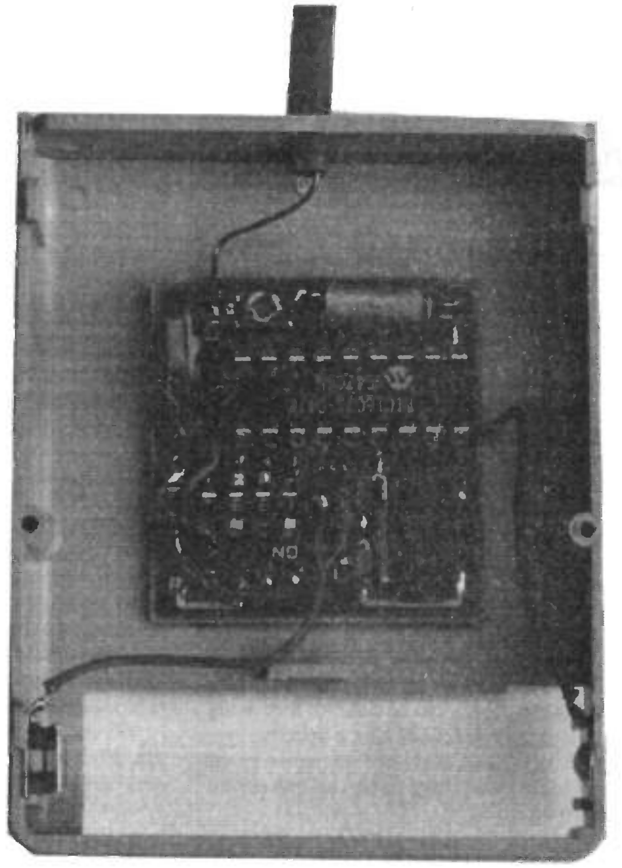


Fig.5. Using a PIC to control transmitter r.f. modulation.

therefore small wire links or zero ohm resistors must be soldered across the pads to effectively connect all of the switches permanently closed.

When a high level is present at pin 13 of IC1, transmitter module IC2 is switched on. Resistor R5 and capacitor C3 are used to limit the current and minimise the slew rate of the signal that drives IC2. The positive pin of IC2 is modulated by a 418MHz carrier wave that excites the inductor L1 and variable capacitor C4 that provides the r.f. signal to the antenna.

This provides a very simple modulation scheme where free space is radiated by r.f. when a high level output is produced by the PIC and not radiated when a low output is produced. This method has the advantage of consuming current for only part of the transmitted data word rather than using a constantly modulated carrier, which would consume current all of the time. See Fig.5.



Positioning of the p.c.b. inside the Transmitter case.

OTHER SENSORS

This design is not limited to the types of sensor shown here. Other types such as light dependent resistors (l.d.r.s), gas sensors, liquid level sensors, pressure switches, proximity detectors, accelerometers, pressure pads, humidity sensors or pressure gauges etc., can all be implemented as necessary without the need for any software change in the transmitter's PIC.

Switch sensors can be directly replaced by S5 with the removal of resistor R3 if necessary.

Note that the value of resistor R1 needs to be adjusted for use with other types of passive resistance sensors (in position R2), or removed if the sensor is an active type.

If the value of R1 is adjusted, it is important to ensure that the current flowing through R1 and position R2 is kept around 50µA. Currents smaller than this may cause the input resistance of the PIC to load the resistor network and produce inaccurate measurements. Similarly, any current higher than this level will result in a reduction of the battery life.

TRANSMISSION RANGE

When it is all properly tuned, transmitter/receiver separation of 10 metres in free space has been achieved. However, in an environment where the signal is blocked by walls and ceilings, due to the relatively low signal power transmitted, this is limited to around five metres.

It should also be noted that as the battery charge deteriorates, the transmitting range will be reduced. With the use of lithium cells, however, this deterioration is very rapid and occurs only at the very end of their useful life. It is a good indicator of a dying battery if many errors are suddenly received in messages during reception.

TRANSMITTER CONSTRUCTION

The printed circuit board (p.c.b.) component layout for the Transmitter is shown in Fig.6. This board is available from the *EPE PCB Service*, code 219.

The completed board is only 33mm × 32mm square by 15mm deep (height). It is double-sided and uses a mixture of standard (through-hole) and surface mount components. The PIC, transmitter module and tilt switch are the only through-hole components, everything else is industry-standard surface mount size.

It would have been possible to reduce the size of the board further by using a surface mount PIC. However, programming adaptors for these devices are expensive and somewhat hard to come by, so a socketed d.i.l. device has been retained for simplicity.

Assembly is relatively simple. It is recommended that a fine tipped soldering iron and pair of tweezers are used to solder the smallest parts as they can easily be destroyed by excessive heat. It is important to solder resistors R4 and R5 before the socket for IC1 as they lie under this socket and are very difficult to access once it is in place.

The socket for IC1 must be soldered on both sides of the board. It is recommended that a piece of 1mm × 2mm × 30mm cardboard is inserted under the socket in order to lift the device up above the board whilst soldering the topside. This ensures that there is enough space on the top of the board to mount the socket whilst the legs are still accessible from underneath it.

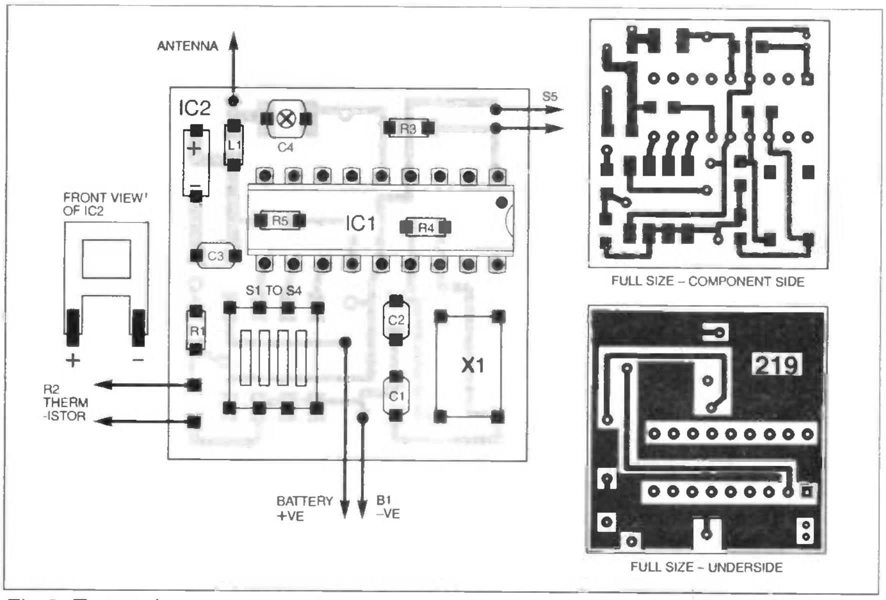


Fig.6. Transmitter component layout on the small "surface mount" p.c.b. The PIC, transmitter module and tilt switch S5 are the only non-surface mount devices.

COMPONENTS

Transmitter

Resistors

R1	56k (see text)
R2	10k thermistor bead, n.t.c.
R3	10k
R4	1M
R5	220Ω

All resistors (except R2) surface mount package 1206.

See SHOP TALK Page

Capacitors

C1, C2	22p ceramic, SM package 1206 (2 off)
C3	220p ceramic, SM package 1208
C4	3p to 5p trimmer, TZBX4, surface mount

Semiconductors

IC1	PIC16C71 microcontroller, pre-programmed (see text)
IC2	LQ-TX418A-S (a.m.) or TXM418-A (f.m.) transmitter module (see text)

Miscellaneous

B1	3·6V lithium cell, AA size
L1	15nH inductor, SM package 0805
S1 to S4	4-way d.i.l. slide switch module, surface mount
S5	tilt switch (see text)
X1	3·6864MHz crystal, surface mount

Printed circuit board available from the *EPE PCB Service*, code 219 (Transmitter); 18-pin d.i.l. socket; antenna, 0.5mm × 90mm solid-core copper wire (see text); handheld plastic case, 56mm × 71mm × 18mm, connecting wire; solder, etc.

Approx Cost Guidance Only £29 excluding battery

The only other slightly tricky part of the assembly is soldering inductor L1. This device is a surface mount 0805 type and measures only 1mm × 1mm × 2mm and is easily damaged. Care must be taken to make sure that no whiskers of solder are between the pads before soldering as removal once soldered is very difficult and will probably render it useless.

Check that the ground connection for the transmitter module is properly made on both sides of the board at every grounding point as this provides a solid ground connection throughout the copper.

Sensors R2 and S5 (temperature and tilt) can be mounted either on the board, or on flying leads as necessary for the specific application.

Finally, note that the positive lead of the transmitter module is marked with a spot. Failure to observe the polarity of this device will result in it not working and is an expensive mistake!

The antenna used is a short whip type. It is simply made from a 90mm length of solid copper wire of 0·5mm diameter with one end soldered to the junction of C4 and L1 on the p.c.b.

The pre-programmed PIC16C71 needs to be firmly placed into the socket without bending any of its pins! Once this is completed, a quick test is to check the current consumption of the unit with S4 switched on. This should be either 0·5mA or 25mA depending on whether or not the unit is transmitting. (A transmission can be forced by manually changing the sensor output e.g. changing the temperature around the sensor.)

The finished Transmitter is tuned using a non-metallic trimmer to adjust variable capacitor C4 for the best performance, but this needs to be completed in conjunction with the finished Receiver unit and will be discussed in Part 2.

OBSERVING MPT1340

This design uses a radio frequency that does not require a licence for use within the UK. However, in order to comply with Home Office regulation MPT1340, it is necessary to enclose the unit within a suitable box so that external adjustment cannot be made to the transmitter module. There are also restrictions on aerial use.

Both the transmitter and receiver enclosures must be clearly labelled as indicated below with lettering not less than 2mm in height:

MPT 1340
W.T. LICENCE EXEMPT

The transmitter antenna must be of an integral type. The Radio Communications Agency (RA) defines an integral antenna as "one which is designed to be connected permanently to the transmitter or receiver without the use of an external feeder". It is important, therefore, that the antenna is not accessible from the outside world and must not be removable.

In this instance, as long as the actual antenna wire is covered by a suitable sheath, such as a length of plastic wire-cladding and sealed at one end using a suitable adhesive, then it can be considered as integral. The receiver antenna can be integral or external as required.

TRANSMITTER ENCLOSURE

Any box suited to the final application can be used to enclose the Transmitter board. The type of box used here allows the user easy access to the integral battery compartment and all switches on the p.c.b.

Flying leads connect the power to the p.c.b. from the battery holder at the bottom of the box. The positive connection is in the centre of the board and ground near the variable capacitor C4. The finished p.c.b. is simply stuck to the base of the enclosure using a sticky pad or glued with a suitable adhesive.

This enclosure also allows easy access to the PIC if any reprogramming is required, and for changing the battery when necessary.

The antenna is brought out through a small hole in the front plate of the enclosure. It must conform to MPT1340 as discussed earlier.

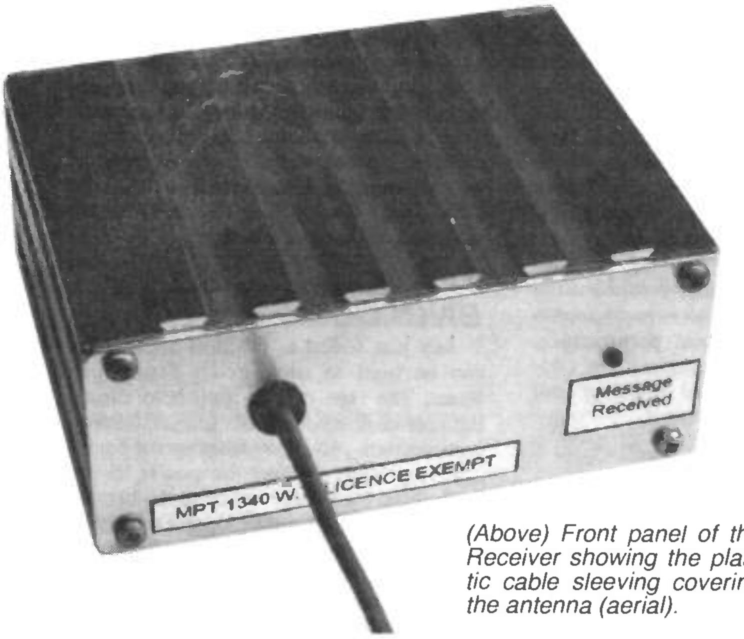
BATTERY LIFE

A single AA type Lithium cell powers the unit. This cell is non-standard with a terminal voltage of 3·6V and capacity of 2·3Ah. The transmitter has a standby current consumption of around 0·5mA and a transmitting consumption of 25mA.

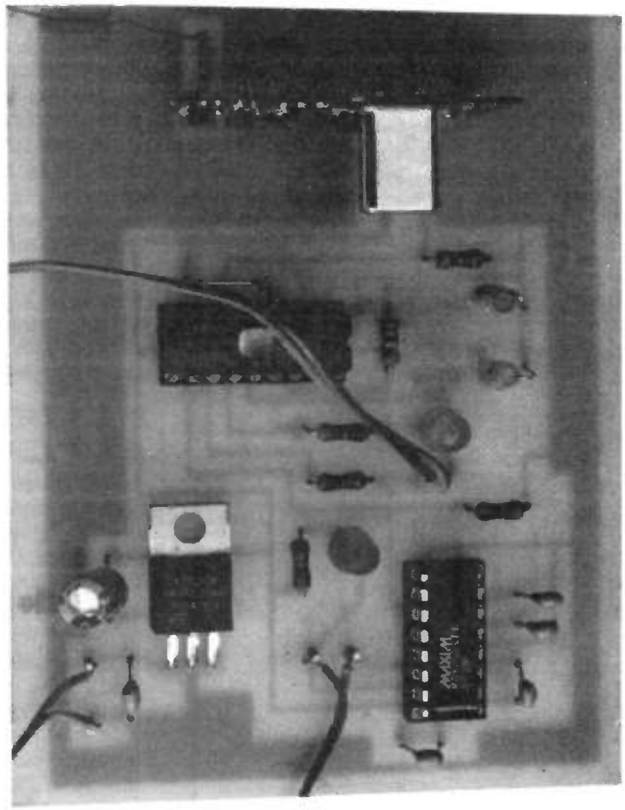
This means that each cell would theoretically last for 4600 hours (around 6·5 months) in standby mode and 92 hours (almost four days) constant transmission. In use the life of the cell will lie somewhere between these two limits, depending on the number of transmissions made.

The type of battery used is not critical, and hence the enclosure does not neces-

Two completed Transmitters. One with remote thermistor sensor and the other showing the required "licence exempt" label.



(Above) Front panel of the Receiver showing the plastic cable sleeving covering the antenna (aerial).



(Right) Layout of components on the completed Receiver p.c.b. The receiver module is shown mounted at right-angles to the board at the top.

sarily require an internal battery compartment. If required, the unit can be powered from any supply between 3V and 6V d.c. Do bear in mind, though, that a high capacity cell is required if the particular application demands that the unit be switched on for long periods at a time.

RECEIVER CIRCUIT

The full circuit diagram for the Receiver is shown in Fig.7. The receiver module (IC3) receives and decodes anything that it happens to receive on the 418MHz channel and translates this information into a logic signal on its Data pin 13.

This information is serially passed into the PIC (IC2) that tests any data for its validity. Once valid data is detected, the PIC passes a serial signal to RS232 line driver (IC4) that is used to interface to the computer.

The communication to the PC is very simple, using no handshaking and only requiring data (pin 2) and ground (pin 5) connections, via socket SK1. However, in order to use some terminal applications which require handshaking, it is necessary to link computer connections RTS (Ready to Send – pin 8) and CTS (Clear to Send – pin 7) together. This must be completed at the back of the connector in the Receiver unit.

There are three light emitting diodes (l.e.d.s) shown in the circuit, D1 to D3. Two of which are mainly used for diagnostic testing during programming, but are also useful when setting up the equipment. The status of the RS232 line is indicated by l.e.d. D1, that of the r.f. channel by D2, and D3 indicates when the unit is switched on.

Indicators D1 and D2 will flash quickly when the unit is receiving and transferring information. If the PIC has received information, but not determined it to be invalid, then D2 will flash but not D1.

The input voltage is regulated down to 5V by IC1. This allows any power supply source from 7V to 30V d.c. to be used. To use the Receiver with an input voltage of 5V or 6V, IC1 should be omitted.

Test point TP1 – connected to pin 12 of the receiver module IC3 – is used when tuning the Transmitter unit in order to achieve the best reception. This pin acts as a Relative Signal Strength Indicator (RSSI) and provides an analogue signal output that corresponds to the strength of the received carrier wave.

RECEIVER CONSTRUCTION

The Receiver uses a conventional single-sided printed circuit board and consists of all through-hole components, apart from the crystal X1. The latter is a

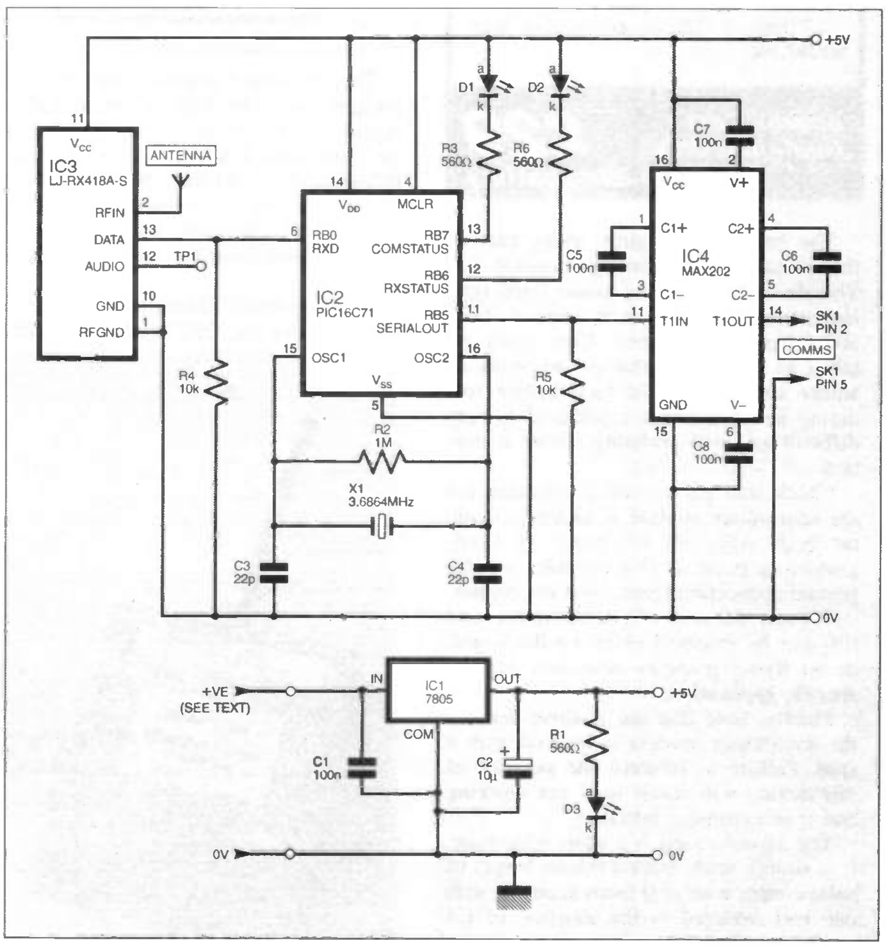


Fig.7. Full circuit diagram for the Receiver section of the Wireless Monitoring System. If the circuit is to be powered from a 5V to 6V source, IC1 can be omitted.

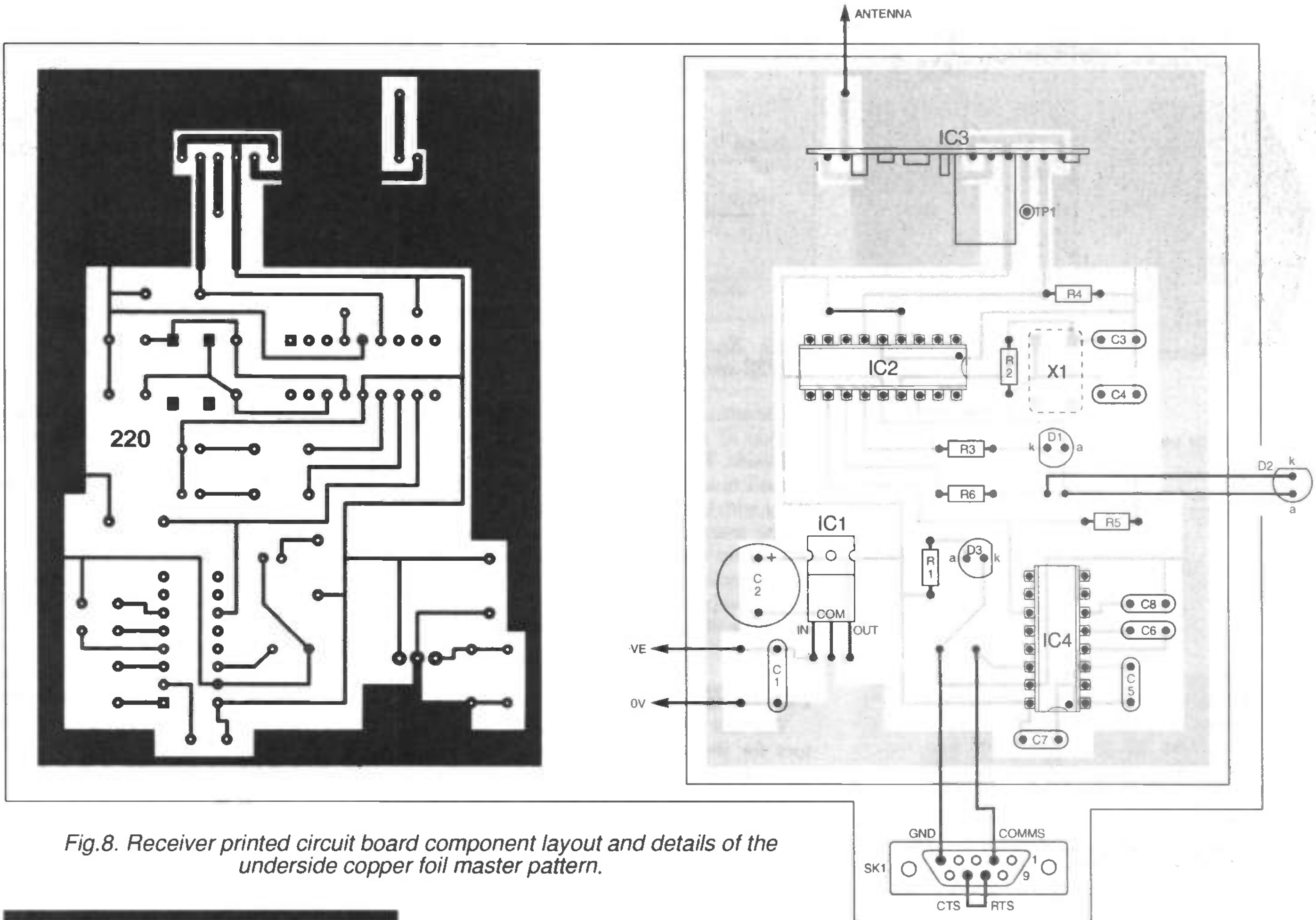


Fig.8. Receiver printed circuit board component layout and details of the underside copper foil master pattern.

COMPONENTS

Receiver See SHOP TALK Page

Resistors
R1, R3,
R6 560Ω (3 off)
R2 1M
R4, R5 10k (2 off)
R7 10k (f.m. adp. – next month)
All 0.25W 5% metal film.

Capacitors
C1, C5
to C8 100n ceramic disc (5 off)
C2 10μ elect, radial 16V
C3, C4 22p polystyrene (2 off)

Semiconductors
D1, D3 red l.e.d. (2 off)
D2 green l.e.d.
IC1 7805, 5V regulator
IC2 PIC16C71 microcontroller, pre-programmed (see text)
IC3 LJ-RX418A-S (a.m.) or SILRX-418A (f.m.) receiver module (see text)
IC4 MAX202 RS232 line driver

Miscellaneous
SK1 RS232 9-pin D-type connector
X1 crystal, 3·6864MHz, surface mount

Printed circuit board available from the *EPE PCB Service*, code 220 (Receiver); 16-pin d.i.l. socket; 18-pin d.i.l. socket; antenna, 0.5mm × 90mm solid-core copper wire; power supply socket, 2·1mm; 9V mains adaptor, 600mA; extruded aluminium case, 107mm × 84mm × 47mm; serial lead to suit; connecting wire; solder, etc.

Approx Cost Guidance Only £39 excl. mains adaptor

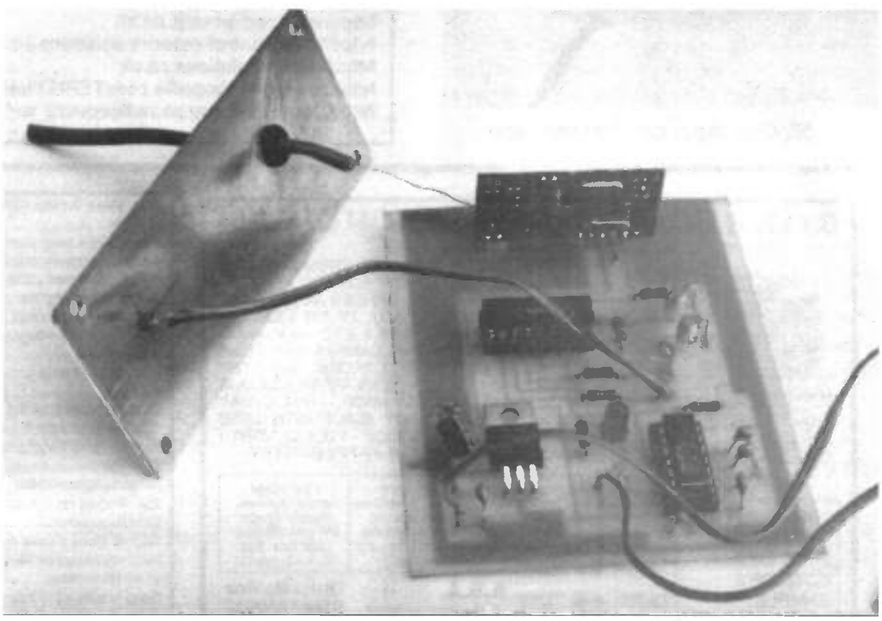
surface mount device and is mounted on the reverse, copper side, of the board. Details of the board component layout are shown in Fig.8. This board is available from the *EPE PCB Service*, code 220.

Construction is straightforward, but note that IC1 and IC4 should be mounted in sockets, Take care when handling IC3 as it is easily damaged by static electricity.

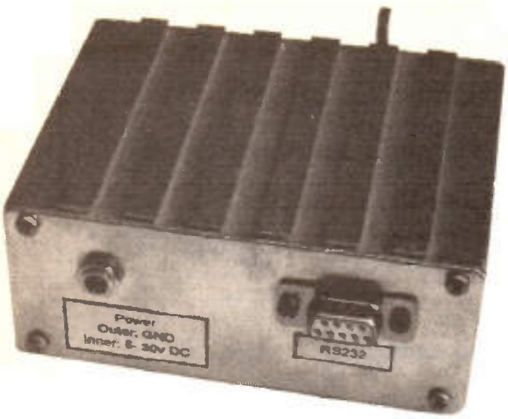
Observe the correct polarity of l.e.d.s D1 and D2. If preferred, they could be mounted on the front of the enclosure via flying leads to show diagnostic information whilst in use. They provide a useful indicator to the number of valid messages that are received.

RECEIVER ENCLOSURE

A fully enclosed metal box for the receiver is recommended as this provides good screening against radio frequency interference and improves performance significantly. The type used here is extruded aluminium with internal slots for p.c.b.s. The advantage of this box is that the two end plates can hold the connectors and the antenna whilst the p.c.b. is firmly held inside.



The r.f. status l.e.d. mounted and wired on the front panel. This can also be accompanied by the RS232 com status l.e.d. if preferred.



Rear view of the completed Receiver.

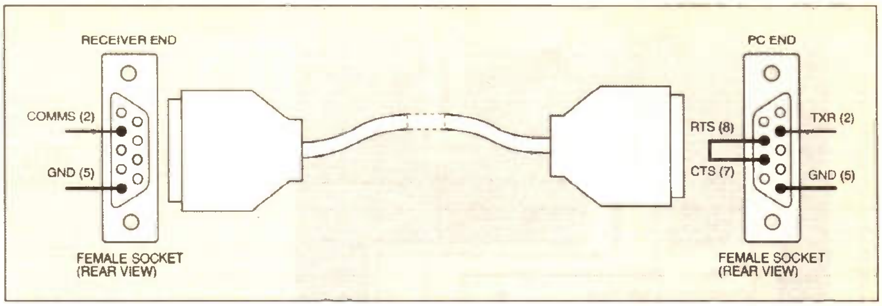
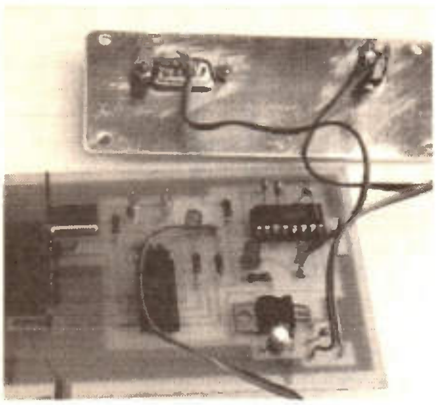


Fig.9. Serial cable interconnection details between the Receiver and the PC RS232 serial port.

The antenna should be connected through the top of the board and soldered on the underside. This can then be led out through a small hole in the front panel of the case along with l.e.d.s D1 and D2, if preferred.

The antenna can be screened inside the box before it reaches the outside world but it has been found not to provide any significant improvement in performance. There should be 90mm of antenna wire outside the enclosure.



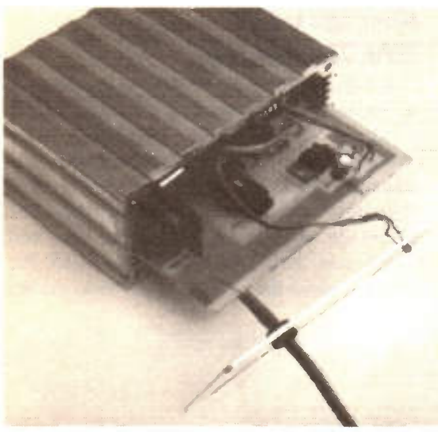
Wiring from the p.c.b. to the D-type connector and the power socket on the rear panel.

RS232

The rear of the unit holds the connectors for the RS232 and power leads. A low voltage d.c. power connector of 2·1mm diameter is used for the power supply as this type is adopted by many of the ready-made mains adaptors to which this unit is well suited. Other power connectors may be used if required.

Note that with some adaptors the outer contact must be connected to ground as this is directly connected to the case. If a plastic socket is used, then ensure that the enclosure is connected to ground via a solder tag at one of the connector screws.

It is not essential to use a D-type connector on the rear of the unit to connect the serial cable, but this is recommended as it allows the use of ready-made serial leads. If a ready-made lead is used, make sure that it is a "straight through" type, i.e. transmit and receive are not crossed over inside the connectors. The necessary connections for the serial cable are shown in Fig.9.



Slotting the p.c.b. into the case.

RESOURCES

Software for the Wireless Monitoring System is available on a 3·5-inch PC-compatible disk from the *EPE PCB Service* (for details see that page in this issue – the software is free but there is nominal post and handling charge for the disk). It is also available for free download from our web site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/wireless.**

Pre-programmed PIC16C71s are available, see this month's *Shop Talk* page. Information on obtaining other "special" components for this design are also given on this same page.

The transmitter boards are supplied as a pair, one for a.m. and one for the f.m. adaptor, codes 219 and 219a, respectively. The receiver boards are also supplied as a pair, again one for a.m. and one for the f.m. adaptor, codes 220 and 220a respectively. See the *EPE PCB Service* page for price details.

Next Month: Testing, setting-up, software and f.m. adapator details.

INTERNET REFERENCES

The following web sites may be of use to any readers interested in developing equipment based on the 418MHz frequency:

http://www.lprs.co.uk	Radio module distributor
http://www.radiometrix.co.uk	Radio module distributor
http://www.control-network-solutions.co.uk	Radio module distributor
http://www.rfsolutions.co.uk	Radio module distributor
http://www.zdwebopedia.com/TERM/t/telematics.html	Some definitions
http://www.open.gov.uk/radiocom/ra_wel.htm	MPT specifications

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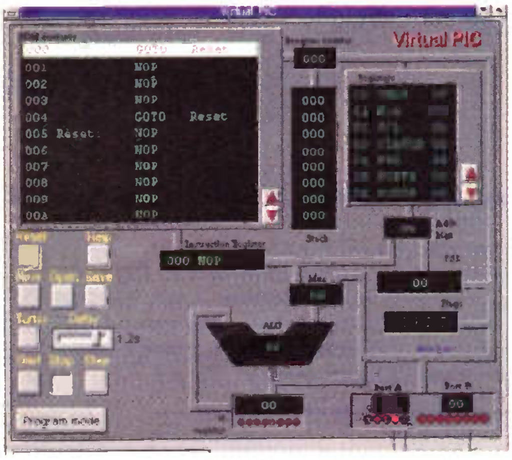
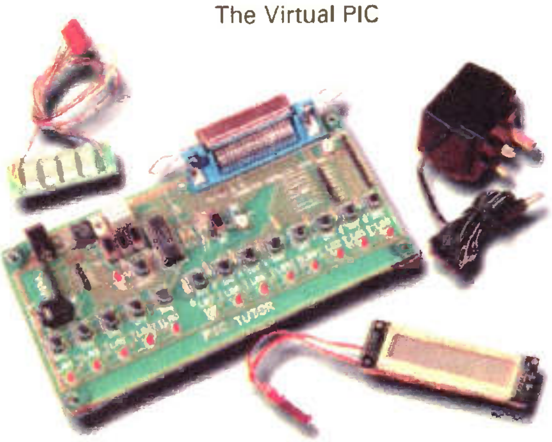


The Virtual PIC



Deluxe PICtutor Hardware

Developed from our famous and incredibly popular *EPE PIC Tutorial* series by John Becker (*EPE* March to May '98) this CD-ROM, together with the PICtutor experimental and development board, will teach you how to use PIC microcontrollers with special emphasis on the PICx84 devices. The board will also act as a development test bed and programmer for future projects as your programming skills develop.

This interactive presentation uses the specially developed Virtual PIC simulator to show exactly what is happening as you run, or step through, a program. In this way the CD brings the *EPE PIC Tutorial* series to life and provides the easiest and best ever introduction to the subject.

Nearly 40 tutorials cover almost every aspect of PIC programming in an easy to follow logical sequence.

HARDWARE

Whilst the CD-ROM can be used on its own, the physical demonstration provided by the PICtutor Development Kit, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work once you have mastered PIC software writing.

Two levels of PICtutor hardware are available – Standard and Deluxe. The Standard unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials – it can be upgraded to Deluxe at a later date, by adding components, if required.

The Deluxe Development Kit is supplied with a plug-top power supply (the Export Version has a battery holder), all switches for both PIC ports plus l.c.d. and 4-digit 7-segment l.e.d. displays. It allows users to program and control all functions and both ports of the PIC and to follow the 39 tutorials on the CD-ROM.

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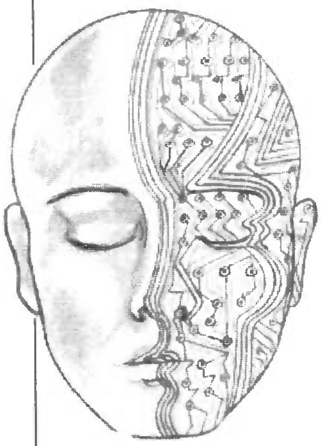

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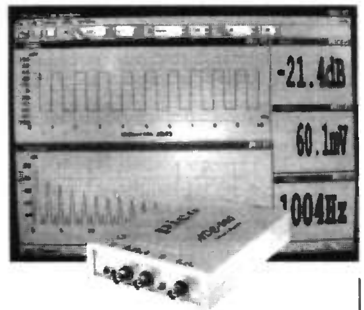

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Zener Diode Tester – A tap on the knee

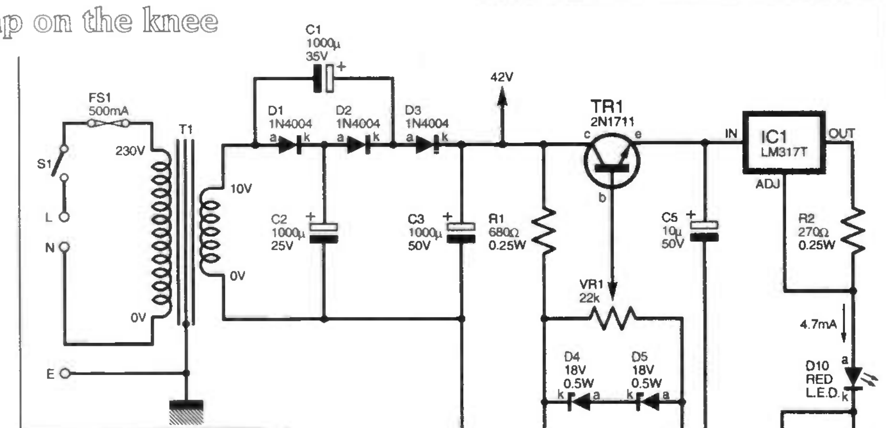
THE PURPOSE of the circuit diagram illustrated in Fig.1 is to help in measuring the value of an unidentified Zener diode. It is centred around a common LM317 voltage regulator (IC1) which is connected in its constant-current mode. The current is set to under 5mA, being calculated by the formula $I = 1{\cdot}25V/R$ and this flows through the Zener diode being tested. A voltmeter can be connected in parallel with the Zener and the Zener voltage read directly.

By adjusting control potentiometer VR1, it is possible to vary the voltage on transistor TR1 emitter (e), which provides an adjustable voltage to the current limiter. VR1 is then adjusted until the l.e.d. D10 illuminates to indicate that current is flowing, when the test voltage may be read.

The circuit operates from a mains power supply. To measure diodes up to, say, 33V d.c. it is normally necessary to use a transformer of 30V a.c. output, but by using a voltage trebler circuit, based around diodes D1 and D2 and capacitors C1 and C2, it is easy to use a much lower secondary voltage (e.g. 10V a.c.) and raise this to a useful 42V d.c. (10V a.c. × 1·414 × 3) which is current limited to about 35mA.

Due care must be taken when working with these higher voltages, and extreme care should be exercised to ensure that all diodes and electrolytic capacitors are correctly polarised.

Gianfranco De Dominici, Greenock, Scotland.



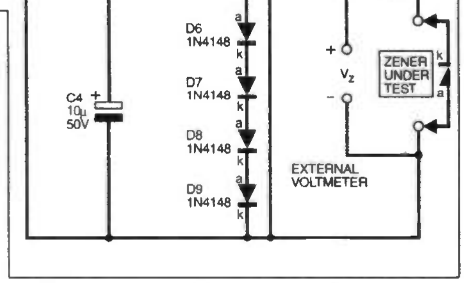
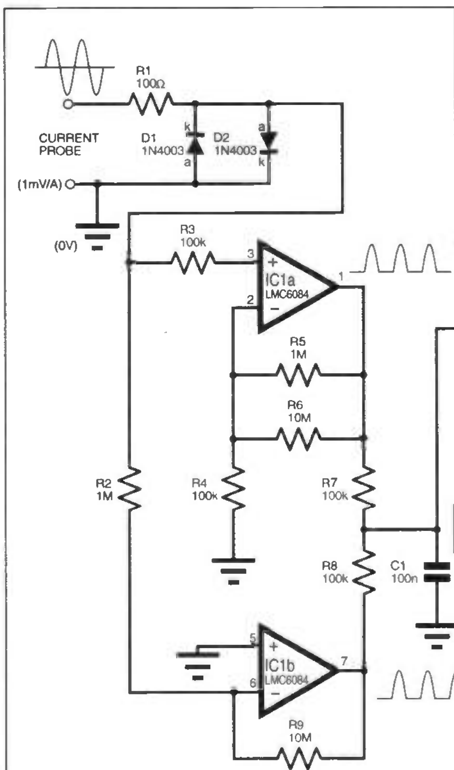


Fig.1. Zener Diode Tester.



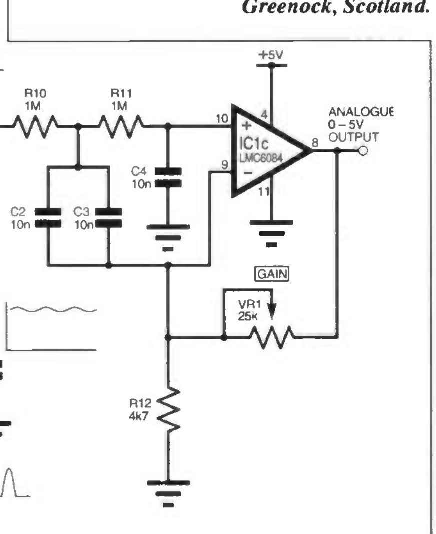


Fig.2. Current probe interface.

Microcontroller Interface for AC Monitoring – PIC the value

THE CIRCUIT of Fig.2 was designed in order to interface a PIC microcontroller to a standard clip-on DVM (digital voltmeter) current probe. The PIC device chosen must have an analogue input and the software depends on the application used.

The circuit utilises low-noise LMC6084 operational amplifiers (IC1a and IC1b) as a precision rectifier and a filter (IC1c) with presettable gain to give a response to the average current. The interface circuit requires a low impedance current probe providing 1mV per ampere to be connected to the input. The accuracy of the circuit is about as good as the 8-bit ADC used within the microcontroller when one per cent resistors are employed.

Gerard la Rooy, New Zealand.

Reverse Polarity Indicator

– Connection Protection

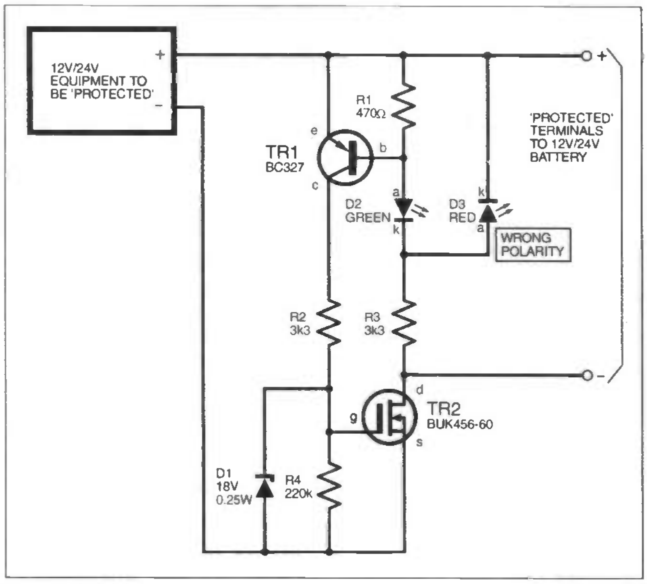
IN ORDER to provide reverse polarity protection for some 12V and 24V d.c. equipment, the circuit diagram of Fig.3 was devised. This uses a MOSFET power transistor, TR2, to virtually eliminate the problem of undesirable forward voltage drop, which would be apparent if ordinary rectifiers were used for protection, and the circuit even outperformed a Schottky diode in this respect.

The voltage drop is determined by the on-resistance of TR2 and the current flowing into the load. Since the MOSFET is used in its reverse-conducting mode it is feasible to expect an effective on-resistance of about 20 per cent below the manufacturer's specifications, which are usually given in forward conducting mode. Two light-emitting diodes (l.e.d.s D2 and D3) are incorporated to indicate correct or reversed polarities.

The circuit can be scaled up by paralleling MOSFETs or by placing a Schottky diode in parallel with the transistor, to get the best of both worlds. It is advisable to heatsink the MOSFET because of its significant positive temperature co-efficient.

Gerard la Rooy, New Zealand.

Fig.3 (right) Circuit diagram for a "low-dropout" Reverse Polarity Indicator for d.c. equipment.



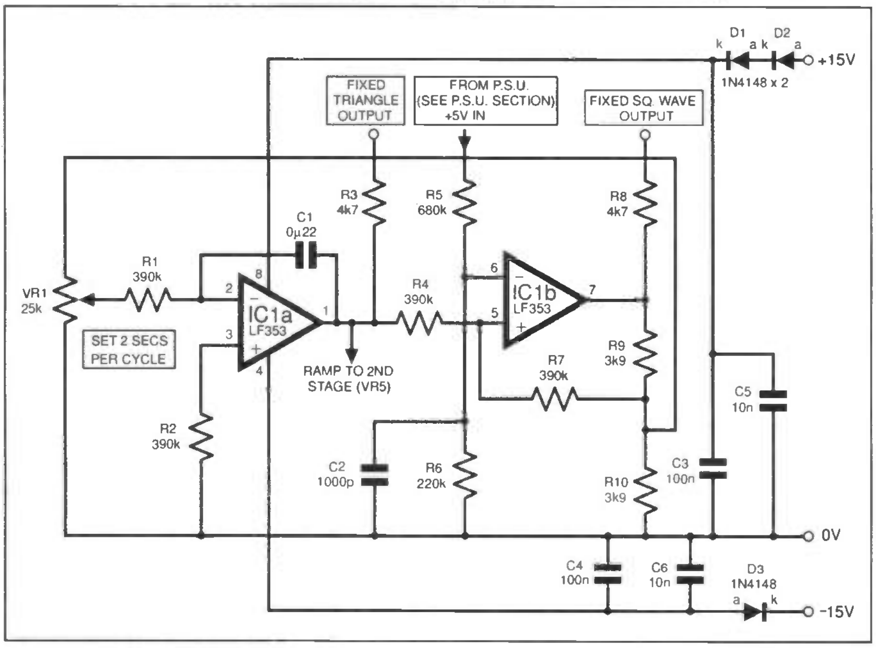


Fig.4a. A.F. Sweep Signal Generator first stage – 0V-11V-0V Ramp Generator.

A.F. Sweep Signal Generator

– More Scope

THE PURPOSE of the A.F. Sweep Generator circuit in Fig.4 (shown in stages) is to provide an audio test signal in the range of 20Hz to 20kHz. This can be set either to a single frequency or a sweep range of up to ten octaves which can be used to check the frequency response of an audio amplifier etc.

The design provides Square wave, Triangular wave and an approximate Sine wave. The output level is 0V to 6V r.m.s.

On the Ramp

The first stage of the generator gives a continuous 0V to 11V to 0V ramp which is used to sweep the audio frequency output, and may also be used as a timebase for an oscilloscope. This should be set to two seconds per cycle using VR1, as the 20Hz to 40Hz octave needs a certain amount of time to complete a few cycles. This stage also provides fixed triangle and square wave outputs.

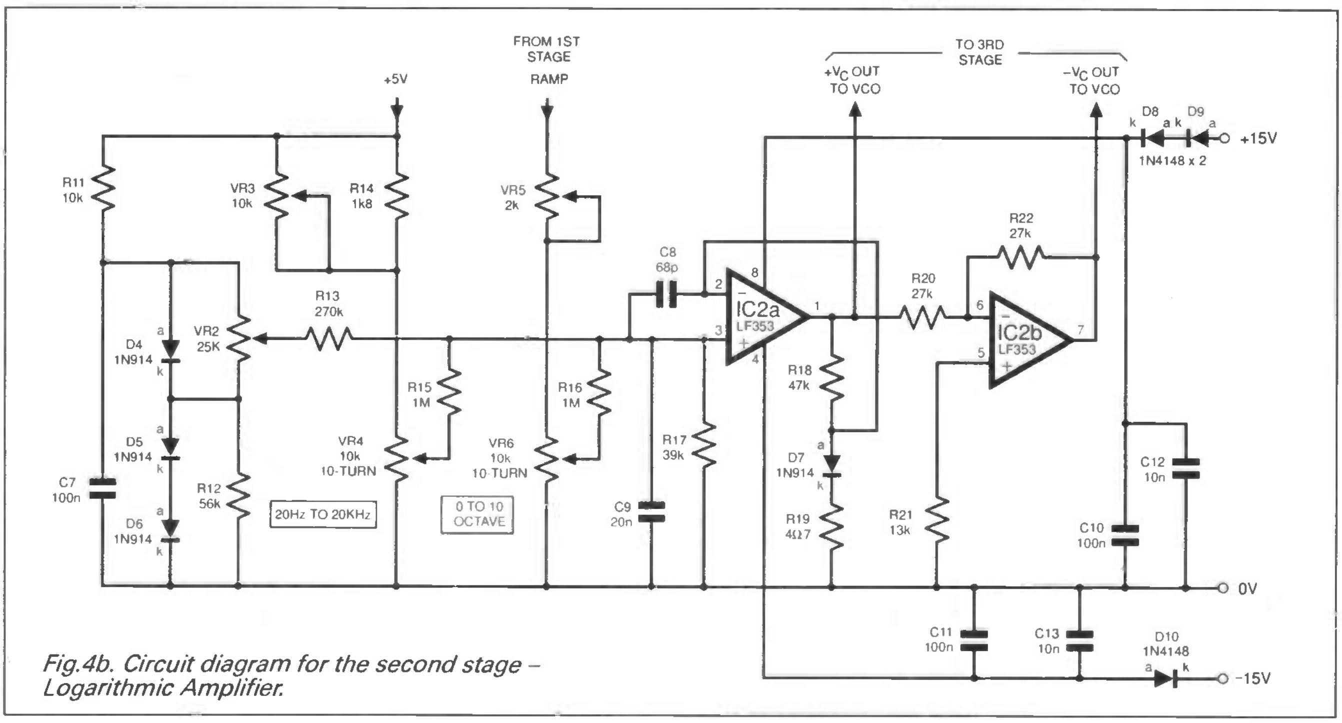


Fig.4b. Circuit diagram for the second stage – Logarithmic Amplifier.

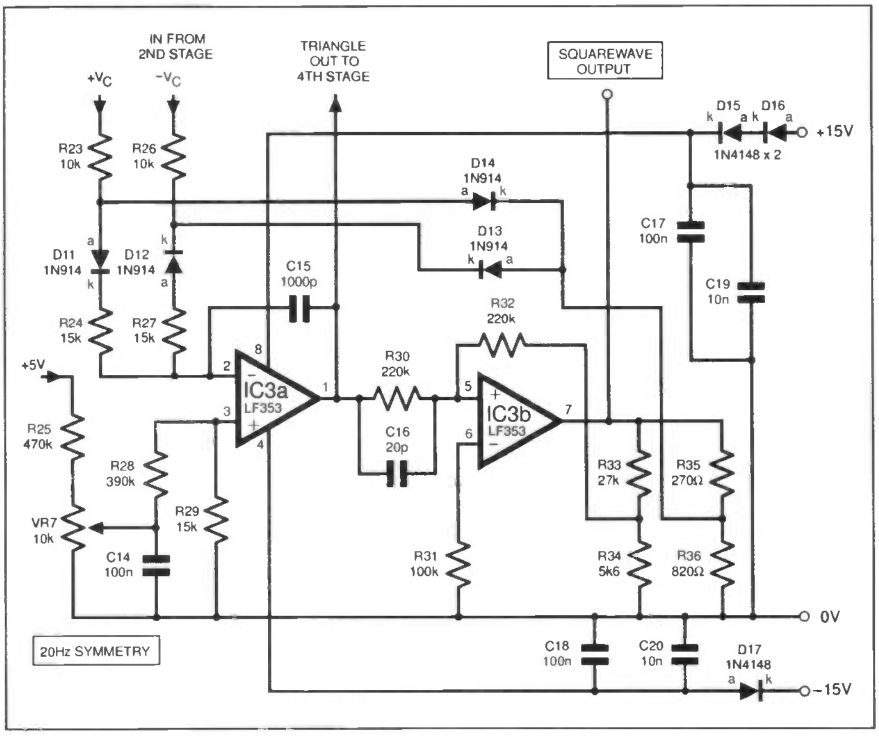


Fig.4c. Circuit for the Voltage Controlled Oscillator (v.c.o.) third stage.

An LF353 gives a fairly symmetrical positive and negative output, although it was found necessary to set a voltage differential using diodes on the positive and negative supply rails. The resulting +13·6V and −14·2V gives a fairly good ±12V output swing.

On the prototype the square, triangular and sine wave outputs were connected to a switch and a 5 kilohm potentiometer and then on to phono sockets. The ramp and square wave output signals were also brought out to front panel sockets for use as a timebase signal. The ramp can be used as channel B input for X/Y plotting, or use a slow timebase (0·1sec/div.), and trigger the oscilloscope on the falling or rising edge of the square wave.

J.D. Gray,
London N10.

Sine of the Times

The second stage produces a logarithmic curve so that ten divisions across an oscilloscope tube correspond to ten octaves: 20Hz, 40Hz, 80Hz, 160Hz, 320Hz, 640Hz, 1280Hz, 2560Hz, 5120Hz, 10240Hz and 20480Hz. Its two outputs labelled +Vc and −Vc connect to the third stage which is a v.c.o. The two signal voltages required are +7V and −7V for 20kHz, 3·5V for 10kHz, 1·75V for 5kHz etc. down to about ±170mV for 20Hz. A square wave is also provided by the v.c.o.

The final stage buffers the triangle wave produced and sets it to 6V (24V pk-pk) and a non-linear impedance formed by diodes D18 to D27 and neighbouring resistors, R43 to R47, is used to generate an approximation to a sine wave. The output is also set to 6V r.m.s. (about 17V pk-pk) using VR8. It is best to use a sine wave for frequency response curves, as square or triangular waves contain odd harmonics.

Power Supply

A mains power supply provides +15V and −15V), together with a 5V reference. For the op.amps, LF353s are recommended particularly where the op.amp is used as a comparator as it has a good slew rate. This is also required to produce a reasonable triangular wave at 20kHz.

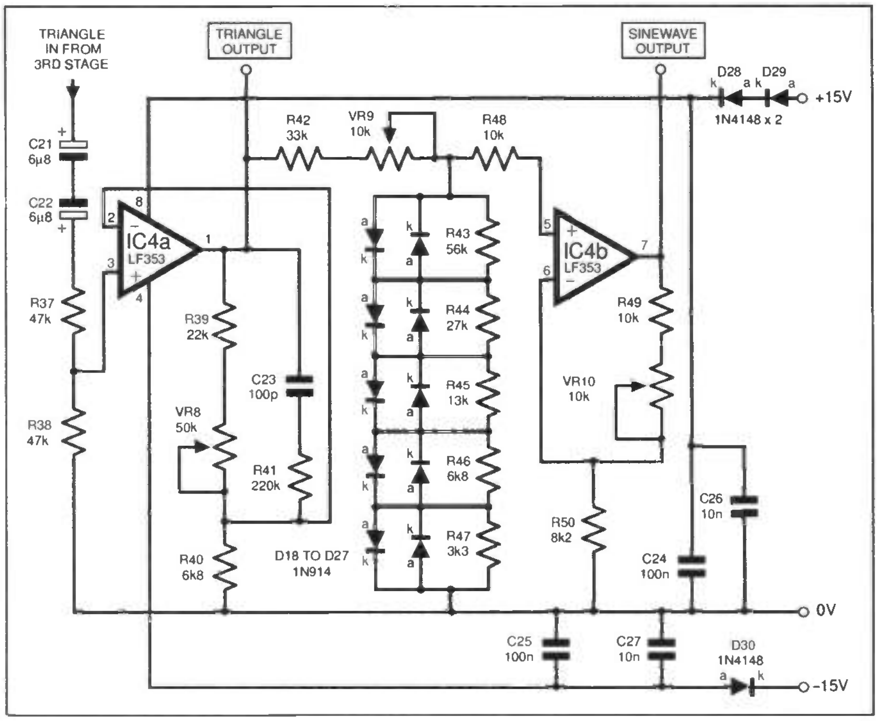


Fig.4d. Circuit diagram for the Buffer stage.

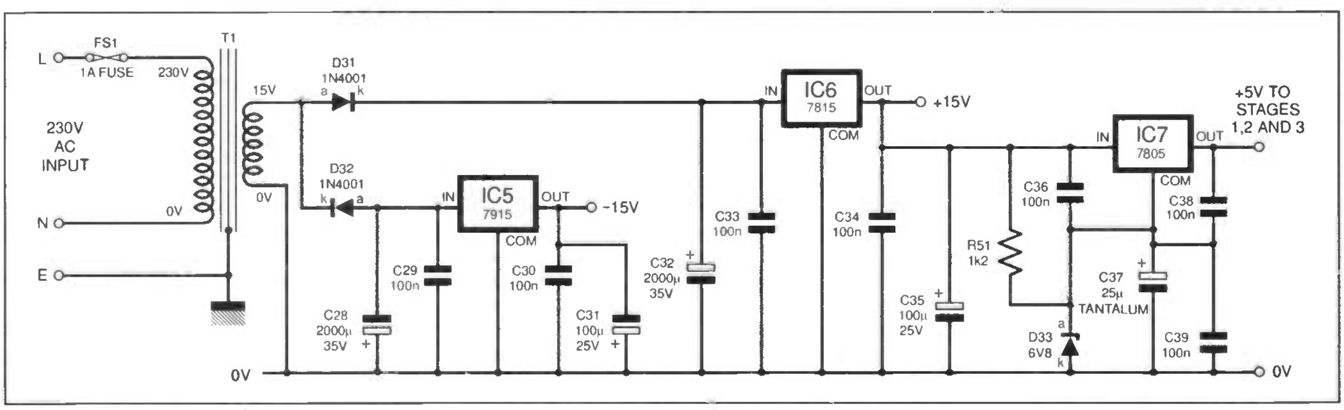


Fig.4e. Mains power supply circuit for the A.F. Sweep Signal Generator.

Special Feature

SCOLAR POWER

TERRY de VAUX-BALBIRNIE B.Sc

Schools switch on to the new government solar initiative.

SURELY everyone has heard of the greenhouse effect and its association with global warming. It comes about because all fossil fuels contain carbon – the chief offenders being coal, natural gas and oil products. As they burn, they release carbon dioxide into the atmosphere and this increases the amount occurring naturally.

A hundred years ago, there were about 300 parts per million (ppm) of carbon dioxide in the air. In recent years this has risen to some 350 ppm – an increase of nearly 17 per cent.

TIPPING THE BALANCE

The sun's high-frequency energy passes through the atmosphere fairly easily. About 30 per cent of it then reflects back into space. However, the reflected energy is at a lower frequency and it is more difficult for this to penetrate the blanket of carbon dioxide.

With the natural balance upset, and less energy flowing back into space, the average temperature of the earth's surface rises. This is very much like a garden greenhouse with the glass taking the place of carbon dioxide (see Fig.1).

Any marked increase in the earth's temperature would have catastrophic consequences in the long run. Melting of the polar ice-caps and the thermal expansion of water would both increase the volume presently occupying the oceans and this would cause large areas of low-lying land to become flooded.

In addition, the fossil fuels will eventually run out. It is therefore vital to reduce our dependence on these fuels and to obtain as much as possible of our energy needs from renewable (everlasting) sources. These include wind, waves and the direct use of solar power.

There seems to be a global wish to reduce the contribution made by nuclear energy because of its inherent danger, problems with disposal of radioactive waste and the ultimate cost of decommissioning the plants.

ON TARGET

To go some way towards reducing our need for fossil fuels, the UK government has set a target to obtain 10 per cent of the national electricity requirement from renewable sources by the year 2010.

Already, wind turbines are making a useful input. These are to be seen in coastal areas and other open places either singly or grouped into "wind farms". A typical medium-size wind turbine (aerogenerator) will produce a peak (maximum) power of some 275kW and they are useful where the amount of wind justifies their use.

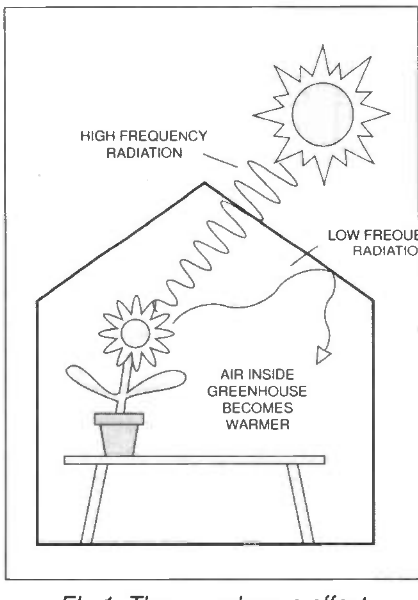


Fig.1. The greenhouse effect.

Wind turbines are an indirect way of utilising the sun's energy (since this causes the differences in temperature which make the wind blow in the first place).

PHOTOVOLTAICS

Apart from such indirect methods, solar power can be utilised directly using photovoltaic cells. These convert some of the energy striking their sensitive surface into direct current electricity. It is important to note the difference between active solar systems which generate electricity and passive ones which simply heat up water and which are less useful.

Photovoltaic cells have the advantage of having no moving parts and are therefore silent in operation and very reliable. The United Kingdom lags behind Japan, Germany, Switzerland and the USA in the use and development of photovoltaic power although it is beginning to catch up.

The photovoltaic effect was first noticed by Antoine Becquerel in 1837 when sunlight shone on one of his electrodes during an experiment involving electrolysis. However, purpose-made devices were not made until the 1870s and used the element selenium. Although selenium is still occasionally used for special purposes, silicon is almost always used today.

Photovoltaic cells are, in effect, diodes where light falls on a *p-n* junction. The energy of the photons creates electron-hole pairs in the material. The electrons can then flow through an external circuit returning to the silicon and re-combining with the holes. This process goes on indefinitely as long a light source exists.

Unfortunately, most of the electrons combine with holes directly in the material itself – that is, without flowing through the external circuit. This is why the efficiency is very low, between about five per cent and ten per cent, depending on type.

A BIT OF FORESIGHT

To raise awareness and to develop the technologies which Britain will need in the next millennium, the Government set up the Technology Foresight Challenge. Ideas were invited for innovative schemes which would fulfil that objective and funding was offered to the winners.

Out of 530 entries, the best 24 were subsequently chosen. One of these was the Scolar programme and this was established in 1996 using £1m from the Foresight Challenge fund. In this, Philip Wolfe of the Intersolar Group fulfilled a wish to raise awareness in the use of photovoltaics in the UK by providing small-scale school-based systems.

Intersolar have considerable experience in the manufacture of thin-film amorphous photovoltaic cells (one of the options used in the Scolar projects). From its factory in South Wales, the company supplies eight per cent of the world market.

Together with Intersolar, the resources of the various other photovoltaic expert groups in industry and the universities were pooled together with the assistance of various financial institutions. Contributions would be sought from the participating schools and the balance of the cost met by the group

A thin-film-silicon facade on a south facing wall – it looks good and generates power too! (Intersolar).

members and government funding. Everything taken into account, the programme total amounts to some £2·5m.

The aim of the Scolar project is to give schools and colleges an opportunity to operate a photovoltaic system of their own. Applications to participate are invited although certain criteria need to be met (interested teachers and lecturers should see the addresses at the end).

The aim is for 100 systems to be in operation by the year 2000. The data from each site will be linked via the Internet to make it available to a wide audience and to aid research into further applications for solar technology. It will also enable comparisons to be made between the different sites.

It is this Internet-based aspect which is the key to the scheme and that which makes it more innovative than many of the larger programmes presently in operation in other parts of the world.

While producing sufficient power to operate a few computers, the scheme gives a unique opportunity for the students to investigate renewable energy in general and solar energy in particular. This will be integrated with the teaching programme and forms links with the National Curriculum – notably in Science, Geography and Design and Technology (D&T).

FINDING THE MONEY

Participating schools are required to pay about one-third of the subsidised cost (about £4500) of the system of their choice. The school's contribution will probably be a mix of the proceeds of fund-raising, local authority grants and sponsorship from local industry. For its part, the school receives a fully-installed photovoltaic panel system, a dedicated computer with Internet connection and an Internet-based resource package.

There are also monitoring facilities, including a control panel which may be placed anywhere in the school (for example, the reception area). This will give a read-out of the power output at any time (in watts) plus the total amount generated (in kWh).

The photovoltaic panels themselves may be presented in a variety of architectural styles. For example, covered walkways, wall cladding or window louvres. The students are encouraged to select the most suitable design for their own environment. They also suggest the best type of panels to use.

The only fully up-and-running Scolar scheme at the time of writing (Autumn, 1998) is at the Cardinal Hinsley High School for boys in Willesden, West London and this was switched on by Energy Minister John Battle on the 14th July, 1998. He also announced a further 16 schools and colleges around the UK which had won approval to participate.

"This is precisely the kind of activity I want to encourage through the Government's Foresight Initiative," said John Battle. "The link with schools and colleges is particularly valuable as it gives first hand experience to the generation that will see this exciting technology come to fruition."

The photovoltaic panels at the school, were chosen to form a canopy over the entrance of the hut used by the Renewable Energy Club run by science teacher, George Nagle.

The club is involved in the small-scale generation of electricity by various renewable means. As well as the photovoltaic panels, the club owns several wind turbines (two of them home-made) and can even produce electricity by pedalling a bicycle coupled to a generator! The total output is collated every twelve hours and the value downloaded on to the Internet.

A "free energy eco-aware" classroom was also established where all the energy to run it (including heating and lighting) was to be obtained from the wind and photovoltaic power. The classroom seats twenty students in a laboratory-style arrangement. Children from neighbouring schools are invited to watch videos and demonstrations. They can also gain hands-on experience in investigations about renewable energy and in the construction of small wind turbines of their own.

WATT'S AVAILABLE?

On a sunny summer day in the UK, the power reaching the earth's surface from the sun is about 1kW (one thousand watts) per square metre. On a cloudy day, it is likely to be about one-tenth of this figure. Even with a conversion efficiency of only five to ten per cent, solar cells could provide between 50W and 100W per square metre peak.

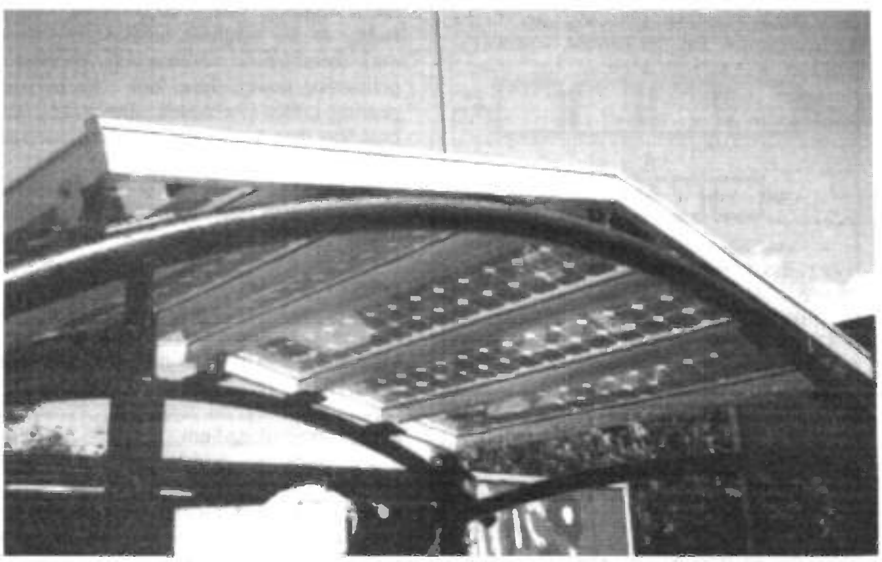
Note that, as a power source for a satellite, solar panels provide a much higher output because the sun's energy reaches them direct rather than through the atmosphere, which absorbs much of the energy.

From a purely "electronics" point of view, that fact that solar cells produce direct (rather than alternating) current seems attractive. However, since much consumer equipment is designed to operate from the mains, an inverter is usually needed to convert the output to 230V a.c. This also makes it easy to integrate the system with the mains so that it can "fill in" at times of low light or high demand.

NO PREMIUM

At the time of writing, a photovoltaic system (after inversion to provide a.c. power) cannot, with advantage, be grid connected as may be a wind turbine. The main reason is that energy cannot be sold on to the grid under the Government's non-fossil fuel obligation (NFFO).

By this scheme, the National Grid buys electricity generated by most renewable means and pays a premium price for it (a few pence more than conventionally-gener-



Crystalline silicon solar panels used at the Cardinal Hinsley school.

ated electricity). The difference is funded by the Government.

The aim is to give encouragement to near-market small-scale generators by, for example, wind, hydroelectric systems and waste-burning. "Near-market" means that the cost of production per kilowatt-hour must approach that generated by conventional means (because, at present, conventionally-generated electricity is still cheap). Without assistance, there might be little hope of these methods developing to the point where they could compete economically in the short to medium term.

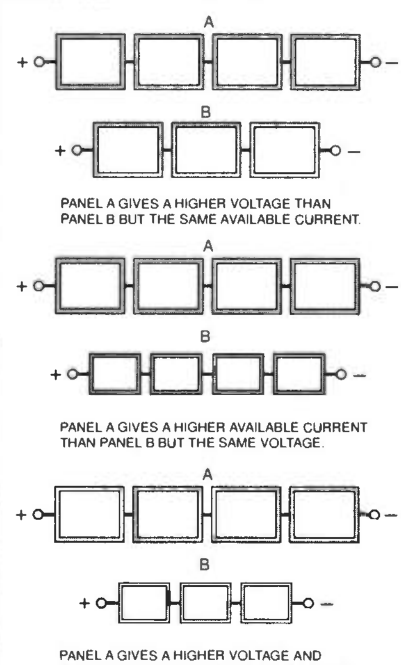
By its nature, the NFFO is aimed at generators having a worthwhile surplus over and above their own requirements (say, 1MW or more) to make the process of metering and sale worthwhile. Unfortunately, photovoltaic power at present costs some five to ten times the retail price of conventionally-generated electricity and (according to Government sources) it could be a decade or more before the prices converge.

It is therefore thought that to buy electricity under the NFFO would not achieve its purpose because the difference in price is too wide. Also, at present, photovoltaic systems are either small-scale projects or used to augment electricity generated by conventional means at a particular site such as a factory or office. There is usually no surplus.

It is interesting to note that the Government is currently reviewing its policy on photovoltaics and alternative energy in general.

GROWN AND SLICED

The Scolar project at the Cardinal Hinsley school uses crystalline silicon cells. However, it is thought that many projects will use thin-film amorphous silicon panels of the type manufactured by Intersolar. Crystalline cells consist of individual wafers of silicon which are grown, sliced and connected together to make a panel.



Different power and voltage configurations with solar cells.

Until relatively recently, this was the preferred method being largely funded by the space industry in the '60s. However, although efficient, the technology is comparatively expensive. Thin-film amorphous silicon has the advantage of being produced by a fully-automated process. This means that the technology is much cheaper per watt of power generated.

Miniature panels of this type are to be seen as the power source in "solar" calculators. They are also used to provide garden and outbuilding lighting where a small lead-acid or nickel-cadmium battery is charged during the day ready for use at night.

PROCESS TECHNIQUE

In the thin-film process, the material is vaporised and allowed to fall on glass where it forms a solid layer 0·3 microns thick. Lasers are then used to define the size of each cell. Since the individual units are produced and connected automatically, each panel has only two connecting leads. The panels are laminated between toughened glass and a rigid substrate which weatherproofs them and makes them robust enough to be handled without breakage.

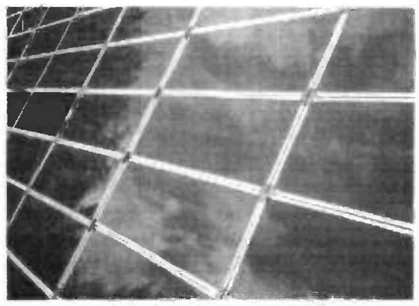
The maximum current output is proportional to the area of each cell and the amount of light falling on all of them. The voltage is proportional to the number of cells connected in series (see Fig.2). Each cell provides an open circuit voltage of about 900mV (0·9V) but, in practice when on load, it gives some 600mV. This remains substantially constant down to low light levels. Practical panels, such as those manufactured by Intersolar, are often designed to provide a nominal 12V, 24V or 48V on-load output.

The key to gaining a useful amount of energy is to use a large total area of panels. To give an idea of the practical output, a one square metre thin-film amorphous panel sited in the UK will give a peak output (that is, in full direct sunshine) of some 42 watts (say 12V at 3·5A). Some power is generated in weak light but, of course, there is virtually no output at night.

For 1kW peak output, an area of about $20m^2$ is therefore needed. Very large panels can be fabricated from smaller standard-sized units and used as the external cladding for a building. Large south-facing (north-facing in the southern hemisphere) arrays may therefore be constructed. As well as generating power, these look attractive, appearing rather like tinted glass. They also cost less than traditional cladding materials such as marble and granite.

As an example, the facade of the Building Research Centre in Watford, consists of a nominal $50m^2$ of thin-film photovoltaic panels (35 panels each 1350mm × 930mm) generating some 2·5kW peak which is the lighting load for a new energy efficient office on site. The expected annual yield is about 1500MWh. Other projects include the photovoltaic panels on a roof at the Ford factory in Bridgend and at the Newcastle United football stadium.

By contrast with these large-scale projects, the Scolar system at the Cardinal Hinsley School is much smaller. It provides only 600 watts peak with an expected annual yield of 450kWh. Even so, the output is sufficient to operate a few



An array of thin-film silicon solar panels. Thin-film silicon is one of the design options for Scolar projects.

computers (a typical PC complete with monitor requires some 100W to 200W).

RAISING AWARENESS

The school-based systems are designed to raise awareness of the future possibilities of photovoltaic power and to be a teaching aid. They are not intended to generate large-scale power and those participating must not see the scheme as a cost-cutting exercise.

Unfortunately, it appears that some head teachers are mis-informed (or over-optimistic!) and have inflated ideas of the capability and little knowledge of the philosophy behind the schemes. One report in a regional newspaper seen by the author stated that there would be sufficient power to provide heating and lighting for a block of twelve classrooms! Maybe this head looked at his capital outlay and calculated how much conventionally-generated electricity could have been bought for that price!

Renewable means of generating electricity have come of age. How much photovoltaics will ultimately contribute to that generated by the wind, waves, tides, geothermal and waste-burning will depend on the rate at which the price of conventionally-generated electricity rises (due to reduced availability of fuel and any "carbon tax" which might be imposed in the future) and how much that generated by renewable means falls (as the technology develops and more people use it beneficially).

PARTICIPATION CRITERIA

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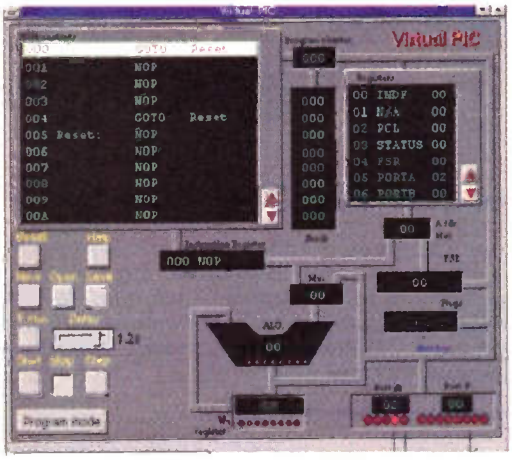

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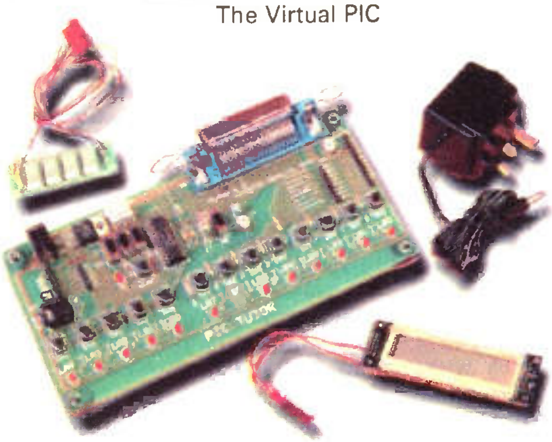

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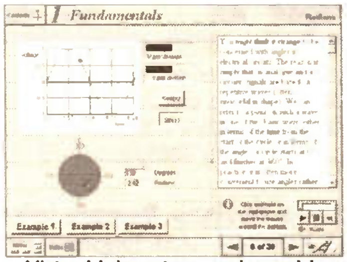

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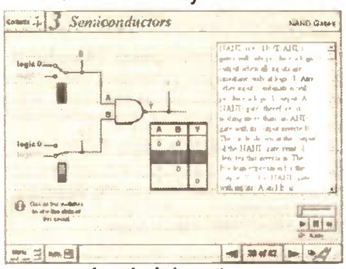

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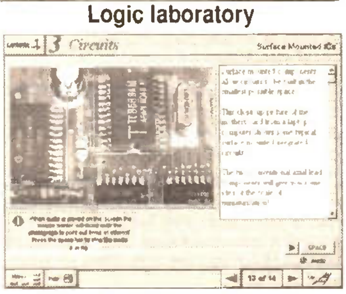

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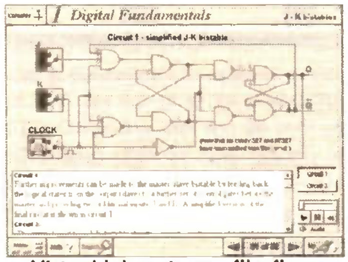

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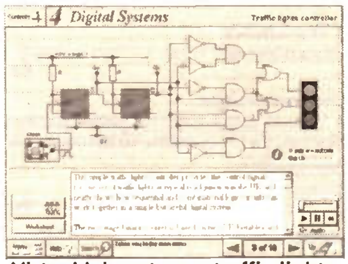

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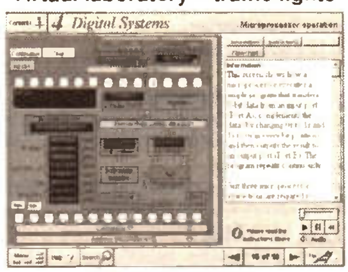

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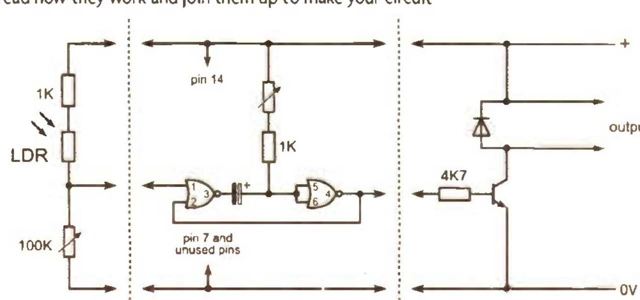

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A Web Browser is required for Modular Circuit Design – one is provided on the *EPE CD-ROM No.1* (see opposite) but most modern computers are supplied with one.

Listing 1

```
INPORT1:    .EQU  $F011        #Assign a label to input port $F011
OUTPORT0:   .EQU  $F030        #Assign a label to output port $F030

            .ORG  $4000        #Set start address to $4000
LOOP:        LDA [INPORT1]     #Load accumulator from I/P port 1
             STA [OUTPORT0]    #Store accumulator to O/P port 0
             JMP [LOOP]        #Jump to LOOP and do it all again
            .END
```

l.e.d. turns on again. (Verify that all of the buttons work by pressing and releasing them in turn.)

Initially, this may seem to be counter-intuitive, because we typically expect that pressing a switch will cause a light to turn on. But our input board is behaving exactly as it was designed, because its pull-up resistors hold the inputs at logic 1, and pressing a switch connects that input to a logic 0.

We could have wired our input board the opposite way around had we wished – but we didn't! Why not? Well one very good reason was that wiring the board the way we did allowed us to introduce a very important point, which is that logic 0s and 1s mean whatever we want them to mean at any particular time.

Before we proceed, reset your PhizzyB and dismiss the PBLink utility (as we noted in Part 3, whilst the PBLink utility is active it will slow your PC, because it's constantly bouncing packets of information back and forth to your PhizzyB).

If you don't have a real PhizzyB, you can replicate this experiment on your simulator. Use the **Memory –> Load RAM** command to load **ccexp1.ram** into the simulator's memory and then set this program running.

Enter a value of 11111111 into the binary field on the generic input board at address $F011 (the binary field is the one indicated by a percent "%" character). Don't forget to click that board's Set button to present this value to the input port, at which time all of the l.e.d.s on the bargraph display will light up.

Now enter the following values to represent the effects of pressing the switches in the real world:

Value	Switch
11111110	0
11111101	1
11111011	2
11110111	3
11101111	4
11011111	5
10111111	6
01111111	7
11111111	None

When you've finished, reset the simulator, and proceed to the second experiment.

EXPERIMENT 2

Inverting the inputs

As we just discussed, we typically expect that pressing a switch will cause a light to turn on rather than turn off. However, one of the great things about computers is that we can use software (programs) to modify the way things work in hardware (the physical bits and pieces in the real world). Let's examine an example of this.

Use the assembler to load your **ccexp1.asm** program and save it out as **ccexp2.asm**. Now add an **XOR %11111111** instruction between the existing **LDA** (load accumulator) and the **STA** (store accumulator) instructions as follows:

LDA [INPORT1]
XOR %11111111
STA [OUTPORT0]

From earlier articles in this series we know that XORing a bit with a logic 1 has the same effect as inverting that bit. In this case we're XORing the contents of our 8-bit accumulator with eight 1s, which will invert each bit in the accumulator. (We could have achieved exactly the same effect using XOR $FF in hexadecimal or XOR 255 in decimal.)

So this new program will loop around loading a value from the input port into the accumulator, inverting all of the bits in the accumulator, and writing this new value to the output port.

Assemble this program to generate the corresponding **ccexp2.ram** file, then use your PBLink utility to download this program to the PhizzyB and set the little rascal running. As you see, the l.e.d.s on the bargraph display now go out, and it's only when you press one of the switches that the related l.e.d. turns on. (Verify that all of the buttons work by pressing and releasing them in turn.)

When you've finished playing, reset your **PhizzyB** and dismiss the **PBLink** utility. Note that you can test this new program on the PhizzyB Simulator using exactly the same input values that you used before.

EXPERIMENT 3

CMPA Instruction

One instruction we haven't looked at before is **CMPA** (compare accumulator), which allows us to compare the numerical value of the current contents of the accumulator to some other numerical value. In order to investigate this instruction, use your assembler to save the **ccexp2.asm** program as **ccexp3.asm**, and then modify this program as shown in Listing 2.

Don't Panic! This isn't as complicated as it looks. We commence with an **LDA** to load a value from the switches into the accumulator, and we follow this with an **XOR** to invert the contents of the accumulator. Now we use a **JZ** (jump if zero) to test whether the accumulator contains zero – if it does we jump back to the **LOOP** label. Thus, this portion of the program simply loops around waiting for us to press one of the switches.

As soon as we do press a switch, the **JZ** instruction fails and we "drop through" to the **CMPA** instruction. One thing you need to know is that the **CMPA** instruction assumes that both values being compared are unsigned binary numbers. (The concepts of signed and unsigned binary numbers were discussed in last month's PhizzyB Bonus Article.)

The way the **CMPA** instruction works is that it compares the current value in the accumulator with another value that we specify. If the value in the accumulator is the bigger, the Carry flag is set to 1 and the Zero flag is cleared to 0. If the two values are equal, the Zero flag is set to 1 and the Carry flag is cleared to 0. And if the value in the accumulator is the smaller, then both the Carry and Zero flags are cleared to zero.

In this particular program, we're comparing the value in the accumulator (which reflects the switch we just pressed) with a binary value of 00001000. So if the value in the accumulator is the bigger, this means that we must have pressed one of the switches numbered 4, 5, 6 or 7.

Alternatively, if the value in the accumulator is not the bigger, then we must have pressed one of switches numbered 0, 1, 2 or 3. (With regard to the previous sentence, note that we specifically didn't say "... if the value in the accumulator is the smaller...". This is because if we press switch 3 the two values will be equal – you have to be very precise when you're talking about the actions of programs.)

Thus, following the **CMPA**, a **JC** (jump if carry) instruction is used to decide what we do. If the carry flag is set, we know that the value in the accumulator was the bigger, and we jump to label **IS7TO4**

Listing 2

```
INPORT1:    .EQU  $F011        #Assign a label to input port $F011
OUTPORT0:   .EQU  $F030        #Assign a label to output port $F030

            .ORG  $4000        #Set start address to $4000
LOOP:        LDA  [INPORT1]    #Load accumulator from I/P port 1
             XOR  %11111111    #Invert contents of accumulator
             JZ   [LOOP]       #If ACC = 0 jump back to LOOP

             CMPA %00001000    #Otherwise compare accumulator
             JC   [IS7TO4]]    #Jump to IS7TO4
IS3TO0:      LDA  %00001111    #Load ACC with 00001111
             STA  [OUTPORT0]   #Store accumulator to O/P port 0
             JMP  [LOOP]       #Jump to LOOP and do it all again

IS7TO4:      LDA  %11110000    #Load ACC with 11110000
             STA  [OUTPORT0]   #Store accumulator to O/P port 0
             JMP  [LOOP]       #Jump to LOOP and do it all again
            .END
```

(meaning "this switch is one of those numbered 7 to 4").

At this point we load the accumulator with a binary value of 11110000, store it to the output port, and jump back to **LOOP** to wait for another switch to be pressed. Note that the 11110000 value we load into the accumulator has no particular significance – it's just something we'll recognize when it appears on the l.e.d.s.

Of course, if the value in the accumulator isn't the bigger when we perform the **CMPA**, then the Carry flag will be cleared to zero, the **JC** instruction will fail, and the program will "drop through" to the **IS3TO0** label (meaning "this switch is one of those numbered 3 to 0") – be careful not to get the letter "O" of "TO" confused with the number "0" at the end of this label.

In this case we load the accumulator with a binary value of 00001111, store it to the output port, and jump back to **LOOP** to wait for another switch to be pressed (again, this 00001111 value has no particular significance).

So let's assemble this program to generate the corresponding **ccexp3.ram** file, use the PBLink utility to download this file to your PhizzyB, and run the program. Try pressing one of the 0 to 3 switches and observe the right-most four l.e.d.s light up, then try pressing one of the 4 to 7 switches and note the left-most four l.e.d.s light up.

Continue to experiment with this program until your heart stops pounding, then reset the PhizzyB, dismiss the PBLink utility, and proceed to the next section. (You can also replicate this experiment on your simulator if you wish – remember to use the binary patterns 11111110 through 01111111 to represent the action of pressing switches 0 through 7, respectively.)

POLLING PROBLEMS

The previous experiment relied on the program looping around reading from the input port and waiting for something to happen. This technique is referred to as *polling*, and it tends to occupy a lot of the CPU's time and resources. Using the polling technique was perfectly acceptable in the case of Experiment 3, because we weren't using the CPU to do anything else anyway, but what if we did want to use the CPU for another purpose?

As an example, here's an experiment you can perform for yourself. Take the simple l.e.d. output board you created in Part 2 and plug it into the external output port at address $F031. Now write a program that performs a simple binary count and displays it on this output board. In fact you can use the **test1.asm** file that was supplied with your PhizzyB Simulator as a basis for this program, but remember to save it out under another name.

Also, you'll have to change the address of the output port to $F031 and the label associated with this port to **OUTPORT1** (remember to change this label wherever it is used throughout the program).

You'll also note that this program contains a simple subroutine called **WAIT**, which is used to slow the count sequence down so that you can see what's happening (subroutines were introduced in Part 3).

Once you have this program running, modify it such that every time it performs a count, it also checks our new polling switch device connected to input port $F011. If none of the switches are pressed, then make the program return to performing its binary count. But if one of the switches is pressed, then make the program perform the same comparison and display the same values to the output port at $F030 as we did in Experiment 3 above (and then let it return to performing its binary count).

As you'll discover, one big problem we find when we try to combine this polling technique with the binary count is that we're trying to do two very distinct things, but that the code for both these things becomes somewhat intermeshed. This makes it difficult to write the program, and also to understand it and modify it later.

Even worse, suppose that you press and release a switch whilst the program is executing the **WAIT** subroutine. In this case your program might not even notice that you'd pressed the switch at all! All of these points mean that the polling technique has to be used with discretion. One alternative is to use a technique caller *interrupt-driven I/O* as discussed presently.

Note that if you find creating the program discussed in this section to be a little too taxing and/or time-consuming, you'll be happy to know that we've created one for you to peruse and ponder, **ccextra1.asm**. It's on the PhizzyB Bonus disk we'll discuss later.

IRQ AND IACK

As discussed in the previous section, there are a number of problems associated with a polling strategy. What we would like to do is to create a program that can concentrate on the task for which it was intended (performing a binary count in this case), without being obliged to constantly keep on checking to see if we've pressed a switch on our input device.

However, when we do press a switch, we want the CPU to respond as quickly as it can by performing the comparison, displaying the result on output port $F030, and returning to its binary count.

To facilitate this sort of thing, the CPU has a special input called the **IRQ** (interrupt request) and a special output called the **IACK** (interrupt acknowledge), as shown in Fig.2.

For a number of reasons (mostly historical), control signals are usually active-low (that is, their active state is a logic 0), and the **IRQ** is no exception. What this means is that we usually maintain the **IRQ** signal at a logic 1, so pulling it to a logic 0 tells the CPU that something interesting is happening (this request is stored inside the CPU in a register called the *interrupt latch*).

Similarly, when the CPU starts to respond to an interrupt (as discussed in a moment), it places its **IACK** output into an active-low state to tell devices in the outside world that it's doing something. (Note that we won't be using the **IACK** output at this time.)

INTERRUPT MASK

Thus far we've introduced four status flags: Z (Zero), C (Carry), O (Overflow), and N (Negative). In fact there is a fifth flag called I (Interrupt Mask). The interrupt mask is somewhat different to the other status flags, in that it is not set as the result of a logical or arithmetic instruction or condition. Instead, the interrupt mask is used to tell the CPU whether of not it is allowed to respond to interrupts.

Following a power-up or reset condition, the interrupt mask flag is initialized to its inactive state (a logic 0 in the case of the PhizzyB). This means that, by default, the PhizzyB will NOT respond to interrupts. Thus, in order for the PhizzyB to accept an interrupt request, we first have to use a **SETIM** (set interrupt mask) instruction, which loads the I flag with a logic 1.

The way this works is that the CPU checks the state of the interrupt mask every time it completes an instruction (Fig.3). If the mask is inactive the CPU proceeds to the next instruction, otherwise it checks the interrupt latch to see if an interrupt has been requested. If no interrupt was requested the CPU again proceeds to the next instruction, otherwise it jumps to a special subroutine called an *interrupt service* routine (discussed a little later).

INTERRUPT BOARD

In order to understand how all of this works, let's consider the second input board described in this month's construction article, the Interrupt Switch board. This board also contains eight switches that are wired in much the same way as the first board. However, in this case the outputs from the switches are used to drive the inputs of an 8-bit register.

The outputs from the switches are also used to drive an 8-input NAND gate. We know that the outputs from the switches are

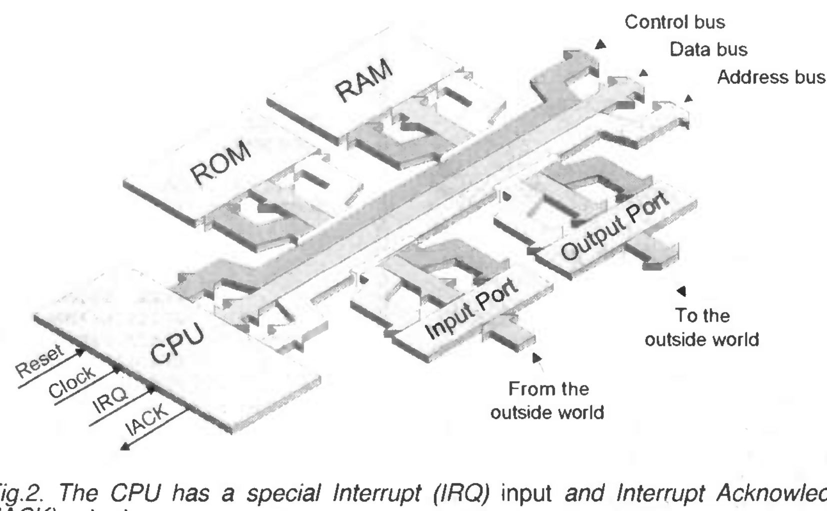


Fig.2. The CPU has a special Interrupt (IRQ) input and Interrupt Acknowledge (IACK) output.

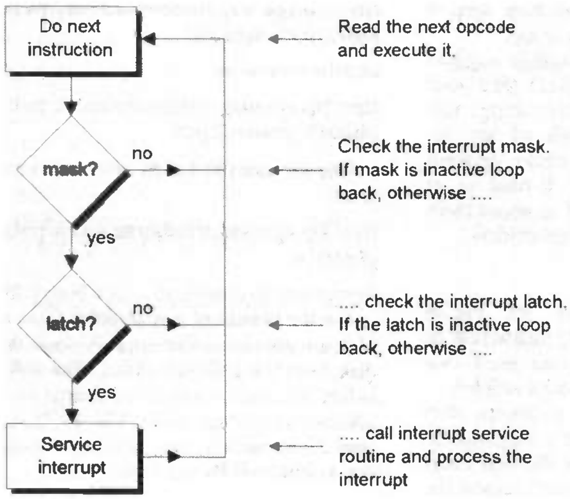


Fig.3. Interrupts handling flow-chart.

usually at logic 1 (due to the pull-up resistors), which means that the output from the NAND gate is usually at logic 0. When any of the switches are pressed, the output from the NAND gate transitions from a logic 0 to a logic 1. This "rising edge" is used to load the 8-bit register with the current values on the switches.

Furthermore, the output from the NAND gate is inverted by another chip to generate an IRQ signal. This means that when a switch is pressed, the resulting logic 1 coming out of the NAND is converted into a logic 0 on the IRQ signal (where this logic 0 is the IRQ's active state).

Let's proceed to an experiment that will let us sink our teeth into all of this ...

EXPERIMENT 4

Interrupt-driven I/O

Before we start, power down the PhizzyB, unplug the polled switch module from the input port at address $F011, and replace it with the interrupt-driven switch board. Also, take the l.e.d. output module you created in Part 2, and plug it in to the output port at address $F031. Now use the assembler to create the program shown in Listing 3 and save this as **ccexp4a.asm**.

The main body of this program loops around writing out a simple pattern to the l.e.d. module. Every time the program goes around the loop it calls a subroutine called **WAIT** that adds an element of delay so that we can see what's happening.

Assemble this program to generate the corresponding **ccexp4a.ram** file. Power-up your PhizzyB, download this program into it, run it to make sure that it works as expected, then reset PhizzyB.

Now save your program as **ccexp4b.asm**, then add the interrupt service routine shown in Listing 4. Add it just after the end of the **WAIT** subroutine and just before the **.END** directive.

This interrupt service routine is very similar to the program from Experiment 3. The first thing we do when we enter the routine is to push the current value in the accumulator onto the stack so that we can preserve it for later. Next we load the accumulator with the value from the switch device and perform the **CMPA** instruction.

Once we've finished comparing the accumulator and storing one or other of our patterns to the output port at $F030, we use a **POPA** (discussed in Part 3) to reload the accumulator's original value from the stack, followed by an **RTI** (return from interrupt).

The **RTI** acts like the **RTS** (return from subroutine) instruction we considered in Part 3, in that it returns the CPU to the point in the program it was at when the interrupt was originally called. (In fact the **RTI** is a little different to the **RTS**, but we won't go into that here – see also the Further Reading section at the end of this article).

But how is this interrupt service routine called? Well, we need to add two more instructions at the beginning of the program following the **BLDSP**, so that it becomes:

.ORG $4000
BLDSP $4FFF
BLDIV COMPARE
SETIM

The **BLDIV** (big load interrupt vector) instruction is used to load a special 16-bit addressing register – the Interrupt Vector – inside the CPU with the address of the interrupt service routine. In this case, we've used the **BLDIV COMPARE** statement, because we know that the assembler will automatically substitute the label COMPARE with its associated address (pretty cunning eh?).

Following the **BLDIV**, we use a **SETIM** instruction to set the interrupt mask to its active state, which will allow the CPU to see future interrupt requests.

What this means is that when we run this program, the CPU will happily concentrate on the main body of the program, which displays our simple rotating bit pattern on the display module connected to output port $F031. However, whenever we press one of the switches on the interrupt-driven switch board, that board will activate the **IRQ** signal, and the CPU will jump to the interrupt service routine.

Thus we see that there are a number of advantages of this interrupt-driven scheme over a polling approach. First, the main body of the program doesn't have to keep on checking the value on the input device. Second, the two functions are kept very separate and distinct, which makes understanding them and modifying them much easier. Third, even if we press a

Listing 3

```
INPORT1:     .EQU    $F011        #Assign a label to input port $F011
OUTPORT0:    .EQU    $F030        #Assign a label to output port $F030
OUTPORT1:    .EQU    $F031        #Assign a label to output port $F031

             .ORG    $4000        #Set start address to $4000
             BLDSP $4FFF          #Load the stack pointer with $4FFF

### Start of main body of program
             LDA     $03          #Load the accumulator with 3
LOOPA:       STA    [OUTPORT1]    #Store ACC to O/P port 1
             ROLC                 #Rotate ACC one bit left
             JSR    [WAIT]        #Jump to the WAIT subroutine
             JMP    [LOOPA]
### End of main body of program

### Start of Delay Subroutine
WAIT:        PUSHA                #Store current ACC onto the stack
             LDA     $0F          #Load ACC with a delay value
LOOPW:       DECA                 #Decrement the ACC
             JNZ    [LOOPW]       #If ACC != 0 jump back to LOOPW
             POPA                 # else get original ACC from stack
             RTS
### END of Delay Subroutine

             .END
```

Listing 4

```
### Start of interrupt service routine
COMPARE:      PUSHA               #Store current ACC onto the stack
              LDA  [INPORT1]      #Load ACC with value from switches
              XOR   %11111111     #Invert the value in the ACC
              CMPA  %00001000     #Compare ACC to %00001000
              JC   [IS7TO4]       #Jump if carry to IS7TO4
IS3TO0:       LDA   %00001111     #Load ACC with 00001111
              STA  [OUTPORT0]     #Store accumulator to O/P port 0
              POPA                #Get original ACC from stack
              RTI                 #Return from interrupt routine
IS7TO4:       LDA   %11110000     #Load ACC with 11110000
              STA  [OUTPORT0]     #Store accumulator to O/P port 0
              POPA                #Get original ACC from stack
              RTI                 #Return from interrupt routine
### End of interrupt service routine
```

switch while the program is in the **WAIT** subroutine the interrupt will still occur, which means that we won't miss a switch-press.

So let's assemble this program to generate the corresponding **ccexp4b.ram** file, download it to the PhizzyB, and set it running. Observe the program driving the display at $F031 as before. Now try clicking one of the 0 to 3 switches followed by one of the 4 to 7 switches and observe that the $F030 display updates as we expect, and the $F031 display then continues with no perceivable interruption.

ANOTHER BONUS ARTICLE

What? Another bonus article? The problem is that there's just so much good stuff to tell you, yet so little time (and space) in which to tell you it all. So what we've done is to write a second bonus article that describes how to use the PhizzyB to time something and to display the result on the simple liquid crystal display (l.c.d.) output device we described in Part 3.

Quite apart from anything else, this new bonus article will also introduce you to the 16-bit addition, subtraction, multiplication, and division subroutines we supplied with your PhizzyB Simulator (you can use the assembler to peruse the **add16.asm**, **sub16.asm**, and suchlike files that you'll find in your data directory).

For your delectation and delight, this second bonus article is available as an Adobe Acrobat PDF file on the *EPE* web site and on disk. See the Bonus Resources section at the end for details on getting this article.

ADDITIONAL EXPERIMENTS

You will have noted that both of the switch input boards discussed this month have an additional 16-pin header, comprising eight signal pins and eight ground pins. This allows you to bypass the switches on the board, and to connect external switches. For example, in the fullness of time we will be attaching microswitches around the periphery of our forthcoming PhizzyBot.

We will then be connecting these switches to one or other of our input switch boards via these 16-pin headers, and using them to detect when the PhizzyBot bumps into something.

But you shouldn't limit yourself to our experiments, because there are a whole lot of things you can do yourself. For example, you might decide to create a model of a road junction with traffic lights. In this case you could easily use the PhizzyB to control the model traffic lights.

Furthermore, you could mount small magnets to the underside of your model cars, and also attach magnetically operated reed-switches under the entrances to the junction. These reed-switches could then be connected to the 16-pin headers on our input switch boards.

As another example, you could create a ramp with one microswitch at the top and another at the bottom, such that rolling a ball down the ramp will trigger one switch and then the other. Coupling this with the l.c.d. module described in our second bonus article would allow you to implement a simple event timer that times how long it takes the ball to roll down the slope.

Obviously these are just simple suggestions. If these experiments don't take your fancy, there are numerous other things you can do. In fact, if you think of any interesting experiments you could perform using these devices, please E-mail us at **info@maxmon.com** and tell us about them and we'll share them with other readers.

SHIFTY BUGS

In PhizzyB Part 3, Jan '99, Fig.2b showed the SHR (shift right) instruction as copying the **MS** bit back into itself (we show the same thing in the bonus article).

This diagram reflects an "arithmetic shift right" and this is the way it's supposed to work (and it *is* the way that the real PhizzyB works), but for some weird reason the simulator actually performs a "*logical* shift right" which means that it shifts a zero into the **MS** bit.

The simplest fix is to force the real PhizzyB to act like the simulator. This can be achieved by following a **SHR** instruction with an **AND** as follows:

```
<instruction>
<instruction>
     :
SHR
AND %01111111
     :
<instruction>
<instruction>
```

This forces the **MS** bit to be a logic 0 (which is what the simulator does incorrectly anyway).

Unfortunately, forcing the simulator to perform an *arithmetic* shift like it's supposed to (and like the real PhizzyB does) is much more painful. There are several ways to achieve this – one of the simplest to understand is to create a **SHRA** (shift right arithmetic) subroutine as follows:

```
# Main body of program
<instruction>
<instruction>
     :
JSR [SHRA]     # Instead of a SHR
               jump to SHRA
               subroutine
     :
<instruction>
<instruction>
```

In the subroutine we use a **JN** (Jump if negative) instruction to decide whether or not to set the **MS** bit to 1 as follows:

```
### Start of subroutine SHRA
SHRA:  JN [SHR1]   # If MS bit is 1
                   jump to SHR1
SHR0:  SHR         # Otherwise just
                   shift right (logical)
       RTS         # Return from
                   subroutine
SHR1:  SHR         # Shift right
                   (logical)
       OR %10000000   # Force MS
                      Bit to 1
       RTS         # Return from
                   subroutine.
### End of subroutine
```

BONUS RESOURCES

The PhizzyB bonus articles can be downloaded via the Internet from the *EPE* FTP site. The first is at:

ftp://ftp.epemag.wimborne.co.uk/pub/phizzyb/ebonus.pdf

and the second at:

ftp://ftp.epemag.wimborne.co.uk/pub/phizzyb/ebonus2.pdf

The file **ccextra1.asm** referred to earlier is at:

ftp://ftp.epemag.wimborne.co.uk/pub/phizzyb/.

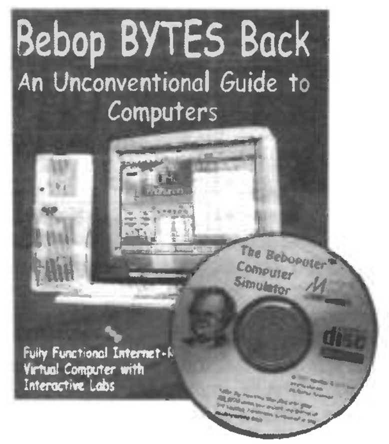
Remember to download it as a binary file.

For the benefit of non-Internet users these files are also available on a 3·5-inch floppy disk from the Editorial office. The software is free but there is a nominal charge to cover admin and postage costs: UK £2.75, Overseas £3.35 surface mail, £4.35 airmail. Order as **PhizzyB Bonus Disk**.

FURTHER READING

The basic concept of interrupts is relatively simple, but as usual there's a lot more to this subject than first meets the eye. For example, we haven't discussed what would happen if you had two input devices, both of which required the ability to trigger an interrupt. Similarly, we haven't discussed what happens if a new interrupt is requested whilst a previous interrupt is being serviced (which leads into the discussion of nested interrupts).

The bottom line is that there's much more to this topic than we can cover here. But turn that frown upside down into a smile, because all is not yet lost! If you want to know more about all of this, then one place to start is our book *Bebop BYTES Back (An Unconventional Guide to Computers)*, which is available from the *EPE Direct Book Service.*



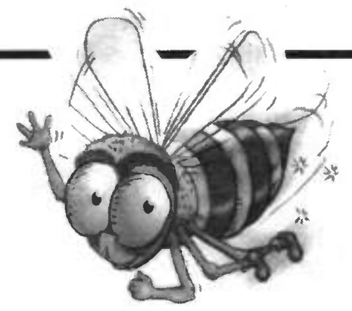
NEXT MONTH

Next month the excitement really starts, because we'll be describing how to build the chassis for our PhizzyBot, and Alan will be describing how to construct a motor controller output board so that the PhizzyBot can go mobile.

Meanwhile we'll be using the switch devices from this month as collision detectors to allow the PhizzyBot to recognize when it's bumped into something.

BEE-LINE

Max and Alvin would love to hear from you via their web site **http://www.maxmon.com.** So, too, would we for possible inclusion on our Readout pages!



PhizzyB COMPUTERS

Construction – 8-bit Switch and Latch

Alan Winstanley

Polling and interrupts set us on course for our super wheelie – the fabulous PhizzyBot!

THIS month's assignment is the construction of two 8-switch input devices for connection to the PhizzyB input port. The first project is a straightforward home-made keypad which hooks directly to the PhizzyB board via the standard 20-way IDC lead used previously. The second project is more ambitious, as it demonstrates how the PhizzyB can handle Interrupts generated by an external system. It incorporates some simple logic circuitry.

For one of the demonstrations, you also need the simple l.e.d. output board, constructed in Part 2.

Both of the projects are expandable. The switch boards can be utilised later on to connect to a series of external switches, including microswitches or limit switches used in robotics or buggy applications – including the forthcoming PhizzyBot, a simple motorised chassis which obeys your every command. Well, most of them. Hence the switches provide a series of simple on-off control signals which can also be utilised in more advanced systems.

Although both circuits are fairly straightforward, assembly is somewhat trickier than the modules previously described, mainly because of the need to interconnect a fair number of parts on a PhizzyB I/O board. It must be said that the interwiring is therefore quite a lot more intricate and challenging, but we give practical advice to help ensure that both modules will function first time. We think it's important that PhizzyB owners gain not only the ability to program the wee beastie, but also to roll up their sleeves and tackle the hardware aspects with confidence. Read on!

SIMPLE 8-BIT SWITCH

The first module is a simple 8-bit switch input unit – see Fig.1a. This contains eight switches (S0 to S7) each having a pull-up resistor (R0 to R7) and a 10nF capacitor to help reduce "noise" and switch contact bounce.

All eight switches operate in the same way. For example, by closing S7, the signal IP7 will be shorted to 0V. When the switch is opened, the IP7 signal will be pulled high again by resistor R7, because if there is no current flowing through the resistor then there is no voltage drop across it. All eight input signals connect to the standard PhizzyB IDC connector as before.

This circuit should be assembled on one half of a 4-up PhizzyB I/O board (combined sections A and B). A new board should be slit down the middle, using a Dremel cutting disk or fine hacksaw blade along the row of holes provided as a guide for this purpose (as discussed in Part 2). Both halves of the complete board will be used to assemble this month's projects.

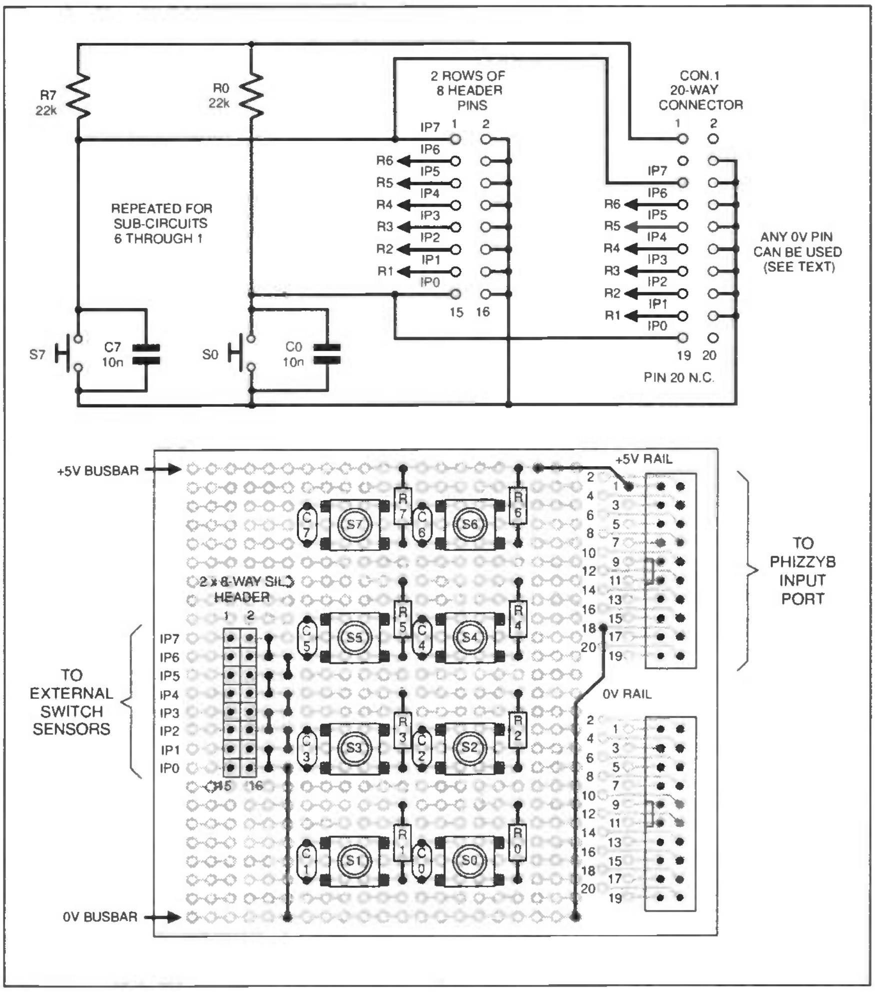


Fig.1. Circuit diagram and board layout for a simple 8-switch input "polling" module.

The recommended layout of components for the 8-bit switch module is shown in Fig.1b. It is very common, when prototyping a circuit, to interwire the components using a "point to point" technique which involves soldering the wire links on the underside of the board. This is perfectly adequate and is, in fact, the only way in which these circuits can be assembled on this board because the switches obscure the above-board holes, rendering them inaccessible.

In order to help with assembly, we've taken the unusual step of not only numbering the switches starting at S0 (instead of S1), but also the accompanying resistors and capacitors, starting at R0 and C0. Thus, all similarly numbered parts are grouped together.

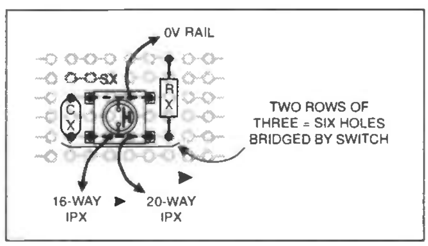
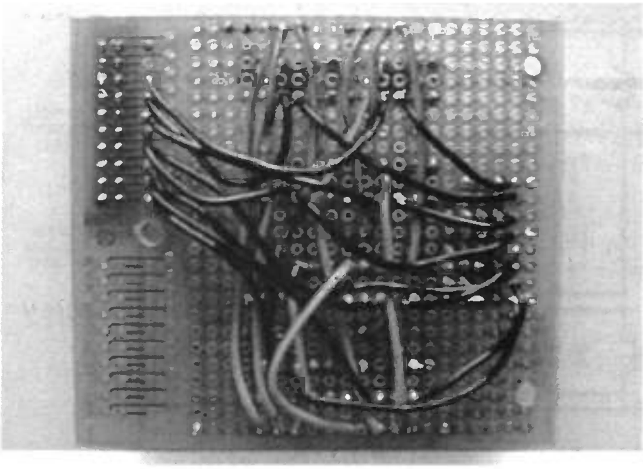


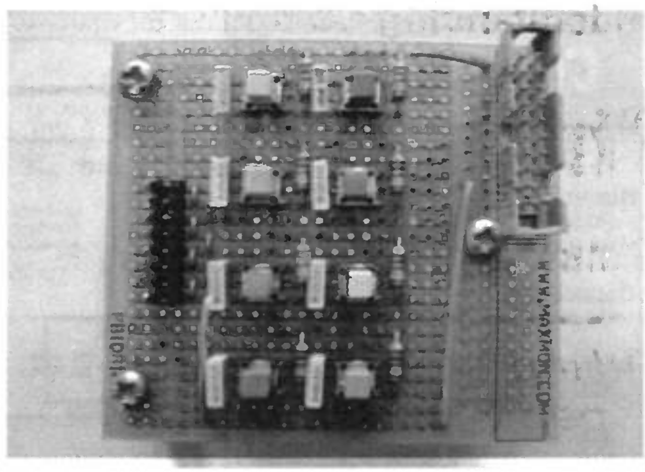
Fig.2. Switch wiring details.

ASSEMBLY

It is best to start assembly by locating the push-switches on the board. The specified types can be made to fit the board without any problems, by very slightly manipulating their pinouts. Each switch has four pins which are paired internally. This means



Under-side wiring for the 8-switch input "polling" module.



Top-side view of the 8-switch input "polling" module.

that the switch can actually be used to form a "bridge" which joins neighbouring copper strips together on the PhizzyB I/O board, see Fig.2.

Note that both busbars are used, the top one supplies +5V to the resistors, and the bottom busbar supplies 0V. Solder the resistors and capacitors into the board next to each switch as shown. Follow on with the two rows of 8-way pin headers (which can be used to hook external switches to the module), then solder the 20-way IDC box header (CON1) into place, observing the direction of the centre notch and pin 1.

With the parts in place, the interwiring should be completed on the underside (solder side) of the board. No wiring diagram is given, as all the relevant information is obtainable from the circuit diagram. Carrying out the wiring will prove straightforward provided that a methodical technique is used. Simply follow the circuit diagram and tick each wire on the drawing when you have soldered it into place.

Single core (solid core) hook-up wire should be used, and we strongly recommend purchasing a small reel of "wire-wrapping" silver-plated Kynar wire (size 1/0.25mm, 33s.w.g. or 30a.w.g.). Although it is very thin diameter, it has heat resistant insulation which won't melt during soldering. A fine diameter soldering bit is essential on the iron, and fine gauge solder will help. Fine gauge wire strippers will be needed as well.

Notice that the six in-line holes at the "top" of each switch, as shown in Fig.2, should be connected to 0V. Similarly, the six in-line holes at the "bottom" of the switch are used to carry the IP signals to the 20-way connector and 16-way header.

You will soon develop your own wiring technique, but remember that the secret is to be really methodical and don't lose your place! The author found it best to strip the insulation from the end of the wire, insert the bared end into the relevant hole and then apply 1mm or so of solder to fill the solder pad and make the connection. Then the wire was cut from the reel and the other end stripped and soldered.

A systematic technique evolved from this and the board was soon completed. Also remember to wire the +5V and 0V rails as per the drawing. To finish off with, a spray-on coating of p.c.b. lacquer on the solder side will protect the soldering from deterioration.

COMPONENTS

8-BIT SWITCH MODULE

Resistors
R0 to R7 22k (8 off)
All 0.25W 5% carbon film.

Capacitors
C0 to C7 10n polyester (8 off)

Miscellaneous
S0 to S7 push-to-make switch, p.c.b. mounting (8 off)
20-way IDC box header (see text); 8-way p.c.b. box header (2 off); half of PhizzyB I/O board (combined sections A and B); Kynar hook-up wire (see text); solder.

Approx. Cost Guidance Only £12

CHECK-IN

Hook the newly constructed switch input module to port $F011 on the PhizzyB. Then the following test program should be run:

```
# Start of program for Board 1
        .org $4000
loop:   lda [$F011]
        sta [$F030]
        jmp [loop]
        .end
# End of program for Board 1
```

Enter it via your keyboard, then assemble and save it as **board1test.asm**, after which load the resulting **.ram** file into the PhizzyB.

When you run this routine (press the Run button on the PhizzyB) all eight "internal" l.e.d.s on the PhizzyB board at port address $F030 will light up. Whenever you press (and hold) one of the switches on

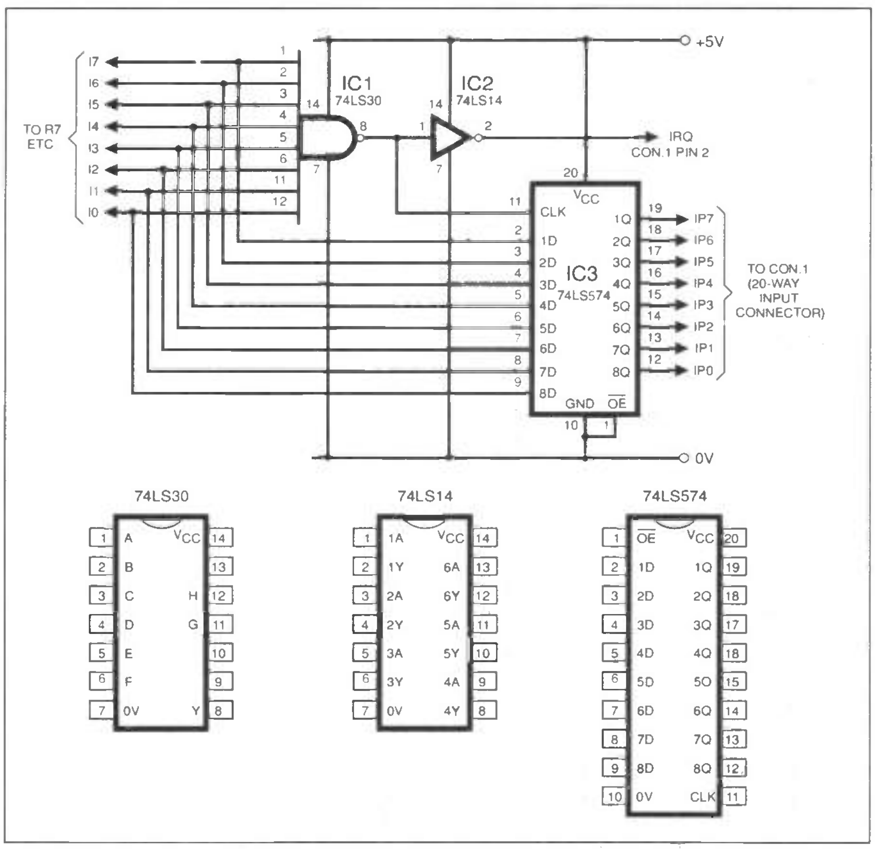


Fig.3(a). Basic circuit diagram of the 8-bit latch and (b) the pinouts of the associated i.c.s.

COMPONENTS

INTERRUPT MODULE

Resistors
R0 to R7 22k (8 off)
All 0.25W 5% carbon film.

Capacitors
C0 to C7 10n polyester (8 off)

Semiconductors
IC1 74LS30 8-input NAND gate
IC2 Schmitt inverter
IC3 74LS574 or 74HCT574 octal latch

Miscellaneous
S0 to S7 push-to-make switch, p.c.b. mounting (8 off)
20-way IDC box header (see text); 8-pin p.c.b. header (2 off); half of PhizzyB I/O board (combined sections A and B); 14-pin d.i.l. socket (2 off); 20-pin d.i.l. socket; Kynar hook-up wire (see text); solder.

Approx. Cost Guidance Only £15

your newly assembled switch module, that corresponding l.e.d. will go out. Release the switch to restore the l.e.d. Test all eight switches this way. There is every chance that the system will work first time. Give yourself a well-deserved pat on the back!

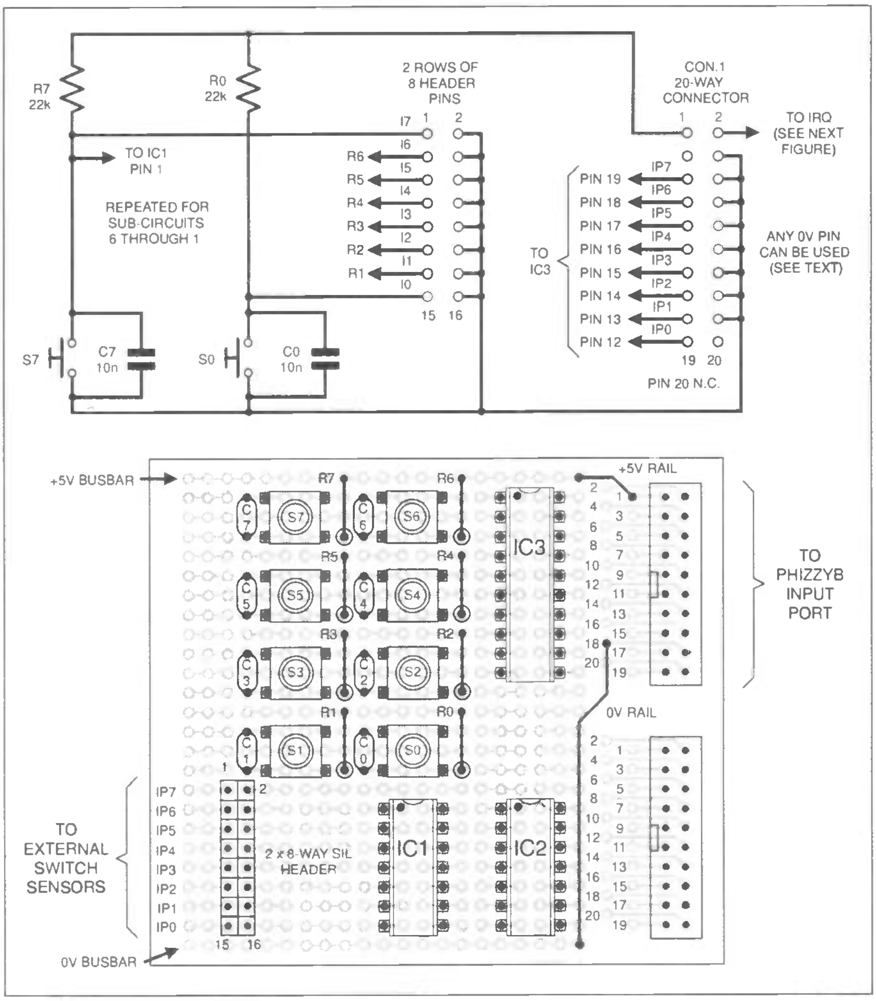


Fig.4. Switch circuit diagram and board layout for the 8-bit interrupt latch.

INTERRUPT BOARD

The second board is considerably more challenging, and we recommend that you allow at least two hours to work through the circuit methodically. The use of narrow-gauge wire-wrapping wire is necessary to accommodate the higher density of the interwiring.

The circuit diagram detailing the interconnection of logic chips used on this board is shown in Fig.3a, with the pinouts of the chips shown in Fig.3b. In Fig.4a, the logic of the switch interwiring to the chips is shown in a similar simplified fashion to that used in Fig.1.

The status of any of the switches S0 to S7 (are they on or off – high or low) is fed jointly to the 8-input NAND gate IC1, and to the 8-bit latch IC3.

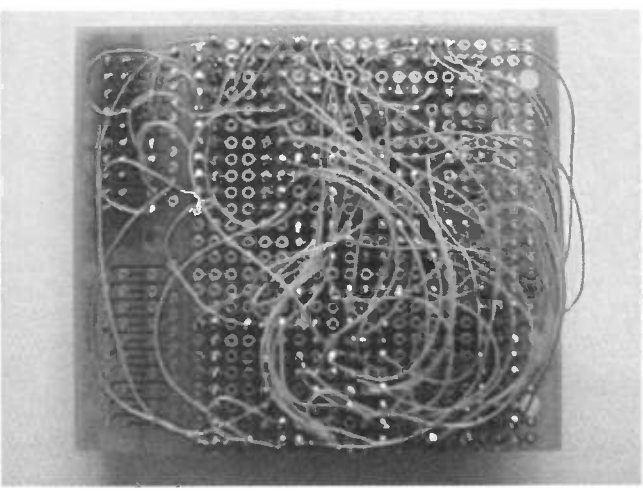
Normally, all the switch outputs are held high by their respective resistors (R0 to R7), and so the output of the NAND gate is low. If one or more of the switches is pressed, the NAND gate output goes high. IC2 inverts the output level from IC1, and the change in level can be used as an interrupt signal (IRQ) by other circuits, including PhizzyB itself.

The output from IC1 also controls the latch IC3. When the CLK pin 11 goes high the data on the other inputs (pins 2 to 9) is copied to the outputs (pins 19 to 12). When the CLK input goes low again, the data now within IC3 remains stored (latched) on the outputs until the next positive-going change on the CLK pin.

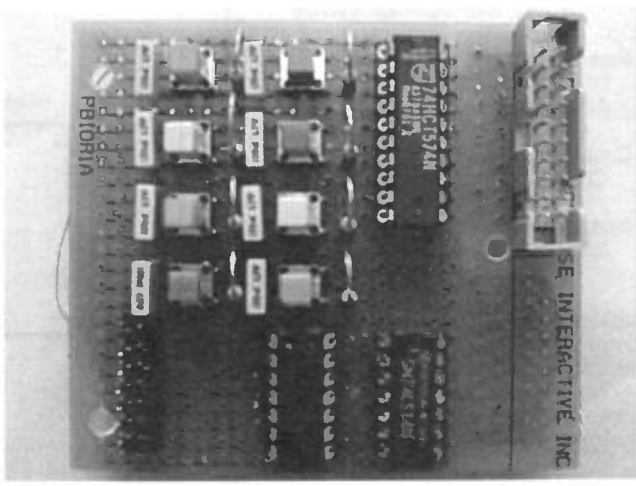
MORE ASSEMBLY

The layout of the components on the board is illustrated in Fig.4b. The assembly routine is the same as before, starting with the switches and surrounding discrete components, noting that this time the resistors should be mounted vertically (bend one wire around the shaft of a screwdriver). It is wise to use dual-in-line sockets to carry the three integrated circuits, which should be retained in their packaging until ready for insertion.

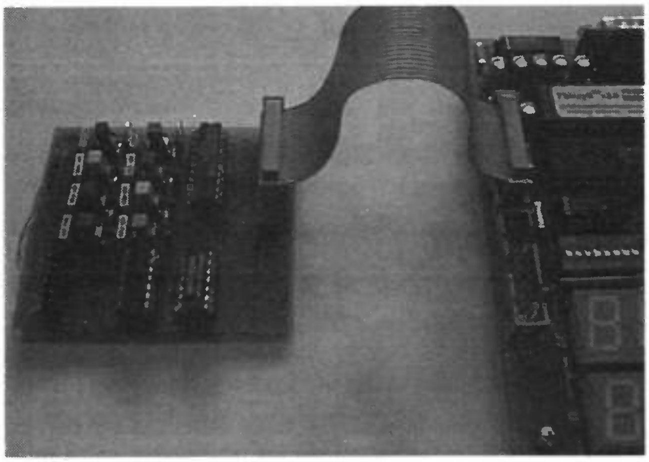
As with the previous board, provided that a completely methodical wiring approach is adopted, there is an excellent chance that the assembled board will work first time. As before, simply take your time



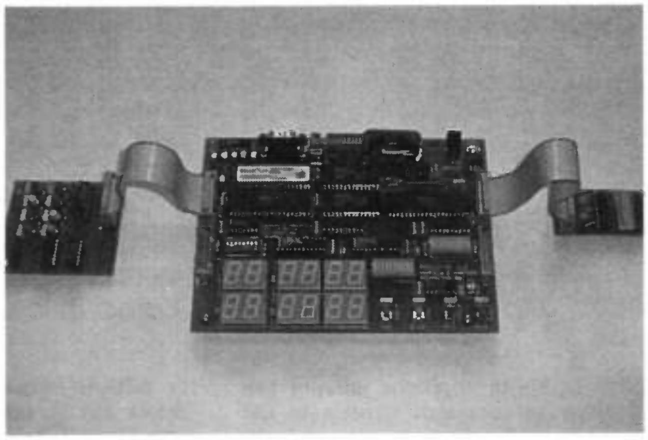
Underside wiring for the 8-bit interrupt latch.



Topside view of the 8-bit interrupt latch.



The 8-bit interrupt latch connected to PhizzyB.



The interrupt latch and l.e.d. output modules connected to PhizzyB.

and don't lose your place. (Lock the door at this point if you have to!)

Once again, the switch is used to bridge neighbouring copper strips in the printed circuit board, to produce strips of six holes. The "top" row of the switch's track is again wired to 0V, as before. This time, though, use the "lower" row of holes under the switch to connect to the 16-way header as well as one input of the NAND gate IC1.

The need to work on the underside of the board can be awfully confusing for beginners, especially with regard to the i.c. sockets, where some mental gymnastics with the pin numbers may be required!

Work through the entire circuit using point-to-point soldering as before. It is very easy to lose one's place when completing the interwiring, so use the same technique as previously, and ticking off each wire in the circuit diagram after it has been installed.

Continue with the 16-pin header: the author soldered a length of bare wire along one set of headers to link them to the 0V bus. Solder the 20-way IDC connector.

It can be tedious trying to double-check the wiring, but you should at least inspect the wiring for any obvious mistakes (dry joints, or wires touching each other). If you are happy that everything seems to be connected correctly (and before you insert the chips), then a practical approach involves simply switching on and see what happens!

If all is well, and after switching off, insert each chip into its corresponding socket.

Finally, a coating of spray-on p.c.b. lacquer will be of great benefit in protecting the rather delicate wiring on the solder side.

INTERRUPT TESTING

In order to demonstrate how a computer program can respond to an externally generated Interrupt signal, the test routine for the Interrupt switch module uses the l.e.d. display board (constructed in Part 2) on PhizzyB output port $F031. The newly-built Interrupt switch board should be connected to the $F011 input port.

The following program is needed to test the board:

```
# Start of program for Board 2
.org $4000
          bldsp $4FFF
          bldiv IRRUPT
          setim
          lda $00
loop:     sta [$F031]
          inca
          jmp [loop]
IRRUPT:   pusha
          lda [$F011]
          sta [$F030]
          popa
          rti
          .end
# end of program for Board 2
```

Enter it via your keyboard, assemble and save it as **board2test.asm**, and load the resulting **.ram** file into the PhizzyB.

Now run the program. The program will display a binary count on the external 8-bit l.e.d. module connected to output port $F031. When you press a switch on the new Interrupt board, this "latches" the values of all the switches into the 8-bit latch IC3, and it simultaneously generates an interrupt signal at the output of IC2.

The interrupt routine IRRUPT loads the value from $F011, outputs it to the internal 8-bit l.e.d. module at $F030 on the main PhizzyB board, and then returns control to the body of the program, which resumes the binary count on the external l.e.d.s. The process happens instantaneously as far as the observer is concerned.

When the first switch is pressed, all of the l.e.d.s at $F030 on the PhizzyB will light up except the l.e.d. corresponding to the switch you pressed. When you release the switch this pattern stays – and it will stay like that until you press another switch. By pressing the Interrupt switches in turn, starting with S7, an l.e.d. will be seen to extinguish on the PhizzyB l.e.d. output port $F030, starting with the most-significant bit (the left-most).

If you have problems, test the simple things first. Check with a voltmeter that all three chips on the Interrupt board are powered with 5V. Are the supplies to the busbars wired? Also look closely to see if any bare wires are accidentally touching each other. The author confesses to having omitted one wire (the clock feed) which, after connection, resulted in the board working exactly as described. The missing wire was easily detected because it had not been ticked off in the circuit diagram!

In the next instalment: we will describe the PhizzyBot, a simple motorised buggy which will respond to the computerised commands of the PhizzyB.

New Technology Update

Ian Poole looks at the latest technologies employed in radio frequency semiconductors used in cellular phones

THE CELLULAR telephone industry has given an enormous impetus to the development of radio frequency semiconductors in recent years. Now a variety of new and improved devices are beginning to make their mark, many of which may not be familiar to those more used to digital or lower frequencies.

However, these devices are widely used in phones and base stations. In view of the enormous volumes being produced, they are not nearly as expensive as they were even a few years ago.

MESFETs

Today the MESFET can be considered as the workhorse for many r.f. applications. As well as being used for many discrete components, the technology also forms the basis of many of the monolithic microwave i.c.s that are used in the cellular industry today.

The name MESFET stands for metal-semiconductor field effect transistor. Surprisingly, these devices were first reported as early as 1966 and the first ones demonstrated in 1967 when FET technology was in its comparative infancy.

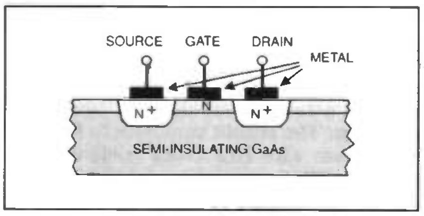


Fig.1. Construction of a MESFET device.

The devices feature gates formed by metal-semiconductor Schottky barrier junctions. The semiconductor material is normally gallium arsenide and the substrate is made to be semi-insulating to reduce parasitic capacitance. Above this is a very thin active layer that is often created using ion implantation, see Fig.1.

Although this is probably the cheapest method of creating the channel, an epitaxially grown one is normally able to give a higher performance because the crystal structure is left more intact. Typically, channel depth is only about 0·2µm and doped to give an *n*-type material. The choice of material and *n*-type doping are made to give the maximum carrier mobility required to enable good high frequency performance.

The small dimensions for the channel are critical to the correct operation of the device, and therefore they have to be accurately controlled. The source and drain regions are normally fabricated using ion implantation.

The contacts for the source and drain are often made from gold-germanium alloys for gallium arsenide devices. The gate contact can be made from a variety of materials including aluminium, platinum, or a complex titanium, platinum, gold layered structure.

Gate length is the key to many of the performance figures, and especially that of the high frequency limit. The standard MESFET processes produce gate lengths of around 0·5µm and this relates to a top operating frequency of about 18GHz. Where higher frequencies are required, a more refined process can produce a gate length of around 0·25µm which enables operation up to frequencies around 25GHz.

One of the main disadvantages of the depletion mode MESFET, the type that is most commonly used, is that it requires a negative voltage on the gate. Whilst this can be derived by placing a resistor in the drain/source circuit, this utilises valuable voltage and means that a separate negative supply is required.

PHEMT

To achieve improved performance, but at a cost, a device called a PHEMT (pseudomorphic high electron mobility transistor) can be used. In the past these devices were only associated with frequencies well into the microwave region. However, they have a number of advantages that have lead to the technology becoming somewhat cheaper and open to use in the cellular phone industry.

These devices possess a heterojunction, i.e. a junction in which not only does the doping change to give *p*-type and *n*-type materials, but also the base material changes. Typically the two materials might be aluminium gallium arsenide (AlGaAs) and gallium arsenide (GaAs). The structure of a PHEMT device is shown in Fig.2.

The key to the operation of the PHEMT lies in the heterojunction. At the junction of the two materials there is a very thin buffer region. This is typically only 30Å to 60Å.

Here the carriers are spacially separated from those in the doped region. This results in the carriers in this region having an exceedingly high mobility, allowing very high levels of performance to be achieved.

However, this performance is at a cost. PHEMT technology requires costly GaAs epitaxial wafers and is one reason why these devices are not as cheap as other devices being targetted at this area of the market.

The higher frequency performance of the PHEMT gives it some advantages in operation, but the key one for cellular telephone use is the fact that it can operate at a lower supply voltage than its MESFET counterpart. Typically these devices can operate down to 3V against 4V for MESFETs.

This is crucial in a market where portability is essential and battery life, size and weight are key factors in determining the success of a product. All of these are dependent upon the current drawn by the product.

Naturally, performance is not everything. Cost is a key driver in the decision about whether to use a device or not and fractions of a penny can lead to significant savings where large quantities are to be used.

In some manufacturing sites production is measured in integer millions. This means that even a penny saved on each unit can result in a cost saving of £10,000 per million units made.

To ensure that the PHEMT is viable to use it must produce the most cost effective design. Unfortunately there are comparatively few manufacturers, unlike MESFETs for which there are far more. Even then, some only manufacture for the more traditional microwave region.

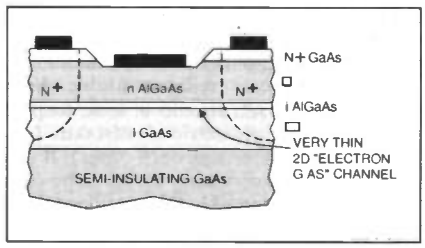


Fig.2. Internal structure of a PHEMT.

However, with the technology for PHEMTs becoming cheaper, and the vast possibilities for sales of these devices into the cellular industry, more companies are entering the market.

HBT

Another device generating a large amount of interest is the HBT or heterojunction transistor. This is a modified bipolar transistor where the emitter and base utilise different materials.

This has the effect of allowing electrons and not holes to be injected into the base region. By utilising this factor in conjunction with careful design of the transistor itself to reduce transit times and minority carrier storage, the response of the transistor can be improved significantly over more traditional approaches.

Those devices that have been targetted at this area of the industry have a flat response to over 3GHz. In addition to this the other advantage of the HBT is that it can run from a single supply rather than the dual supply normally employed for MESFETs and PHEMTs.

The final advantage of the HBT is that it is manufactured with a vertical structure. Because of the topology, it is found that vertical structures support a higher power density than lateral devices which include MESFETs and PHEMTs. This makes them ideal for power amplifier applications.

Whilst it may seem that the HBT has impressive credentials, it is not the ideal device it may appear at first sight. The high material cost of this device is a major set back in an industry that is fiercely price sensitive because of the highly competitive nature of the business. This alone will considerably reduce its usage.

To overcome this, manufacturers are looking carefully at the fabrication techniques used for the device. The tolerances are far less than those for more common devices like MESFETs where an emitter width of only 2μm is quite common.

It is also possible to fabricate more HBTs than MESFETs on a particular sized die. This should mean that it will be possible to reduce the cost of these devices considerably as processes are improved.

The other problem that has dogged the HBT is its reliability record. It is thought that this has mainly resulted from the manufacturing process. This is being addressed by the manufacturers of these devices and already a ten-fold improvement has been seen.

With further improvements a certainty, it should be possible to bring these devices into line with the requirements of the industry. Even then it may take a while for the devices to be fully accepted as they will still have a reputation to change. Fortunately in an industry changing as fast as the cellular phone industry this should not be a major problem.

Golden Oldies

Whilst many look at the new and upcoming technologies, there is still a lot of life left in the more traditional devices. Ordinary bipolar junction transistor technology can still provide excellent performance at a low price. MOSFET technology can also give a good account of itself.

However, it is likely that in the coming years there will be a steady change from the more traditional technologies to the newer ones like MESFETs, PHEMTs and HBTs.

SHOP TALK

with David Barrington

Wireless Monitoring System

Under normal circumstances sourcing and locating parts for the *Wireless Monitoring System* could have been quite a nightmare, particularly regarding the use of surface mount devices to obtain such a compact design for the Transmitter. Thanks to the guidance of the author, James Humphris, in highlighting some of the "specials", the task has been eased quite considerably.

Starting with the Transmitter. The grey palm-sized plastic case came from the M-series stocked by **Farnell** (☎ ***0113 263 6311*** or **http://www.farnell.com**), code 775-629. Next, the 2-pin a.m. 418MHz transmitter module type LQ-TX418A is stocked by **Maplin**, code NV08J. It is also possibly stocked by **Radio-Tech** (☎ ***01992 576107***), but not shown in their advert. Check both for prices.

The following surface and non-surface mount devices are all listed by Farnell or Maplin. Murata TZBX4 series trimmer capacitor; F-code 499-432 (min 10 off); M-code VI65V (blue). Siemens 15nH SM inductor, F-code 200-566 (min 10 off); 3·6864MHz crystal (surface mount), F-code 699-822; 4-way surface mount d.i.l. switch, F-code 693-730.

Due to the dangers associated with mercury, we prefer to recommend that readers use the non-toxic version of the tilt switch listed by Maplin, code DP50. This should cost just over £1.

The Receiver should not cause anywhere near as much concern as the only surface mount device here is the 3·6864MHz crystal. This is listed by Farnell, code 699-822.

However, the only source we have found for the extruded aluminium case is from the CCN range stocked by **Maplin** (**http://www.maplin.co.uk**), code YN50E (CCN80). Just in case you have trouble finding the MAX202 RS232 line driver chip, this can also be ordered from the above, code VQ46A.

The Receiver module carries the model designation LJ-RX418A-S and was also obtained from Maplin, code NV09K. Again, try Radio-Tech for alternative price.

This only leaves us with the easy bit, the Trans/Rec PIC chips, software and printed circuit boards.

Those readers unable to program their own PICs can purchase ready-programmed PIC16C71s for the Transmitter and Receiver from **Magenta Electronics** (☎ ***01283 565435*** or **http://www.magenta2000.co.uk**) for the inclusive price of £5.90 **each** (overseas add £1 for p&p). There are two versions of the Transmitter software; one for the Tilt sensor, and one for the Temperature sensor. Please indicate version(s) required when ordering pre-programmed transmitter PICs.

Software for the *Wireless Monitoring System* is available on a 3·5in. PC-compatible disk from the *EPE PCB Service*, see page 140. There is a nominal admin charge of £2.75 each (UK), the actual software is *Free*. For overseas readers, the charge is £3.35 surface mail and £4.35 air mail. If you are an Internet user, it can be downloaded *Free* from our FTP site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/wireless**.

The transmitter printed circuit boards are supplied as a pair, one for a.m. and one for the f.m. adaptor (next month), codes 219 and 219a. The receiver boards are also supplied as a pair, again one for a.m. and one for the f.m. adaptor, codes 220 and 220a respectively. See the *EPE PCB Service* page 140 for price details.

PIC MIDI Sustain Pedal

Apart from a ready-programmed PIC, if you are not into "blowing your own", then the rest of the parts required to knock together the *PIC MIDI Sustain Pedal* should be shelf items.

The neat looking footpedal depicted in the article came from **Maplin (http:\www.maplin.co.uk)**, code DU99H. It must be a simple push-to-make, release-to-break type and not one that toggles state each time it is operated. The MIDI lead also came from the same company, code YZ26D.

For those readers who do not have the facilities or time to program their own PIC chips, a pre-programmed PIC16C54-XTP microcontroller is available from **Magenta Electronics** (☎ ***01283 565435*** *or* ***http://www.magenta2000.co.uk***) for the all inclusive sum of £5.90 (overseas add £1 for p&p). *(We understand they will be supplying the 84 version.)*

If you do intend to do your own programming, the software listing is available from the Editorial Offices on a 3·5in. PC-compatible disk, see *EPE PCB Service* page 140. There is a nominal admin charge of £2.75 each (UK), the actual software is *Free*. For overseas readers the charge is £3.35 surface mail and £4.35 airmail. If you are an Internet user, it can be downloaded *Free* from our FTP site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/MIDIpedal**.

PhizzyB – 8-bit Switch and Interrupt Modules

Although component sourcing should not be a problem, you will certainly need lots of patience when you transform this month's *PhizzyB* circuits into working projects.

Selection of the "keypad" switches is the most important factor to consider when putting parts together for the *8-bit Switch* and *Interrupt* circuits. These must be 4-pin 6mm × 6mm p.c.b. mounting types, with each contact connected to two pins (parallel) for easy mounting. This arrangement is used to "bridge" tracks on the p.c.b.

Be careful, some "tactile" switches seem OK but dimensions may vary slightly. The ones used in our modules were ordered from **Farnell** (☎ ***0113 263 6311*** or **http://www.farnell.com**), code 176-433. Switch caps if required, 262-419.

Kynar solid-core hook-up wire is used extensively in "wirewrapping" applications in industry and should be available from most of our component advertisers. A small reel should only set you back just over £2. The semiconductor devices should also be widely stocked.

Experience of purchasing the headers and multi-way cable should have been gained when sourcing previous parts. If you have not already purchased the 4-section p.c.b. this is available from the *EPE PCB Service*, code 216 (see page 140).

Light Alarm

There is not a lot of room inside the case of the *Light Alarm* when all the components have been installed, so the selection of a "sub-miniature" type for the power on/off switch does make a difference. The threaded-fixing one in the model was purchased from **Maplin**, code FF77J. They also supplied the handheld case, with battery compartment and contacts, (code KC954D) and the 3V to 24V d.c. (5mA at 12V) low-profile, p.c.b. mounting buzzer, code KU58N.

If you ask for the light dependent resistor simply by quoting "one ORP12 please", most advertisers should recognise it and come up with the device or a suitable equivalent that will function in this circuit.

The small printed circuit board is available from the *EPE PCB Service*, code 218.

READOUT

John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

WIN A DIGITAL MULTIMETER

The DMT-1010 is a 3½ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

Every month we will give a DMT-1010 Digital Multimeter to the author of the best *Readout* letter.

✯ LETTER OF THE MONTH ✯

ARROWS

Dear EPE,

Having what I consider to be a strong "mechanical bent", I fell into the same hole that a lot of "rank amateurs" fall into when understanding arrows on semiconductor schematics (diodes and transistors) versus electron flow. Some have suggested changing the convention, but I feel there is a better way.

When teaching somebody new about current flow, never mention that years ago they got it wrong, it is not important in the beginning. Electrons flow from negative to positive, like-poles repel, and so on.

When it comes to understanding circuit theory and symbols, refer to the arrow as being a pointer to the cathode on a semiconductor in the same way a diode is banded at the cathode end. After that it falls into place faster. Don't mention the arrow as a flow indicator but rather as a pointer on a symbol and you don't get confusion.

My second point is about PLCs. I read with interest the discussions on them over the last few years and understand that they (as a subject) would not fit into your magazine format.

They are, however, one of the first hands-on contacts that fitters, plumbers and electricians have with electronic control systems and certainly were responsible for getting me involved in this rewarding and educating field (I don't miss stamp collecting).

Surely a solution would be to build one as a project using a PIC or similar. Say eight I/O with an I²C capability, relay-capable outputs and D-to-A facilities. Future add-on projects could be high speed counters, digital readout etc.

As well as being a great training aid and the next step in PIC multi-function applications, it would be ready to be put into burglar alarms, pulse counters and flow meters, level controllers, and so on.

A few screw terminals and it would be a useful module or building block, as well as filling the desire of some readers to understand modern PLC control systems.

Top mag, highly educational and I get a lot of pleasure from it every month.

Carl S. Wilde,
Acacia Ridge, Queensland, Australia

Certainly, I absolutely agree that historical references to current/electron flow are immaterial to understanding electronics. Personally, I don't care which way either flow, as long they do so somewhere and are predictable. My own early entry into electronics (many decades ago) was aided by simply thinking that in a circuit diagram "electricity/power" was required across the top and bottom, and that "signals" flowed from left to right.

The arrows, where they existed (the rectifier symbol was the only one I recall that used an arrow – the modern diode symbol), simply told me that a "one-way" street existed and that, as with traffic, "electricity" and "signals" must follow in the direction the arrows pointed. Concepts of "anode" and "cathode" were utterly alien to me for a long time – it was the arrow that mattered. Indeed, the rectifier symbol used + and – notations where we now use "k" and "a" (cathode and anode).

There was (and still is), of course, the anomaly that some symbols use arrows that have nothing to do with electrical flow direction. They merely indicate that the value of the component is variable – as with potentiometers and tuning capacitors, for example.

I find it interesting to recall my understanding of the valves I played around with in the early '60s. My concept was of signals flowing left to right into the grid of the valve, up the tube and out the top and to the right again. There was no thought of anything flowing down through the tube, but there were no arrows on valves to indicate flow of anything.

Nowadays, we are given at least some guidance on flow of "something" by the arrows on diodes and transistors. Again it is the symbol that is important to the basic understanding rather than the names given to the various points of contact at the symbol. Names are only a convenience used to allow easier communication of common meaning between people. They don't necessarily affect the mental image of a situation when looking at a symbol. Indeed, it can be argued that symbols should never include names, the symbol itself containing all the information required to understand its meaning.

Hence a symbol that includes wording for its meaning to be understood is, surely, a bad or inadequate symbol (it is accepted that some i.c.s are too complex for their function to be adequately symbolised). For instance, I hate the British Standards (BS) symbols for logic gates – identical rectangles with additional "wording" within them (1, &, ≥1), to denote their function! It must have been a committee of mathematicians that invented them rather than a team of working electronics engineers (you've heard the rumour that the camel is a horse invented by committee, haven't you?). Does anyone know the origin of the BS symbols?

The American (MIL/ANSI) system of logic gate symbols (as used in EPE) is far more informative of meaning at a glance. We have the same attitude towards resistor symbols – zig-zags rather than rectangles (even though rectangles are simpler to draw on a CAD package).

Mind you, one could take this argument to extremes and propose that we should all use Chinese for written communication – symbols that originate in the portrayal of individual concepts rather than using (as most other languages do) groupings of symbols (alphanumerics) that represent the spoken interpretation of concepts – a double translation in effect. However, memorising all the symbols must be a problem (although the Chinese obviously manage it), and what about typewriter/computer keyboards? A major difficulty! (Views from readers of oriental origin invited!)

On your other point, PLCs (programmable logic controllers), we still feel that instruction in these is beyond our "charter". However, again views are invited.

BT ON-LINE – HOW?

Dear EPE,

At an average cost per month of £10 to get on-line, my Scottish Ancestry baulked and my Old Age Pension went into decline, so I was surprised when included with my telephone bill (7 Sept) were brief details of BT Click.

I telephoned the freefone number but the young lady didn't know what this was and suggested I ring back in about a fortnight (?). Which I did. The second young lady didn't know anything either. The comment about the freefone number fell on stony ground.

I gave it a couple of days and phoned again. The third young lady was a bit more helpful and took all my details and said someone would call back. Thirteen days later I was phoned back and the caller spent almost ten minutes trying to answer my simple questions like "Will it run on Windows 3.11?" and "How much will it cost?". He promised to send CD-ROM or a Floppy Disk – he didn't know which.

Nothing had arrived by 26 Oct so I wrote to London BT HQ which brought not even an acknowledgment. Then I saw *Sunday Times* quarter page advert with a different freefone number. Telephoned Monday morning. The man said I had got the wrong number.

I shouldn't have said all those things about incompetence etc, etc, but the line went dead. Then a brief ringing tone and I then spoke more or less rationally to another young man who said it needed 16MB of RAM (which it doesn't), but said he would send a CD-ROM.

Two months after my first enquiry (at 75 you're not sure how many more months there are still to enjoy) the CD-ROM arrived. Made all the connections, wires trailing across the floors, and opened up the disk. A little window appeared with the message "This programme needs a '486' or Pentium".

I've only just upgraded to 386, for goodness sake. I'm afraid the doubtful delights of the Internet and digital highway are not for me.

Peter McBeath,
Morpeth, Northumberland

This reminds me of the sort of corporate competence on which our renowned columnist Barry Fox so often comments! Ironically, we are all so used to receiving (and probably turning down) all-too-frequent tele-sales offers for double-glazing, kitchens and so on, we probably assume that tele-marketing is an effective way of doing business.

Naturally, then, when it is we who actually want to initiate a tele-purchase, we expect to achieve what we want without difficulty. How frustrating that, in this instance, it's the line operators themselves who effectively turned you down through apparently not knowing their own product.

AIR THEM!

Whatever your views on electronics and allied subjects, air them in public, either through *Readout* or our *Chat Zone* via www.epemag.wimborne.co.uk

BOARDER LINE

Dear EPE,

What are the minimum recommended track widths and separations to use when designing p.c.b.s, with relation to voltage and current?

Also, what are the recommended u.v. exposure times for photo-sensitive boards (I exposed two 100mm × 160mm single-sided boards separately for four minutes. One board etched OK but the other had about 1cm of copper left on either side.

Are there any books you can recommend on these subjects?

Stuart Pearson, via the Net

Our On-line Editor, Alan, received these queries and replied direct to Stuart as follows (I'll add a few words in a moment):

Assuming 1oz (about 35 microns I think) copper and assuming 15°C above ambient is acceptable and the board won't burst into flames (!), then a track width of 8mm relates to 30 amps absolute maximum. You can reduce the track width pro-rata from this, and guesstimate/adjust for heavier gauge copper foils.

The recommended track separation with relation to voltage is:

Up to 50V	0·5mm
51V to 100V	0·7mm
101V to 170V	1·0mm
171V to 250V	1·2mm
251V to 500V	3·0mm
Over 500V – dodgy!	

Exposure time depends a lot on different brands of u.v. etch-resist lacquer. I usually go for 15 to 20 minutes for pre-coated boards. Seldom have I found over-exposure to cause damage unless the board has very fine tracks. As I expect you know, it is impossible to re-expose for a further period, so I tend to be generous with the u.v. time.

You need to do some dummy test strips to see how the boards react to different exposures, because it also depends on how "fresh" your u.v. tubes are, how close they are to the copper, etc.

If you spray on the lacquer yourself by aerosol, it's very much harder to get consistent results in the u.v. stage. This is because the coating is not uniform thickness. I buy pre-coated boards for this reason.

Book-wise, there's a bit of info (but not much) in the *Art of Electronics* (Horowitz and Hill). It should be good enough to get you off the ground (as it were).

You might also care to read my series of *Build Your Own Projects* (Nov '96 to Mar '97) – it includes a lot about making p.c.b.s and project assembly. (See our *Back Issues* page.)

Alan Winstanley

And, of course, Robert Penfold's book How to Design and Make Your Own P.C.B.s *is also a worthy source of info (BP121, available through our* Direct Book Service).

Alan's experience with exposure is interesting! Having had many years professional p.c.b. manufacturing experience, my own is somewhat different. I still use the u.v. equipment I bought over 20 years ago and (amazingly) it still has the same u.v. tubes that it came with. They appear to be just as brilliant as they were then since exposure times are still around the same period for given materials. The u.v. unit's exposure area measures about 21 inches by 12 inches (53cm × 30cm) and has six 15 watt tubes, at a distance (estimated) of about 2 inches (5cm) below the image glass. The unit has a foam-padded clip-down lid to ensure adequate pressure between the board and its image master.

These days I buy my photo-resist boards from three sources. Mega Electronics of Saffron Walden, RS Components and Farnell Components (depending on what I else I need to order). Mega, by the way, specialise in printed circuit making equipment and materials, with a strong emphasis on supplying to educational establishments.

Typically, Mega and RS materials require an exposure time of two and half minutes with celluloid (photograph film) images created via a plate camera. Images on translucent drafting film using a 24-pin dot matrix printer and a computer require about four minutes 15 seconds. Farnell's materials used with the same image types are typically just under twice as long.

Development is in a solution made from pure caustic soda crystals (bought from a chemist as 100 per cent pure) diluted 25gms to one litre of water. Ideally, I prefer the temperature to be at the "photographic room-temperature" of 20°C (68°F), at which the development time is two minutes.

It is important in the development process that the solution is agitated by gently rocking it backwards and forwards in the tray. Don't be too vigorous, though. As you do so, the unrequired etch-resist will be seen to float way from the board. At the end of the two minutes, the copper should be nice and clear in the non-track regions, leaving a good clean-edged image (usually dark-blue) of the tracks themselves.

Now wash the board in luke-warm water to remove the caustic soda solution. It's recommended that you should use rubber household gloves while handling the caustic soda – although I don't bother just for the few seconds my hands are in contact with it, giving them a thorough wash in running water after completion (some people might be unusually sensitive, however).

The board can then be etched in the usual way (for this I do use gloves – usually – of the heavy-duty nearly elbow-length type). Avoid contact with the track image until after etching is complete. The etch-resist, although fairly hard, can be damaged if rubbed, the effect of which may not be apparent until after etching, when over-etched (and possibly absent) tracks might be seen!

An important point to note is that the caustic soda solution should not be too weak, which will result in an unclean image – tracks surrounded by speckled areas where the developing is incomplete. A similar effect can occur if the exposure time is too short.

In fact, provided the solution is mixed up to the recommended strength, this should not normally become a problem for a long time. I make two litres a time and, as a calculated guess, probably develop around two square metres of board a year. Following development, I return the solution to its bottle, which is made of dark-brown glass. It is stored (well-stoppered and well-labelled!) in a cupboard in the workroom, and there's probably a year to 18 months between renewals. The usual sign that it's reaching exhaustion is when development times begin to extend to three minutes at 20°C. This is normally preceded by sediment appearing at the bottom of the bottle.

Contrary to Alan's experience, I do find that over-exposing the image in the u.v. unit is problematic. However dense the image, and however good the contact is between the board and the translucent/transparent master, the u.v. light tends to seep in around the edge of the track images. Normally (correct exposure time) this is not apparent on the final result. However, if exposure is too long the effect becomes noticeable as imprecise edges to the tracks. In extreme cases, thin tracks (those between i.c. pads, for example – typically 10 to 15 thou) can cease to exist. It is essential, of course, that you ensure the image and board are in perfect contact, and remain well sandwiched together throughout the exposure period.

Readers having less-powerful u.v. units will find that their exposure times will be longer than mine, and it could be that an apparent tolerance to overexposure does exist – although the ratio of tolerance may still be about the same relative to the optimum exposure period.

I re-iterate Alan's advice about doing tests for optimum u.v. exposure times. This should be done for each new batch of photo-sensitised board, from whatever source. All you need to do is use a few small cut-offs, exposing them and a selected area of the image required for different periods and developing each after exposure. Timings to within the nearest 15 seconds are normally satisfactory.

Exposure tests should also be done if you change the material on which the master image is printed, i.e. from one batch of drafting film to another. It should also be done if you suspect that the density of the master image itself is different to normal (a printer ribbon getting a bit thin, perhaps – I keep one ribbon solely for p.c.b. image making).

It is also worth noting that photo-sensitised boards have a shelf-life (use before date). I have variously found this to be quoted between six months and a year from date of purchase.

Incidentally, I have heard of people suspending u.v. bulbs over the image/p.c.b./glass sandwich. I dread to think about what inconsistencies this must generate. For a start, it is believed that many so-called u.v. bulbs are little more than ordinary tungsten bulbs with a u.v. filter coating and so the exposure times must be horrendously long. Further more, the evenness of illumination must be nearly non-existent, being brighter at the centre of the illumination, falling off rapidly at the edges, a situation aggravated by the closeness at which the bulbs are to the sandwich. Such bulbs should be confined to discos!

Like Alan, I would not even consider pre-coating boards myself – instinctively feeling that I could never achieve consistency with them. Would any readers care to offer comments on their experience with this method?

Finally, remember that there are three key words when it comes to good p.c.b. imaging – Time, Temperature and Ingredients. Relate them consistently and you too will achieve good results (my wife says this is also the requirement for cooking, so why can't her husband cook?)!

SLASHED PIC SITE

Dear EPE,

I have just noticed that in my letter published in *Readout* of Aug '98, my web site mentioned is incorrectly printed – a dot has been printed instead of slash. The correct address is **http://members.aol.com/LearnPIC**.

John Morton, via the Net

Sorry John! Readers, John has set up his site for PIC users, especially beginners. It was originally set up to supplement his book PIC Beginners Guide *published in May '98 by Butterworth-Heinemann, although it is completely general in scope and does not rely in any way on knowledge of the book.*

HIGH LANGUAGE

Dear EPE,

I note with interest the letter (Dec '98) regarding the use of higher level languages for programmes used in computer type projects. It would be nice to see some projects using C, for example. However, there may be difficulties.

The standard C compilers, such as Borland C V5 and Microsoft Visual C, do not allow I/O ports to be accessed directly as in the older Turbo C and MS C V5.0. They have been designed for the 32-bit operating systems of Win 98 and NT and as such you cannot specify an actual I/O port as an address.

The means of accessing I/O ports is via Windows programming techniques and treating ports as files. The programmes would be very complicated for many non-professionals and I feel would be beyond the scope of your magazine.

The depth of coverage you provide is excellent and I would not like to see the content diluted for the sake of fashion in the IT world.

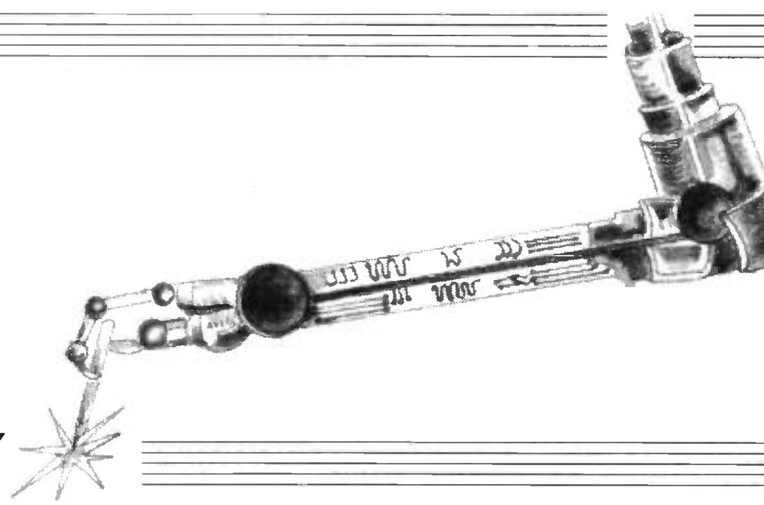
Ken Brown, Ireland, via the Net

Thanks, useful comments – but alarming. Whilst I have not used a '98 machine I do write in machine code for the '95, accessing ports directly through register addresses. Am I to understand that '98 does not allow this? That would make many of my programs unworkable in a machine having '98 installed, which would be a great shame since most will run on any machine from an 8086 upwards to a Pentium (with '95 installed).

More feedback on this requested, please!

Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY

This month our electronic agony uncle, armed with Dremel in hand, dissects an electret microphone capsule to see what makes it tick. We also follow up on relay contact ratings and make a heartfelt plea on behalf of a Singapore reader in need of some non-corrosive etchant!

Electret "Mics."

My thanks and greetings to regular reader ***Mike Howell*** of Westville, South Africa who writes:

Firstly, congratulations on your excellent Circuit Surgery *columns – my only complaint is that* EPE *can't give you more space!*

Can you help with a question on the correct use of electret microphones? An old constructional project called the Acoustic Probe *by Andy Flind (EE Nov. 1987) is a personal favourite, but having searched through my Back Issues all the way back to 1977, I can't seem to find any information on electrets.*

The Acoustic Probe used a crystal microphone in its design which I hope to substitute the microphone for an electret type. It was so good that I made up a second board, this time using a fibreglass parabola for listening to bird and animal noises out here in the Bush! (The acoustic probe is also invaluable when looking for lost cats!)

PS – In circuit diagrams, what on earth is meant by V_{cc}, V_{dd}, V_{xx} etc.?

The *Acoustic Probe* is one of those memorable constructional projects which lives on and on, and I'm pleased to say that it is still available today in kit form from Magenta Electronics (**www.magenta2000.co.uk**). The project is a form of electronic stethoscope which can be used to listen to ticking watches, or diagnose engine faults. (Readers, please note that we cannot supply Back Issues dating back so far but Magenta do include a reprint of all the constructional details with each kit.)

Andy is well known to regular readers for producing some fascinating designs, including our *Mind Machines* and *TENS Units*. The *Acoustic Probe* design used a crystal microphone insert which was hooked to a junction f.e.t., see the circuit extract in Fig. 1.

The microphone was actually incorporated into a special probe assembly which could be touched onto the object to be monitored (e.g. near the crankshaft of an engine block, or onto the bearings of a motor) and an amplifier then reproduced the audio signal over a pair of headphones.

A crystal microphone is a high impedance sound transducer which generates a tiny electric signal in response to the sound waves that impinge on the crystal insert. This is as a result of the *piezoelectric effect* (many say *pee-ay-tzo*, others, including myself, say *peet-zo-electric*.) The piezoelectric effect is used in some cigarette or barbecue lighters in which a tiny crystal is struck and the resulting electrical impulse is used to create a spark.

Since the crystal has a very high impedance – several megohms – then it is necessary to ensure that the impedance of the following stage is high enough so it will not load the signal. In this design the circuit used a 2N3819 junction f.e.t. as the first stage to match the input impedance.

In the circuit extract of Fig. 1, the f.e.t. (field effect transistor) TR1 is biased as a source follower which tracks the signal on its gate (g) terminal. The resulting a.c. signal is fed to an i.c. amplifier which drives the headphones. The main point is that the crystal microphone generates a signal itself and requires no biasing.

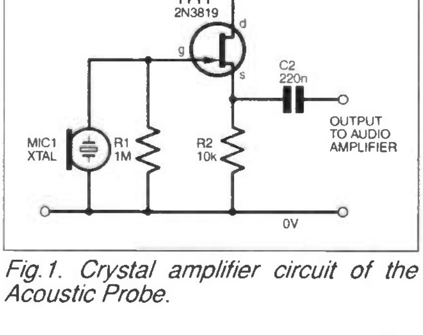


Fig.1. Crystal amplifier circuit of the Acoustic Probe.

Micro Surgery

As for how an electret microphone works, well it did not take too long to find out by applying a little "circuit surgery", which involved slicing one open with a Dremel!

Some readers will know that the electret is also known as an electret "condenser" microphone. Younger readers won't be aware that *condenser* is actually the old-fashioned word for **capacitor**, which yields a clue as to the operation of an electret capsule.

The result of examining the internal components of a typical electret condenser microphone insert is shown in Fig.2. I sacrificed a type EU6 electret microphone ordered from ElectroValue Ltd.

A little bit of reverse engineering on the resulting debris revealed that there were two electronic components inside. Firstly a transistor which was marked only as "K596" – I couldn't find this in my data library but some detective work on the Internet (on the Motorola web site: **http://mot2.mot-sps.com/ppd/html/smsignalxref.html**) indicates this is probably a KSK596, for which Motorola suggest a 2N5484 as an alternative.

A further check on the National Semiconductor web site (**www.natsemi.com**) on this latter number gave a general description of an "*n*-channel r.f. amplifier designed primarily for electronic switching applications such as low on-resistance analogue switching" – which instantly identifies the device as a MOSFET transistor (as I would expect).

The electret microphone also incorporated a single one-eighth watt discrete resistor, which didn't quite withstand the onslaught of my Dremel. It is soldered onto the tiny p.c.b. which forms the underside solder contacts of the microphone. So where is this "capacitor" in this condenser microphone – where does the audio signal come from?

Mind the Gap

The answer is soon revealed by separating the microphone into its individual parts, see Fig.2. A wafer-thin metal disc forms a *diaphragm* which vibrates when struck by sound waves. A plastic ring underneath acts as a separator and an insulator. Underneath that insulator is a second steel disc which is tack-welded directly to the gate terminal wire of the MOSFET transistor.

A gap is therefore created in the centre of the plastic ring: in other words, an air-spaced capacitor is formed. So the encapsulated air acts as the capacitor *dielectric* and the two metal discs act as capacitor "plates". Mystery solved, Mike!

Sound waves enter the module through a hole on top of the capsule, which means the microphone is omni-directional in nature – its sound response does not depend on the direction in which it is pointed. (A unidirectional microphone is more sensitive to sound in one direction.) The sound pressure waves cause the metal diaphragm to compress the airspace underneath, creating a variation in the tiny capacitance (a few picofarads I would guess) which is relative to the sound pressure and frequency.

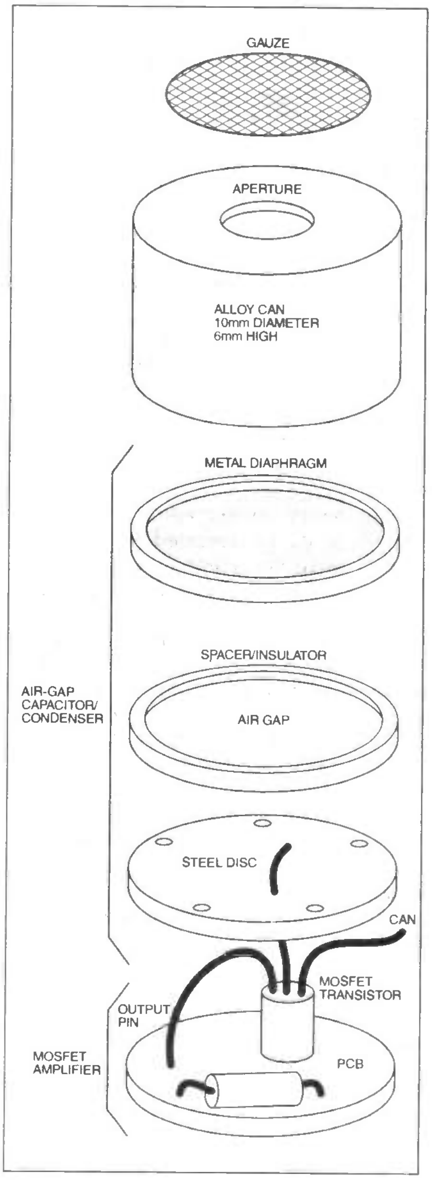


Fig.2. Exploded view of an electret "condenser" microphone. (A plastic internal moulding is not shown.)

This "capacitor" has an extremely high impedance or capacitive reactance, hence the need for a built-in MOSFET transistor immediately behind the resonating chamber to act as a buffer. The internal resistor biases the transistor.

Finally, the whole assembly is crimped into an aluminium can. I noted that there are 2-pin and 3-pin microphones available, but the only real difference is the screening arrangement for the capsule.

One difference between the electret and a crystal microphone is, of course, that the electret's built-in MOSFET requires an external supply voltage. Typically a 1·5V cell can be used but roughly 5V is suggested along with a resistor.

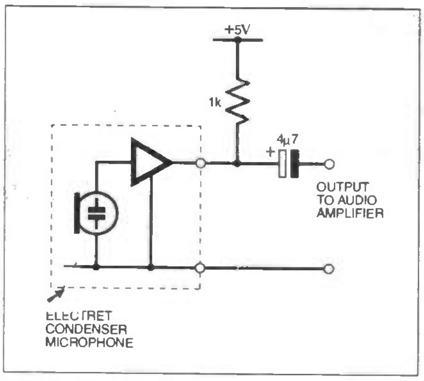


Fig.3. Circuit for a simple microphone stage using an electret condenser capsule.

We are not talking hifi and there is no rocket-science involved here. You could try a configuration such as that shown in Fig. 3. You will need to experiment, but don't be afraid of the device – there is very little to them as you can see!

Textbook Voltage

To answer your second question on the subject of voltage designations used in diagrams and data sheets; historically the terminology V_{CC}, V_{BB} etc. relates to the biasing arrangements of bipolar transistors. They are terms which are taken for granted and I can understand the puzzlement: textbooks often introduce expressions such as "$+V_{CC}$" out of nowhere.

A voltage V_{CC} is that which biases the collector(s) of a transistor circuit, and V_{EE} biases the emitter(s). V_{BB} would be the base bias voltage. The term "$+V_{CC}$" has fallen into common use to denote the positive supply rail in a bipolar transistor circuit, and V_{EE} the 0V or negative rail

The same nomenclature can be used to designate the voltages *between two terminals* of a transistor. You will see these used a lot in manufacturer's transistor data sheets or in catalogues. Look especially for:

V_{CEO} – the maximum permissible collector-emitter voltage with the base "open"

V_{CBO} – the maximum voltage allowed between collector and base

V_{EBO} – the maximum emitter-base voltage.

As examples, the BC548 is rated at V_{CEO} 30V, V_{CBO} 30V and V_{EBO} 5V. Notice that the V_{EBO} specification is often very low in comparison – usually just a few volts – and is one to keep an eye on when designing circuits.

The same kind of designation is used in the field of digital integrated circuits. V_{DD} and V_{SS} describe MOS digital circuit supply voltages. In fact engineers use the terms with reference to the individual transistors within the chip.

For example, in last month's issue I described the internal circuitry of a typical 4017 Johnson Counter chip. Obviously, I didn't resolve right down to the individual transistors fabricated in the die.

Since MOSFET transistors are used internally, the 4017 pinout data shows V_{DD} and V_{SS} for the power supplies pins – this time they relate to the *drain* voltages ($+V_{DD}$, the positive supply rail) and the MOSFET *source* voltages (V_{SS} or 0V rail) for the "transistor" circuit within. I hope this clears up any confusion.

Relays – More Contacts

In the December 98 issue I gave a comprehensive low-down on the meaning of relay specifications. I'm grateful to ***John Rastall*** who followed up on my piece about relay contact ratings:

You wrote that you weren't too sure why minimum switching current was sometimes specified, though you guessed it was about overcoming contact resistance. Well, you're right – almost!

Most good relay contacts are silver-plated to improve their performance. Higher-spec. relays have gold-plated contacts instead. However, silver does oxidise, albeit slowly, so they tarnish over time. This acts as an insulator and introduces a resistance.

A relay producer has two ways of overcoming this – either design the moving contact so it wipes across the surface of the fixed contact with every operation (thereby self-cleaning the contacts – but only with regular use) or, ensure that the current broken by the contacts when they open is large enough to generate a small arc. This will burn off any deposits. Hence the minimum switching capacity you see in some catalogues.

Thanks for sending the extra information, John.

PCB Facilities in Singapore

I receive E-mail from all over the world and the following item comes from ***Nelson Ng*** in Singapore, who writes with a heartfelt plea:

I have been an electronics hobbyist for over two years, however, I have been unable to find any etching solutions for the development of printed circuit boards here in Singapore. The main reason is that, because of high population densities, Singapore has a considerable number of high-rise flats, and drainage is through copper piping.

Many years ago, when Ferric Chloride was freely available, some hobbyists tended to abuse it by pouring the used solution down the drains . . . you can guess the rest. Under the Corrosive Substance Act the sale of this compound was banned to individuals, and factories must be licenced to purchase it.

Therefore, the only way to develop printed circuit boards is to use commercial developers and pay quite a price for it, so we hobbyists are restricted to stripboard (Veroboard, tripad, wire-wrapping, point-

to-point soldering and so on). Is there any way to develop low-volume, say one or two, printed circuit boards at a time? Moreover, is there an alternative to Ferric Chloride which could be legally available.

What a fascinating insight into the problems faced by our international readership. On the topic of p.c.b. production, I often recount the story told by the late Alan Sproxton of Home Radio (Components), a former Surrey-based distributor who used to write for *Everyday Electronics* many years ago.

In mixing some Ferric Chloride solution, he once wrote, he tipped a whole jar of Ferric Chloride compound into a shallow tray full of water. The heat generated by the exothermic reaction caused the compound to melt a hole in the tray, which was made of plastic . . . (However he was correct to add the compound to the water, and not the other way round.)

Etchants can be extremely unpleasant to use and must always be treated with respect. The subject of the disposal of used etchant is an equally difficult one to handle responsibly.

In the Bag

Unfortunately, corrosive agents are a necessary part of p.c.b. production. For hobby use I always recommend the Seno GS Etch-in-a-Bag system which is available from several advertisers.

This uses a (nearly) sealed system whereby the etchant is retained in a heavy-gauge polythene bag and is released over the board using a simple system of removable seals. When the etchant is exhausted, a neutraliser powder (supplied) can be added and the whole lot thrown in the domestic refuse. I find it is the best product for etching boards at home.

If Ferric Chloride has been banned in your country, one alternative etchant is sodium persulphate, e.g. as produced for "Press'n'Peel" (Maplin MC49D). The product is designed to address the special problems of the electronics industry, including uniformity of etching and lack of staining (it says here). It is classified as an oxidising agent. Check your local regulations to see if such a compound would be permissible.

Buy the Net

It is possible to produce printed circuit boards "by Internet" – i.e. by E-mailing the design files to manufacturers, they will turn them round and send back the finished thing. (A gentleman can buy a made-to-measure suit the same way: a tailor in Yorkshire, UK modems the measurements through to the maker in Belgium and the suit is then delivered from mainland Europe by air freight!)

Elizabeth Nolan of Beta Layout in Ireland (**www.pcb-pool.com**) offered to help you with one-off printed circuit boards. They operate on a prototype p.c.b. "pooling" principle where set-up costs are amortised amongst a number of designers, thus bringing down the traditionally high tooling, set-up, and film costs which would otherwise be charged for a one-off prototype.

This is an excellent way of reducing start-up costs but unfortunately the typical figures I received won't appeal to the hobbyist: a prototype p.c.b. from scratch (e.g. a standard Eurocard 160mm × 100mm) weighed in at roughly £49, although that did include all origination and set-up costs. Mr. Ng commented that such a cost is approximately 10 per cent of an average monthly salary in Singapore!

Commercial users might bear this system in mind though, check for more details from Beta Layout's web site. Meantime if any readers anywhere can produce a solution to this thorny problem I will gladly pass ideas on.

CIRCUIT THERAPY

Circuit Surgery is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF, United Kingdom. E-mail **alan@epemag.demon.co.uk**. Please indicate if your query is not for publication. A personal reply cannot always be guaranteed but we will try to publish representative answers in this column.

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128 pages **Order code EP1** **£2.45**

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS SEE THE NEXT TWO ISSUES OF EPE.

Note our UK postage costs just £1.50 no matter how many books you order!

PROJECT CONSTRUCTION

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AUDIO AMPLIFIER CONSTRUCTION
R. A. Penfold
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The preamplifier circuits include low noise microphone and RIAA types, a tape head preamplifier, a guitar preamplifier and various tone controls. The power amplifier designs range from low power battery operation to 100W MOSFET types and also include a 12 volt bridge amplifier capable of giving up to 18W output.

All the circuits are relatively easy to construct using the p.c.b. or stripboard designs given. Where necessary any setting-up procedures are described, but in most cases no setting-up or test gear is required in order to successfully complete the project.
100 pages **Temporarily out of print**

RADIO / TV VIDEO

ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS
R. A. Penfold
This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.
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The aim of the experimenter will be to make a measurement or confirm a principle, and this can be done with relatively fragile, short-life apparatus. Because of this, devices described in this book make liberal use of cardboard, cooking foil, plastic bottles, cat food tins, etc. These materials are, in general, cheap to obtain and easily worked with simple tools, encouraging the trial-and-error philosophy which leads to innovation and discovery.

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This concise book tells the story, and shows the reader how to construct and use 25 indoor and window aerials that the author has proven to be sure performers.

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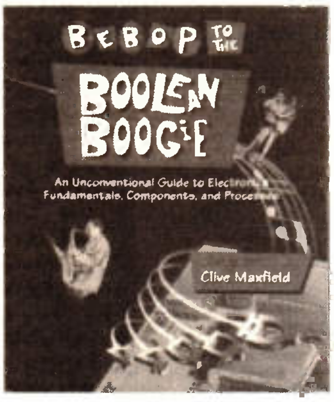
The Foreword by Pete Waddell, Editor, *Printed Circuit Design*, reads:

"Personally, I think that the title of this tome alone (hmmm, a movie?) should provide some input as to what you can expect. But, for those who require a bit more: be forewarned, dear reader, you will probably learn far more than you could hope to expect from *Bebop to the Boolean Boogie*, just because of the unique approach Max has to technical material. The author will guide you from the basics through a minefield of potentially boring theoretical mish-mash, to a Nirvana of understanding. You will not suffer that fate familiar to every reader: re-reading paragraphs over and over wondering what in the world the author was trying to say. For a limey, Max shoots amazingly well and from the hip, but in a way that will keep you interested and amused. If you are not vigilant, you may not only learn something, but you may even enjoy the process. The only further advice I can give is to 'expect the unexpected'."



This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!).

Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day. . . .

By importing these books ourselves we have managed to make them available in the UK at an exceptional price.

Bebop Bytes Back

By Clive "Max" Maxfield and Alvin Brown

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An Unconventional Guide To Computers

Plus **FREE CD-ROM** which includes: Fully Functional Internet-Ready Virtual Computer with Interactive Labs

The Foreword by Lee Felsenstein reads:

1. The more time you spend with this book and its accompanying CD-ROM, the more you'll get out of it. Skimming through it won't take you where you want to go. Paying serious attention, on the other hand, will teach you more about computers than you can imagine. (You might also see a few beautiful sunrises.)

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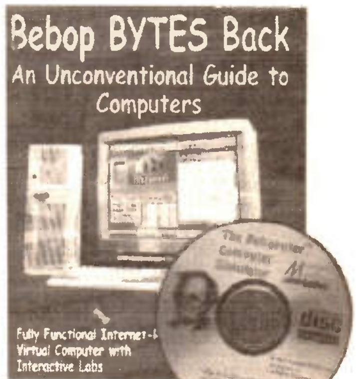

3. When you're done, you won't look any different. You won't get a trophy or a certificate to hang on your wall. You'll have some knowledge, and some skill, and you'll be ready to find more knowledge and develop more skill. Much of this will be recognisable only to someone who has the same knowledge and skill.

This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the accompanying CD-ROM (for Windows 95 machines only) contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the book contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers.

If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this one!

Audio and Music

VALVE & TRANSISTOR AUDIO AMPLIFIERS NEW
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Contents: Active components; Valves or vacuum tubes; Solid-state devices; Passive components; Inductors and transformers; Capacitors, Resistors, Switches and electrical contacts; Voltage amplifier stages using valves; Valve audio amplifier layouts; Negative feedback; Valve operated power amplifiers; Solid state voltage amplifiers; Early solid-state audio amplifiers; Contemporary power amplifier designs; Preamplifiers; Power supplies (PSUs); Index.

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AN INTRODUCTION TO PIC MICROCONTROLLERS
Robert Penfold
Designing your own PIC based projects may seem a daunting task, but it is really not too difficult providing you have some previous experience of electronics. The PIC processors have plenty of useful features, but they are still reasonably simple and straightforward to use. This book should contain everything you need to know.
Topics covered include: the PIC register set; numbering systems; bitwise operations and rotation; the PIC instruction set; using interrupts; using the analogue to digital converter; clock circuits; using the real time clock counter (RTCC); using subroutines; driving seven segment displays.
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A. Flind
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AUDIO AND MUSIC

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Along with the electric guitar, sections are also included relating to acoustic instruments. The function of specialised piezoelectric pickups is explained and there are detailed instructions on how to make your own contact and bridge transducers. The projects range from simple preamps and tone boosters, to complete active controls and equaliser units.
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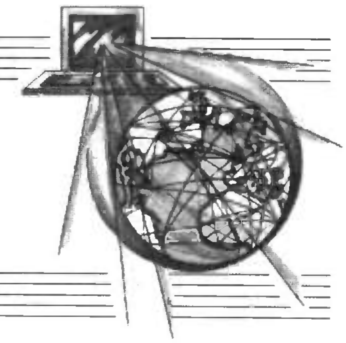
SURFING THE INTERNET

NET WORK

ALAN WINSTANLEY



NET WORK is our monthly column specially written for readers having access to the Internet, whether at home, work, school or college. The column is designed to keep you posted with latest Internet developments here at *EPE* and to offer practical hints, tips and pointers in the ever more complex world of Internet connectivity.

The arrival of the Internet means that the *EPE* reader can, for example, obtain technical data about integrated circuits, or find out about device substitutions with barely a second thought – once you know where to look, you can have manufacturer's data or technical information delivered to your desktop in minutes. Since there has always been a long-running argument about the cost and availability of manufacturers' data books, the arrival of the world-wide web resolves them all at a stroke.

As an example, my *Circuit Surgery* column this month includes a typical example of how the Internet was used routinely to obtain some information about a mysterious transistor which as you'll read, was contained in an electret microphone. Whilst that example is quite a trivial one, it nevertheless demonstrates neatly that with just a little detective work, an experienced user can use the Internet to quickly find a solution to a particular problem at very little cost.

Freeserve Rising Fast

While AOL and Demon Internet fight it out to see who can rightly advertise the claim of being the largest service provider in the UK, last month I asked readers for feedback concerning Freeserve, the new ISP marketed by High Street retailer Dixons which is completely free, apart from local rate phone calls. Freeserve is clearly having a significant impact in the home dial-up market. Behind the scenes it is operated by Planet On-Line (**http://theplanet.net**), which itself is owned by Energis (**www.energis.co.uk**), who provide some of the routing for others including Demon Internet (now owned by Scottish Telecom). Interesting times are therefore ahead, and the dial-up sector may well have to re-align itself to cope with Dixons' new upstart, perhaps by rising above it to offer added value services designed for the more discerning power user, which is what Demon Internet would argue forms the core of their dial-up business anyway.

I received a number of very positive replies from readers about Freeserve, and one or two critical ones, but the consensus is clearly that it is free so don't knock it (I wasn't). However, I would again say that beginners should be aware of the high support costs at £1 a minute and there are a number of reported cases where browsers, newsgroup or dial-up networking settings were "taken over" by Freeserve.

It takes experience to understand the impact of any changes made to a stable setup, and more experience still to unravel them, so I would repeat that newcomers to the Internet ought to tread carefully before signing up. Alternatives such as AOL or CompuServe cost only a few pounds a month and make a good starting point, with proven software that generally works flawlessly and will get you moving.

On the other hand, anyone reasonably confident about Windows computing is likely to find a Freeserve connection very tempting, if not as a main connection then certainly to back-up an existing one. Freeserve is expanding all the time, and already includes POP3 mail and free web space with more services being slated for the future. All you have to do to retain your account is use it at least every 30 days. The take-up of Freeserve has been guesstimated at over 400,000 customers, but there was no indication of the churn rate, and given that users are at liberty to create more than one account (say, for isolated use or test purposes) and then let them expire, I would expect the fall-out rate to be high once the initial start-up feeding frenzy begins to filter through.

The general feeling voiced in some of the Freeserve newsgroups as well as the Turnpike newsgroup **demon.internet.support.turnpike** (Turnpike at **www.turnpike.com** is a useful dial-up access and mail software package suitable for the majority of UK-based ISPs – and it runs with Freeserve) is that its users welcome and appreciate the free service, and only a minority have had subsequent problems when they tried to de-install it. There are minor grumbles about connectivity and routing but I saw nothing particularly worrying.

Give it a Whirl

Yesterday, I tried Freeserve. However, I heeded the advice of some other users who commented that the free Dixons CD can be troublesome, so I avoided that altogether and signed up on-line without the need to install any special browser or even to use MSIE 4.0. The web site **www.tarrcity.demon.co.uk/tp/add-0091.htm** gives all the practical details of how to set up an initial Dial-Up Networking (DUN) "connectoid" to enable a temporary connection to be configured to the Freeserve registration server, to avoid the possibility of wrecking an existing setup (Internet Explorer 4.0 settings in particular). The web site contains tips and data that might help an experienced user avoid some pitfalls.

Having quickly configured a temporary DUN session, I dialled up the Freeserve secure server and completed the formalities in about five minutes. The online registration process involved reading through a long raft of totally indigestible Terms and Conditions with which I finally lost patience, then I also skipped through an impertinent questionnaire and selected a suitable hostname of "nwin" – hence I became the proud owner of the moniker **al@nwin.freeserve.co.uk**. I seem to remember that's how "epemag" was born when I opened the very first *EPE* E-mail account.

To be fair, the Freeserve on-line registration warns that it will change your Internet settings, and there is an option to cancel. It is at this point that the experienced user will probably say "no thanks" though others may decide to go with it. There were no further problems and a welcome E-mail from Freeserve was immediately delivered to my newly created mailbox. I now have a free backup connection which works, but it is still too soon to pass judgment on Freeserve. I must say that I have experienced several line drops after dialling in (which doubles the cost of the call), though I have not had any problems with stability or speed.

At that rate, the consumer really can't go wrong, provided that they are duly aware of the possibility of the installation messing around with their settings should they desire to remove it. Freeserve will undoubtedly cost other ISPs some lost dial-up business, though a professional user will probably not wish to be seen to be making do with a "free" address.

More to Come

In the coming months, I will be discussing more Internet services and applications which may help the *EPE* reader to get more out of the Internet. For example, I'll be looking at free web pagers that deliver messages to your desktop when you're on-line, various real-time "chat" and messaging services, and examining in-depth what is probably the world's most popular software download at the moment – ICQ, which is a real hoot to play with. According to site statistics, 600,000 people a week agree.

As usual, I have placed some ready-made links for you to click on, in the *Net Work* page of the *EPE* web site. I welcome suggestions by E-mail to **alan@epemag.demon.co.uk**. My Home Page is **http://homepages.tcp.co.uk/~alanwin** which was recently updated. See the amazing photos of my 70 m.p.h. drive down the main runway of my local airport in a Barracuda Fire Tender, courtesy of Humberside International Airport! See you next month.

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MORE READERS NEXT MONTH
Don't miss out
(see page 83 for details)

EPE NET ADDRESSES

EPE FTP site: **ftp://ftp.epemag.wimborne.co.uk**

Access the FTP site by typing the above into your web browser, or by setting up an FTP session using appropriate FTP software, then go into quoted sub-directories:

PIC-project source code files: **/pub/PICS**

PIC projects each have their own folder; navigate to the correct folder and open it, then fetch all the files contained within. *Do not try to download the folder itself!*

EPE text files: **/pub/docs**

Basic Soldering Guide: **solder.txt**

EPE TENS Unit user advice: **tens.doc** and **tens.txt**

Ingenuity Unlimited submission guidance: **ing_unlt.txt**

New readers and subscribers info: **epe_info.txt**

Newsgroups or Usenet users advice: **usenet.txt**

Ni-Cad discussion: **nicadfaq.zip** and **nicad2.zip**

UK Sources FAQ: **uksource.zip**

Writing for *EPE* advice: **write4us.txt**

Ensure you set your FTP software to ASCII transfer when fetching text files, or they may be unreadable.

Note that any file which ends in **.zip** needs unzipping before use. Unzip utilities can be downloaded from : **http://www.winzip.com** or **http://www.pkware.com**

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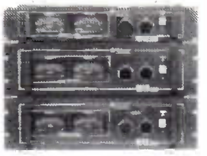

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PRICE:- £179.00 per pair

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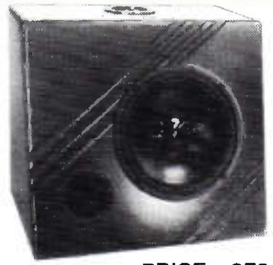

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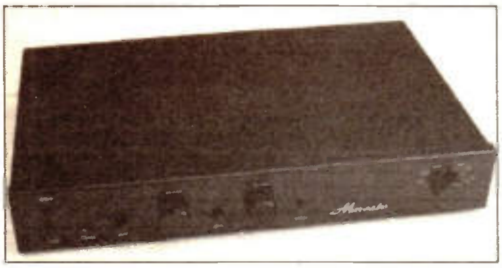

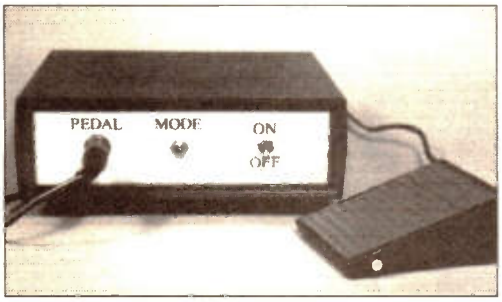

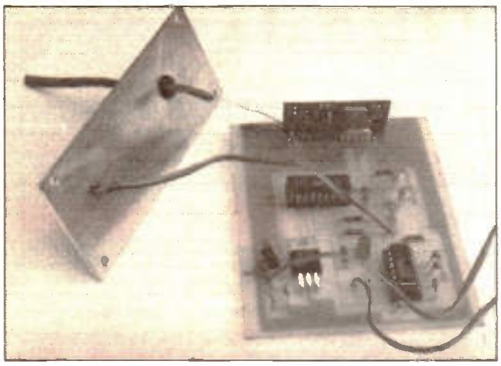

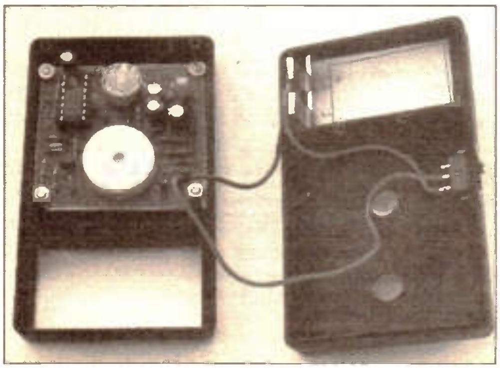

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Next Month
ETI readers join us
– see page 83

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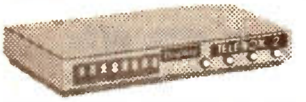

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TELEBOX ST for composite video input type monitors	£36.95
TELEBOX STL as ST but fitted with integral speaker	£39.50
TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6 mHz sound specification.
*For cable / hyperband signal reception Telebox MB should be connected to a cable type service. Shipping on all Telebox's, code (B)

NEW **State of the art PAL (UK spec) UHF TV tuner module with composite 1V pp video & NICAM hi fi stereo sound outputs. Micro electronics** all on one small PCB only 73 x 160 x 52 mm enable full software control via a **simple 2 wire link** to any IBM type computer. Supplied complete with **simple working program and documentation**. Requires +12V & + 5V DC to operate.
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3½" **CONNER** CP3044 40mb IDE I/F (or equiv.) RFE	£69.00
3½" **RODIME** RO3057S 45mb SCSI I/F (Mac & Acorn)	£69.00
3½" **QUANTUM 40S Prodrive** 42mb SCSI I/F, New RFE	£49.00
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Mitsubishi FA3415ETKL 14" SVGA Multisync colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including **IBM PC's** in CGA, EGA, VGA & SVGA modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE**. Many features: Etched faceplate, text switching and **LOW RADIATION MPR** specification. Fully guaranteed, supplied in EXCELLENT little used condition.

Tilt & Swivel Base £4.75 **Only £119** (E) Order as MITS-SVGA
VGA cable for IBM PC included.
External cables for other types of computers CALL

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Full multisync etc. Full 90 day guarantee. £325.00 (E)

Just in - Microvitec 20" VGA (800 x 600 res.) colour monitors. Good SH condition - from £299 - CALL for info

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with **both RGB and standard composite 15.625 Khz video inputs** via **SCART socket** and separate phono jacks. Integral audio power amp and **speaker for all audio visual uses**. Will connect direct to **Amiga and Atari** BBC computers. Ideal for all **video monitoring / security** applications with **direct connection to most colour cameras**. High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested - guaranteed
Dimensions: W14" x H12¾" x 15½" D. **Only £99** (E)

PHILIPS HCS31 Ultra compact 9" colour video monitor with **standard composite 15.625 Khz video** input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive square black plastic case measuring W10" x H10" x 13½" D. 240 V AC mains powered. **Only £79.00** (D)

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Superbly made UK manufacture. PIL all solid state colour monitors, complete with composite video & *optional* sound input. Attractive teak style case. Perfect for Schools, Shops, Disco, Clubs, etc.In EXCELLENT little used condition with full 90 day guarantee.

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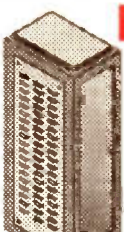

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Virtually New, Ultra Smart
Less than Half Price!

Top quality 19" rack cabinets made in UK by **Optima Enclosures Ltd.** Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and louvered removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the ***most versatile we have ever sold***. Racks may be stacked side by side and therefore require only two side panels to stand singly or in multiple bays.
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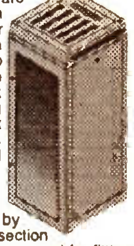
Over 1000 racks, shelves, accessories 19" 22" & 24" wide 3 to 46 U high. Available from stock !!.

32U - High Quality - All steel RakCab



Made by **Eurocraft Enclosures Ltd** to the **highest possible spec**, rack features **all steel construction** with removable side, front and back doors. Front and back doors are **hinged for easy access** and all are lockable with five **secure 5 lever barrel locks**. The front door is constructed of double walled steel with a **'designer style'** smoked acrylic front panel to enable status indicators to be seen through the panel, yet remain unobtrusive. Internally the rack features fully slotted reinforced vertical fixing members to **take the heaviest of 19" rack equipment**. The two movable vertical fixing struts (extras available) are pre punched for standard 'cage nuts'. A **mains distribution panel** internally mounted to the bottom rear, provides 8 x IEC 3 pin Euro sockets and 1 x 13 amp 3 pin **switched utility socket**. Overall ventilation is provided by fully louvered back door and double skinned top section with top and side louvres. The top panel may be removed for fitting of **integral fans** to the sub plate etc. Other features include: fitted castors and floor levelers, prepunched utility panel at lower rear for cable / connector access etc. Supplied in **excellent**, slightly used condition with keys. Colour Royal blue. External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23¾" W)
Sold at LESS than a third of makers price !!

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shipping charges for RAM / CPU upgrades is code B

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STOP PRESS ANNOUNCEMENT

NEXT MONTH

Next month we will be joined by the readers of ETI. *We have just purchased* ETI (Electronics Today International) *from Nexus Special Interests Ltd, and will merge the magazine into* EPE *from the March 99 issue. This will mean you will be getting an even better magazine and, with the strength of an increased readership, we will be able to continue to bring you the widest range of projects, features, news and products to buy.*

Watch out for the familiar Everyday Practical Electronics *logo on the news-stands – from next month you will also see the* ETI *logo on the cover, as shown below. See the Editorial page for more details.*

TIME AND DATE GENERATOR

With the availability of cheap video cameras, more and more people are adding surveillance cameras to the exterior and interior of their homes. Cameras connected to a video recorder will record all sorts of amusing and sometimes nefarious activities, and usually it is useful to know the precise time that these events occurred. The generator inserts a steady and easily readable time and/or date caption onto any composite video signal. The time and date information is displayed at the bottom of the screen.

Although originally intended for adding time and date information to security cameras, it is equally useful for adding time and date to home videos for those who have not got this capability built into their video camera. This design is based on a PIC16C84 which performs the real time clock function and display character generation. The main features of the unit are: ● Adds time or date or both to a composite video signal (NTSC, PAL and SECAM video signals) ● Selectable character height of 5, 10, 15 or 20 lines ● Inverse or normal video display ● Day and month display are swappable for those who prefer the American standard ● Leap year correction ● Year 2000 compliant.

AUTO CUPBOARD LIGHT

Commercial battery-operated cupboard lights are widely available in DIY stores and by mail order from electronic component suppliers. These lamps are useful as a simple means of lighting up a cupboard or other dark area. They are also handy for garden sheds and other places where no mains supply exists.

The one drawback is that if they are left on, the batteries are exhausted with monotonous (and expensive) regularity. This simple project provides automatic timed control of the light.

SMT SMOKE ABSORBER

When working with tiny surface mount devices (SMDs) the constructor is drawn closer to the circuit in order to get a clear view of the soldering operation. Close working with SMDs therefore involves a much higher risk of solder fumes being inhaled and potential bronchial problems. The smoke absorber is very compact and can be placed close to any circuit during population. It will remove the solder fumes from the immediate area.

The smoke absorber is automatically triggered by the heat from the soldering iron and it switches off after about half a minute unless re-triggered. Very useful for all hobbyist soldering operations.

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- Easy to build & use
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- Detects gold, silver, ferrous & non-ferrous metals
- Efficient quartz controlled microcontroller pulse generation.
- Full kit with headphones & all hardware

KIT 847....................£63.95

PIC PIPE DESCALER

- SIMPLE TO BUILD
- SWEPT FREQUENCY
- HIGH POWER OUTPUT
- AUDIO & VISUAL MONITORING

An affordable circuit which sweeps the incoming water supply with variable frequency electromagnetic signals. May reduce scale formation, dissolve existing scale and improve lathering ability by altering the way salts in the water behave.
Kit includes case, P.C.B, coupling coil and all components.
High coil current ensures maximum effect. L.E.D. monitor

KIT 868 ....£22.95 POWER UNIT.........£3.99

SPACEWRITER

An innovative and exciting project. Wave the wand through the air and your message appears. Programmable to hold any message up to 16 digits long. Comes pre-loaded with "MERRY XMAS". Kit includes PCB, all components & tube plus instructions for message loading.

KIT 849.....................£16.99

12V EPROM ERASER

A safe low cost eraser for up to 4 EPROMS at a time in less than 20 minutes. Operates from a 12V supply (400mA). Used extensively for mobile work – updating equipment in the field etc. Also in educational situations where mains supplies are not allowed. Safety interlock prevents contact with UV.

KIT 790...........................£28.51

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Our latest design – The ultimate scarer for the garden. Uses special microchip to give random delay and pulse time. Easy to build reliable circuit. Keeps pets/pests away from newly sown areas, play areas, etc. Uses power source from 9 to 24 volts.

- RANDOM PULSES
- HIGH POWER
- DUAL OPTION

Plug-in power supply £4.99

KIT 867...............................£19.99
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1 WATT O/P, BUILT IN SPEAKER, COMPACT CASE
20kHz-140kHz
NEW DESIGN WITH 40kHz MIC.

A new circuit using a 'full bridge' audio amplifier i.c., internal speaker, *and* headphone/tape socket. The latest sensitive transducer, and 'double balanced mixer' give a stable, high peformance superheterodyne design.

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KIT 856...£28.00

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Our very popular project – now with ready built probe assembly and diecast box. Picks up vibrations amplifies, and drives headphones. Sounds from engines, watches, and speech through walls can be heard clearly. Useful for mechanics, instrument engineers and nosey parkers! A very useful piece of kit.

KIT 865.......................£29.95

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DUAL OUTPUT TENS UNIT

As featured in March '97 issue.

Set of 4 spare electrodes £6.50

Magenta have prepared a FULL KIT for this excellent new project. All components, PCB, hardware and electrodes are included.
Designed for simple assembly and testing and providing high level dual output drive.

KIT 866.... Full kit including four electrodes £32.90

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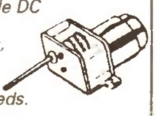

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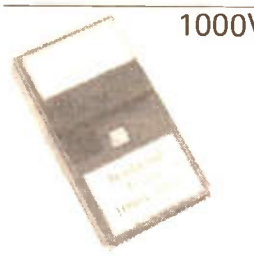

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3-NOTE DOORCHIME

IDEAL BEGINNERS PROJECT

Uses SAB0600 chip to produce natural sounding 3-note chime. Adjustable pitch – so that two can be used for front and back doors.
Kit includes P.C.B., all parts and instructions.
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EELONGATED LOGO

With the merger of *Everyday Electronics* and *Practical Electronics* back in November 1992 we have been saddled with the cumbersome title of *Everyday Practical Electronics*. Whilst it was *EE* that bought out *PE*, the *PE* title had a longer history and many loyal readers, so we wanted to keep both names. Over the years there have been a number of editorial discussions on whether or not we should change it to something rather less of a mouthful – it doesn't roll off the tongue, does it? We have never actually reached a decision on this so things were simply left alone. However, I guess we are about to be forced into making a move quite soon.

Why? Because we have just purchased *Electronics Today International (ETI)* and from next month we will be merging that into *EPE*. For at least a few months you will be seeing both the *EPE* and *ETI* logos on our front cover, and elsewhere through the magazine, but it will clearly be silly to call ourselves "Everyday Practical Electronics and Electronics Today International", or even EPETI so perhaps we could go for some shorter combination – your suggestions would be of interest.

Personally, I favour dropping back to just the initials of *EPE*, perhaps with the word International underneath – maybe we could use a dynamic new logo like the one for *EPE Online* – see page 129. Or perhaps we should become EPEI, or PEI, or EEI or even EPEI – the list goes on.

CHANGE BUT NO CHANGE

One thing all this does mean is that your copy of *EPE* will *not* change dramatically – you will still find all the regular news, features, projects, theory and help that we bring you each month; although you will probably notice a couple of small changes to titles of things like our *Innovations* pages or *Techniques*, just to make sure those readers coming to us from *ETI* feel at home. We also hope to add to our range of advertisers so that there will be a greater selection of things to buy in each issue. In fact all that will happen is that *EPE* will become an even stronger magazine with the ability to bring you even better projects and features.

We will, of course, go on packing every page full of information and bringing you the widest range of full constructional projects plus news, features, theory, etc. and not forgetting all our regulars like *IU*, *Circuit Surgery*, *Techniques*, *Readout*, *News* and *Network*.

Make sure you don't miss out on your copy. We suggest you place an **order now** as demand is bound to be very high. Details of the content of the March issue can be found on page 75. Don't worry, we won't be putting up the price of your magazine.

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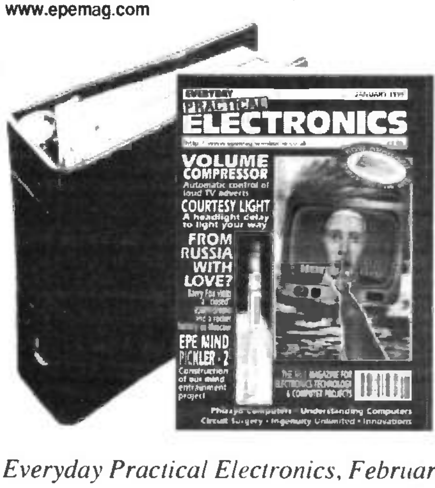

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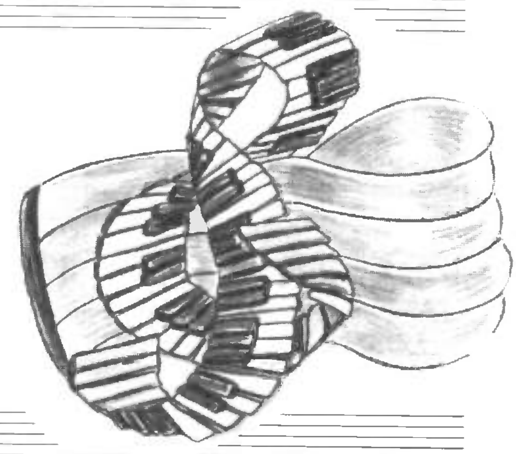


PIC MIDI SUSTAIN PEDAL

ROBERT PENFOLD

Take your PIC from sustain to glissando effect with this low-cost MIDI pedal.

IN THE pre-MIDI era it was common for synthesisers, electronic pianos, etc. to have a socket for a pedal-operated switch. The footswitch normally functioned as a sustain pedal, with the last note or notes played being held on for as long as the pedal was operated.

This is similar to, but not quite the same as the sustain pedal of a piano. A few instruments had sockets for other types of pedal, or could switch the single pedal input to a different function.

VERSATILE PIC

In the post MIDI era this type of input is virtually extinct, and functions such as sustain and swell pedals are handled via the MIDI input. This offers great versatility, and in many ways is a step forward, but it brings a major drawback in that simple switches are no longer sufficient. In order to add even simple pedal functions such as sustain and portamento it is necessary to have some fairly complex and expensive electronics to produce the proper signals to drive a MIDI input.

This problem has now been mitigated to a large extent by the availability of inexpensive microcontrollers such as the PIC range of processors. A MIDI Sustain Pedal was described in the May 1995 issue of *EPE*, and this used a UART plus 10 other integrated circuits.

The PIC based design featured here can be switched to operate as either a Sustain Pedal or a Portamento type, and uses no integrated circuits other than the PIC microcontroller itself. Unlike its predecessor, this unit uses so few components that it is suitable for those having limited experience at electronic project construction, including complete beginners.

MIDI BASICS

MIDI (Musical Instruments Digital Interface) is a form of serial signal, and it is in many ways similar to the ordinary RS232C system used in computing and other applications. It is different to the RS232C system in several respects though, and one of these is the nature of the signals generated.

The RS232C system uses voltages of about plus and minus 12V to represent the two logic levels, whereas MIDI utilizes a current loop system. A switching transistor at the output of a sending device is switched off to represent logic 1, and turned on to represent logic 0. MIDI uses normal eight-bit bytes, and each byte is sent one bit at a time.

With this serial approach to exchanging signals it is essential that the transmitting and sending devices remain accurately synchronised. Otherwise the receiving device will be reading bit 5 when the transmitting device is actually sending bit 4 or 6!

TIMING

The use of standard baud rates is the main aid to accurate synchronisation. MIDI operates at 31250 baud, which simply means that a continuous stream of signals would be sent at a rate of 31250 bits per second. This rate may seem to be an odd choice, but it is easily implemented using standard 1MHz, 2MHz, and 4MHz crystals in the clock oscillator (1MHz divided by 32 = 31250Hz).

There is another aid to accurate synchronisation in the form of additional bits sent with each byte of data. The most important of these is the *Start bit*.

Under standby conditions the output transistor is switched off, but to indicate the start of a byte it is switched on for a duration that is equal to the length of one data bit (31·25ms). This indicates to the receiving device that it must read in the first data bit about 46·87µs later, which is about half way through the first data bit.

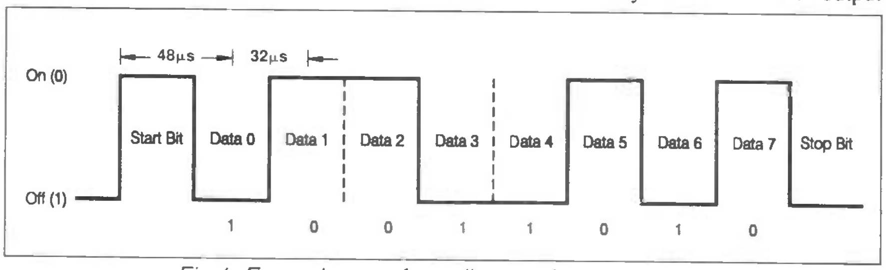
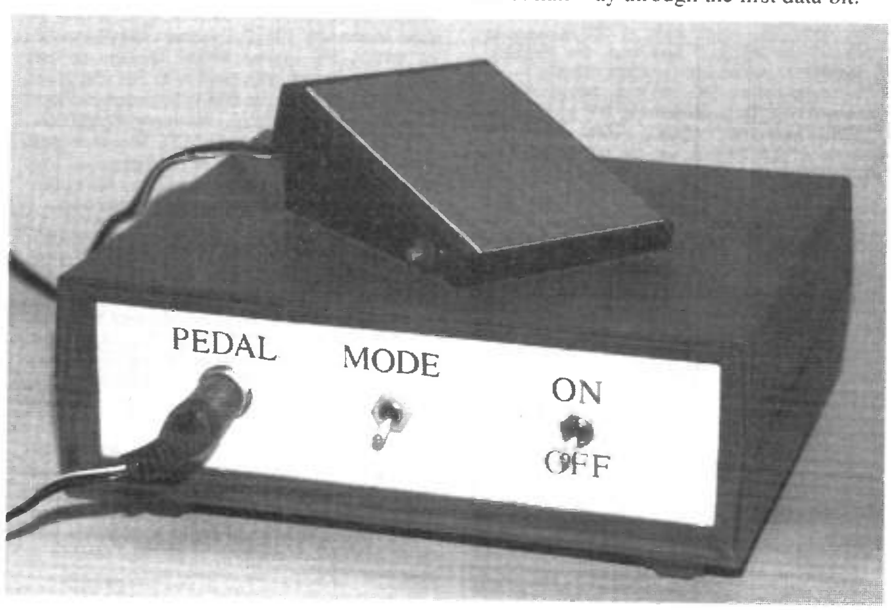


Fig. 1. Example waveform diagram for a MIDI byte.



The other data bits are then read in at 31·25μs intervals. The least significant bit is sent first, working through to the most significant bit.

Finally, the Stop bit is sent, but this is really just placing a small gap between the end of one byte and the beginning of the next. This gives the receiving device time to digest one byte of data before the next is commenced. This general scheme of things is demonstrated by the example waveform of Fig.1.

GETTING THE MESSAGE

Normal MIDI messages are coded into one, two, or three bytes, and in this case we are using control change messages that have three bytes. The first byte is the Status byte, and this has to be considered as two nibbles, which have separate functions.

The four most significant bits indicate the type of message that is being sent. In this case the message is a control change type, and this has the binary code 1011.

The least significant nibble carries the channel number, and is from 0000 (channel 1) to 1111 (channel 16). In an application of this type the channel used is not usually of any significance, and the convention is for channel 1 to be used.

The second byte carries the control number, and indicates which control must be altered. MIDI status bytes always have the most significant bit set at 1, while data bytes have this bit set to 0. This means that data bytes can only contain values from 0 to 127 (decimal).

Most of the available control numbers have been assigned to specific controls or to special functions. Here we are controlling the sustain and portamento functions, which are respectively control numbers 64 and 63.

The third byte carries the new setting for the control, and under the old scheme of things it could only be 0 (off) or 127 (on). The current system is more easy-going, with values from 0 to 63 switching a control off, and values from 64 to 127 switching it on.

As there is a large amount of MIDI equipment still in use that predates the current MIDI specification, it is essential to use values of 127 to switch on a control and 0 to turn it off.

In order to give the desired effect the PIC MIDI Sustain Pedal must generate a three byte message to switch on the Sustain or Portamento function, and a slightly different message when the pedal is released in order to switch it off again. The three byte message required to switch ON the sustain effect (top), and the slightly different message needed to switch it OFF is shown in Fig.2. The only difference is that the final byte is 127 in the first message, and 0 in the second.

receiving device. This opto-isolation helps to avoid problems with earth loops, and also reduces problems with digital noise finding its way into the audio stages of MIDI instruments.

The screen of the connecting cable connects to pin 2 of SK2, and it is therefore earthed to the 0V supply of the Pedal Unit. However, it is *not* connected to anything at the receiving unit, and there is no direct electrical connection between the Pedal Unit and the MIDI device that it controls. Resistors R4 and R5 provide current limiting d.c. points that, together with a resistor in the receiving device, set the l.e.d. current at approximately the required figure of 5mA.

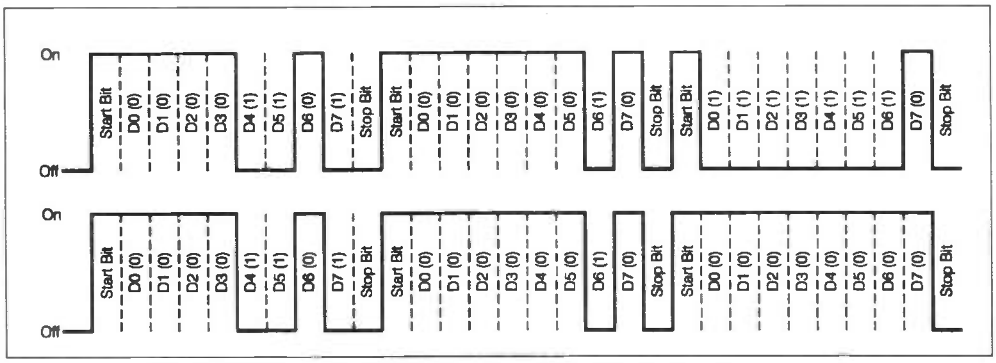


Fig.2. MIDI sustain ON (top) and sustain OFF (bottom) messages.

CIRCUIT OPERATION

The circuit diagram for the PIC MIDI Sustain Pedal is shown in Fig.3. The circuit is based on a PIC16C54 microcontroller, IC1, and in order to guarantee the accurate timing required in this application a crystal controlled clock circuit, formed by capacitors C2, C3 and crystal X1, is used. A 4MHz clock frequency is the maximum that the 16C54-XT/P can handle, but is more than adequate to give good timing accuracy.

Only two lines of port B are used, and these monitor switches S1 and S2. S1 is the Pedal footswitch and it is monitored by RB0, at IC1 pin 6. Line RB1, at IC1 pin 7, monitors S2, which is the Mode switch.

The output signal is generated on RA0 (IC1 pin 17), which drives the common emitter switching transistor TR1. This transistor drives the internal l.e.d. in an opto-isolator at the input of the

A supply potential of about 4V to 5V is required, and a 4·5V battery pack is probably the most practical power source. Even though a relatively high clock frequency of 4MHz is used, the current consumption of the circuit is typically just under 2mA, which should give around 1000 to 2000 hours of operation from each AA-cell battery pack.

SOFTWARE

As with many PIC based projects, the hardware is ridiculously simple because the software is doing most of the work. Only a brief operating description follows, but the software is available from the Editorial Office on a 3·5in. disk, see *PCB Service* page. If you have access to the Internet it can be downloaded free. See *Shoptalk* page for details of obtaining a ready-programmed PIC16C54-XT/P microcontroller.

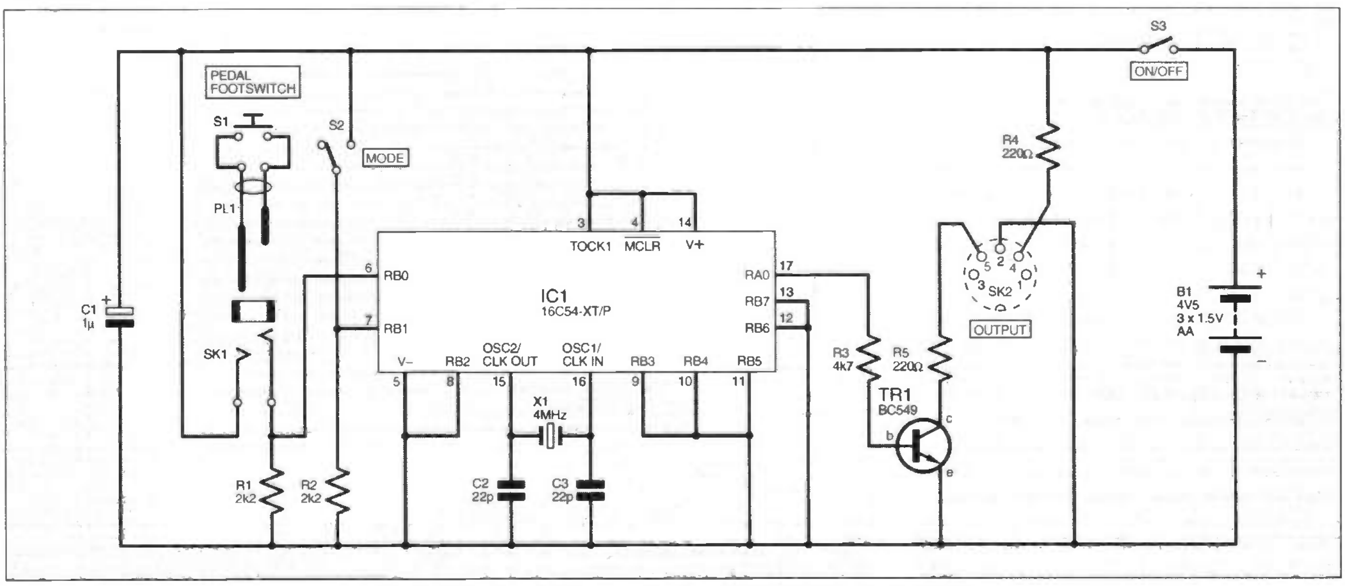


Fig.3. Full circuit diagram for the PIC MIDI Sustain Pedal.

MAIN LOOP

The main program loop monitors Pedal switch S1, and calls a series of three subroutines when S1 is pressed. These subroutines each generate one byte of the message that switches on the appropriate control. There is a slight complication here, because the control number used in the message must be 63 or 64 (Portamento or Sustain), depending on the setting of Mode switch S2.

The simple solution is to include both subroutines in the main loop, but with each one preceded by a bit test instruction that results in the subroutine being skipped if switch S2 is at the wrong setting. This results in a control number of 63 being used if S2 is *open*, or a control number of 64 being used if it is *closed*.

Once the three subroutines have been called and the "control on" message has been sent, switch S1 is monitored again. There is no need for a delay here to provide contact de-bouncing, because this is effectively provided by the millisecond or so that it takes to send the first MIDI message.

CONTROL OFF

When S1 is released, the main loop calls three subroutines that generate the "control off" message. This operates in exactly the same manner as before, but a different subroutine is used for the third byte.

This generates a data byte containing a value of 0 rather than 127, so that the control is switched off instead of being switched on. The program then loops back to the beginning and monitors S1 again.

The subroutines generate the serial bytes using the same basic process. A bit set or bit clear instruction is used to set RA0 high or low, as required, and a simple delay loop then provides a suitable delay before the next bit is generated. This process is repeated ten times, once for each bit (eight data bits plus start and stop bits).

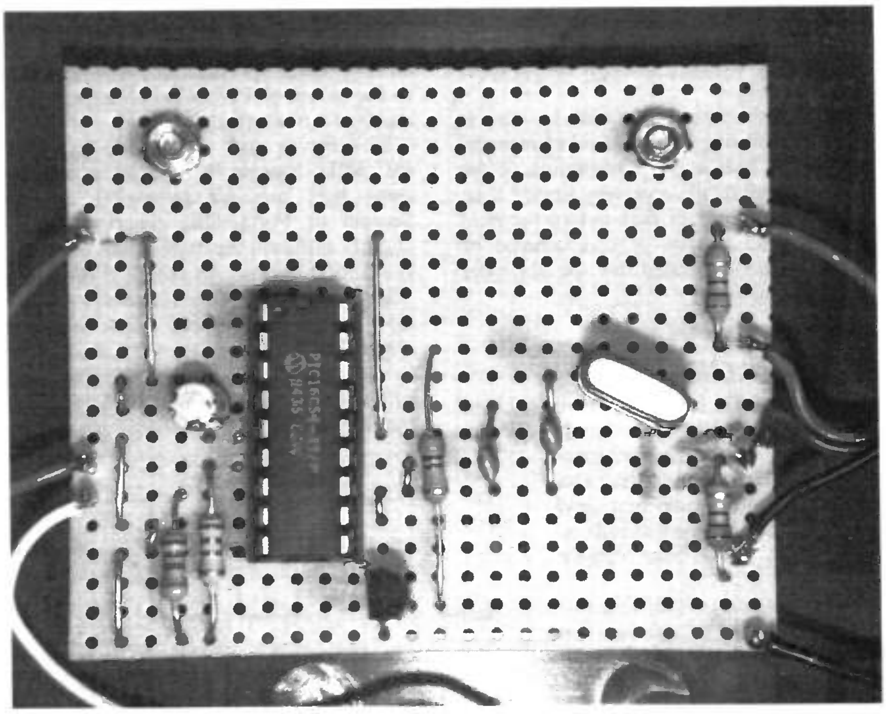
Although it is a rather long-winded way of handling things, this method does make it easy for the experimenter to change the value of any bit in any byte. It is merely necessary to change the appropriate BSF message to a BCF type, or vice versa.

CONSTRUCTION

Details of the stripboard component layout and the hard wiring are provided in Fig.4. The underside view of the board showing the required breaks in the copper strips also appears in this diagram. The board measures 24 holes by 20 copper strips.

With very few components and link-wires to deal with, construction of the board is quite simple. However, bear in mind that the PIC microcontroller is a CMOS device, and that it therefore requires the usual anti-static handling precautions. It must be fitted in a d.i.l. socket and not soldered directly into the board.

Do not plug it into its socket until the unit is complete in all other respects, and try to handle the pins as little as possible when plugging it into the holder. The PIC chip should be stored in its anti-static packing and kept well away from any potential sources of static electricity. Crystal X1 must be a miniature wire-ended type if it is to fit easily into this layout.



Layout of components on the completed stripboard. Make sure you include the four very small link wires.

ASSEMBLY

This unit can take one of two general forms. The obvious approach is to build it as a sort of pseudo effects pedal, complete with a built-in foot-operated switch on the top panel.

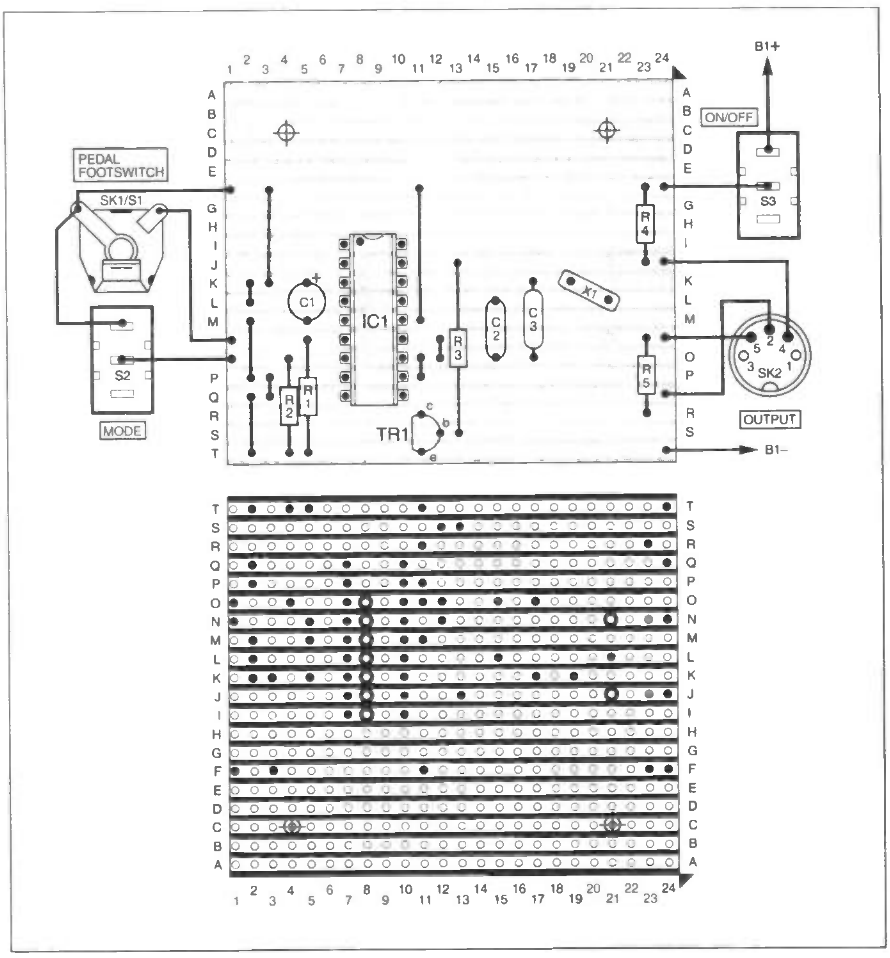


Fig.4. Stripboard topside component layout, interwiring to off-board components and underside view of the copper tracks showing locations of breaks required in the strips.

COMPONENTS

Resistors

R1, R2	2k2 (2 off)
R3	4k7
R4, R5	220Ω (2 off)

All 0·25W 5% carbon film

See SHOP TALK Page

Capacitors

C1	1µ radial elect. 50V
C2, C3	22p ceramic plate (2 off)

Semiconductors

TR1	BC549 *npn* silicon transistor
IC1	PIC16C54-XT/P pre-programmed microcontroller (see text)

Miscellaneous

S1	foot-operated or pushbutton switch; push-to-make, release-to-break (see text)
S2, S3	s.p.s.t. min toggle switch (2 off)
SK1	standard mono jack socket, with matching plug (see text)
SK2	5-way 180° panel mounting DIN socket
B1	4·5V battery pack (3 x AA size cells in holder)
X1	4MHz miniature wire-ended crystal

Metal case, type and size to choice (see text); 0·1 inch matrix stripboard, measuring 24 holes by 20 strips; 18-pin d.i.l. socket; battery connector (PP3 type); MIDI lead; multistrand connecting wire; solder pins; solder, etc.

Approx Cost Guidance Only £14
excl. case, pedal switch & batts.

If you take this route it is essential to use a suitably strong case. A die-cast aluminium box is a popular choice for this type of thing, and cases of this type are very tough indeed.

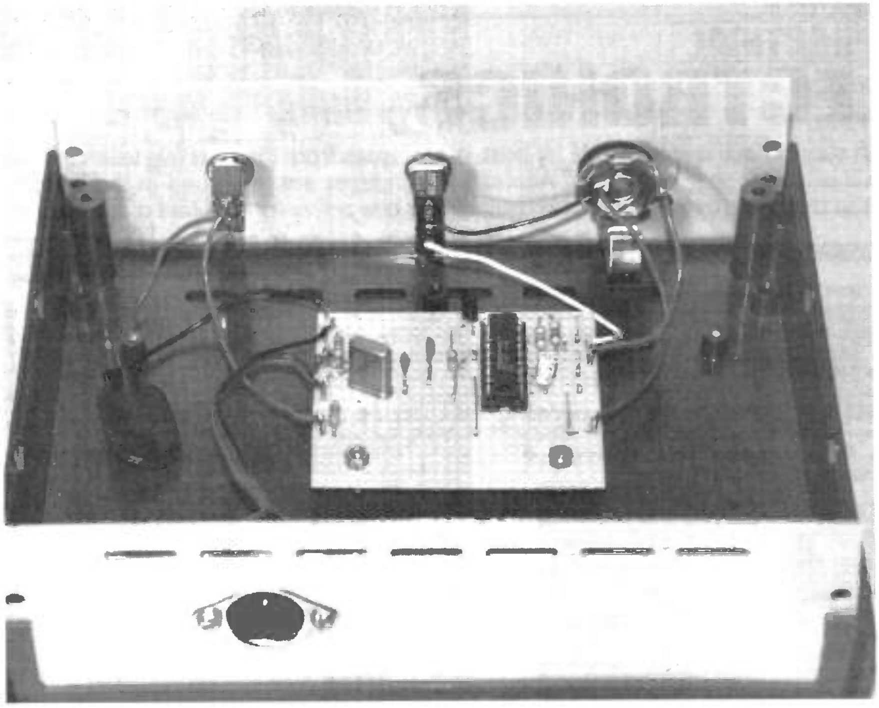
A simple folded aluminium box should be strong enough though, and represents a much cheaper alternative. Most plastic cases are not well suited to this application.

FOOTSWITCH

The switch used for S1 must be a fairly tough component having a large button that can be easily operated by foot. A small pushbutton switch of the "cheap and cheerful" variety would be very difficult to operate and would probably not stand up to the rough treatment likely to occur in this application. It must be a simple push-to-make, release-to-break type, and not one that toggles state each time it is operated.

The popular alternative approach, and the one used for the prototype, is to build the unit as a conventional project, and to use a separate "custom" pedal switch for S1. Switches of this type are usually fitted with a lead about one metre long terminated in a standard jack plug.

Therefore, if this method is used, a standard jack socket is fitted to the case and connected in place of S1, as shown in Fig.4. Again, the switch used for S1 must have a simple push/release action, and not some form of successive operation.



Positioning of the circuit board inside the prototype metal instrument case and wiring to the front panel mounted switches and "pedal" jack socket. The MIDI 5-way DIN connector is mounted on the rear panel.

IN USE

Using a crystal controlled clock avoids the need for any setting up. Provided socket SK2 is a 5-way (180 degree) DIN socket connected in the manner shown in Fig.4, the unit can be connected to the synthesiser or other MIDI instrument using a standard MIDI lead.

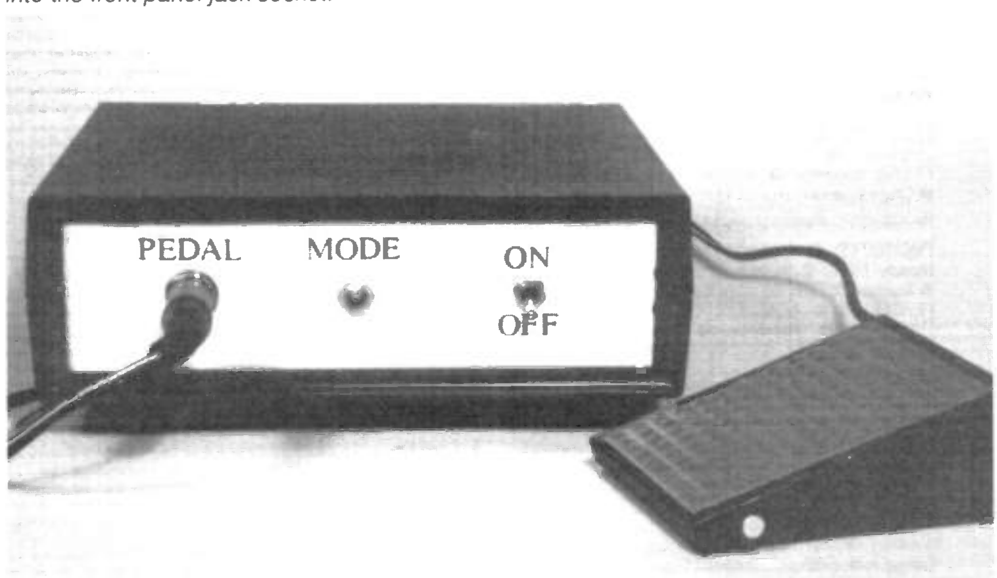
This has so-called straight connection, with pin 2 on one plug connecting to pin 2 on the other, pin 4 connecting to pin 4, and pin 5 connecting to pin 5. Note that some 5-way DIN audio leads have cross coupling of the pins, and that they are unsuitable for use with MIDI equipment.

It is probably best to start with the Sustain effect (S2 open), as this one is implemented by most MIDI instruments. Notes should hold on indefinitely with S1 pressed, but the MIDI instrument will only respond properly if it is set up correctly. Where appropriate, the MIDI interface must be enabled, and the instrument must either be set to receive on channel 1 or set to Omni mode so that it will respond to messages on any channel.

With the unit switched to the Portamento mode (S1 closed) the instrument will "glide" from one note to the next giving a glissando effect, rather than jumping in pitch from one note to the next. Unfortunately, this control is not implemented on many instruments.

A check of the MIDI implementation charts for your instruments will show which particular control numbers are implemented. There is obviously no point in building this project unless at least one of your instruments responds to control number 63 or 64.

Completed PIC MIDI Sustain Pedal with a typical pedal type footswitch plugged into the front panel jack socket.



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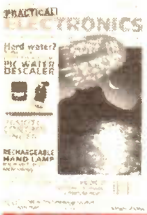

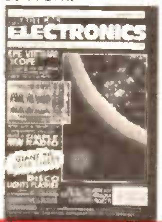

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FEATURES ● 8051-based EEPROM Microcontrollers ● TEACH-IN '98 – An Introduction to Digital Electronics – 8 ● Circuit Surgery ● Techniques – Actually Doing It ● Ingenuity Unlimited

JULY '98

PROJECTS ● PIC16x84 Toolkit ● Noise Cancelling Unit ● Low Battery Indicator ● Greenhouse Computer – 1.
FEATURES ● Using the L200CV Voltage Regulator ● TEACH-IN '98 – 9 ● Ingenuity Unlimited ● Circuit Surgery ● Net Work.

AUG '98

PROJECTS ● Lightbulb Saver ● Float Charger ● PC Transistor Tester ● Greenhouse Computer – 2 ● Time Machine Update.
FEATURES ● TEACH-IN '98 – 10 ● Circuit Surgery ● Techniques – Actually Doing It ● Ingenuity Unlimited ● New Technology Update ● Net Work ● IVEX PCB Cad Review.

SEPT '98

PROJECTS ● Mains Socket Tester ● Personal Stereo Amplifier ● Greenhouse Radio Link ● PIC Altimeter.
FEATURES ● TEACH-IN '98 – 11 ● Ingenuity Unlimited ● Circuit Surgery ● Interface ● Net Work ● Crocodile Clips Review.

OCT '98

PROJECTS ● Voice Processor ● Digiserv R/C Channel Expander ● Reliable Infra-Red Remote Control ● PC Capacitance Meter.
FEATURES ● Easy PCB Making ● Using LM335 and LM35 Temperature Sensors ● Circuit Surgery ● Ingenuity Unlimited ● Net Work ● Electronics Principles 5.0 Review.

NOV '98

PROJECTS ● PIC Tape Measure ● T-Stat Electronic Thermostat – 1 ● PhizzyB Computers – 1 ● 15-way Infra-Red Remote Control.
FEATURES ● Circuit Surgery ● Ingenuity Unlimited ● New Technology Update ● Net Work – The Internet ● Easy PC for Windows 95 Review ● *FREE* EPE CD-ROM No.1.

DEC '98

PROJECTS ● EPE Mind PICkler–1 ● Fading Christmas Lights ● Handheld Function Generator ● Damp Stat Electronic Thermostat ● PhizzyB Computers–2.
FEATURES ● PhizzyB Computers–2 Understanding Computers ● Circuit Surgery ● Ingenuity Unlimited ● Interface ● Net Work – The Internet ● 1998 Index ● *FREE* 48-page Understanding Passive Components booklet.

JAN '99

PROJECTS ● Alternative Courtesy Light Controller ● Twinkle Twinkle Reaction Game ● Volume Compressor ● PhizzyB Computers–3 ● EPE Mind PICkler–2.
FEATURES ● New Technology Update ● From Russia With Love ● Circuit Surgery ● PhizzyB Computers–3 ● Net Work.

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Please note we are not able to supply copies (or 'stats of articles) of *Practical Electronics* prior to the merger of the two magazines in November 1992.

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M2/99

Innovations

A roundup of the latest Everyday News from the world of electronics

CLOSING THE NET

Barry Fox reports that media moguls now have their eyes on the Net.

RUPERT Murdoch now wants to create his own, closed, Internet. The media magnate's satellite broadcast company BSkyB is working with British Telecom, the Midland Bank and Matsushita (Panasonic) to offer an all-electronic trading infrastructure called Open which uses proprietary technology to deny users open access to the Internet.

The joint venture, British Interactive Broadcasting, is heavily subsidising the cost of digital satellite receivers which have been designed to let viewers progress seamlessly from watching movies and sport to purchasing goods and services from firms which will pay BIB a commission of up to 20 per cent.

Retail chains including Woolworths, Iceland and Great Universal Stores have already pledged to offer home shopping on BIB's Open service, the Midland Bank will provide on-line banking and Ford, Unilever and Coca Cola will inject their adverts. There will also be a games site. After trials starting late this year, Open will ramp up to a full consumer launch in the third quarter of 1999.

Subsidies from BIB currently halve the cost of Sky's digital satellite set-top boxes, to under £200. Sky's fitters install the necessary dishes free. The viewer only has to agree to let the fitter connect the receiver to a phone line. The fitter will even lay extension phone wires free if necessary. Over 100,000 people have signed up since Sky launched its digital TV service on 1 October '98.

The moment the receiver box is connected, its internal 28·8 kilobits/second modem automatically dials BIB's central computer to register the box's serial number. The modem then dials out to report when the box owner watches pay-per-view movies or sports events. Even if no PPV charges are incurred, the modem dials out intermittently to confirm it is still connected. If the viewer unplugs the phone, Sky can send signals over the air which stop the receiver working and then claim back the subsidy.

The box has on-board memory which stores the electronic programme guide software developed by US company OpenTV to tell viewers what TV programmes are available. As BIB's Open rolls out, Sky will transmit a series of software upgrades by satellite which automatically download to convert all receivers in the country into interactive terminals.

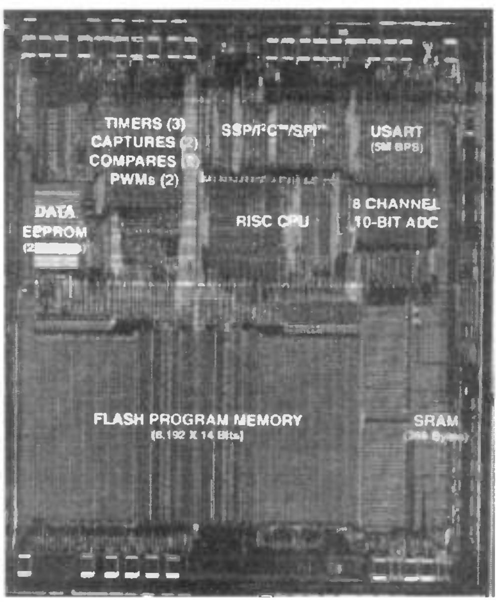
The upgraded software will allow E-mail for personal messages and targeted mailshots, but it cannot access the Internet and display HTML pages. Instead, the satellite will continuously deliver information at a rate of 68Mbit/s. The viewer browses this, going on line only when a transaction is carried out or a game played.

The infra-red eye on the satellite receiver, currently used with a remote control to switch TV channels, can interface with a keyboard. "It's like a shopping mall" says BIB's Chief Executive James Ackerman "Businesses will lease space. It will be much cheaper for them than running a shop".

Ackerman hopes to reach 14 million shoppers within five years, with data capacity from the satellite trebling to cater for up to ten virtual shops, half a dozen information providers, a games site and financial services. BIB is planning online gambling.

If viewers use their TVs to access the Open service, instead of paying a Service Provider to connect to the open Internet by PC, BSkyB and BIB can build and control a new electronic marketplace. But since BIB was formed in May 1997, Dixons has launched Freeserve which offers open access to the entire Internet at no charge, in return for a personal shopping profile of the user.

NEW FLASH PICS



We have been expecting it for some time, and now Microchip have sent it – information on the introduction of two new 8-bit flash microcontrollers.

What is significant about the PIC16F876 and PIC16F877 is that they are, in effect, greater-capacity versions of the renowned PIC16F84 (and PIC16C84) devices. These, as so many of you are aware, can be re-programmed again and again without the need for u.v. erasure (in other words, they can be regarded as EEPROM devices). This makes them ideal microcontrollers to use for project development.

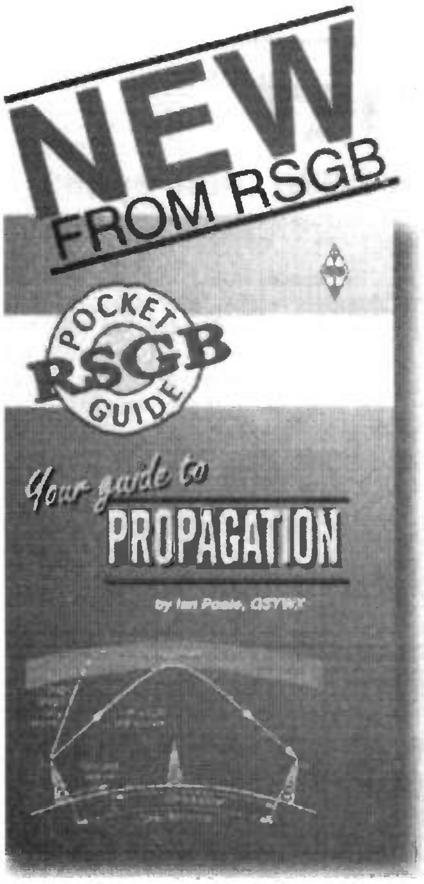
These new RISC-based flash devices are also the first to use Microchip's innovative Migratable Memory technology, which provides socket and software compatibility among all equivalent ROM, OTP and flash memory controllers.

The PIC16F876 and PIC16F877 feature 8K × 14 bits of *Enhanced* Flash program memory, 256 bytes of EEPROM data memory, and operate between 2V and 5·5V. Additionally (and importantly) they include integral 5- to 8-channel 10-bit A/D converters, RS485-type UART, and up to 5MIPS performance at 20MHz.

We shall be investigating these new and long-awaited devices a.s.a.p. There are more due to be introduced as well. We intend to upgrade our *PIC16x84* programmer to cater for these PICs – watch our pages!

For more information contact Arizona Microchip Technology Ltd, Microchip House, 505 Eskdale Road, Winnersh Triangle, Wokingham, Berks RG41 5TU. Tel: 0118 921 5858. Fax:0118 921 5835. Web: http://www.microchip.com.

PROPAGATION



THE Radio Society of Great Britain (RSGB) has published a new book – *Your Guide to Propagation*. Whatever your interest in radio (says the press release), understanding the propagation of signals is of great importance. If you wish to hear or work DX stations around the world, it's vital to know not only the characteristics of each band, but how other influences, such as time of day and state of the sun, can affect it.

To help non-scientists get the most out of their radios, the RSGB has produced this handy, easy-to-read guide which is packed with information. Moreover, it's written by Ian Poole G3YWX who, of course, is the respected author of our monthly *Technology Update* column.

The chapter titles are: Introduction to Radio Wave Propagation; Radio Waves; The Atmosphere and the Sun; Ionospheric Propagation; Ionospheric Storms and Aurora; Predicting, Assessing and Using HF Propagation; Other Ionospheric Modes; Tropospheric Propagation; Meteor Scatter; Appendix.

The book costs £6.99 (excl p&p). It has 88 pages (177mm × 111mm). ISBN: 1-872309-69-6.

For more information contact: Radio Society of Great Britain, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE. Tel: 01707 659015. Web: www.rsgb.org.

E.O.C.S. PICS UP

READING through the Electronic Organ Constructors Society (E.O.C.S.) latest magazine (Nov '98), we were pleased to see that they too are interested in PIC microcontrollers. Indeed, it appears to have been our *PIC Tutorial* series (Mar-May '98) that has helped to get them involved.

Honorary Secretary Don Bray, we are told through the magazine's pages, held the South Coast Branch meeting at his home in October. Amongst other things of importance to such a society, he also demonstrated PIC Tut and its board to the gathered members.

The report continues, "Don explained how useful and interesting he found the course and some of the things he hoped to do with suitably programmed chips in his instrument. Most people (but not everyone present) seemed to recognise and feel able to share his enthusiasm".

Qualified praise it may be (*not everyone?!*), but it's still praise! Good luck to you all at the E.O.C.S. with your endeavours – perhaps with this latest mention of you from us (bribed, of course, by your mention of PIC Tut!) some more of our readers might care to join you.

Anyone with an interest in electronic organs and such things is encouraged to join this active society. It has branches around the country – and has had for decades.

More details from Don Bray, 34 Etherton Way, Seaford, Sussex BN25 3QB (tel: 01323 894909) – tell him *EPE* told you to ask!

SQUIRES TOOL CAT

SQUIRES' 1999 model and craft tools catalogue has landed on the News Desk with a thump! It must be the biggest yet – over 330 A4 pages of all the tools that any hobbyist who loves making things by hand would love to own and use. And, let's face it, all of us who find enormous pleasure in making something always want as many tools around as funds permit (indeed, many of us delight in owning tools just for the sake of it – one day, we think, we'll need them!).

So, Squires's cat really ought to be on your workroom bookshelf – there's so much in it (too much to itemise but we doubt if you'll spot many omissions) to tempt you. It's all well illustrated, priced and indexed.

Squires also exhibit around Britain at various craft exhibitions and fairs – we'll be surprised if you haven't already met them if you enjoy such outings.

For more information, contact Squires Model & Craft Tools, Dept EPE, 100 London Road, Bognor Regis, PO21 1DD. Tel: 01243 842424. Fax: 01243 842525.

CROSSPAD

CIT, Computerised Information Technology Ltd, have sent us information on CrossPad which, with its revolutionary handwriting recognition software, is "an innovative product at its best".

This sleek and lightweight machine is just slightly bigger than an A4 pad. It can save around 50 pages of your handwritten notes, transport them to your PC, convert them all to ASCII text. As a PC file you can search, store, save, re-organise, cut and paste, E-mail and fax all your notes in handwritten form or ASCII text.

CrossPad is compatible with virtually all Windows 95 applications.

For more information, contact Computerised Information Technology Ltd., Dept EPE, 20 Potters Lane, Kiln Farm, Milton Keynes, Bucks MK11 3HF. Tel: 01908 260082. Fax: 01908 260084. E-mail: info@cituk.com.

BANNING JUNK

AT last – the Government has issued draft regulations designed to grant consumers protection against unwanted direct marketing "junk" faxes and phone calls.

The proposals will give consumers the power to refuse all unsolicited direct marketing calls, by opting out and registering with a centralised list of subscribers who don't want to receive these calls.

Interestingly, to quote the press release from the DTI, "the Government reserves the right to amend the Regulations ... this could include introducing an *opt-in* approach, under which such calls would only be allowed to be made to consumers who had agreed to receive such calls".

What is also needed (somehow) is better protection against junk E-mails that pester those of us on the Net – including material that some people may find offensive, and possibly illegal in Britain.

MASSIVE TEST GEAR RANGE

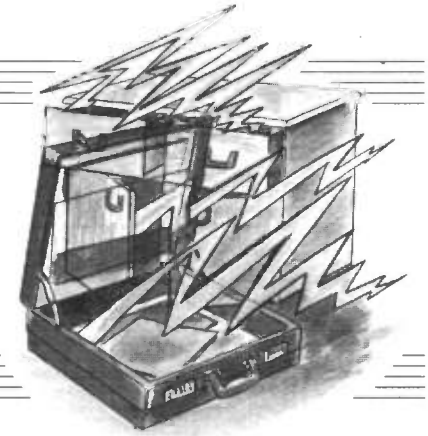
IF you are looking for a much wider range of test gear than stocked by many suppliers, the latest Test and Measuring catalogue from PID (Professional Instrument Distributors) could well have what you want.

Over 600 test and measurement instruments are detailed, covering what seems to be every conceivable aspect of electronics. The 56-page full-colour catalogue is free to anyone who asks – it's a pity, though, that it does not give prices for the items illustrated. The PID covers the UK for sales, calibration, repairs and hire.

For more information contact PID, Dept EPE, 3 Brackenley Court, Embsay, North Yorks BD23 6PX. Tel: 01756 799737.

Constructional Project

LIGHT ALARM



GAVIN CHEESEMAN

A take it with you, low-cost, pocket-sized, light-activated alarm

QUITE often, situations arise where it is useful to have a simple alarm that can be placed with personal items to alert the owner if they are being tampered with. There are many ways of producing such a device, each with its inherent advantages and disadvantages.

In this article, we look at a circuit that is triggered by the presence of light. Although relatively simple in concept, the unit has a wide variety of uses ranging from indicating when a cupboard or drawer has been opened to operating as a simple luggage alarm.

CIRCUIT DETAILS

The full circuit diagram for the Light Alarm is shown in Fig.1. It will be seen that the circuit is based around the 40106 hex Schmitt inverter, IC1. Power to the circuit is controlled by switch S1 with capacitors C2 and C6 acting as supply de-coupling.

Darlington transistor TR1, combined with capacitor C1, diode D1 and resistor R1, effectively provide a delay period after switch-on, in which the circuit is unaffected by the ambient light level. This acts as a kind of exit delay to allow you a short time after switching on before the alarm is triggered and can be useful when placing the unit in a cupboard, drawer etc.

The circuit is temporarily prevented from triggering by holding IC1a pin 1 high for the duration of the switch-on delay. Initially, when switch S1 is first closed, the voltage across capacitor C1 is negligible and enough current flows through the base (b) of TR1 to ensure that it is switched on.

As capacitor C1 begins to charge the voltage drop developed increases until a point is reached where current ceases to flow in the base of TR1. At this point TR1 turns off and the voltage at IC1 pin 1 then becomes a function of the potential divider comprising R3, VR1 and R4, a light dependent resistor (l.d.r.) as discussed later.

A Darlington transistor has been chosen for TR1 because it requires only a very small base current to switch on. Diode D1 is included to ensure that capacitor C1 is discharged at power down.

LIGHT WORK

The circuit makes use of a light dependent resistor, R4, to detect the ambient light level. This is connected in series with preset potentiometer VR1 (wired as a variable resistor) and resistor R3, forming a potential divider. The combined effect of the resistance of each element in the divider chain determines the input voltage to IC1a at pin 1.

The l.d.r. (R4) has a high resistance in the dark but this falls drastically when the device is exposed to light. As a result, the voltage at IC1a pin 1 is heavily dependent on the ambient light level, increasing in darkness and falling notably in bright light. The luminance level at which the input voltage to IC1a reaches the switching threshold can be varied by adjusting preset VR1.

In a dark environment, where the voltage at IC1a pin 1 is above the switching threshold, the output on IC1a pin 2 sits in a logic low state. In this condition the alarm output is disabled.

If the voltage at pin 1 of IC1a falls below the switching threshold (due to light falling on the sensor), this results in a logic

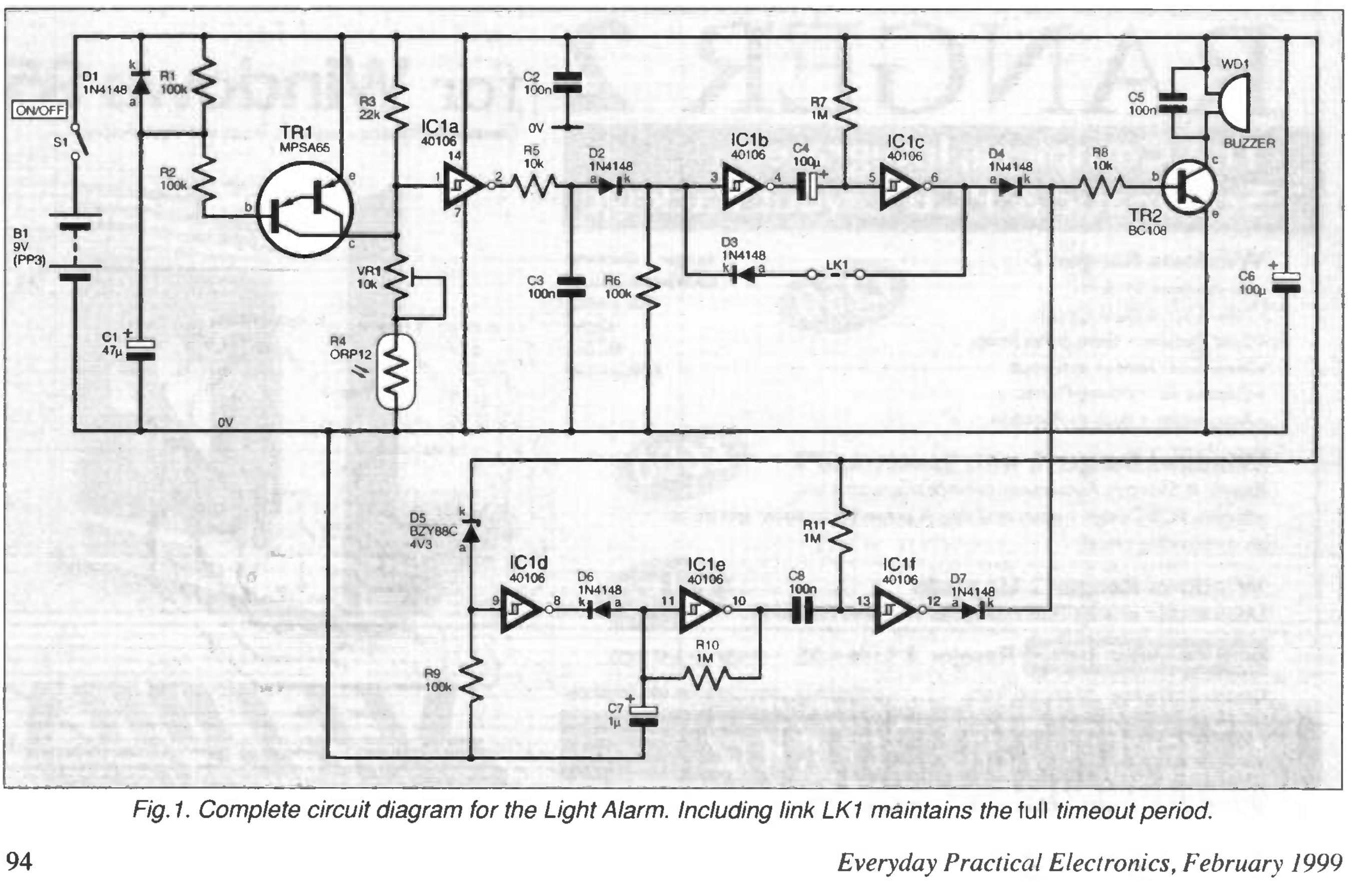


Fig.1. Complete circuit diagram for the Light Alarm. Including link LK1 maintains the full timeout period.

high at pin 2. Under this condition, D2 is forward biassed, pulling IC1b pin 3 high. As a result, pin 4 of IC1b switches to logic low and this initially applies a logic low condition to IC1c pin 5, via capacitor C4.

This causes the output at IC1c pin 6 to switch to logic high. At this point capacitor C4 starts to charge via resistor R7, resulting in an increasing voltage level at IC1c pin 5. When this voltage reaches the switching threshold, the output at pin 6 switches back to a logic low state.

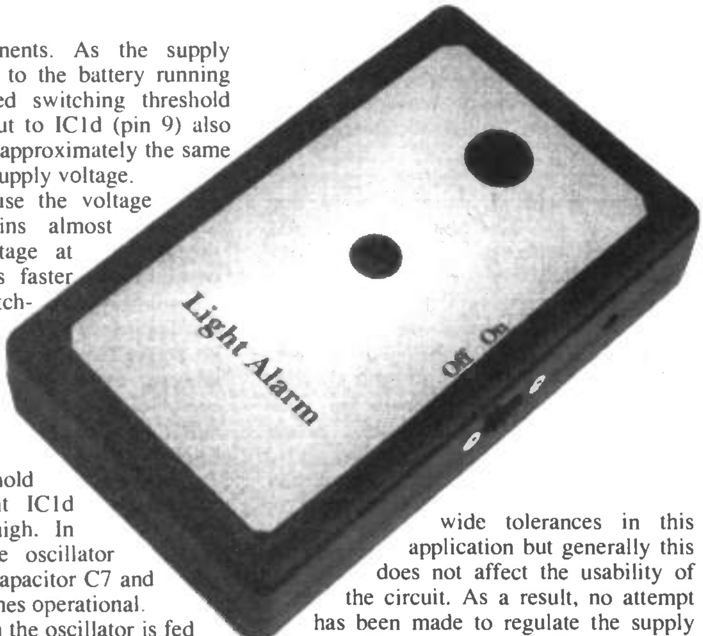
If a wire link (LK1) is fitted, the output from IC1c pin 6 is connected back to pin 3 via diode D3. This has the effect of maintaining a high output at pin 6 until the timeout is complete even if the trigger event is only momentary. If the link is not fitted the output will switch high only for the period that light is falling on l.d.r. R4.

In both cases, when IC1c pin 6 switches to a high condition this turns on transistor TR2 activating buzzer WD1. Resistor R8 limits the transistor base current. Capacitor C5 helps to reduce any high frequency noise coupled onto the supply from the buzzer.

ON THE LOW SIDE

The remaining parts of the circuit serve to provide a low battery indication. The function of this part of the circuit is based on the fact that when correctly biassed, Zenor diode D5 maintains a relatively constant voltage drop independent of supply voltage.

At normal supply voltages the output at IC1d pin 8 is low inhibiting the low frequency oscillator formed by IC1e and associated components. As the supply voltage drops due to the battery running down, the required switching threshold voltage at the input to IC1d (pin 9) also drops but remains approximately the same percentage of the supply voltage.



However, because the voltage across D5 remains almost constant, the voltage at IC1d pin 9 drops faster than the i.c.s switching threshold as the supply voltage drops. Eventually, a point is reached where the input voltage falls below the threshold and at this point IC1d pin 8 switches high. In this condition the oscillator formed by IC1e, capacitor C7 and resistor R10 becomes operational.

The output from the oscillator is fed to capacitor C8, resistor R11 and IC1f which effectively narrow the pulse width reducing the average current consumption of this section of the circuit when active. The output at IC1f pin 12 is fed to the base (b) of transistor TR2 via diode D7 and resistor R8.

When the low battery condition is active, the buzzer is powered up for the duration of each pulse producing a repetitive beeping sound. At normal supply voltages the output at IC1f pin 12 is low and therefore does not affect the operation of the rest of the circuit.

Circuit timings and thresholds have wide tolerances in this application but generally this does not affect the usability of the circuit. As a result, no attempt has been made to regulate the supply voltage and standard tolerance capacitors have been used.

CONSTRUCTION

All the components for the Light Alarm, except the On/Off switch and battery, are mounted on a single, small printed circuit board (p.c.b.). The component layout and full-size copper foil master are shown in Fig.2. This board is available from the *EPE PCB Service*, code 218.

Referring to the component layout in Fig.2, start construction with the low profile components, such as the resistors and diodes, working up to the larger parts.

COMPONENTS

Resistors

R1, R2, R6, R9	100k (4 off)
R3	22k
R4	ORP12 light dependent resistor
R5, R8	10k (2 off)
R7, R10, R11	1M (3 off)

All 0·6W 1% metal film

See SHOP TALK Page

Potentiometer

VR1	10k enclosed carbon preset, vertical

Capacitors

C1	47μ radial elect. 16V
C2, C3, C5 C8	100n disc ceramic (4 off)
C4, C6	100μ radial elect. 16V (2 off)
C7	1μ radial elect. 63V

Semiconductors

D1 to D4, D6, D7	1N4148 signal diode (6 off)
D5	BZY88C4V3 4·3V Zener diode
TR1	MPSA65 *pnp* Darlington transistor
TR2	BC108 *npn* transistor
IC1	40106BEY CMOS hex Schmitt inverter

Miscellaneous

S1	s.p.d.t. sub-min. slide switch
WD1	3V to 24V d.c. low-profile, p.c.b. mounting buzzer; 5mA at 12V
B1	9V PP3 type battery, with clips

Printed circuit board available from the *EPE PCB Service*, code 218; plastic case, with battery compartment, size 103mm × 62mm × 23mm; 14-pin d.i.l. socket; multistrand connecting wire; M3 3mm (1/8in.) spacers, M3 16mm (5/8in.) countersink head bolts, M3 nuts and M3 shakeproof washers (4 off each); solder pins; solder etc.

Approx Cost Guidance Only **£17** excluding battery

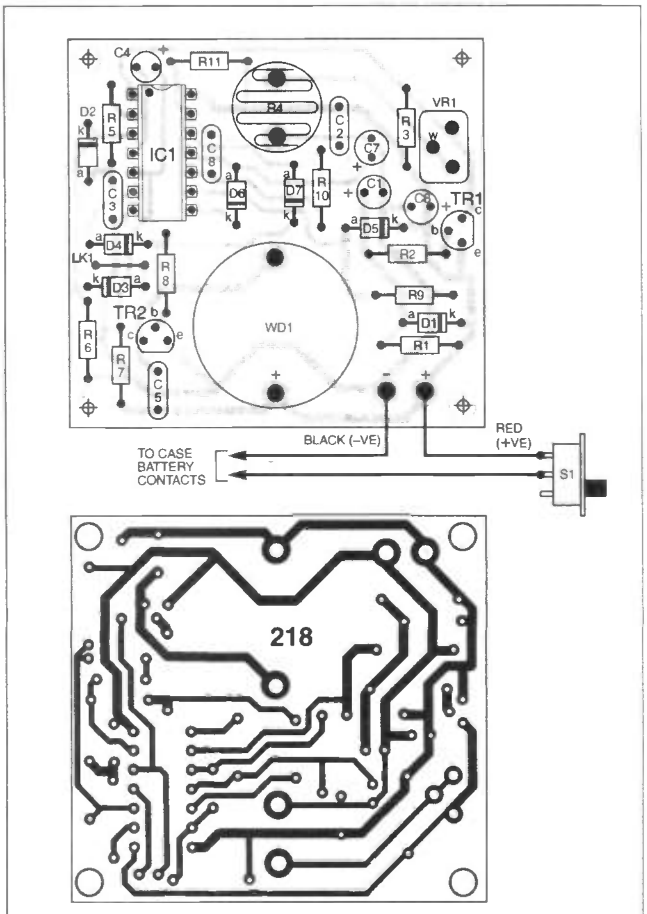


Fig.2. Light Alarm printed circuit board component layout, full-size copper foil master and wiring to the battery connector and On/Off slide switch.

It is recommended that an i.c. socket is used for IC1 to prevent any possibility of heat damage to the i.c. during soldering. Do not insert the i.c. into its socket at this stage.

Take care that all polarised components are inserted with the correct polarity. The notch on the i.c. and socket should correspond with that on the component layout.

The polarity of the electrolytic capacitors are marked on the layout diagram with a positive (+) symbol, whereas most capacitors are now marked with a negative (−) symbol on their component body. Therefore, when inserting the capacitors into the p.c.b., ensure that the lead adjacent to the negative symbol on the component is positioned in the hole furthest from the plus symbol on the overlay.

Transistors and diodes should be inserted on the board such that the shape of the component body corresponds with that on the component layout. The cathodes (k) of the diodes are indicated by a band at one end of the component. The polarity of the specified buzzer WD1 is clearly marked adjacent to its pins and the positive connection is marked with a plus symbol in the component layout diagram Fig.2.

ASSEMBLY

It is necessary to wire the battery terminals and On/Off switch S1 to the p.c.b. Ordinary hook-up wire can be used for these connections. It is recommended that you use p.c.b. solder pins to connect these leads to the board, see Fig.2. These should be inserted into the appropriate holes in the p.c.b. from the track side, and pressed into position using only a minimum amount of pressure.

When soldering the p.c.b. take care that you do not create any unwanted dry joints or solder short circuits across copper tracks/pads. Once all components are in place, and before you plug IC1 into its socket, it is best to double check your work to avoid later problems.

TESTING

It is probably best to test the Light Alarm before it is finally installed into its case. There is nothing worse than spending time tidying everything up only to find that when you test the unit some rework is required on the p.c.b. and you have to start all over again.

Snap the battery into its connector, taking care to observe the correct polarity. The circuit is designed to operate from a 9V PP3 type battery. The unit may also be powered from a bench supply set to 9V for testing purposes if this is more convenient. If you use a bench power supply, it is recommended that the output current is limited to less than 100mA, just in case there is a fault on the circuit board.

If you have a multimeter, it may be useful to temporarily connect this in series with the positive (+V) supply lead, set to measure d.c. current. Set switch S1 to the On position.

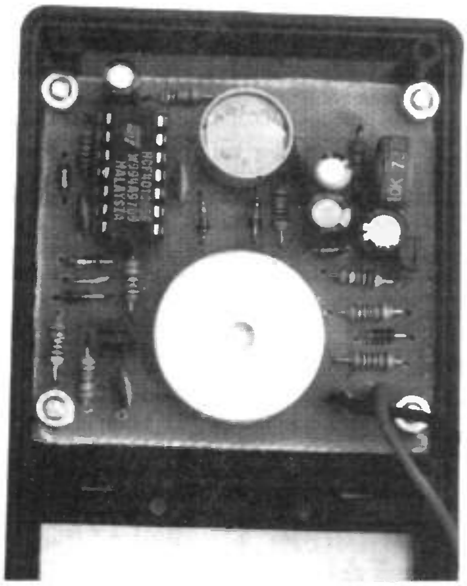
The current consumption should momentarily peak and then slowly drop as capacitors in the circuit charge. The current should settle at around 0·2mA when buzzer WD1 is silent. If the current reading exceeds 10mA at any time after the initial switch on pulse, switch off and re-check the board for short circuits or incorrectly fitted components.

SETTING UP

Set preset VR1 to about the central position of its track using an appropriate screwdriver or trimming tool. Initially, ensure that the p.c.b. is positioned such that the l.d.r. is exposed to bright light.

Assuming all is well, when power is first applied to the circuit, there should be no sound from the buzzer. After a few seconds, the switch-on delay should be complete and at this stage, if sufficient light is falling on the l.d.r., the buzzer should emit a continuous piercing tone. The buzzer should continue to operate for a few seconds until the circuit times out.

When the buzzer has stopped sounding, momentarily place your hand over the l.d.r. so as to obscure the light. When you remove your hand the buzzer should once again sound until the timeout period is complete.



Circuit board bolted into the lower half of the case.

If the link wire (LK1) is fitted, the buzzer should sound for the whole timeout period even if the l.d.r. is only exposed to light for a short period. If the link is not fitted, the sound should only continue as long as the l.d.r. is exposed to light. There is no reason why an off-board switch cannot be connected in place of the link if you prefer the operating mode to be selectable.

Adjusting preset VR1 changes the sensitivity of the circuit to light. Different settings should result in the circuit triggering at different light levels.

If you are using a variable power supply you can test the operation of the low battery indication by reducing the supply voltage. To carry out this test, either cover the l.d.r. before switching on or wait until the timeout is complete and the circuit is silent.

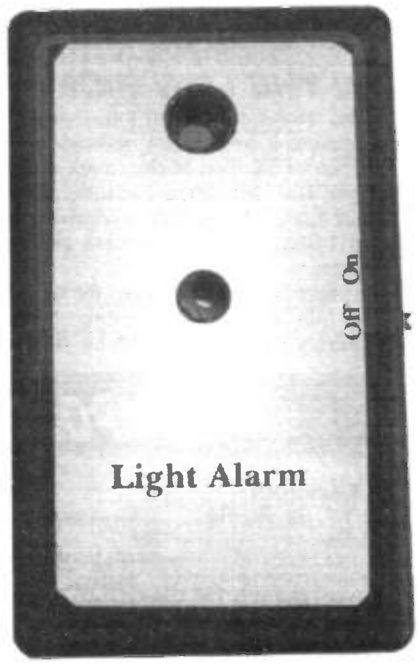
If everything is working correctly, as you reduce the supply voltage you should reach a point where the buzzer starts to emit repetitive beeps. This is the low battery indication and typically comes into operation at supply voltages below approximately 4V.

FINAL ASSEMBLY

Having completed the testing and setting up of the completed circuit board, it is time to install it into its case. The recommended case measures only 103mm × 62mm × 23mm. This case is convenient for small projects like the Light Alarm as it also has a built in battery compartment and an optional belt clip, which may be fitted if required.

It is necessary to drill several holes in the case for the p.c.b. fixings and for switch S1. The p.c.b. can be temporarily dropped into the case to provide a template for the board mounting holes. Countersink the holes for the p.c.b. and switch mounting screws so that the screw heads are level with the case when fully inserted. The case material is relatively thin so make sure that you do not over-drill the countersinks.

Holes are also required in the case immediately above the light dependent resistor (R4) and the buzzer WD1 so that these components are unobstructed. It is essential



The light "window" and sound exit holes should align with the l.d.r. and warning buzzer when the case is closed up.

to the operation of the circuit that sufficient light can fall on the l.d.r. The approximate positioning of these holes may be seen in the photographs of the finished Alarm.

Switch S1 is mounted in a convenient position on the side of the case such that it lines up with any legend on the front panel label. The switch is mounted in the front half of the case without the detachable battery cover and is fixed in position using two M2 countersink head screws, see photographs. The mounting holes of the specified switch are threaded, so there is no need to use nuts.

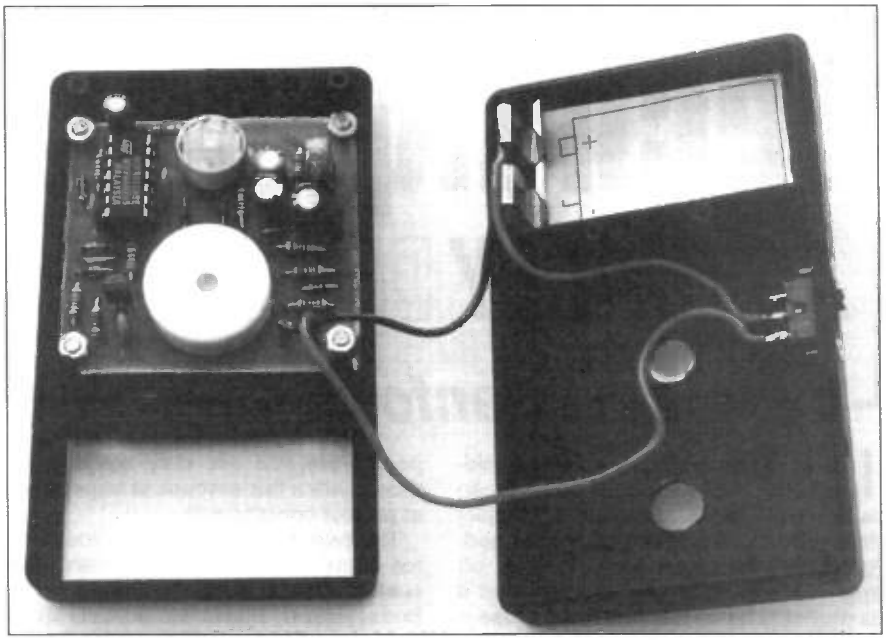
The p.c.b. is installed into the lower half of the case, the part with the battery cover. It should be mounted on M3 spacers and is held in place using M3 countersink head screws and M3 nuts. Do not forget to fit the shakeproof washers, as these help to prevent the screws from becoming loose due to vibration etc.

Before fitting the two halves of the case together, it is necessary to route the wires to the battery terminals through the gap at one end of the battery compartment. When the wires are routed correctly, the case sections should fit together with ease and there should be no excessive gaps.

The two halves of the case are held together using the two screws supplied. To fit these it is necessary to remove the battery cover to expose the two fixing holes. Insert and tighten the screws until the two halves of the case are held firmly together. Do not apply excessive force as this will tend to strip the thread cut into the plastic pillar by the screw.

The battery area is intended to accept a PP3 battery. There are slight differences in size between different makes of PP3 battery and you may find some types are a fairly tight fit. However, if you have problems, do not try to force the battery cover into position as this may damage the battery or case.

A front panel label may be made up from some thin card and attached to the front of the case using a suitable adhesive. Carefully align the label with switch S1 and the edges of the case. It will, of course, be necessary to cut two holes in the label corresponding with the position of the holes drilled in the case for the l.d.r. and warning buzzer.



Wiring between the two halves of the completed Alarm case. The p.c.b. is situated in the section which takes the battery cover. Note the siting of the On/Off slide switch on the side of the case.

IN USE

The Light Alarm lends itself to a variety of different uses. A typical application would be to indicate unauthorised access to cupboards or drawers. Alternatively, the alarm could be used to give warning that your briefcase has been opened.

Of course, the alarm will only work in any application if sufficient light falls on the l.d.r. sensor when the alarm is required to trigger. The unit is not generally suitable for use as a building intruder alarm as it has limited sound output level and is relatively easily disabled.

In some cases the Light Alarm may be arranged to trigger if an item is removed. You may be able to place the object that you are trying to protect on top of or over the alarm such that significant levels of light are prevented from falling on the l.d.r. sensor. If the item is removed, light falls on the sensor and the alarm sounds.

Depending on the light level where the alarm is being used it will be necessary to adjust the setting of preset VR1 to provide the most appropriate response. A small hole can be drilled in the side of the case adjacent to the preset potentiometer to cater for this. The setting should be such that in the dark condition, the alarm is not triggered and in the light condition the unit is triggered reliably.

Positioning is also important. You need to make sure that the l.d.r. is reliably exposed to light under the conditions where it is intended that the alarm should be triggered. For example, if the unit is used in a drawer, sufficient light must fall on the sensor when the drawer is open. It is obviously no good placing the alarm under piles of paperwork, because the chances are it will just not work

TIMEOUT

Whether or not you decide to fit the link wire will depend on your application. If you are using the alarm to warn of unauthorised access, you will probably want the unit to continue to sound for its timeout period or until switched off. Therefore, in this case link LK1 will need to be fitted. However, if you are using the alarm as an audible reminder that, for example, a darkroom door is open, then link LK1 should be omitted.

If you are unhappy with the alarm timeout period, this can be changed by adjusting the value of C4 and/or R7. Alternatively, if you wish you can disable the alarm timeout entirely by fitting a link in place of C4.

IN CONSIDERATION

The Light Alarm is intended to operate at normal room temperature. Extremes of temperature may affect the operation of the alarm and should therefore be avoided.

In particular, circuit timings will be altered and the operation of IC1 may become unpredictable. Some CMOS devices can be notoriously unreliable at low temperatures. Similarly, avoid damp locations.

The light alarm is a simple project but can give surprisingly good performance when properly used. We have covered the basic applications but there are probably plenty more.

Some readers may like to experiment with a different sounder in place of WD1 to give more output or provide a different sound. This should be possible so long as you do not exceed the maximum current and power ratings for transistor TR2.

Techniques
ACTUALLY DOING IT!

by Robert Penfold

IT IS some time since we last considered the vexed topic of what to do when your newly constructed project fails to work. Fears of the finished gadget failing to work seems to put off many would-be project builders, but it is probably fair to say that this excuse is rather less justified than it once was, and the percentage of failures is quite low these days.

Methods of construction have improved, as have many of the components. The amount of pre-publication checking for both books and articles containing electronic projects has increased over the years, and this has greatly reduced the likelihood of you being "led up the garden path"! This produces a situation where projects are actually far more complex than they used to be, but the chances of problems arising are much less.

Important Decisions

Things are still far from foolproof, but like any creative skill, electronic project construction would not be a worthwhile hobby if it posed no challenge. For beginners the most important advice is to choose projects that are within their capabilities.

Select projects that are reasonably straightforward both mechanically and electrically. Initially you will not have a detailed understanding of how projects work, but build projects where you at least understand exactly what they are supposed to do. In the past it was not unusual to receive letters from readers experiencing difficulties with projects that they clearly did not understand properly.

Fortunately, letters from readers who are "out of their depth" are relatively rare these days. Possibly readers are heeding our advice to choose something that is easy to use and understand, such as a simple car or household project, and not something like a piece of highly advanced test equipment that is only fully understood by the designer and his mother!

Perhaps people are just more down to earth these days. In any event, you can save yourself a great deal of hassle by avoiding the temptation to start with grandiose projects that are totally unsuitable for beginners.

Only construct projects that are battery powered, and therefore safe. The mains supply is potentially lethal, as are any projects that connect to it. Mains power projects are only suitable for those with a fair amount of experience at project construction.

The two main construction methods for circuit boards are stripboard and custom printed circuit boards (p.c.b.s). Both types of board are actually quite easy to use, but custom p.c.b.s represent the more foolproof method.

Stripboard is drilled with a regular matrix of holes, and in most projects less than 10 per cent of these are actually used. A custom printed circuit board, as its name suggests, is specifically designed for a particular circuit and has just one hole per leadout wire or pin. This greatly reduces the risk of making a mistake in the first place, and any mistakes that are made will usually become apparent before the circuit board is completed.

Bridge Too Far

If a newly constructed project is clearly failing to operate properly *it is not a good idea to leave it switched on*. This could result in damage to some of the components, and expensive semiconductors are particularly vulnerable.

If there is an obvious problem with a project ***switch it off at once*** and recheck the component layout, wiring, etc. Experience suggests that the vast majority of problems are due to short-circuits between copper tracks on the underside of the circuit board.

There have been problems with accidental short-circuits on printed circuit boards for as long as there have been p.c.b.s, but modern designs tend to be relatively small and intricate. This greatly exacerbates the problem, making it difficult to complete anything but the most simple of boards without producing at least one or two "solder-bridges".

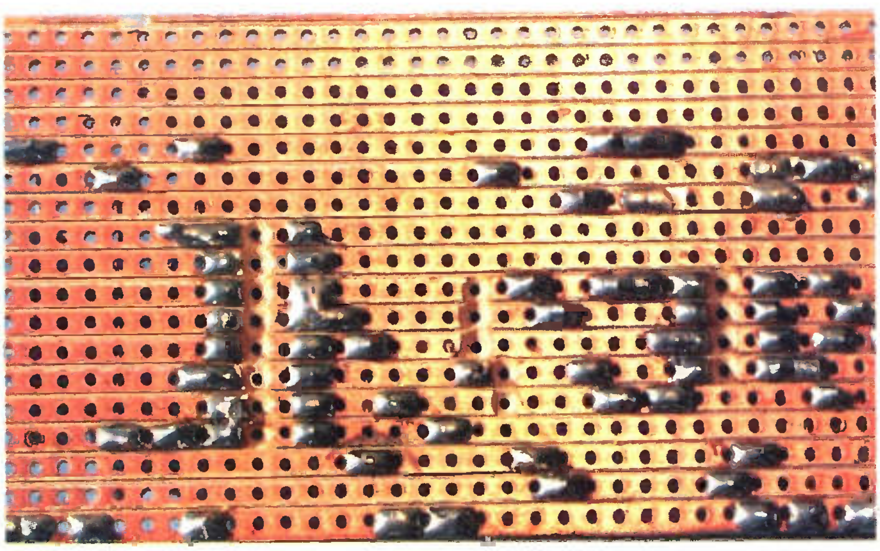
These bridges will usually be spotted while you are constructing the board, and in most cases can be "wiped" away with the bit of the soldering iron. Where there is a large amount of excess solder it is better to use a proper desoldering tool.

Clean Sweep

Some of these short-circuits are caused by minute trails of solder that are very difficult to see with the naked eye. They may actually be hidden under excess flux, and the underside of the board will have to be cleaned in order to bring them to light. There are cleaning fluids designed specifically for cleaning printed circuit boards, but a vigorous brushing with an old toothbrush seems to do the job very well.

Even if you have very keen eyesight some form of magnifier now has to be considered part of the standard toolkit for electronic project construction. Even a simple magnifying glass will make it easier to spot any solder trails, but the ideal tool for the job is an 8x or 10x loupe (also known as a lupe) of the type sold for viewing photographic slides and negatives.

With the board thoroughly cleaned, a thorough visual inspection using a powerful magnifier should soon reveal the cause of any short-circuits. This type of short-circuit is now so common that routinely cleaning boards, checking them for problems prior to testing rather than switching on and hoping for the best, is considered a *must*.



Solder bridges are most likely to occur where joints are tightly packed, especially around d.i.l. integrated circuits. The larger solder blob is a type that should be instantly spotted and rectified. The smaller one at the bottom left-hand corner of the cluster is less obvious, but should soon be spotted when giving the board a careful inspection with an "eyeglass".

Heat Of The Moment

Most beginners at electronic project construction have no previous experience of electrical soldering. Unfortunately, there is not enough space available here for a fully detailed description of soldering techniques, but this is certainly a skill that you must master before undertaking your first project. (If you are an Internet user, why not visit our web site at: **http://www.epemag.wimborne.co.uk /solderfaq.htm** for the low-down on the art of soldering.)

There are soldering kits available that include an iron, a matching stand, some solder, and a detailed instruction leaflet. These are ideal for beginners, and mostly seem to offer excellent value for money.

Soldering is not particularly difficult, but being realistic about things, you will need a certain amount of practice before becoming really proficient at it. It is worthwhile buying some stripboard and some cheap components such as resistors, and practising your soldering by fitting the components on to the board.

You will have to sacrifice a pound or two on wasted board and components, but you will learn a great deal from the exercise. A small initial outlay of time and money here can save a great deal of frustration when you start project construction in earnest.

When inspecting the underside of the board, examine the soldered joints for any abnormalities. You may be using too little solder, possibly resulting in some joints where the wire and copper pad are covered in solder but are not actually connected.

Beginners tend to make the joints rather slowly which can lead to problems with so-called "dry" joints. A joint of this type looks quite normal at a glance, but the solder does not produce a reliable electrical contact.

With modern solder and components this type of thing is now very rare. However, if a joint has an irregular appearance and the solder has a crazed finish rather than a shiny surface it would probably be worthwhile removing the old solder and re-doing the joint.

With the exception of semiconductors, modern components are reasonably heat resistant. However, if you take too long to complete joints it is still possible that damage will occur. If a component shows any physical signs of heat damage, such as a darkening in colour or if it has become slightly misshapen, replace it with a new one.

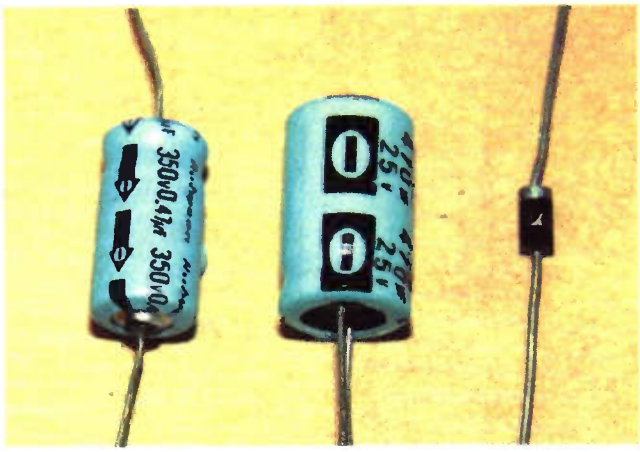
Semiconductors are mostly mounted in holders, but transistors and diodes are often soldered direct to the board. Extra care needs to be taken when fitting these in place.

It is a matter of "practice makes perfect", and you can save yourself a lot of problems by learning to solder quickly and neatly before dealing with any semiconductors.

Under Suspicion

If there are no signs of any problems on the underside of the board, or if after correcting any that are found the project still fails to work, go back and check the component layout again. First check that every component is in the right place, and that you have not accidentally swapped over two resistors.

The components that are most likely to cause problems are those that must be fitted the right way round. This mainly means semiconductors and electrolytic capacitors. Layout diagrams and the shape or markings of components normally make the correct orientation quite clear, so there are few excuses for getting it wrong.



The polarity of polarised components is clearly marked on the components themselves, and should be marked unambiguously on component layout diagrams. Note the band on the diode designating the cathode (k) end.

There is a potential cause of confusion with some d.i.l. integrated circuits that lack the usual dot and notch at the pin one end of the body. It seems to be increasingly common to have a white band across this end of the component instead.

Do not be fooled by moulding marks at the other end of the body that can look a bit like the standard notch. These marks are usually larger and less deep than the proper notch, but there should be the dot and (or) band as well, making the correct orientation unambiguous.

Hit List

Here are a few general points to try when checking a project that appears to be all right, but stubbornly refuses to work.

- Are the d.i.l. integrated circuits fitted in their holders correctly? A pin can sometimes buckle inwards or outwards so that it does not make electrical contact with the holder.

This is not always obvious from a visual inspection, particularly if the pin has buckled inwards. Remove the integrated circuits, check that the pins are all straight, and then refit them. Buckled pins can usually be straightened by pressing them against a small screwdriver blade with a fingernail.

- Give the components a firm pull. This will often bring to light any "dry" joints, soldered joints you have missed altogether, or any broken components that have detached leadout wires.
- If an l.e.d. (light-emitting diode) fails to work it is probably connected the wrong way round. The cathode (k) lead of a standard panel l.e.d. is usually indicated by having that lead shorter than the other lead, and the cathode side of the body is often flattened slightly. This method is something less than universal though, and with some of the "fancy" l.e.d.s currently on sale there is no obvious way of determining their polarity.

This leaves little option but the "suck it and see" approach. Connecting an l.e.d. round the wrong way is unlikely to damage it incidentally. Its reverse breakdown voltage may be exceeded, but the series resistor or other current limiting circuit will prevent any damage.

Is the project actually switched on? It is just a matter of time before you make the classic mistake of forgetting to switch on or overlooking that all-important component – the battery.

Battery connectors are notoriously unreliable. Try pressing the clip hard onto the battery to see if it makes the project burst into life. Slightly compressing the female connectors with pliers will usually get loose clips to operate reliably. Battery holders for AA and similar cells are also something less than completely reliable.

Make sure that the terminals of the batteries and the holder are clean, removing any corrosion with light use of fine sandpaper. An inexpensive test meter is useful for checking that the battery voltage is getting through to the circuit board.

Testing Time

A multimeter is also useful for making continuity checks on switches, which may not operate in the way you think they do. Is "on" really "on", and "off" actually "off"? Often a project seems to be working irrationally, but it is just that one or more of the switches do not function as expected, giving automatic operation when you expect the project to work in manual mode, or something of this nature.

A multimeter can also be used to check cables for short-circuits or broken leads, and to check that plugs and sockets connect together properly. It is an essential piece of test gear that newcomers should buy sooner rather than later.

Modern components are very reliable, and duds are few and far between. It helps to bear in mind that if you get everything connected together properly your projects will work. On the other hand, they will never work if you do not "take the plunge" and actually build them.