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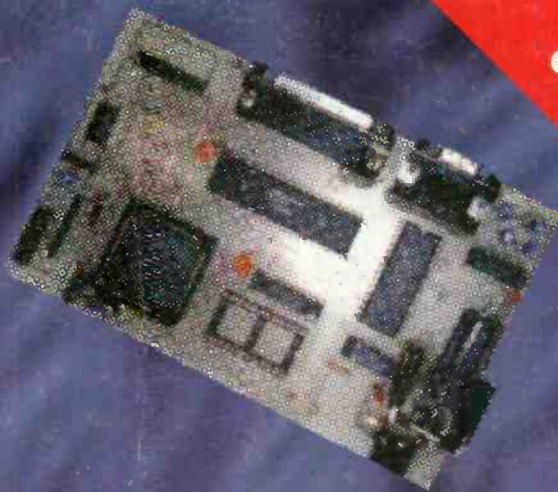
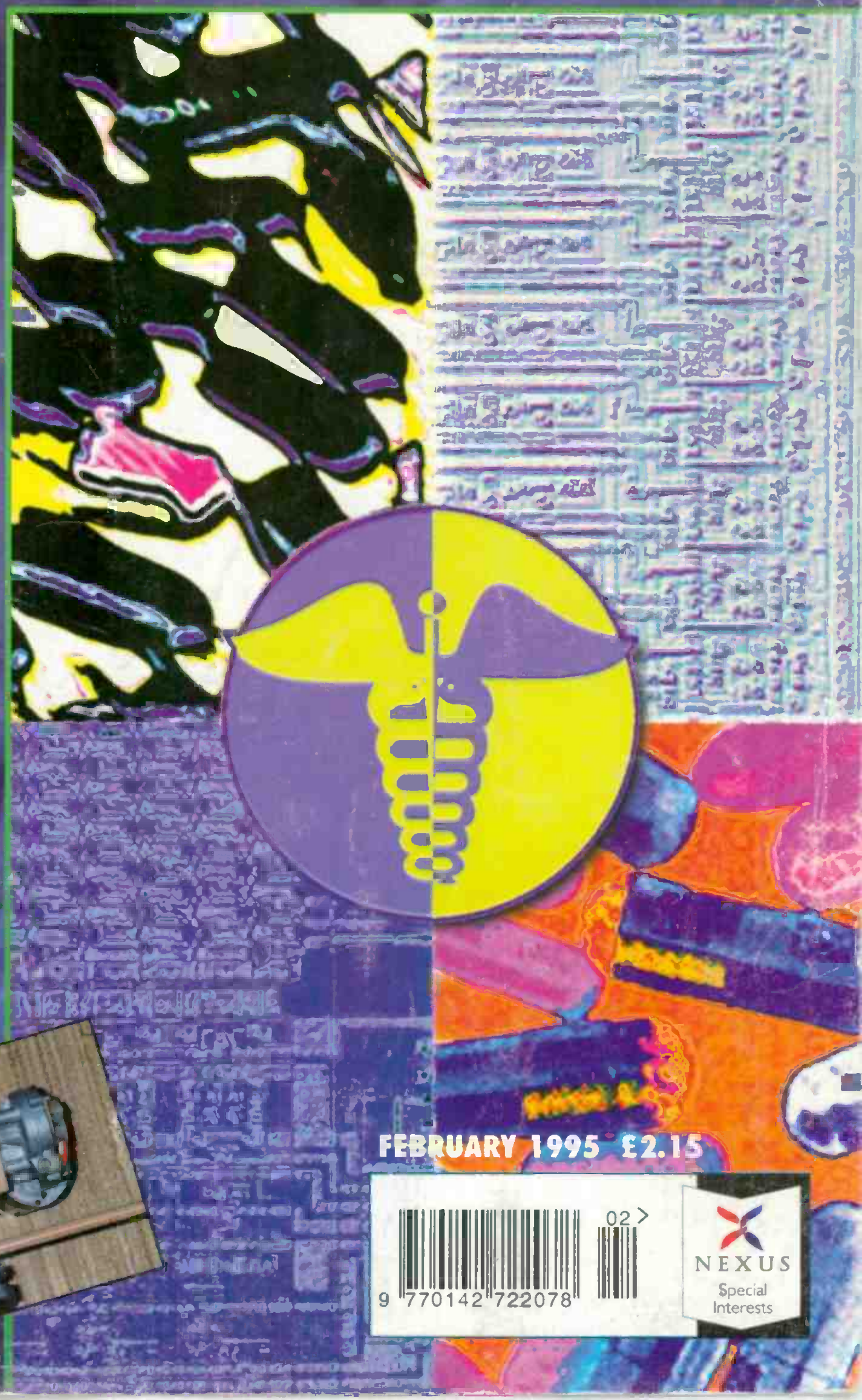


Electronics in medicine



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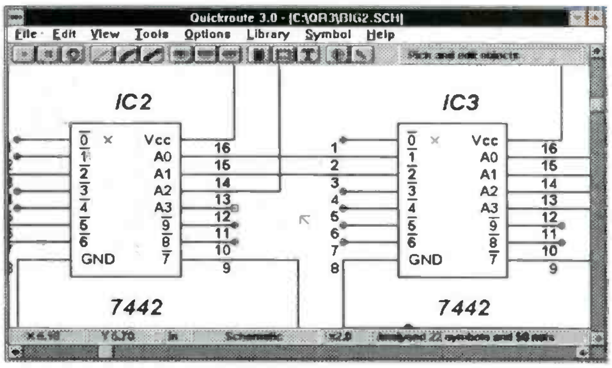

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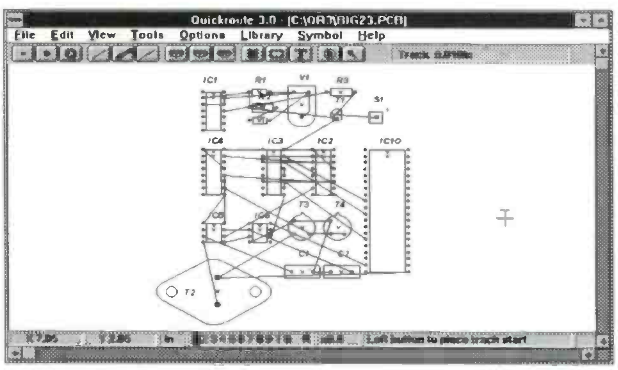

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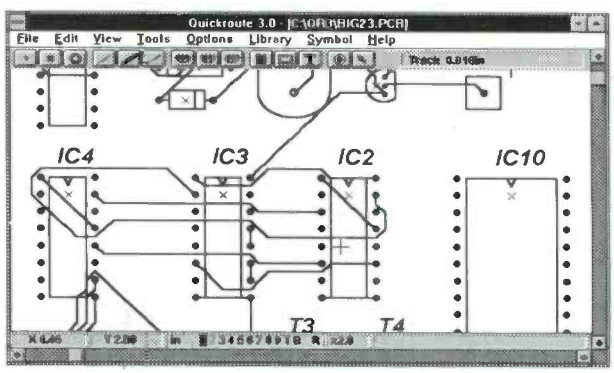

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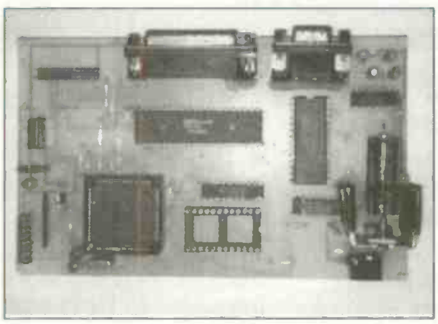
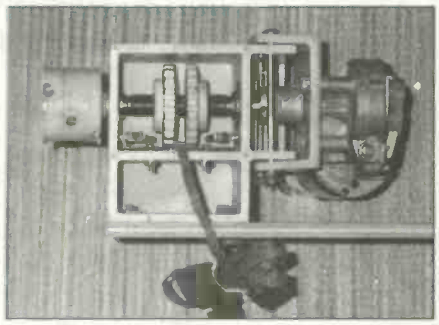




Regulars

ETI News...

ELECTRONICS TODAY INTERNATIONAL

60 MHz, 12-bit, waveform digitiser for the PC

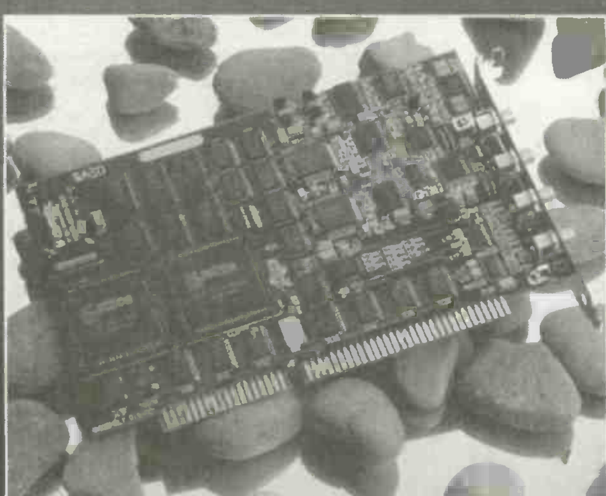
Reading-based Strategic Test and Measurement Systems Ltd have just announced the availability of their DA60 waveform digitiser board, which the company claims to set a new world standard for computer based data acquisition speed, accuracy and price. The 12-bit high resolution DA60 captures 60 million samples per second on a single channel, or 30 million samples per second on each of two simultaneous channels, making it the fastest product of its type in its price range.

The DA60 is an ISA Bus compatible card featuring an analogue bandwidth of 30MHz on each of its two signal channels and a total of 512K samples of on-board memory. Digitally controlled attenuators allow for setting each channel's gain over a 34dB range in 0.2dB steps.

The DA60 is well suited for a wide range of applications within the fields of ultrasound, communications, radar and automated testing. The board occupies one ISA slot, is less than 18cms in length and is supplied with a library of C language functions and source code that simplify the development of applications programmes.

The DA60 has four input signals, consisting of two analogue inputs, an external trigger and an external clock. The analogue inputs have a full-scale voltage range of 100mV p-p to 5.0V p-p. Trigger modes are single shot and segmented. The trigger level is adjustable with the DA60's 8-bit DAC. Clock oscillators for the digitiser are 20MHz and 30MHz, with clock dividers of 1,2,4,8,16,32,64 and 128.

The DA60 costs £3995, and for further details contact Strategic Test on 01734 575150.



Digital clock thermometer from Maplin

The new digital clock thermometer from Maplin Electronics is an attractive white LCD dual purpose clock that displays the time as well as the ambient temperature in either Centigrade or Farenheit. The neatly styled, compact unit has an easy to read 17mm high LCD display and is ideal for use in the home, greenhouse, office or car.

A three-position selector switch on the back of the unit selects either Temperature in Farenheit, Temperature in Centigrade, or Time. In either of the two temperature modes, the time display can be instantly viewed by pushing the clock button on the front of the unit. the temperature sensor is positioned at the top left hand side of the unit's face.

The unit is powered by a single AAA size battery (supplied), and costs £5.95. It is available from any branch of Maplin or via mail order, for further details ring 0702 552911.

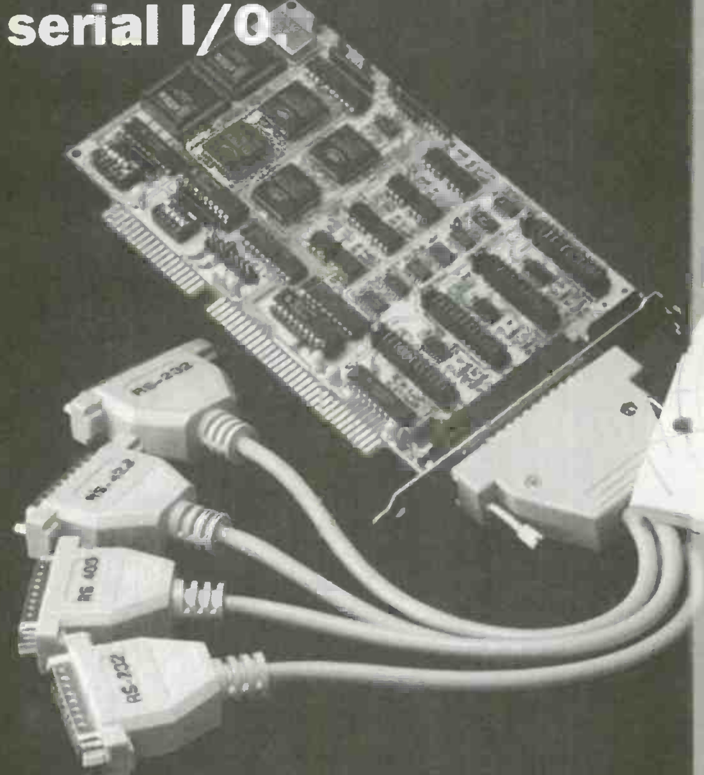
Electronic insect killer from Maplin

One of the latest products to come from Maplin is an ultraviolet electronic insect killer. The unit emits harmless UV light which attracts flying insects into the trap where they are then killed by a high voltage charge. Because it uses no chemicals or sprays this trap is both safe and hygenic and thus ideal for use in the home, office, kitchen, shops etc.

The unit uses very little power and is connected to the mains via a cable, this is supplied together with a 1A plug. The complete unit costs £9.99.

It is available from any branch of Maplin or via mail order. For further details ring 0702 552911.

High speed multi-interface 4-port serial I/O.



For further details contact IMS on 0703 771143.

The latest in a growing line of PC communications cards to be announced by Southampton based Integrated Measurement Systems Ltd is the PCL-746. This is a high speed, multi-interface four port serial communications card. Each port can be configured individually to be either RS-232, 422 or 485 providing a versatile range of transmission protocols on a single card.

The PCL-746 features four high speed 16C550 UARTs (with on chip FIFO buffer) reducing CPU load and ensuring a higher throughput and reliability in serial I/O, particularly for Windows based applications. With the high speed buffer the 746 card can support baud rates of up to 115Kbps.

The PCL-746 can be configured with all four ports set as normal PC serial COM1...COM4 ports, with default addresses and interrupts. Alternatively, for enhanced mode of operation, all four ports can be set to share the same interrupt. This shared interrupt can be set to an extended AT interrupt level. This simplifies programming, speeds up interrupt processing and frees low level hardware interrupts for other devices.

In R-485 mode the card provides efficient communications over long distances up to 4000ft, it also automatically senses the direction of incoming data and switches its transmission direction accordingly. The PCL-746 is also compatible with Arnet 4-port cards supporting SCO UNIX/XENIX. It is supplied complete with ComLIB software, a powerful programming library for PC serial I/O applications.

SINGLE CHIP LCD DOT MATRIX DRIVER MICROCONTROLLER

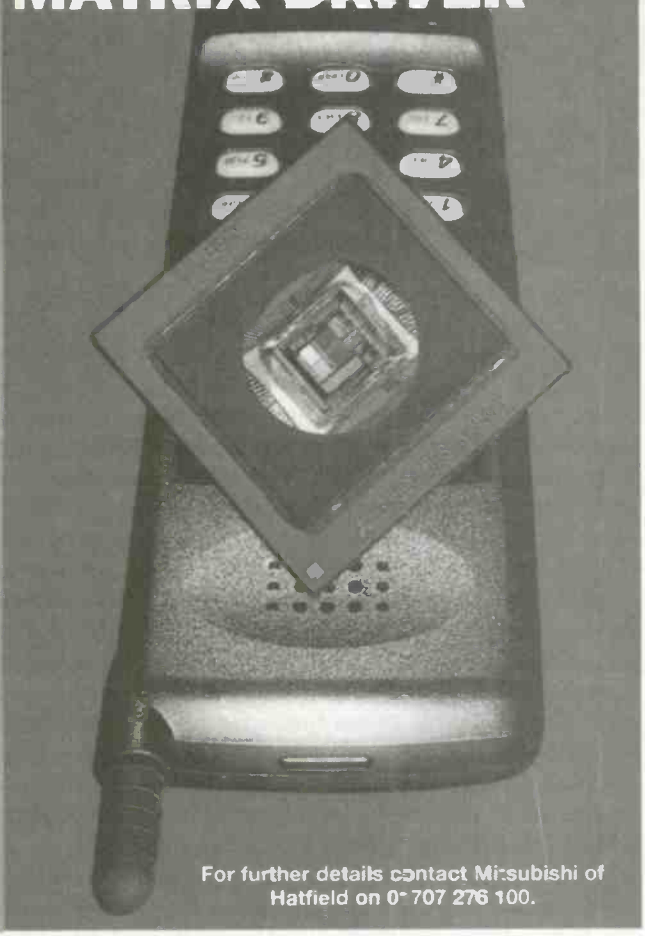
Mitsubishi is announcing the introduction of the M37500 series of single chip 8-bit CMOS microcontrollers. The new devices include a direct drive dot matrix LCD and are the latest in a series of specialist ICs for dedicated microcontroller applications.

The M37500 Series microcontrollers are ideal for mobile telephones, business telephones and other consumer, office and industrial equipment requiring a large capacity LCD display with keyboard control. The devices provide an LCD controller and driver featuring 80 segments and 16 commons, two 16 bit timers, three 8-bit timers, real time clock function, six I/O ports with programmable internal pull-ups, key-on wake up function and two serial I/Os supporting both UART and clock synchronous communications.

Two versions are available in the microcontroller series. The M37500M5 comes with 20Kbytes of on chip ROM and 640bytes of RAM. The M8 versions have 32Kbytes of ROM and 1Kbytes of RAM. Both types feature an area of on-chip RAM for the LCD display of 160bytes.

These chips can operate down to 2.5V whilst typically consuming only 20uA in the low speed operating mode. Special power-saving modes further reduce current consumption to typically 0.1uA, making these devices especially suitable for very low power and battery applications.

The M37500 series microcontrollers come in 160pin, 24mm square quad flat packs and EPROM, OTP and mask ROM devices are fully supported. Support software is provided by a highly optimised ANSI C compiler, interactive simulator, and structured relocatable macro assembler.



For further details contact Mitsubishi of Hatfield on 0707 276 100.

Low cost manufacturing defects analyser

The Texas based company Testronics, a leader in Automated Test Equuipment, has recently introduced the Model 405A, a low cost manufacturing defects analyser. The unit is designed to quickly and accurately identify manufacturing defects such as opens, shorts, solder bridges, and missing, reversed, incorrect and/or defective components.The 405A uses the industry standard GenRad style 2270 receiver interface.

The systems switch cards provide a true 6-wire matrix allowing any combination of configurations. Also, there is no limit as to the number of guard pins that can be used during any single measurement. This is important when testing complex circuits where there are many parallel component paths. The switch cards use SMD technology and plug directly into the receiver's spring probe array. By plugging directly into the receiver, cables are eliminated, thereby dramatically improving measurement performance and test speed.

Complex impedences are accurately measured by the use of a multiple frequency AC stimulus measurement unit. The real as well as the imaginary current is measured. The quadrature current measurement technique enables the testing of very small capacitors, even in complex circuit arrangements.

Each pin of every IC is automatically characterised with respect to itself and to all other points on the board, not just to Vcc or GND. Each IC is scanned to measure and record its forward voltage drop (Vf) as well as its Delta forward voltage drop, (_Vf), when the current is increased. This dual threshold scan provides the characterisation of two specific points along each IC's semiconductor junction VI curve.

The system software provides full use of variables. The user can input data into the program during testing to provide on-the-fly program branching. This feature is extremely important when testing a board that may have several options or versions. The operator can be prompted to input the specific option number. The program can then branch and test the components associated with the selected option. Mathematical operations can also be performed on variables. The results of an individual measurement can be stored into a variable and manipulated.

For more information contact Testronics, 1320 Millwood Rd, McKinney, TX 75069, USA. Tel:(214)542 3111.

Credit card-sized PC motherboards

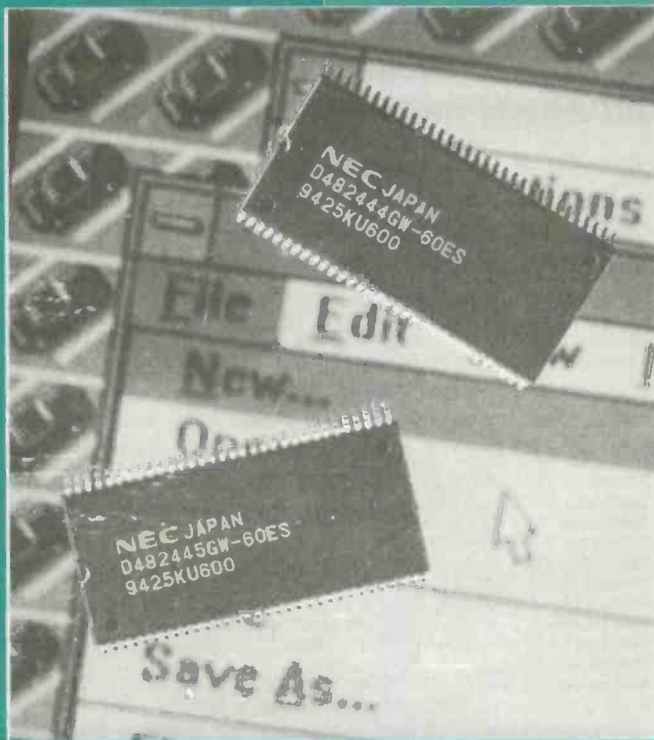
Epson have launched the world's first credit card-sized IBM PC/AT compatible motherboard. With a footprint of only 85.6mm x 54.00mm, the EPSON CARD-386 consists of the Intel 386 SL super set, VGA controller, ROM, RAM, FDC and keyboard controller, and broadens the potential application of PC technology into fields as diverses as POS systems, factory automation systems, measuring equipment, VTRs, faxes and vending machines.

B:To enable the EPSON CARD-386 to connect to devices and external peripherals, Epson have developed a new 236-pin interface, able to support all IBM PC/AT functions as well as an ISA bus and numerous I/O ports. Designated EASI (Epson All-in-one System Interface), it is intended as an industry standard interface for credit card-sized PCs.

Making full use of Seiko Epson's expertise in mixed assembly and watch technology, the EPSON CARD 386 uses Tape Automated Bonding (TAB) technology to mount components such as the CPU and I/O controller, surface mount technology to mount the memory ICs, and Chip-On-Board (COB) technology for the other devices. Available in versions operating at both 3.3V and 5.0V, it features 1MB or 4MB or RAM and 128KB or 256KB of ROM. Because of the many standard software tools and hardware components already available for the IBM PC/AT, development environments for the EPSON CARD-386 can be realised both quickly and easily. This will allow developers to cut time to the market and the costs involved in hardware and software design. For further details contact Epson of Hemel Hempstead, on 0442 227331.

JEDEC compliant 4Mbit VRAM

NEC Electronics has started sampling a fully JEDEC compliant 4Mbit video RAM (VRAM). JEDEC is the US based standard body that defines the functionality and pin-outs for many semiconductor devices. Compliancy means that users, such as PC manufacturers, will not be tied to a particular manufacturer and will have flexibility of supply.



A VRAM is essentially a DRAM with an extra I/O port, enabling a faster data transfer rate. They are used in desktop and portable PCs, (particularly those running Windows type applications) workstations, video cameras, and video recorders.

The 4Mbit devices are organised as 256K x 16bits, so are ideal for use in 16bit (65,536) colour applications. They are functionally compatible with NEC's 2Mbit VRAMs and have a serial clock cycle time as fast as 18ns.

The 4Mbit VRAM is available in two operational modes, with random access performance down to 60ns. The uPD482444 is a fast page mode device, whilst the uPD482445 is an extended output fast page mode device which can improve the fast page read performance by up to 20%.

Both versions feature a full width split serial buffer, the two halves of which function independently. Hence one half can be outputting data while the other half is being loaded with the next data to be output. This removes the need to pause between reading rows (that is, it eliminates "flyback" time) and permits data to be output continuously at high speed.

The serial buffer is bi-directional, so the VRAMs are suitable for use in serial input applications such as video cameras and video recorders. Other capabilities include a flash write mode, a block write mode and the stopping column mode, which accelerates tiling operations. These features greatly increase performance of the system when running Windows type applications.

For further details contact NEC at Milton Keynes on: 0908 691133.

UV banknote checker from Maplin

Fake banknotes can be detected by simply shining ultraviolet light on them. The genuine notes should absorb the UV whilst the forgeries should reflect it. This means that when a note is held under this unit a genuine one will reflect very little light whilst a forgery will light up with a bright violet colour.

This mains powered banknote checker is built in a rugged black plastic housing that is designed for desk or counter use. The unit is fitted with a top mounted on/off switch and about 1m of mains cable, it comes complete with 13A plug. The unit costs £7.99 on a special offer open until 28th February 1995. It is available from any branch of Maplin or via mail order. For further details ring 0702 552911.

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Electronics and the doctors of the future

A look at how technology is set to revolutionise medicine, within twenty-five years we will hardly recognise the doctors and hospitals of today - electronics, computers and robots will probably have taken over

Star Trek fans will recall that in several episodes of the original TV series Dr McCoy referred to the medical practices of the late twentieth century as being little more than barbaric butchery. Somewhat extreme, perhaps, by today's standard. But clinical medicine has, largely thanks to the use of new technology and new scientific discoveries, advanced in leaps and bounds in the quarter century that has passed since those classics of science fiction were first shown.

Viewed even from today's standpoint, the medical practices of 25 ago were primitive, and yes, in some cases they were even barbaric. At that time doctors did not have the equipment and techniques that are now available, the wide range of specialist body scanners, diagnostic equipment, medical databases and expert systems, endoscopes, keyhole surgery, microsurgery, etc. Not to mention the specialist drugs that are now designed on computer to precisely target specific problems.

Medicine has come a long way in 25 years, but these advancements will look insignificant when compared with the changes that will take place over the next 25 years. What was science fiction may by then start to become science fact. In the rest of this article we will take a look at some of the ways that technology is set to revolutionise the practice of medicine.

Gathering information about the patient

At the forefront of the medical technology in use today is the wide range of scanners and diagnostic equipment that are available to help doctors make a quick and accurate diagnosis. Probably the most important of these is the Body, or CAT, Scanner. The term CAT stands for Computerised Axial Tomography, and refers to a computational technique which allows a detailed image to be created of a slice through the patient's body.

Prior to the development of the CAT scanner the only way that a doctor could see what was happening inside a patient was to use a conventional X ray image of that part or in more extreme cases to cut open the patient and have a look. The latter procedure being not the best for the patient.

The trouble with X rays is that they only really show the bones and parts of the body which have been made visible by the use of special chemicals. X rays do not produce a very good image of soft tissue (skin, muscles, blood vessels, body organs, brain, nerves, etc.), and most medical problems are concerned with soft tissue.

With a CAT scanner it is possible for the doctor to look at detailed images of soft tissue as well as hard tissue such as bones. Indeed, with newer CT scanning techniques such as PET and MRI scanning it is now possible for doctors to not only examine the shape and position of various organs but to also observe them functioning in real time. To look at the flow of blood in the heart or the brain, to watch the pattern of nerve impulses in the brain as the patient responds to various stimuli, even watch the patient thinking. With MRI scanning, it is even possible to look at biochemical changes that are taking place deep inside the body with a resolution as fine as a couple of millimetres.

Another imaging technique which has been developed over the last 20 years is the use of ultrasonics, a technique which has become very important in the diagnosis of heart disease and in the detection of foetal abnormalities. This technique relies upon the various amounts of sound energy which are either absorbed or reflected by different organs in the body. A variation which like X-ray CT scanners can be employed to build up an image of the inside of the body. Because low power ultrasound is relatively harmless, such imaging systems can be used in real time, a feature which is particularly useful when examining the heart.

The early CT scanning equipment simply produced two-dimensional images which closely resembled conventional X-ray images. With advances in computer technology during the last ten years these images were then enhanced by the addition of colour. Later on, additional features were added which allowed the image data to be subjected to a wide variety of computer image enhancement and feature extraction techniques.

With these techniques it is possible for the doctor to acquire a lot more information from a given scan. But the designers of CT systems are now going one step further. They are creating systems which can take a number of scans and from them build up a three-dimensional image of the part of the patient's body in which the doctor is interested.

To these large imaging systems must be added the wide range of laboratory diagnostic equipment that can be used to perform biochemical analysis on biopsy samples etc. Equipment which can now be used to very quickly identify the presence of a wide range of different biochemicals, antibodies and pathogens.(see the feature on the Electronic Nose in September ETI).

Computerised Tomography

The principles behind the CT scanner were developed independently in the early 1970s by two people, the South African physicist Allan.M.Cormack, and the British engineer Sir Godfrey Hounsfield. The first working instrument was constructed in England by Hounsfield. The result was a medical revolution for which these two innovators were jointly awarded the Nobel Prize in 1979.

The principle behind CT scanners is simply that varying amounts of energy from a beam of X-rays passing through the body will be absorbed. The amount that is absorbed being dependent upon the type of tissue, the denser it is the more it will absorb. If we then take a very thin beam of X-rays and repeatedly pass this beam through the body at different angles in a plane then we can use mathematical techniques to analyse the collected data and reconstruct a picture of the body in that plane.

The mathematical technique is referred to as tomography, and to produce an image it is necessary to perform an enormous number of different calculations. It was therefore the availability of small powerful computers which really made it possible to build CT scanners.

The enormous success of the early X-ray based CT scanners led researchers to examine other ways of building up CT images. One of these was auto radiography. This involved injecting the patient with a radioactively labelled chemical and using the CT scanner to measure the varying output of radioactivity. The data from this scan can then be used to reconstruct an image of the body section in much the same way as the X-ray technique, but with the important difference that by carefully choosing the radioactively labelled chemical, it is possible to identify those parts of the body where that chemical is concentrated or used.

The radio isotopes used in this form of CT auto radiography were very carefully chosen. What they use are radioisotopes which emit positrons, sub atomic particles which resemble electrons but carry a positive charge (for this reason such scanners are usually referred to as Positron Emission Tomography, or PET, Scanners). When one of these positrons is emitted by the radioisotope it immediately combines with a nearby electron. These two particles annihilate each other but in the process they emit two gamma rays travelling in opposite directions. It is these gamma rays which are detected and used to build up the PET CT image.

The first PET scanners came into use in the late 1970s and early 1980s, and were used to display images of brain activity, glucose metabolism, oxygen consumption, blood flow and interaction with drugs. This gave rise to a revolution in neurosurgery, neurophysiology, and indeed human physiology in general. Now for the first time doctors could see the body working without cutting into it.

In the mid 1980s another CT scanning technique was pioneered, the MRI, or Magnetic Resonance Imaging, system., a technology which has now given rise to some of the most powerful scanning and diagnostic devices available to the medical profession. This system depends upon the fact that in the presence of a strong magnetic field many atoms behave as little compass needles, and by careful manipulation of the magnetic field it is possible to align all the atoms.

If, under these conditions, we then use a pulse of radio waves to jolt the atoms in a precise controlled manner, they will emit a detectable radio signal that is unique to the number and state of the atoms under test. This is the magnetic resonance. By carefully adjusting the magnetic field and the radio wave pulse, it is possible to collect information about all the different atoms in the sample.

This means that an MRI CT scanner can be used to build up images of the body that target specific atoms, such as oxygen, or haemoglobin, and thus give the doctor a precise image of physiological activity. MRI scanners have two other important advantages. They pose little or no biological risk to the patient and can thus be used in real time and over a continuous period. They also offer the highest resolution of any CT scanner being capable of resolving features as small as two millimetres.

Technology in the operating theatre

The wide range of imaging technologies now enables doctors to see with considerable detail what is going on inside the body of a patient allowing them to, for example, locate very small tumours. But this is not the only type of technology which is available to today's doctors. Fibre optics and digital imaging technology are used to create devices, such as endoscopes, which can be inserted into the body and allow the doctor to actually look at various organs without having to perform major surgery.

These devices have enabled surgeons to make major advances in surgical techniques, the so-called keyhole surgery. This type of surgery is beneficial to the patient since it does not involve opening them up and exposing them to the risk of serious infection as well as the stress of what is, after all, a major wound. It involves the use of a special type of endoscope with a steerable tip equipped with surgical tools which can be used to remove tumours, diseased tissue etc. The cutting can be done by laser beam, and images of the organ being operated upon can be shown, magnified on TV screens in front of the surgeon.

Advancements in surgery involving very small organs, such as repairing small blood vessels in the brain, or correcting the lens of the eye to restore vision have called into use technology which owes much to robotics. Special micro-manipulators make it easier for the surgeon to perform work on a very small scale, again using images magnified on a large TV screen to enable him to see what he is doing.

Putting it all together

From the above brief sketch of some of the technologies involved in modern medicine one can see that over the last quarter century medicine has gone from being largely a craft skill where a doctor's most important assets were his eyes, his hands and his knowledge of medicine, to one where the support technology is absolutely essential. The doctor is now part of a high technology information collection and analysis system, he potentially has at his disposal enormous amounts of information generated by very sophisticated devices, and it is his job to make best use of that data to cure the patient.

It is improvements in this flow of information which will produce much of the advance in clinical medicine in the future. Initially doctors wanted the output from equipment such as CT scanners to be in a form that they were familiar with, a black and white X-ray type image. But gradually doctors have come to accept that data in electronic form can be used in more creative ways. They are accepting images on a monitor screen rather than as hard copy, and are becoming used to the idea that such images can be manipulated and selectively enhanced to pinpoint specific features of interest.

They are now starting to use systems which can construct three-dimensional images, and it is here that we are beginning to see the start of the great revolution that lies ahead. The creation of virtual images of the patient which are constructed using information drawn from a number of different imaging systems and sensors. The realisation that enormous advances in medicine are possible by optimising the use of available information.

Into the future

In a number of key medical centres across the world, doctors, engineers and computer scientists are now working on the development of systems which will perform this task of making optimum use of available information. We are already seeing in a handful of European and US hospitals hip replacements being done using highly integrated information systems that use scanner-derived 3D data to design a replacement joint and then with the aid of the same data use a robot to accurately cut away the diseased bone and position the replacement.

In Boston, doctors have demonstrated another example of integrating some of the available technologies. They have performed the first 'trackless' surgery for breast cancer which removed the tumour but left no mark on the patient's body. This was performed by using real time data from an MRI scanner to locate the tumour and then guiding the equipment that would destroy it by using a direct a focused beam of ultrasound.

In both these cases, doctors are starting to bring the full power of technology to bear upon specific aspects of clinical medicine. They are optimising the way that information derived from devices such as body scanners is used. This has been made possible because doctors have now learned to accept and use technology. This has been especially true in surgery where surgeons have now taken the great step forward in moving from traditional operating techniques to the use of minimal invasive techniques, the so-called 'keyhole surgery'.

In keyhole surgery, the surgeons have to rely on tiny video cameras and minute surgical instruments inserted through a very small aperture in the body to perform the operation. An operation which is performed without being able to directly see or touch the organs involved. This is the great leap which has already been taken and which will open up the way to the medical technology of the future, to telemedicine, virtual operating theatres, etc.

Modern technology can give an enormous amount to the medical profession in the form of new tools and new techniques. But their use will result in an unprecedented revolution in what is technologically a very conservative profession. Doctors in the future will be half medical man, half information technologist. This means that if we are to take advantage of the advances that technology is offering the medical profession then it is essential that medical schools are established which can produce new generations of doctors who are technologically literate enough to be able to cope with the systems which will be offered to them.

The development of this type of technology will also require changes in public and government attitudes to health care. Curiously, the general public are probably more willing to accept the use of technology in medicine than the medical profession. There are still plenty of tales to be heard of body scanners being bought for a hospital by public subscription and then left unused by the doctors simply because they did not know how to use the technology to the best advantage.

As far as governments are concerned, the funding of hospitals will have to change. The new generations of integrated operating theatre with its real time scanners, virtual reality controls etc. will be enormously expensive. The operating theatre in Boston which has been built to perform 'trackless' breast cancer surgery is reputed to have cost $50million for the theatre alone, and with theatres being increasingly dedicated to specific classes of operation, there may be a need for over 50 different types of operating theatre in a 21st Century hospital designed to cater for all illnesses. For this reason alone, hospitals will start to specialise, and specialisation will increase the use of telemedicine.

Technology is offering the medical profession an array of devices and techniques which if properly used will revolutionise health care. The hospital of the not too distant future could more closely resemble the medical centre of the Enterprise, and perhaps in another quarter century doctors will look back on today and think how primitive medicine was in 1995.

Telemedicine

For some years the US Army has been secretly developing a very high technology form of medicine which has brought together keyhole surgery, virtual reality, robotics, and satellite communications links to allow doctors to treat, even perform operations, on patients who are perhaps thousands of miles away from the doctor. The first field tests of this work will be carried out some time in 1995, and should lead to armies being equipped with armoured operating vehicles that can be positioned at the front and in which soldiers will receive emergency surgery from medical staff located in safe areas 20 to 30 miles away or perhaps even on the other side of the world.

Some of the basic concepts behind this work were apparently tested during the Desert Storm operation in the Gulf. Indeed, the director of the biomedical technology unit in the US Department of Defence, Colonel Richard Satava, was also the medical commander in that operation. The only real problem which still exists is the time lag in communications over long distances. When this is overcome it should then be possible for a surgeon to perform an operation on a patient located thousands of miles away, in a third world country without facilities, in a submarine, or on a space station.

The system consists of two main components; the surgical workstation that is used by the doctor and the remote operating theatre. The surgeon wears a special headset which gives him full stereo sound and voice interaction with the technician who is manning the remote operating theatre. The surgeon stands at a special console which primarily consists of what is described by the designers as a multi-display operating screen which gives him a full sized image of the part of the patient which is being operated upon, plus displays of various vital signs, etc.

At the front of the console are two specially designed hand controllers that are capable of giving him full sensory feedback as well as transmitting his movements to the remote operating theatre.(in areas such as robotics, remote operating systems and artificial intelligence, the US Department of Defence has access to technology which is probably a decade in advance of anything that is available to civilian users)

At the remote operating theatre there is a specially designed robot surgeon, the movement and actions of which are directly controlled by the surgeon at his console a thousand miles away. So if the surgeon moves the right hand controller forward and picks up a specific instrument from a virtual tray of instruments displayed on the control panel then the remote robot will make the same movement and pick up the actual instrument from a tray of instruments. The movement of the robot arm will exactly mimic the movement of the surgeon, and the video image displayed on the console is exactly the same as the view which the surgeon would see if the patient was actually before him.

The robotic surgeon and its human surgeon controller are working on an exact one to one basis, if the surgeon moves his controller ten centimetres to the right then the robot will also move the corresponding arm ten centimetres to the right. But, there is no reason why this relationship should be maintained, the controlling computer could be used to effectively shrink the surgeon and thus allow him to work on small parts of the body such as the eye.

This is exactly what researchers at McGill University in Montreal are doing. They have designed special miniature robotic manipulators which can use miniature surgical tools with far greater precision than any human surgeon and are working on systems which will use these robot manipulators in conjunction with virtual imaging systems for specialist eye surgery.

In the civilian world some of the other key elements of telemedicine are already in use. The Bagrit Centre at Imperial College London have developed a system for electronically transmitting X-ray images between hospitals. It may sound easy but such images contain a lot more data than an ordinary photograph and thus have to be scanned at very high resolution; the result is an enormous amount of data which needs to be compressed in order to be transmitted within a reasonable time.

Video images are also being used to allow specialists to give advice to a doctor in another part of the country. BT engineers have developed a special televideo link utilising 128Kbps digital video transmitted over standard fibre optic ISDN phone lines. Using special videolink terminals, it is possible for the specialist to examine the patient and interact with the patient's doctor in order to provide more precise advice and diagnosis.

The telecommunications giants like BT and Sprint, and some of the world's largest computer and medical equipment manufacturers such as DEC and Hewlett Packard all see telemedicine as being very important in the future. Many of them are working in collaboration to develop the medical technology of the future - development which may get a considerable boost as a result of the recent Pentagon inspired involvement of some of the main defence contractors in the USA.

Virtual surgery

The enormous advances in virtual reality systems over the last few years has not gone unnoticed by the developers of medical technology. Using data derived from CT scanners it is already possible for doctors to construct and view a 3D image of that part of a patient's body in which they are interested. Again, using virtual reality techniques, it is possible for the doctors to rehearse the steps involved in an operation using this virtual model and thus anticipate any problems which may be encountered.

Work has already started on creating a virtual model of the human body. This is being built up using CT scanner data and has a feature resolution of just 1mm. This electronic virtual cadaver is designed to be used in training medical students and will replace the traditional requirement for specimen dissection. Surgeons will also learn to perform operations by working on virtual organs and body parts before being let loose on living patients. It will also be used by doctors to help them plan complex and new operations.

A bit further into the future and we could well start to see surgeons wearing head-up display type virtual reality glasses which could be used in conjunction with imaging systems to give the surgeon virtual X-ray vision. In such a system, a virtual image would be superimposed upon the actual image seen by the surgeon and could, for example, enable him to precisely pinpoint the location of a small tumour and thereby prevent unnecessary removal of, or damage to, body or organ tissue.

Yet even further down the line, but already the subject of much serious development work by the US Department of Defence amongst others, is the gradual elimination of any clear distinction between what is being simulated and the simulation. Operating on a virtual reality patient and on a real patient will become indistinguishable.

To reach this point, designers will have to draw on much of the technology for handling information which is now used by the military; in particular, the pilot of a fighter aircraft. The head-up displays, the data fusion systems for integrating data from a range of different sensors. Simulators which are capable of integrating real objects as well as simulated objects, and the teleoperation of remote units.

With this type of instrumentation tailored to the needs of the surgeon researchers, such as those at MIT, we may see the surgeon of the future sitting in a simulator that will give him the capability to 'fly' through a 3D virtual representation of the patient's body which is derived from constantly updated data produced by a CT scanner. In this virtual environment, the surgeon will be like the shrunken scientists who travelled through a patient's body in the film Fantastic Voyage.

The virtual surgeon will have at his disposal artificial intelligence systems which will enable him to accurately locate dangerously placed blood vessels, tumours, lesions, diseased tissue etc. Other information systems will show him the exact state of the patient's physiology and vital signs. Yet others will allow him to access medical databases that will enable him to look up information on any aspect of the operation, patient history etc.

He will also have controls in his 'cockpit' which are connected to teleoperator robots which will perform all the actual surgical operations in a remote theatre that could be next door or a thousand miles away - robots which will be equipped with sensory capability way beyond that of the human surgeon, such as high definition spectroscopy that can detect diseased tissue from healthy tissue, microscopic vision that will enable even the smallest artery to be repaired, or avoided. All using keyhole surgery techniques which mean that the patient will be back to living a normal life within day or two.

Robodoc

Many people may shudder at the idea of being operated on by a robot, but in truth a robot is probably capable of doing many surgical operations far better than a human surgeon. We are not, of course, talking about a robot taking complete control of an operation but rather of robots being used as specialist tools to enable a surgeon to do a better job. However, in the future, robots using sophisticated artificial intelligence capabilities will undoubtedly be used to perform certain tasks in a more independent manner.

A perfect example of the current use of medical robots is a robotic drilling arm called Robodoc which is currently being used to perform hip replacement operations at the University of California, Davis. Here the robot is being used to remove bone and create a perfect fit between the bone and the prosthesis which will eliminate the need for cementing the prosthesis in place and thus ensure fewer post-operative problems.

Robodoc is just a special version of a small industrial robot which is programmed using data derived from CT scans and from the prosthesis manufacturer. It is just the first of many areas in which robots will be used in medicine; they are already being used in certain areas of brain surgery and robotic manipulators are allowing surgeons to make considerable advantages in the area of microsurgery by effectively 'shrinking' the surgeon with respect to the patient.

At MIT, they are working on shrinking the surgeon even more. They are building small robots which can be inserted into the abdominal cavity, or the intestine and, if they can be made small enough, some of the larger blood vessels. These small robots, the first generation of which are little bigger than the end of one's thumb, are already wandering around the labs. Equipped with special imaging systems and micro manipulators, they will enable surgeons to examine internal organs and perform certain surgical operations.

In the more distant future, but probably within the next quarter century, developments in micro-mechanics should enable doctors to place a wide range of robotic devices directly into the body of patients. Micro-miniature chemical analysis systems will be implanted into various organs and used to analyse the physiological state of that organ and, where necessary, release small quantities of drugs that will correct imbalances.

MICROCONTROLLERS

An introduction

By Robin Abbot to the use and programming of the Arozona Micro Systems PIC Microcontroller

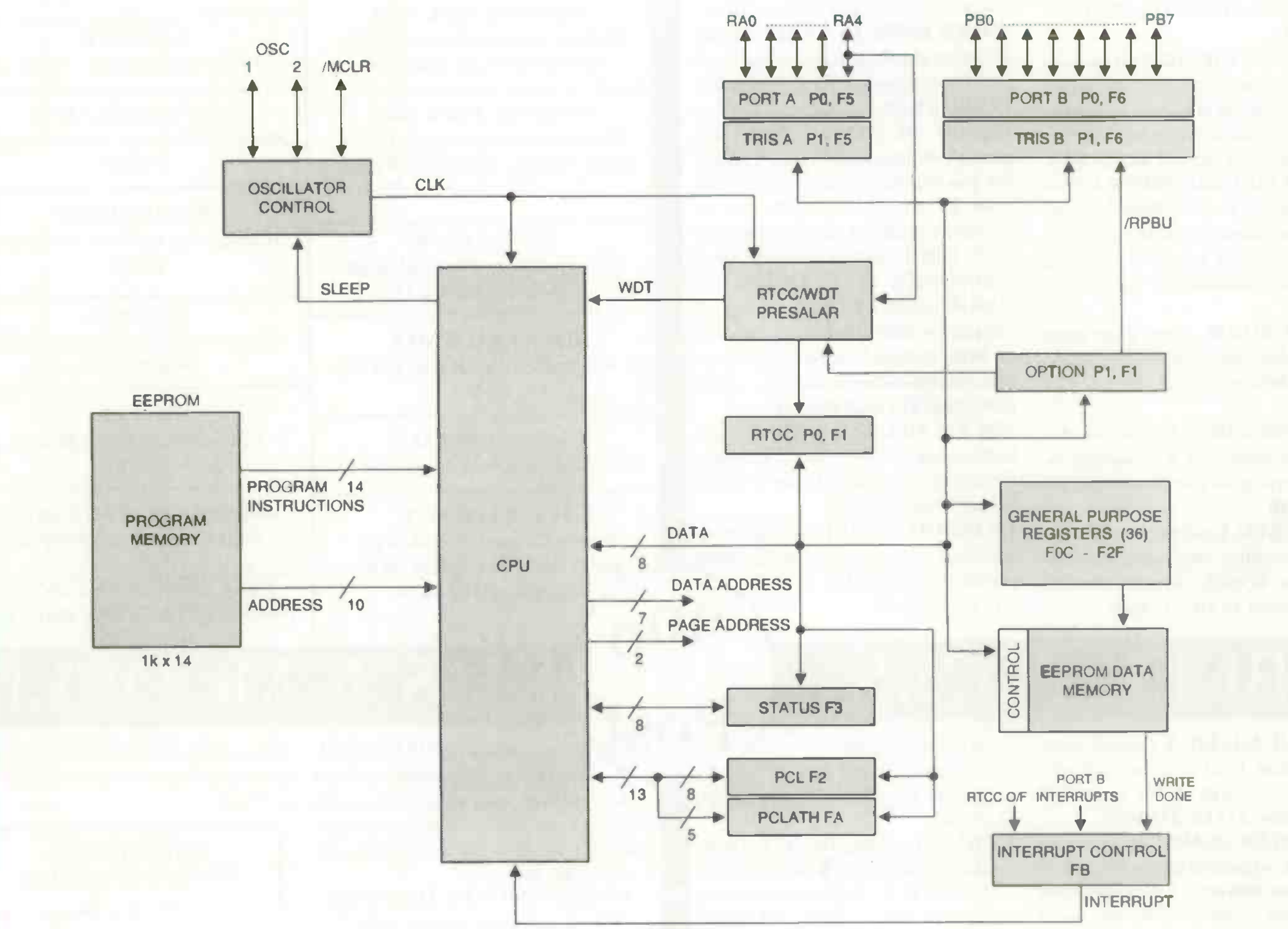


Fig 1 Architecture of the 16C84

Any engineer who has attempted to repair or examine any item of domestic equipment designed over the last few years must have noticed that manufacturers seem to be achieving more and more functionality with less and less circuitry. Often complex digital functions are achieved with only one or two chips. These chips are very often application specific integrated circuits (ASICs) or micro-controllers.

ASICs are integrated circuits that implement many thousand identical gates (usually NAND gates) in an array that is manufactured for all customers identically until the final layers of interconnect. These final layers are specified by the customer and allow complex digital functions to be implemented. ASIC's can be very cheap to produce, but have a long development cycle and are very expensive in small quantities. They are not suitable for small production runs or for the hobbyist.

Micro-controllers are single chip microprocessors which implement ROM and RAM within one package, and which usually have a number of other functions on chip such as general purpose input and output ports, clock/counters, serial ports and A to D converters. They are usually of fairly low cost and their development systems and programmers are often available at a reasonable price.

One of the more popular series of micro-controllers is Microchip's PIC. The PIC devices are relatively cheap and have assemblers and emulators available for the PC which may be downloaded free of cost from the Microchip bulletin board (see end of article for details). Programmers are readily available at a price suitable for small development or for the home hobbyist. PIC chips have been used commercially in infra-red controllers, bar code readers, EPOS terminals and in controllers for many white goods.

This article looks in detail at some of the PIC series of controllers, and an example of their use is presented. The devices considered are the PIC16C5X series, the PIC16C84 and the PIC16C71. I have used the devices within an EPROM programmer, as the main logic in a light gun system and as auxiliary processors in more complex systems to drive displays, read keyboards, and control timing functions.

Modern PIC devices are implemented using CMOS technology. At low clock rates, they are suitable for battery operation (35KHz or less), and even at 4MHz clock rates power dissipated can be as low as 60mW.

Architecture

The PIC contains a central processing unit, ROM, RAM, a real time clock/counter, general purpose input/output ports, sleep circuitry (to conserve power), a watchdog timer (to recover soft ware errors), and an oscillator. The architecture of one of the PIC devices (PIC16C84) is illustrated in figure 1. Some devices in the PIC series have additional features such as EEPROM data memory, A/D converters, PWM outputs for motor control, and serial ports.

system may require a relatively large amount of program space. In the PIC, the amount of RAM is actually fairly limited (between 32 and 80 bytes in the smaller devices). However, there is considerably more program memory (from 512 to 2K words).

In a traditional micro-processor system such as one based on a Z80 or a 6502, the data and program share the same address space. The program can address itself and, if in RAM, can even modify itself. In the PIC the program never needs to access itself and the PIC implements separate address and data busses for the program space and the data (RAM) space. This is known as a Harvard architecture. As all instructions fit into one instruction word, the size of RAM is not a limitation for most applications.

The separate program and data bus architecture allows the PIC to perform an operation on the RAM space at the same time as it is reading the program space, thus all instructions can be performed in one machine cycle (with the exception of instructions which can be performed in one machine cycle (with the exception of instructions which cause a jump which takes two machine cycles). This allows extremely simple software timing loops to be constructed. See fig 2·

PIC devices all have input/output (I/O) ports which are completely general purpose (any bit may be input or output and changed during program execution). Port A has 4 or 5 bits, Port B has 8 bits and Port C has 8 bits. Port C is only available on the larger devices. Although I/O pins may seem limited PIC devices are ideally suited to serial communications with other devices using only 1 or 2 pins, and there is a series of EEPROM devices specifically intended for use with the series.

Table 1 shows some of the range of devices available and their special features.

TABLE 1

Device Prog size	Max. RAM	Bytes of	Interrupts	I/O pins	Special Features
PIC16C54	512	32	No	13 (5+8)	
PIC16C55	512	32	No	21 (5+8+8)	
PIC16C56	1K	32	No	13 (5+8)	
PIC16C57 PIC16C71	2K 1K	80 36	No Yes	21 (5+8+8) 13 (5+8)	4 input (multplexed)
				A/D converter	
PIC16C84	1K	36	Yes	13 (5+8)	64 byte EEPROM data area

PIC devices are available in a number of variants. EPROM versions have a ceramic case with a window to enable erasure and are most suitable for development - being about six times more expensive than one time programmable versions! One time programmable (OTP) versions have no capability for erasure and have plastic packages. The devices have variant codes as follows:

/JW	Ceramic package with erasure window
/RC	OTP plastic package with resistor/capacitor oscillator
/XT	OTP plastic package with crystal/resonator oscillator

The oscillator allows the use of crystal, ceramic resonator or resistor/capacitor timing circuits with minimum external components. The oscillator type may be selected at programming time for /JW types. The oscillator provides a clock which has a period known as a T-state (a 4MHz clock has a T-state which is 250nS long). 4 T-states make up a machine or instruction cycle which is the minimum time that an instruction will take to execute (with a 4MHz clock the machine cycle is 1uS long, thus the minimum time per instruction is 1uS).

In most applications for which a micro-controller is appropriate, the amount of information which needs to be stored about the system is usually small, although the control of the

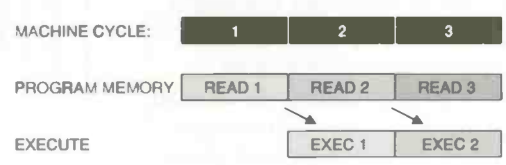


Fig 2 Simple software timing loop

Using the PIC

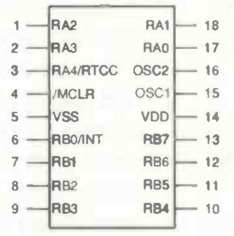
For the purposes of this article we will look in detail at the PIC16C84. This is an EEPROM device and thus it is reprogrammable easily, even when installed in a system. It is one of the second-generation PIC devices which has interrupt control and a larger stack than the earlier devices and which allows up to 8 levels of program subroutine nesting. It is available in 4MHz or 16MHz clock versions. It also has 64 bytes of EEPROM data memory which can be read or programmed during operation to store data which must be maintained through power loss. Most of the features of the PIC16C84 are similar to other PIC devices; only the EEPROM facilities are unavailable in other devices. The PIC16C71 is almost identical to program - it has an A/D converter and 4 input multiplexer to the converter.

Figure 3 shows the pin out of the PIC16C84. Figure 4 shows the circuit diagram of a PIC application where the device is using a crystal oscillator. Note that there are only 4 components external to the PIC ! The reset pin (4) is tied to Vdd in most applications, this causes an automatic reset of the PIC when the power is applied. To allow reset during operation the pin should be tied to Vdd with a resistor and can then be pulled low to reset the chip.

The decoupling capacitor should be fitted as close to the chip as possible.

The I/O pins have a drive capability of 20mA when configured as outputs, and an input drive requirement of less than 1uA when configured as inputs. The outputs are sufficient to drive LEDs directly (via a series dropping resistor if required).

The PIC has an 8 bit real time clock counter (RTCC). This may be configured to count external signals (driven to pin RA4), or may be used to count cycles of the internal oscillator. There is a programmable prescalar to divide the input to the RTCC by values from 1 to 256. It is possible to cause an interrupt when the RTCC overflows; this may be used to cause regular interrupts for timing purposes.



NOTE: RA0 IS PORT A, BIT 0
RB3 IS PORT B, BIT 3
ETC.

Fig 3 Pin out of PIC 16C84

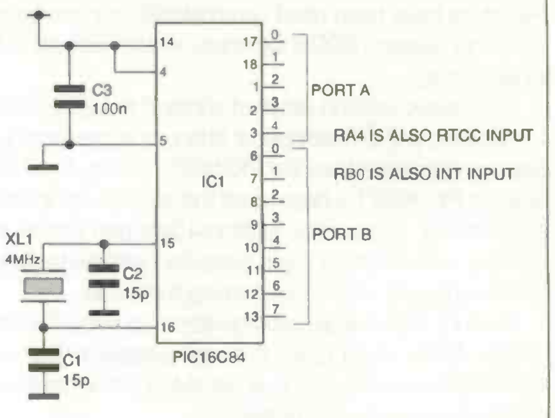


Fig 4 Simple PIC application Circuit

Address	Page 0	Bits 7	6	5	4	3	2	1	0	
0	INDIRECT									Used in indirect addressing
1	RTCC									Real Time Clock Counter
2	PCL									Lower 8 bits of program counter
3	STATUS	IRP	RP1	RP0	TO	PD	Z	DC	C	Status register
4	FSR									Indirect register address
5	PORT A	-	-	-	RA4	RA3	RA2	RA1	RA0	Port A, input/output
6	PORT B	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0	Port B, input/output
7	PORT C	RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0	Not used on PIC16C84
8	EEDATA									Data to or from EEPROM
9	EEADR									Address of EEPROM to access
A	PCLATH									High 5 bits of program counter
B	INTCON	GIE	EEIE	RTIE	INTE	RBIE	RTIF	INTF	RBIF	Interrupt control register
C 2F										General Purpose Registers (36)

Fig 5 Memory map of PIC 16C84 showing Page 0 and page 1

Address	Page 1	Bits 7	6	5	4	3	2	1	0	
0	INDIRECT	RBPU	INTEDG	RTS	RTE	PSA	PS2	PS1	PS0	Same as page 0
1	OPTION									
2	PCL									Same as page 0
3	STATUS	IRP	RP1	RP0	TO	PD	Z	DC	C	Same as page 0
4	FSR									Same as page 0
5	TRIS A									Port A data direction (out = 0)
6	TRIS B									Port B data direction (out = 0)
7	TRIS C									Not used on PIC16C84
8	EECON1	-	-	-	EEIF	WERR	WREN	WR	RD	EEPROM control
9	EECON2									Not a physical register
A	PCLATH									Same as page 0
B	INTCON									Same as page 0
C 2F										Same as page 0

Programming the PIC

The PIC series is programmed in PIC assembler. The lack of program memory and small size of most applications limits the use of higher level languages, although a BASIC interpreter is available on the Stamp computer.

PIC assembler is similar to other assembly languages. Labels may be used anywhere that a number could be used, and may have any combination of letters, underscores and digits up to 32 characters. Labels may be assigned to a value using the EQU directive. The ORG directive identifies the location for the current assembly. The PIC assembler is available from Microchip - see the later section on development tools.

To understand programming of the PIC, it is useful to look at the data memory map; figure 5 shows the memory map of the PIC16C84. The data memory area has a 7 bit address. It is split into two areas, the lower area is known as page 0 and the upper area as page 1. Note that the bottom 12 bytes of each page are special function registers and have addresses from 00 to 0B. Each page is 127 bytes long and the page to be used is selected using two bits in one of the special function registers. Addresses from 0C to 2F are general purpose read/write registers (RAM), and are duplicated in each page. Addresses from 30 to 7F are unimplemented and if read return 0's.

There is one working register known as the W register, which is used to store temporary values during operation.

As previously mentioned it is not possible to read the program memory; special techniques are available to implement data tables, these are described later in this article.

Some of the special function registers are described below, the use of the others is described in the later section on advanced programming.

Page 0, Address 1, RTCC

This is the 8 bit RTCC value. It may be read or written.

Page 0, Address 3, STATUS (also Page 1, Address 3)

This byte holds the processor status (normally known as flags on other processors). It contains the following bits:

Bit 0	C	Carry bit. This bit is set if there is a carry out from the previous operation. Note that a subtract is executed by adding the 2's complement of the second operand so that 2-3 will result in -1 and C=0, and 3-2 will result in 1 and C=1. This behaviour for subtraction is the opposite of what would be expected for most processors.
Bit 1	DC	Digit carry. This bit is set if there is a carry out from the 4th low order bit of the resultant.
Bit 2	Z	Zero bit. This bit is set if the result of the previous operation was zero.
Bit 3	PD	See advanced programming section.
Bit 4	TO	See advanced programming section.
Bit 5	RP0	The RP0 and RP1 bits are used to select the page
Bit 6	RP1	which is addressed by the data bus. Page 0 is addressed if RP0 and RP1 are both 0, Page 1 is addressed if RP0 is 1 and RP1 is 0. Note that as the STATUS register appears at address 3 in all pages, then the current page may be selected from any page.
Bit 7	IRP	Used in indirect addressing, see advanced programming section.

Page 0, Address 5, PORT A

Page 0, Address 6, PORT B

Addressing these registers will read or write the bits of Port A or Port B. Port A reads or writes pins RA0 to RA4, Port B reads or writes pins RB0 to RB7. Reading a bit which is configured as an output will return the last value written to the bit. See TRIS A and TRIS B below for a description on how to set port bits to inputs or outputs.

Page 1, Address 5, TRIS A

Page 1, Address 6, TRIS B

These registers set the port bits to inputs or outputs. If a bit in the TRIS register is set low then the corresponding pin on the port will be set to output. Thus setting bit 3 of TRIS A to 0 will make pin RA3 an output.

Instruction set

There are only 37 instructions available illustrated in table 2. They divide into three groups:

1) Byte oriented register operations.

These instructions all operate on a register on its own, or on a register in combination with the W register. Instructions which return a result may direct the result to the W register or to the register specified in the instruction. This is achieved by putting a ',' and then an F or W after it. F will direct the result to the original register, W will direct the result to the W register.

For example, to add the contents of the W register and register number 2B and to put the result in the W register the following instruction is used:

ADDWF 2BH,W

To do the same, but to put the result back into register 2B the following instruction is used:

ADDWF 2BH,F

This latter form where the result is written back to the original register is very common. The ",F" may be left out and the instruction may be abbreviated to :

ADDWF 2BH

2) Bit oriented register operations

These instructions operate on single bits of the specified register file. For example to set bit 3 of register number 7 to 1 then the following instruction is used:

BSF 7,3

3) Literal and control operations

These operations either operate on the W register with an 8 bit literal value, or affect the operation of the controller.

Control instructions

The following instructions are used to control program flow and to perform subroutine calls.

CALL label	This instruction calls the subroutine at the specified address. Operation continues after the call instruction when the subroutine returns. This instruction takes two machine cycles.
RETURN	This instruction continues program operation from the point at which the subroutine was called. This i nstruction takes two machine cycles.
RETLW value	This instruction continues program operation from the point at which the subroutine was called. Before returning the W register is filled with the value supplied in the Instruction. This instruction takes two machine cycles.
BTFSC reg,bit	This instruction tests the bit speci fied in the register specified. If it is clear then the next instruction is skipped (two machine cycles), if it is set then the next instruction is executed (one machine cycle).
BTFSS reg,bit	As BTFSC, but the next instruction is skipped if the bit is set, and executed if it is clear.
INCFSZ reg,dest	This instruction increments the defined register putting the result back in the register or W as defined by dest. If the result is zero then the next instruction is skipped (two machine cycles), otherwise it is executed (one machine cycle).
DECFSZ reg,dest	As INCFSZ except that the register is decremented.

Examples

The following example code shows how to set port B to output

```
    INCLUDE "16C84.EQU" ; BRING IN STANDARD
                        LABELS
    ORG 0                    ; START AT LOCATION 0
    BSF STATUS,RP0           ; SET REGISTER FILE TO
                               PAGE 1
    CLRF TRISB               ; SET ALL PORT B BITS
                               TO OUTPUT
    BCF STATUS,RP0           ; SET BACK TO PAGE 0
    CLRF 20H                 ; USE ADDRESS 20 AS
                               INDEX REGISTER
WLOOP MOVF 20H,W             ; MOVE INDEX TO W
```

```
    MOVWF PORTB              ; MOVE W TO PORT B
    INCFSZ 20                ; INCREMENT INDE
    GOTO WLOOP               ; GO BACK IF INDEX IS
                               NOT YET 0
FOREVER GOTO FOREVER         ; CODE IS COMPLETE,
                               LEAVE PORT B AT FF
```

and then write all hex values from 00 to FF to that port. Note the use of ORG which sets the address for the code in program memory, labels which are any string at the start of a line, and comments which start on a line following a ';' character.

The first line (INCLUDE "16c84.EQU") includes a file which defines all the special function registers and bits in easy to understand mnemonics. Thus "BSF STATUS,RP0" is equivalent to "BSF 3,5" - but much easier to understand !

If the processor has a 4MHz clock then it is possible to work

```
    INCLUDE "16C84.EQU" ; BRING IN STANDARD
                          LABELS

    ORG 0                ; START AT LOCATION 0
    BSF STATUS,RP0       ; 1
    CLRF TRISB           ; 1
    BCF STATUS,RP0       ; 1
    CLRF 20              ; 1
WLOOP   MOVF 20,W        ; 1             *
    MOVWF PORTB          ; 1             *
    INCFSZ 20,F          ; 1/2           *
    GOTO WLOOP           ; 2             *
FOREVER GOTO FOREVER     ; 2
```

out the time that will be taken between output changes. The same code is shown below with the time taken in machine cycles shown for each instruction.

When the INCFSZ is executed during the loop it will take 1 machine cycle until the final instruction as its result is not 0. Thus the total loop time is the sum of all the starred (*) instructions i.e. 5 machine cycles. As each machine cycle is 4 oscillator clock periods the total time between output changes is 5uS. The total time required to execute the program (until it reaches the forever label) is:

4 (First 4 instructions)
+
5*255 (All outputs except the final value)
+
4 (Final loop time, no goto)

1283uS Total time 1.283mS

The next example is a complete application. The PIC is used as serial to parallel converter. The input is from a standard RS232 serial port which should be set to 9600bps, 8 bit, no parity, 1 (or more) stop bits. The output is 8 bits on port B which are set to the next received value from the serial port. When a new byte is received, a positive going, short pulse (approx. 1uS) is output on the strobe line. During the reception of the byte the LED is turned on to confirm operation of the serial port. The PIC uses a readily available 3.58MHz colour crystal.

Figure 6 shows a circuit diagram, and figure 7 shows the code required to implement it. Note that only 45 words of program space (4.4% of that available) is required !

Advanced programming
Interrupts

There are four sources of interrupt on the PIC16C84. These are edge change on pin RB0, RTCC overflow, change of input on pins RB4, RB5, RB6 or RB7, and end of EEPROM write. On an interrupt, the program calls the subroutine located at address 4. On completion of the interrupt routine the program should use a RETFIE instruction to return to the interrupted point.

The INTCON register controls the interrupts (see figure 5), its bits have the following functions:

- RBIF This bit is set if RB<7:4> have changed, causing an interrupt.
- INTF This bit is set when an INT interrupt occurs (on RB0).
- RTIF This bit is set if an interrupt occurred due to the RTCC overflowing.
- RBIE This bit enables the RBIF interrupt (if set to 1).
- INTE This bit enables the INTF interrupt (if set).
- RTIE This bit enables the RTIF interrupt (if set).
- GIE This bit is the global interrupt enable. All interrupts will be disabled if this is set to 0. It is set to 0 by an interrupt which causes the interrupt routine to be called and is set back to 1 by a RETFIE instruction.

RBIF, INTF and RTIF must be checked and reset (if they were set) in the code for the interrupt; failure to do so will cause repeated interrupts.

```
   org 4 origin for interrupt code

intcode:movwf savew       ; location to save W
                            register
   swapf STATUS,W         ; move status to W - not
                              affecting flags
   movwf savestat         ; location to save
                status
                ...
endint:swapf savestat,W ; get back status
        movwf STATUS
        swapf savew       ; swap digits in savew
                             (no status effect)
      swapf savew,W       ; and get back to W
                            (no status effect)
      retfie              ; return from interrupt
                             (set GIE to 1)
```

The interrupt pin (INT-RB0) is either rising or falling edge triggered. The edge is selected by the INTEDG bit of the OPTION register. If this bit is 1 then rising edge interrupt is enabled, otherwise if 0 then falling edge interrupt is enabled.
The interrupt code should save the status and W registers, suitable code is shown below:

Real Time Clock Counter

The RTCC may be configured to take its input from the on chip oscillator, or to take its input from the external RTCC input on pin RA4. When it is configured to use the instruction cycle clock, it actually updates once every 4 internal oscillator clocks, e.g. at a 1MHz rate with a 4MHz external crystal. It is an 8 bit counter which may be set to trigger an interrupt when it clocks from value FF to value 00. The RTCC may be read or written.

The OPTION register controls the RTCC (see figure 5). The bits which affect the RTCC are as follows:

PS0-PS2 These bits control the pre-scalar division rate. If the prescalar is enabled then the input to the RTCC is divided by the prescalar in accordance with the table shown:

PS2	PS1	PS0	Division in pre-scalar
0	0	0	Divide by 2
0	0	1	Divide by 4
0	1	0	Divide by 8

0	1	1	Divide by 16
1	0	0	Divide by 32
1	0	1	Divide by 64
1	1	0	Divide by 128
1	1	1	Divide by 256

PSA If this bit is set to 0 then the pre-scalar is used, if set to 1 then the pre-scalar is not used (it is then used for the watchdog timer - see below).

RTE RTCC signal edge. If set to 0 then increment RTCC on the rising edge of RA4, if set to 1 then increment on the falling edge of RA4 (if the source is set to the external pin).

RTS RTCC source. If set to 0 then the RTCC uses the internal instruction cycle clock, if set to 1 then it uses the RA4 pin.

Port B pull ups

Port B has weak pull ups to Vdd which may be enabled or disabled by the RBPU bit in the OPTION register (see figure 5). If this bit is set to 1 then approximately 50K pull ups will be enabled on all port B pins; if set to 0 then these pins will float if not externally driven. This is to reduce the need for external pull-ups when port B pins are used as inputs.

Sleep mode

The PIC may be set into sleep mode when there is no activity. In this mode the oscillator is stopped, the program stops executing, but the I/O ports are maintained in the state which they held before sleep mode was entered. In the status register the PD bit is cleared and the TO bit is set in the STATUS register. The watchdog timer continues running. The device may be woken from sleep mode by an external reset, or by any enabled interrupt (even if interrupts are globally disabled using GIE).

In sleep mode the PIC consumes less than 35uA.

To enter sleep mode the SLEEP instruction is executed.

Watch Dog Timer

The watch dog timer (WDT) is designed to guard against software failure or overload, or noise induced failures. The WDT must be reset at regular intervals to prevent it overflowing. If enabled, then as it overflows the PIC will be reset. It is possible for the PIC to detect a Watch Dog failure reset using the bits in the status register.

The watch dog is enabled or disabled when the device is programmed.

The use of the watch dog is mainly restricted to resilient commercial applications, and is not further considered here. Many developers will disable the WDT when they program the PIC as failure to periodically reset the WDT will cause unexpected device resets which can make debugging very difficult.

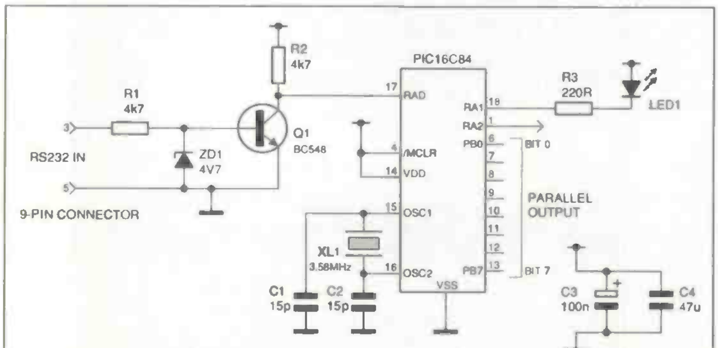


Fig 6 Circuit for code shown in Fig 7

Indirect Addressing

Indirect addressing is used whenever the program needs to use the contents of one register (or W) to select an operation on another register. To achieve this, the address of the register which is required is written to FSR - register number 4. Now any access to register 0 will actually access the register which has the address found in FSR. To select the page, bit 7 of FSR is the lower bit of the page select and bit IRP of the STATUS register is the upper bit of the page select. Thus, if bit 7 of FSR is 1, and IRP is 0, then page 1 will be addressed by the lower 7 bits of FSR.

As an example, the following code fragment will clear all registers from address 20H to 2FH.

```
    movlw 10H             ; 16 registers to clear
    movwf index           ; index is a general
                    purpose register
clearloop  movlw 20H      ; Registers to clear are
                            20H above index
    addwf index,w         ; address of register to
                            clear
    movwf FSR    ; move to indirect address
                    register
    clrf 0                ; clear register
                            addressed by FSR
    decfsz index          ; now loop index times
```

Calculated program jumps

It is possible to write to the program counter (register 3, PC), to cause a program jump. In this case, the program will jump to the address formed by the 8 bits written to the PC and the 5 bits (of which only 2 bits have meaning in the PIC16C84) of register PCLATH (register 0A). The jump occurs when the bottom 8 bits are written to PC. For an example see the section on data tables below.

Data tables

As it is not possible to read program memory, data tables must be implemented using some special techniques based on calculated jumps. The RETLW instruction returns from a subroutine with a specific value, so if a subroutine is called which then

```
GETCODE   CALL GETDATA ; CONVERT    VALUE IN W
                         TO 7 SEGMENT VALU
          OTHER CODE HERE
          ORG 100        ; DATA TABLE IS
                              LOCATED HERE
          RETLW 3FH      ; CODE FOR VALUE 0
          RETLW 06H      ; CODE FOR VALUE 1
          RETLW 5BH      ; CODE FOR VALUE 2
          RETLW 4FH      ; CODE FOR VALUE 3
          RETLW 66H      ; CODE FOR VALUE 4
          RETLW 6DH      ; CODE FOR VALUE 5
          RETLW 7DH      ; CODE FOR VALUE 6
          RETLW 03H      ; CODE FOR VALUE 7
          RETLW 7FH      ; CODE FOR VALUE 8
          RETLW 6FH      ; CODE FOR VALUE 9
GETDATAM  OVWF TEMP      ; SAVE W BRIEFLY
          MOVLW 1
          MOVWF PCLATH   ; TABLE AT LOCATION
                           100,SO PCLATH IS 1
          MOVFW TEMP     ; GET BACK W
          MOVFW PC       ; DO THE JUMP
```

makes a calculated jump to a RETLW instruction with the required return value then this can be used to implement a data table. The example shows the technique. In this case the value in the W register (from 0 to 9) is converted to a code which represents that value on a 7 segment display. On the display segment A is the LSB (bit 0) and segment G the MSB (bit 6).

EEPROM

The EEPROM is 64 bytes long. It can be written or read through the control registers shown in figure 5. To protect against accidental erasure, a very specific write sequence must be employed. The EEPROM typically has a life of 1,000,000 erase/write cycles, but can be read indefinitely.

Use of the EEPROM is described fully in the Microchip data book.

Development tools

Microchip have an assembler available for the PC called MPALC. This will assemble files for any of the PIC series into object files which may be used for simulation, or directly in one of the PIC programmers to program a PIC.

There is also a PIC simulator for the PC. This is very useful for testing programs in advance, as it allows the user to set up expected inputs and to test the program responses. It allows break points, and single stepping and emulates most of the features of the PIC series including interrupts, the RTCC and watchdog timer.

The assembler and simulator are available for download free of charge from the Microchip bulletin board; this gives the opportunity to try sample programs and to test them. The documentation for the programs are also available on the board, although it was somewhat lacking last time I looked at it!

To use the bulletin board :

1) Set your communications package and modem to 8 bit, No parity and one stop bit; note that this is not the same as Compuserve.

2) Dial the nearest direct Compuserve access number (you do not need a compuserve account to access the board). The London access number is 0171-490-8881.

3) Type <RETURN>, ignore any garbled message which may appear.

4) Type <RETURN> again and "Host Name:" will appear.

5) Type"MCHIPBBS<RETURN>" and the Microchip BBS connection will be made.

6) You will need to register and check out the special areas devoted to PIC programming. Registration is free.

There is also available a cheap programmer for use with development and very small production runs. This is called the PICSTART16-B system and costs about £170. It includes a programmer, the assembler, emulator and programming software, sample chips, and data books. This system will handle any of the 18 or 28 pin PIC chips.

Large scale production programmers and In Circuit Emulators (ICE) are available but are prohibitively expensive for hobbyist use. A number of general purpose programmers will also handle PIC devices.

Figure 7, Serial to parallel converter example

```
; This example code implements a serial
to parallel converter
; First set up some constant values
  include   "16c84.equ"     ; bring in
                              standard
                              definitions
   rxbit      equ 0         ; Bit 0 on port
                              a (RA0) is
                              the input
   ledbit     equ 1         ; Bit 1 on port
                              a RA1) is the
                              LED drive pin
   strobe     equ 2         ; Bit 2 on port
                              a (RA2) is
                              the strobe
                              output
   rxbitv     equ 1           ; These are
                              the values of
                              the bits
                              (i.e.2^bit)
   ledbitv    equ 2
   strobev    equ 4

   rxser      equ 0CH       ; Received
                              character
                              register
   intindex   equ 0DH       ; Index
                              register
                              used in
                              receive
                              character
   intindex1  equ 0EH       ; Index
                              register used
                              in receive
                              character
; Start by org'ing code, note no inter-
rupts so we can run over location 4

              org 0      ; Restart location
; This is the start up code and main
schedule loop
start        clrf intcon   ; No interrupts
             clrf porta    ; clear port A
                             and port B
                             for initial
                             output
                             clrf portb
             bsf status,   ; Switch to
             rp0             page 1
             movlw 80      ; options, no
                             pull ups on
                             port B, RTCC
                             internal
             movwf optreg
             movlw rxbitv ; Port A is all
                             outputs
                             except
                             receive bit
             movwf trisa
             clrf trisb    ; Port B is all
```

```
                         outputs
        bcf status,rp0 ; return to
                         lower page
       bsf porta,ledbit; turn off the
                         LED (low=cn,
                         high=off}
; Main loop

schedule  call rxchar    ; Wait until we
                           receive a
                           character
          movfw rxser    ; Get received
                           character to
                           W
          movwf portb    ; Write new
                           value to port
                           B
          bsf porta,
          strobe         ; Strobe signal
                           high
          nop            ; leave 1uS
          bcf porta,
          strobe         ; and strobe
                           signal low
                           again
          goto schedule  ; and back for
                           next
                           character
; This is the receive handler - used for
reception of data on the serial port at
9600bps
; At 9600bps and clock=3.58MHz then 1
bit=93 instructions, 1/2bit=47
instructions
; A byte received on the serial line
will have the following form:
; ----|_______| bit 0 | bit 1 | .... |
bit 7 |-----
; stop     start        data     stop bit
; (high)   (low)                 (high)
; This routine returns the received
character in the register rxser
rxchar btfsc porta,rxbit ;1/2 Wait for
                              serial line
                              to fall -
                              start bit
          goto rxchar    ; 2
          bcf porta,
          ledbit         ; 1  Turn on the
                              LED
          movlw 8        ; 1  pick up 8
                              bits
          movwf intindex ; 1
          call delay 46  ;    48 delay to
                              just after
                              middle of
                              start bit
                         ;    so that
                              first
                              sample is
                              1.5 bits
                              after start
```

```
      rxloop                call delay 83
                       ;    85 delay
                              routine
      nop              ; 1  add 1 cycle
                            to make
                            exactly 93
                            cycles
      bcf status,c     ; 1  start by
                            clearing
                            carry
      btfsc
      porta,rxbit      ; 1/2now test the
                            input bit
      bsf status,c     ; 1  and set carry
                            if the input
                            bit was 1
      rrf rxser,f      ; 1  rotate in
                            data, LSB
                            arrives first
      decfsz intindex  ; 1  now
                            decrement
                            the bit
                            counter
      goto rxloop      ; 2  and loop -
                            TOTAL 93
                            CYCLES/BIT

waitend btfss porta,
      rxbit            ;    now wait for
                            end of last
                            bit if it was
                            0.
      goto waitend     ;    - otherwise
                            we'd run
                            straight back
                            in o this
                            routine
      bsf porta,ledbi  ;    turn the LED
                            back off
      return           ;    return during
                            the stop bit
; delay routines for above, delaynn will
delay for exactly nn instructions
delay 46 movlw .14; 1 loop time=3
(n-1)+7
delex  movwf intindex1 ; 1
d34loop decfsz
intindex1              ; 1/2=3.(14-1)+7
       goto d34loop    ; 2
       nop             ; 1  =46
       return          ; 2
       delay 83 movlw
       .25             ; 1  loop
                            time=3.(n-
                            1)+11
       nop             ; 1
       nop             ; 1
                            =3.(25-1)+11
       goto delex      ; 2  =83

end
```

SMART MAINS CONTROL SYSTEM

A SMART mains control system designed by Dr Pei An allows a computer to control up to 93 different mains devices using signals actually transmitted through the mains power cable

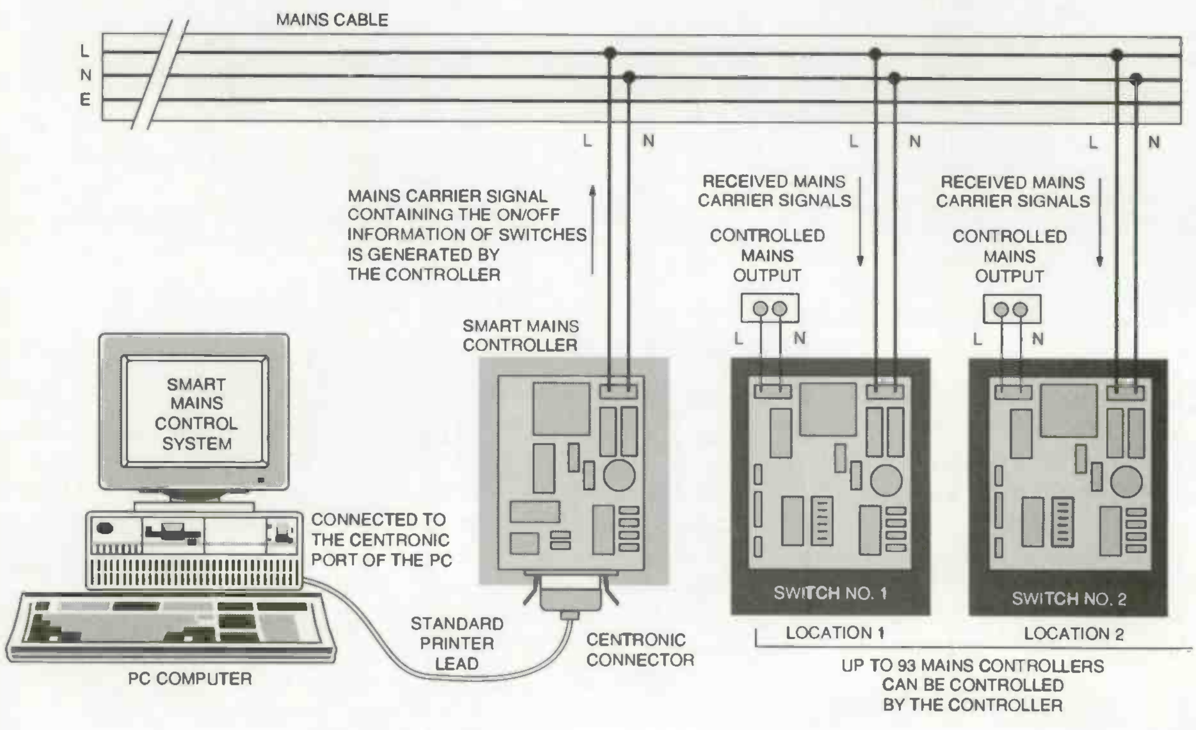


Figure 1 Computer controlled SMART mains control system

This mains controller is a system which allows up to 93 individual mains switches to be controlled by a personal computer. This system is 'smart' because the switches are not controlled by any control wires connecting the switches to the computer. The control commands to tell the switches to turn on or off are generated by a computer-based controller and transmitted through the existing mains lines in a building. The switches detect the message and carry out corresponding actions. The schematic of the system is shown in Figure 1.

This system has a huge advantage over the conventional system. In the conventional system, each mains switch has to be controlled by separate wires for controlling the on and off of the switches. This requires investment as well as effort to install the wiring in the building. Once the wiring is installed, the switches cannot be moved freely. However, the SMART mains control system solves all these problems.

CAUTION

It must be pointed out the this mains control system is connected directly to 240V AC and therefore danger exists to the constructors. Physical contact with the mains can be lethal and every precaution must be taken to prevent this from happening. If constructors have any doubts, please ask advice from competent electricians.

The smart mains control system consists of a master controller (transmitter) controlled by a PC and up to 93 switches (receivers) as shown in Figure 1. The controller sends ON/OFF commands to the switches through the mains and the switches receive the signal, analyse the commands and carry out actions.

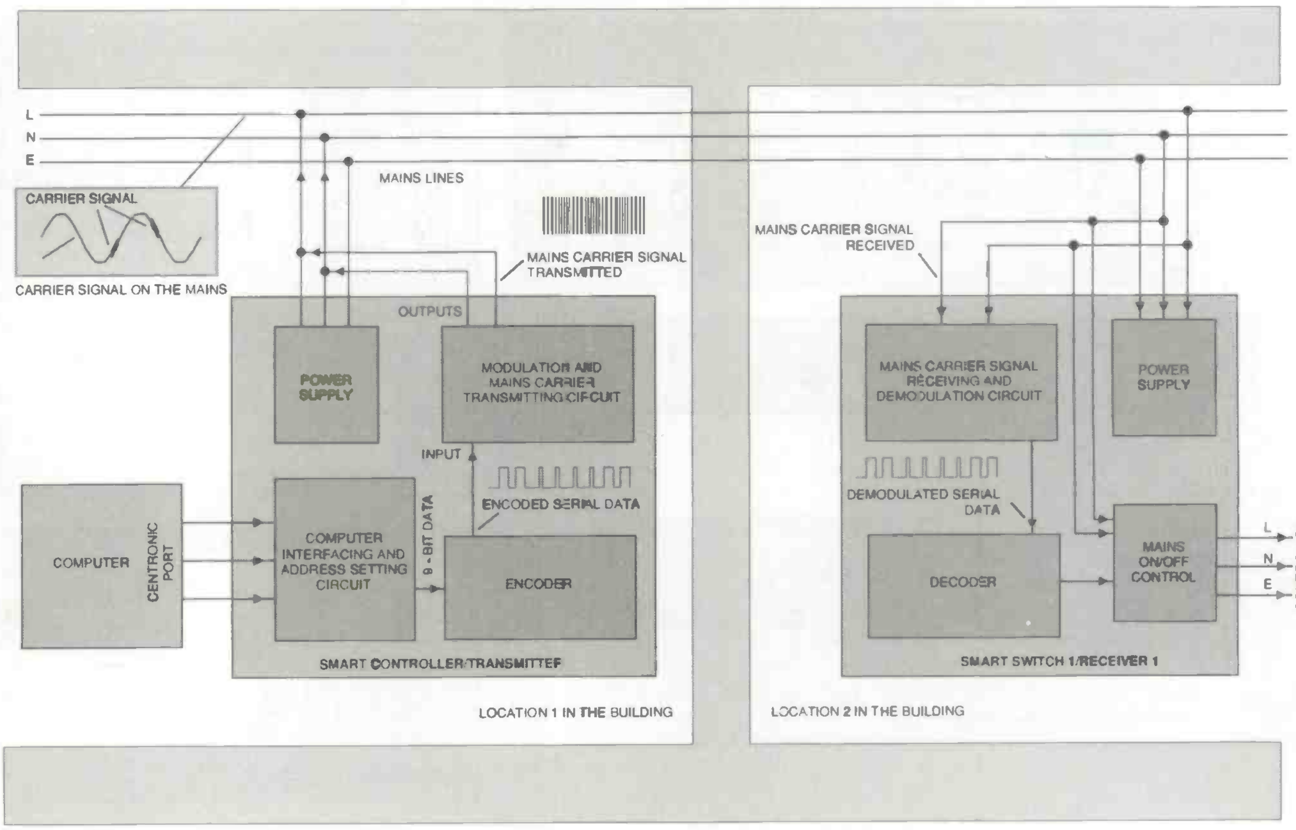


Figure 2 Block diagram and working principle of the SMART mains control system

Inside the controller (transmitter) there is a 9-bit parallel data encoder which converts a 9-bit digital data into the serial data (Figure 2). This 9-bit data is supplied by the computer and it contains a 5-bit address and 4-bit control data. The encoded signal is fed into a modulation and mains carrier transmitting circuit (Figure 2) which firstly modulates the encoded serial data using a Frequency Shift Keying (FSK) technique. That is when a logic low is received at the input of the circuit, a tone burst of 127.8 KHz is generated at the output; when logic high is received, a tone burst of 122.5 KHz is generated. These signals are coupled to the mains lines and superimposed onto 240V AC. Therefore a 9-bit data is transmitted on the mains line in a form of a series of tone bursts at frequencies of either 128 KHz or 123 KHz. This carrier signal is then transmitted via the mains to various parts of the building.

Each switch is connected to the mains either via mains plugs or by direct wirings. The carrier signal on the mains lines are detected by a mains carrier signal receiving and demodulation circuit (Figure 2). In this circuit, the signal passes various filters and is processed by a circuit based on a so-called Phase Lock Loop (PLL) tone decoding technique. If a signal of frequency 128 KHz is received, it produces logic low at its output. If a signal of frequency 123 KHz is received, it produces logic high at the output. Therefore after this circuit, a series of digital data is reproduced which should be identical to that generated by the encoder of the controller. This signal is fed into a decoder IC (which is in pair with the encoder in the controller) which decodes the received serial data back into 9-bit parallel digital data. Each switch has a particular address ranging from 1 to 93 determined by a 5-bit address and three ON/OFF control lines. If the received address of the command matches the preset address, the switch will perform switching according to the status of one of the three control lines. If it does not match the preset address, the switch will ignore the commands and maintain its previous status.

The controller (transmitter)

The controller consists of four units; namely, the computer interfacing unit, the encoder, the modulation and mains carrier transmitting unit and the power supply unit. Figure 2 shows the unit diagram of the controller and Figure 3 gives the circuit diagram of the controller.

The computer interfacing unit contains an ILD74 which is a dual opto-isolator IC and a 74LS164 8-bit shift register IC (IC2). The opto-isolator which is configured to a non-inverting circuit, is used to ensure complete isolation of the computer from the controller. Refer to Figure 3; an 8-bit data is serially loaded into the shift register 74LS164 using DATA (Pins 1 and 2) and CLOCK (Pin 8). Loading data into the register is described briefly below: The data bits (MSB first) are held stable on the DATA inputs and a short pulse of low-to-high-then-low is applied to the CLOCK (Pin 8) input. At the rising edge of the clock signal, the data bit is shifted. After eight such operations, the 8-bit data can be loaded into the shift registers. The circuit can be controlled by any I/O ports of computers having at least two independent output lines. The present controller is controlled by the Centronic port of the computer.

The encoder circuit incorporates a M145026 encoder IC. The pin-out functions of the IC are shown in Figure 4(a), together with the decoder IC M145027 which is in pair with the

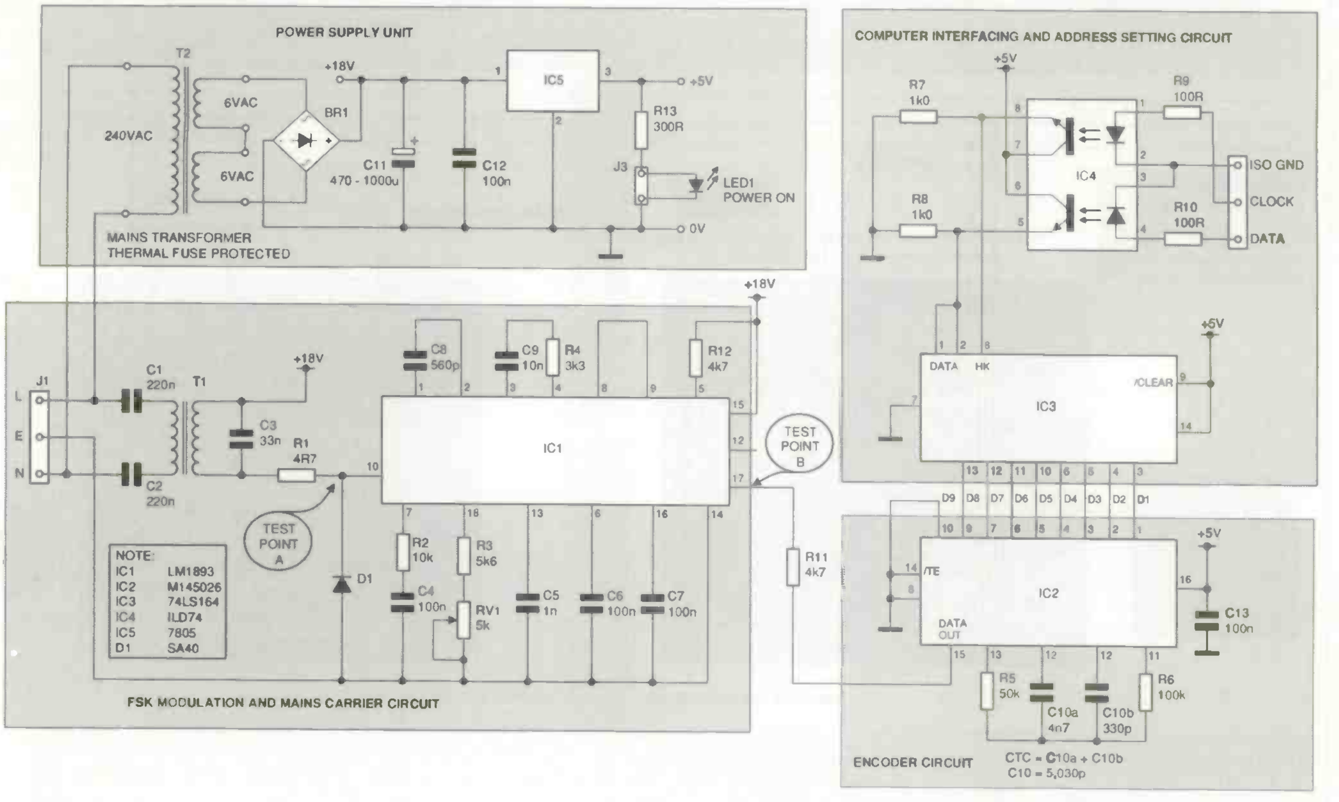
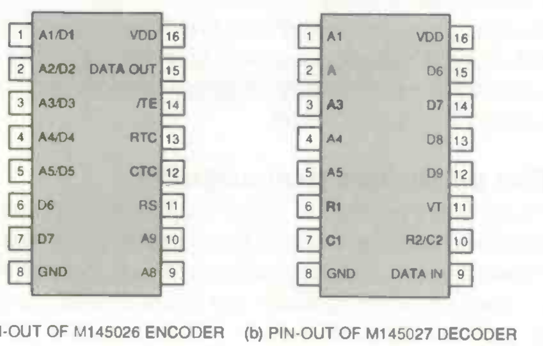


Figure 3 Circuit diagram of the SMART controller (transmitter)



(a) PIN-OUT OF M145026 ENCODER (b) PIN-OUT OF M145027 DECODER

Figure 4 Pin-out of M145026 encoder and M145027 decoder ICs

encoder. GND (Pin 8) and VDD (Pin 16) are connected to the negative and positive rail of the power supply which is in the range between 4.5V and 18V. A typical application of the encoder and the decoder is shown in Figure 5. The encoder will serially transmit nine bits of trinary data defined by the state of the A1/D1 to A9/D9 inputs from Data Out (Pin 15). These inputs can be in three states (0,1 and open) allowing 39=19683 possible codes. The present card, however, only utilises two states: 0 and 1. Also, in the present application, the last bit A9/D9 is connected to ground because the 74LS164 shift register only provides 8 outputs. The encode transmission is initiated at the low-transition edge of the -TE input (Pin 14, Transmission Enable). In the present application, -TE input is wired to the ground and this makes the encoder transmit data continuously.

Each data bit is encoded into two data pulses. A logic zero will be encoded as two consecutive short pulses, a logic 1 by two consecutive long pulses (see Figure 5, encoded data format). During each transmission the encoder will output two identical data words. This redundant information is used by the decoder to reduce errors. RS (Pin 11), CTC (Pin 12) and RTC (Pin 13) are connected to the external resistors and capacitors to set the clock frequency for the serial data transmission. Their values should be determined according to the manufacturers' data sheet. The values of capacitors and resistor for some clock frequencies are summarised in Figure 5. In the circuit, the clock frequency is chosen at 1.71 KHz. This requires that RTC (R5), RS (R6) and CTC (C10a+C10b) to be 50 KOhm, 100 KOhm and 5080 pF. The value of CTC is made up by two capacitors, 4n7 and 330 pF, connected in parallel.

The output of the encoder is connected to the signal modulation and mains carrier circuit. The heart of the circuit is the LM1893 Bi-line Carrier Current Transceiver which is specially designed for the purpose of transferring serial data bi-directionally between remote locations using the mains lines. The transmitting (Tx) and receiving (Rx) modes are selected by Tx/Rx input (Pin 5, see Figure 3). The IC requires a power supply of 14-30V. V+ (Pin 15) and GND (Pin 14) are connected to the positive and negative rails of the power supply.

When the Tx/Rx pin is held high the chip is in the transmitting mode (Tx). The input digital data up to 5 KHz is fed into the Data In input (Pin 17) to generate a switched 0.9871/1.0221 control current to drive a low temperature coefficient current (I)-Controlled Oscillator (ICO), the central modulation frequency of which (F0) is between 50 to 300 KHz and is determined by R3, VR1 and C8. The signal passes through a sine-wave shaper which delivers a current sinusoid through an automatic level control (ALC) circuit to a current output amplifier. The ALC circuit is used to provide a stable output signal with changing mains impedance. C4 and R2 control the dynamic characteristics of the ALC circuit. Drive current from the Carrier I/O (Pin 10 which is an output when the IC is in transmitting mode and is input when in receiving mode) develops a voltage swing on the resonant tank T1. This voltage then passes through the step-down transformer T1 and coupling capacitors C1 and C2 onto the mains lines. The tank transformer serves as a further means of isolation and matches the impedance of the power line so as to produce the maximum carrier signals on the mains. C3 is chosen so that the tank resonant frequency is equal to F0 to allow the maximum passage for the carrier signal to the mains line. R1 and D1 are used for protecting the IC from damage during the transient voltage surges which are frequently present on the power lines.

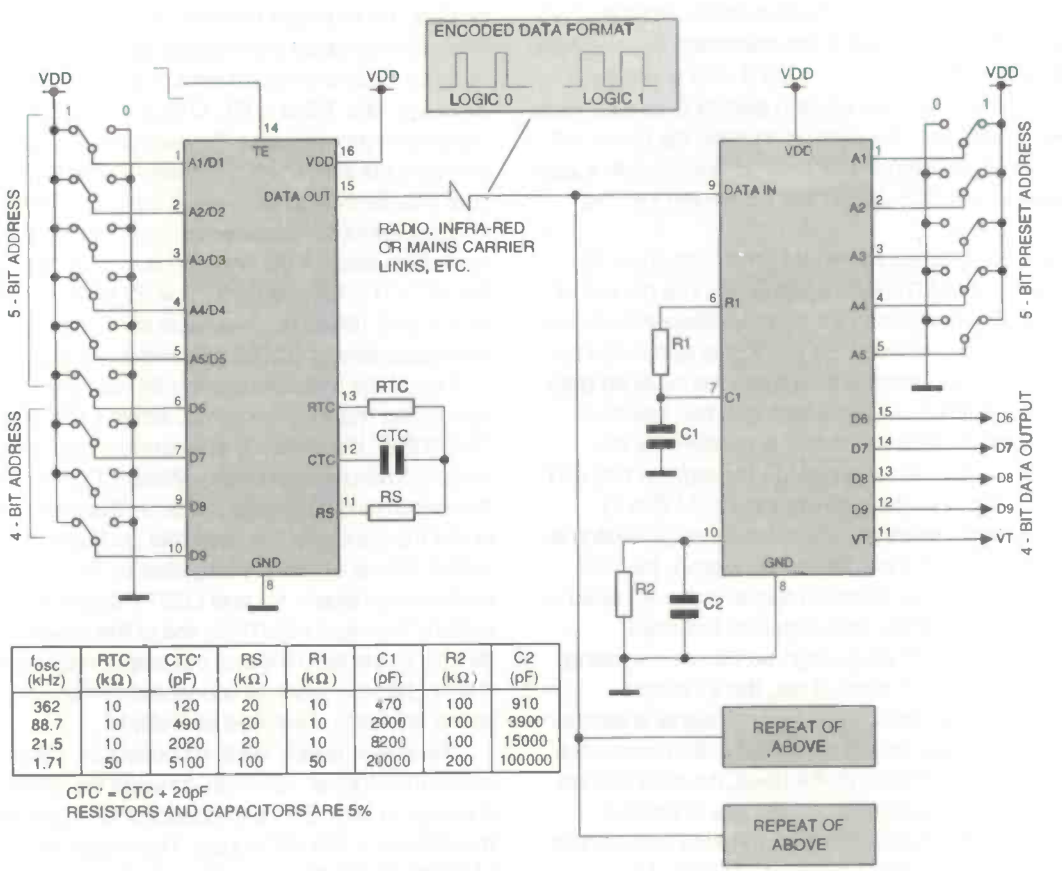
When Tx/Rx (Pin 5) is low, the chip is configured as a receiver. The transmitting section is disabled. The signal picked up by the receiver is the sum of various signals present on the mains lines. It includes the carrier signal which is useful to us, the mains 240V AC component, the mains line broad-band noise and transient voltage spikes. The signal is fed into the receiver's input highpass filter consisting of C1, C2, the tank coil T1 and the bandpass filter made up of C3 and T1. These filters allow the carrier signal and band-limited noise to pass and attenuate heavily the 240V AC and transient spike energy. The signal is fed into the Carrier I/O receiver input (Pin 10). The balanced Norton-limiter amplifier removes DC offsets, attenuates line frequency, performs as a bandpass filter, and limits the signal to drive the Phase Lock Loop (PLL) phase detector. The output signal from the phase detector containing AC and DC data signal, noise, system DC offset, and other frequency components passes through a RC lowpass filter and finally through an impulse noise filter to produce serial data at the open collector output data out (Pin 12). C7, C6, C5 etc are the components determining the characteristics of the receiving circuit.

The power supply system consists of a thermally protected mains transformer T2 which converts the 240V AC into 12V AC. A bridge rectifier BR1 and capacitor C11 are used to convert this AC into a 17V DC supply. It is used to power the LM1893 IC. This power supply is also converted to a 5V supply by a 7805 (IC5), for supplying the power to the 74LS164 shift register and M145025 encoder. LED1 is used for indicating the power on of the controller.

The controller operates in such a fashion that the computer writes an 8-bit data into the shift register via the Centronic port. The first 5 bits represent the address of the switch. The other 3 bits are used to command the switch to go ON or OFF. This parallel data is encoded into a serial data form and it is FSK modulated and superimposed onto the mains lines.

The switches (receiver)

The switch consists of 4 units, the mains carrier receiving and demodulation circuit, decoding circuit, relay circuit and power supply circuit. The circuit diagram of the switch is given in Figure 6.



f_{osc} (kHz)	RTC (kΩ)	CTC' (pF)	RS (kΩ)	R1 (kΩ)	C1 (pF)	R2 (kΩ)	C2 (pF)
362	10	120	20	10	470	100	910
88.7	10	490	20	10	2000	100	3900
21.5	10	2020	20	10	8200	100	15000
1.71	50	5100	100	50	20000	200	100000

CTC' = CTC + 20pF
RESISTORS AND CAPACITORS ARE 5%

Figure 5 Typical application of the M1 40527 decoder

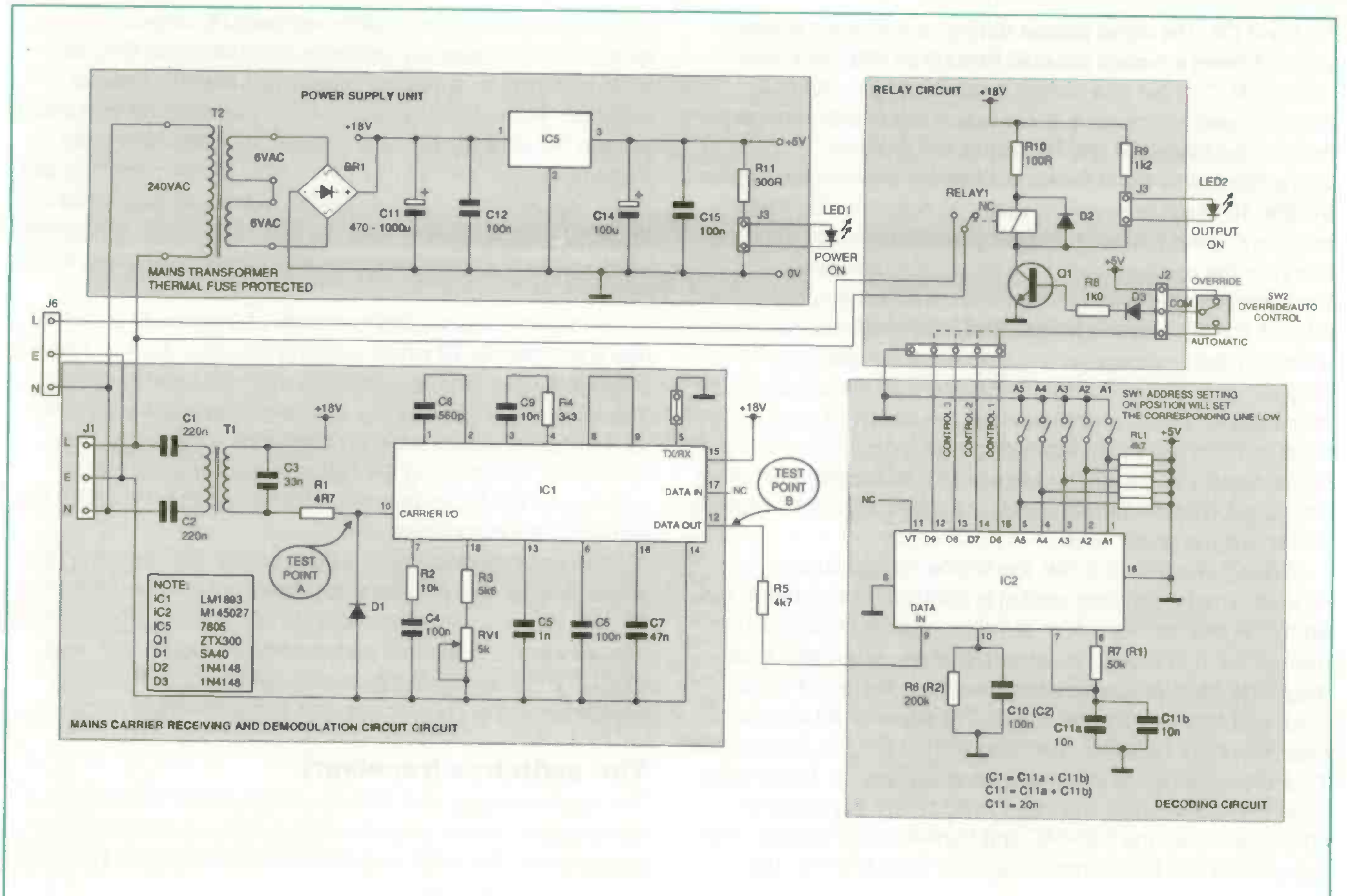


Figure 6 Circuit diagram of the SMART switch (receiver)

The mains carrier receiving and demodulation circuit is based on the LM1893 IC as used in the controller. In the switch, the IC is configured to the receiving mode (Tx/Rx is held low). The description of the IC and associated electronic circuits have been described in the controller section. In brief, the circuit will pick up the carrier signal from the mains and demodulate it into a serial digital data form. This serial data is then fed into the decoding circuit.

The decoder circuit incorporates a M145027 decoder IC which is in pairs with the M145026 encoder IC. The pin-out of the IC is shown in Figure 4(b) and a typical application is shown in Figure 5. The decoder receives the serial data generated by the encoder, checks it for errors and outputs the received data if it is valid. The transmitted data (consisting of two identical data words) are examined bit by bit as it is received by the decoder. The first five bits are assumed to be address bits and must be encoded to match the address inputs, A1 (Pin 1) through A5 (Pin 5) of the encoder. The address of the switch is set by a DIL switch SW1. If the address bits match, the next four data bits are stored in an internal register and compared to the last valid data stored. If the data matches, the Valid Transmission output (Pin 11) will go high on the second rising edge of the 9th bit of the first word. If not, the VT output remains low. Between the two data words, no signal is sent for three data bit times. As the second encoded word is received, the address must again match and, if it does, the data bits are checked against the previously stored data bits. If the two words of data match, the data is transferred to the output data latches and appears on D6 (Pin 15) through D9 (Pin 12) outputs. It will remain until new data replaces it. In the same time, the VT transmission output pin is brought high and will remain high until an error is received or until no input signal is received for four data bit times. Although the address information is encoded in trinary fashion, the data information must be either a one or a zero. A trinary (open) will be decoded as a logic one. R6 and R7, C10 and C11 are resistors and capacitors connected to the decoder. The values of these components should be calculated according to manufacturer's data sheets. In Figure 5, values for some transmitting clock frequencies of the encoder are listed. In the present circuit, the clock frequency of the encoder is at 1.71 KHz. This requires that R7, C11, R6 and C10 to be 50 KOhm, 20,000 pF, 200 KOhm and 10000 pF. The value of 20,000 pF is achieved by two capacitors of 10,000 pF connected in parallel.

One of the 3 data outputs is fed into the relay circuit. J2 selects the mode of operation. When COM is connected to OVERRIDE, the switch is in override mode (the switch will be switched on unconditionally). When COM is connected to Auto, the switch is in automatic mode. In this mode, the switch is under the control of the controller and acts as an intelligent switch. Signal at Pin 2 is amplified by TR1 and controls the mains relay Relay1. R9 and LED1 indicate the ON/OFF of the switch. The input NEUTRAL line of the mains plug is connected directly to the NEUTRAL of the output mains socket. The input mains LIVE line which is connected to the LIVE of the output mains socket is controlled by Relay1.

The power supply system consists of a thermally protected mains transformer T2 which converts the 240V AC into 12V AC. A bridge rectifier BR1 and capacitor C11 are used to convert this AC into a 17V DC supply. This supply is connected to the LM1893 IC and the relay. The 17V DC is also converted into a 5V power supply by IC5, 7805, for supplying the power to the M145026 encoder.

Programming the controller

The controller is able to interface with any I/O cards of computers, provided that the cards at least have two independent outputs. The current application utilises PC's Centronic ports (printer ports). The DATA and the CONTROL lines are connected to the DB 0 and DB 1 of the DATA port of the Centronic port, respectively. On the 36-way female Centronic-type connector, those two lines correspond to Pin 2 and Pin 3 of the connector.

It is useful to give a brief introduction to the Centronic port at this point. The port originally was designed for connecting printers to the computer. However, it can be used for much wider applications. The Centronic port consists of three separate I/O ports, namely, the DATA port, the CONTROL port and the STATUS port. The DATA and CONTROL ports are output ports. The STATUS port is an input port. The DATA port transfers the actual data during the communication between the computer and the external devices; the CONTROL port is a handshake port by which the computer issues controls to the external devices; the STATUS is another handshake port from which the computer reads the information issued by the devices. A PC can support up to 3 Centronic ports which are labelled LPT1, LPT2 and LPT3. For the purpose of explaining how to control the Centronic port, let us consider LPT1. The I/O addresses of the DATA, CONTROL and STATUS are 888, 890, 889 decimal, respectively. To send data to the DATA port of the LPT1, the follow commands can be used:

```
In Turbo Pascal:        PORT[888]:=x
In BASIC:               OUT 888, x
```

In which x is the decimal value of the data to be sent. To read data from the STATUS port the following commands can be used:

```
In Turbo Pascal:        y:=PORT[889]
In BASIC:               y=INP(889)
```

In which y is the decimal value of the data received. The control software for the SMART controller is described below: Firstly the 8-bit data which contains the 5-bit (D0 to D4) address and 3-bit (D5 to D7) control lines is chopped into bit form. Then the MSB of the data is sent to DB0 of the DATA port. Next, a low-to-high-then-low pulse is issued by the DB1 of the DATA port. This will latch the bit to the shift register. The above procedure is repeated seven times to send the rest of the data bits to the shift register.

A sample program written in Turbo Pascal 6 is listed below. When running the program, it first asks users to input the address of the switch to be controlled and then the time period of OFF and ON of the switch. After this, the program will make the selected switch to switch on and off according the specified time periods.

Next Month...

we will start on the construction of this project

List of the SMART MAINS CONTROLLER control program

```
program smart_controller;
uses
   dos,crt;
var
   address,i,j,swaddress:integer;
   weight:array[1..12] of integer;
   delaytime,lighttime:real;

Procedure bit_weight;
begin
     weight[1]:=1;
     for i:=2 to 12 do weight[i]:=weight[i1]*2;
end;

Procedure send_address(address:integer);
{send the address to the 74LS164 shift
register}
var
   sw:array[1..12] of byte;
begin
     for i:=12 downto 1 do
         begin

sw[i]:=0;
              if address>=weight[i] then begin

address:=addressweight[i];

sw[i]:=1;
                                          end;
         end;

{load sw values into the 164 registers}
     for i:=12 downto 1 do
         begin
              port[888]:=sw[i];   delay(1);
              port[888]:=sw[i]+2; delay(1);
              port[888]:=0;       delay(1);
         end;
end;

Procedure intialization;
begin
     clrscr;
     writeln('SMART MAINS CONTROL');
     write('Input the address of the SMART
switch: '); readln(swaddress);
     write('Input the delay period (second):
'); readln(delaytime);
     write('Input the light on period (second):
'); readln(lighttime);
end;

Main Program
begin
     intialization;
     bit_weight;
     repeat
     send_address(swaddress+32); {place the
chopped bit on DATA line, DB0 of the DATA port}
     delay(round(lighttime*1000)); {CLCCK line,
DB1 of the DATA port is made high}
     send_address(swaddress+0); {Clock Line,
DB1 of the DATA port is made low again}
     delay(round(delaytime*1000));
     until keypressed;
end.
```

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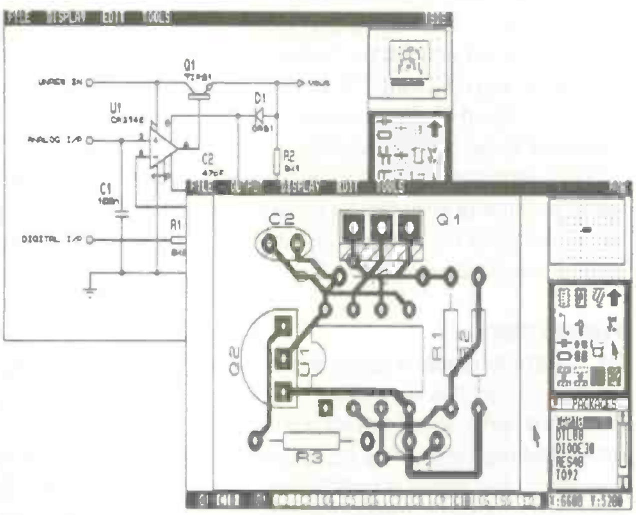

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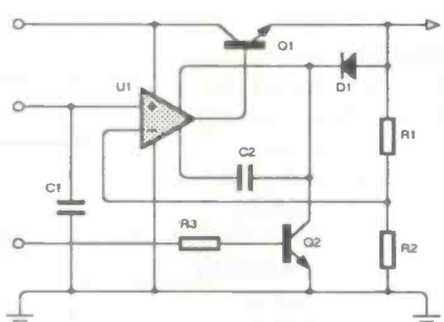

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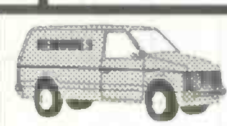

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Alarming Ideas

We are currently faced with an explosion in the number of thefts of personal computers. In this article, Jason Sharpe looks at a number of practical techniques which can be employed to deter the thief

The increase in theft means that most people's lives have been touched by crime. The criminal is often aided by those with the "It won't happen to me" attitude, who leave counter-measures until it is too late. Increasingly audacious criminals ignore conventional alarm systems. They often know how to disable mass-produced devices. While house and car alarms are deterrents, some thieves are not put off by them. One burglar took to climbing in through upstairs windows and stealing jewellery while the occupants were on the ground floor and the alarm was off. When alarms are on, some thieves will break in, remove an expensive item, such as a video, and be off before anyone notices. Such break-ins often take place in cars, where radios are the targets.

Unfortunately, counter-measures that injure the criminal are likely to land you in court on an assault charge (in the UK at least). The only thing the innocent citizen can do is to make life as hard as possible for the criminal. This article presents a few obstacles to put in the way of the thief. None is guaranteed to prevent your property being stolen, but every little helps. The devices are designed to protect individual items 24-hours a day, even when the main alarm in not on. They are also useful where a full alarm system is not possible, such as students halls of residence, which have become popular with those seeking consumer electronics.

Optical Loop Alarm

The first line of protection is to attempt to deter removal of expensive items. This can be done by attaching sensors to the items. Shops selling electronic goods often stick micro-switches, connected in a normally closed (N.C.) loop, to items to protect them. Special plastic cases are used to enable the micro switches to be easily attached to equipment. In domestic situations these alarms can be set off when the protected item is moved during cleaning, etc. In a house, a thief may also have time to tamper with the loop, and possibly short out the sensors.

This alarm uses a length of polymer fibre-optic cable threaded through the devices to be protected. Fibre optic cable cannot be shorted out, and it can be used in electrically noisy environments. Connectors can be inserted into the fibre (such as the 'dnp' connectors from RS) for added versatility. As the polymer will not corrode, it could be used outside to protect bikes and garden equipment, which have become popular targets for criminals.

Transmitter

The emitter, LD1, is switched on and off at approximately 20kHZ by IC1. Normally a 555 produces an asymmetric output. This is because the timing capacitor (C2) is charged via the two timing resistors (R1 & R2), and discharged via one timing resistor (R1). In this circuit, diodes D1 and D2 force the capacitor to be charged via R2, and discharged via R1. As R1 and R2 are equal, the output is a square wave that spends the same amount of time low as it does high (i.e. it has 50% duty cycle). Resistor R3 determines the strength of the output signal, and will be discussed shortly.

Receiver

D1 is a photo diode; it produces a voltage proportional to the amount of light it is exposed to. IC1, a MOS-FET input, C-MOS output op-amp, forms a high gain amplifier. C1 removes unwanted high frequency components. C4 and R2 form a high-pass filter. The signal is buffered by a NAND gate connected as an invertor. When the NAND gate's input goes high, its output goes low, discharging C5 via D3.

Fig 12 shows the waveforms. Pin 6 of IC1 produces a square wave when the optical input signal is present. The peak voltage of the square wave depends on the strength of the signal. IC2 pin 4 goes low when the voltage on its input exceeds ~70% of the supply voltage. When pin 4 is low, pins 1 & 2 of IC2 are held low. When pin 4 goes high, C5 charges via

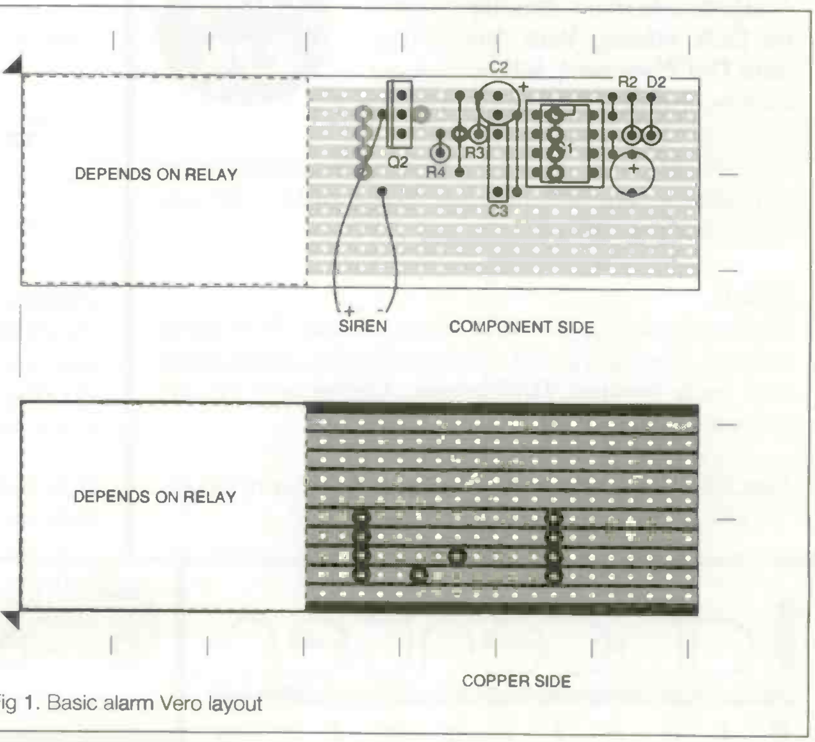


Fig 1. Basic alarm Vero layout

R3. If the fibre is cut, the input of IC2 will go low, allowing C5 to charge. When pin 1 of IC2 reaches ~70% of the supply voltage, its output will go low, setting the S-R latch formed by the two remaining NAND gates. R4 and C6 ensure that the latch is reset when power is applied. The latch output is buffered by a high gain Darlington power transistor.

To maximise the length of fibre that could be used, the receiver was designed to work with very small input signals. According to the specification, the emitter and detector used can of communicate over a maximum of 20 metres of fibre. The prototype was developed using a 220 Ω resistor for R1 (transmitter), and 5 metres of fibre, with a 5v supply. For a 5 metre length of cable, using a 100 Ω resistor for R1 produces good results. 20% to 30% of the power is lost per metre of fibre. Thus, for longer fibres R1 may need to be decreased (the peak current though LD1 should not exceed 100mA). For very short pieces of fibre, R1 must be increased. If D1 (receiver) receives a signal that is too strong, the alarm will also be set off. For example, for with a 15cm piece of fibre, R1 (transmitter) had to be increased to 2k7.

The maximum length of fibre also depends on the data transmission frequency. The transmitted pulse is stretched as it travels down the fibre optic cable. Some rays take longer paths than others and so arrive later at the detector, as shown in Figure 11. This causes the output pulses to be longer than the input pulses. At high frequencies, low logic signals (i.e. logic zero) can be totally masked by this action. The effect at 20kHz is ne.g.ligible.

Construction

Both circuits can be easily constructed on stripboard. Three small holes must be made to mount the emitter and detector. Place the emitter/detector on the strip board and note where the two small plastic le.g.s at the front are on the board. Make holes for them with a sharp pointed scalpel or PCB drill. When these holes have been made, mount the emitter/detector and mark where the fixing bolt hole must be made. The hole should fall between two tracks. If you are lucky, you may be able to make the hole and still have a small amount of track on either side to conduct the signals to/from the pins. If not, solder wire around the gap. Now press the emitter/detector firmly into the board and solder it in the orientation shown in Figure 4. Finally use a nylon 8BA (or M3) nut and bolt to fix it to the board.

Transmitter

To reduce the likelihood of unwanted noise being amplified, the component leads in the receiver input section have been kept short. Resistor R1 is soldered underneath the board between pins 2 and 6 of IC1. The lead of C1 should be bent and soldered across several tracks, as shown in Figure 5. No problems have been experienced when the unit is used without a case, but for maximum reliability it should be mounted in its own metal case.

Fibre

The condition of the ends of the fibre can greatly affect the maximum cable length possible. Transmission is improved by polishing the ends of the fibre. However, special polishing equipment is expensive. A simple and cheap way to achieve good terminations is as follows. (i) Cut the fibre on a flat surface with a sharp knife. (ii) Carefully strip off 2mm of the black cladding with a sharp knife. (iii) Place the end of the fibre about 1cm from a naked flame (Figure 14). The end of the fibre should round off, leaving a smooth surface. If exposed to the heat for too long, bubbles may form in the fibre. Don't put the flame too close, as the fibre burns quite well! The cladding can be removed by running a sharp knife around it, and then pulling it off. Try not to score the fibre as it will allow light will escape, reducing transmission power.

Testing

To preserve your hearing during testing, replacing the siren with a lamp, or LED and resistor, is advised. Connect the receiver and transmitter with a length of fibre optic cable. Push the fibre into the emitter/detector, holding it there as the collar is tightened. Next, apply power to the transmitter, and then the detector (or to both simultaneously). The unit will work from a 5v to 15v supply. The indicator should remain off until the fibre is cut, or removed from the emitter/detector. Once set, the indicator will remain on, even if the connection is restored. Reset the unit by removing the power for a few seconds.

If the unit does not work, check the circuit for shorts, tracks that have not been totally cut, incorrectly oriented diodes, etc. If the unit still does not work and the indicator is permanently on, try varying R3(transmitter). If available, use an oscilloscope to check the waveforms match those in Figure 12. If IC1 pin 6 (receiver) is permanently high, the signal is probably too strong; try increasing R3 (transmitter). If a wave is present, but IC2 pin 4 remains high, the signal is too weak; check the fibre ends are well finished and pushed fully home. If that fails, decrease R3.

In Use

The fibre can be threaded through ventilation slots, or purpose made holes. Do not bend the fibre with less than a 15mm radius. To allow easy removal, the fibre could be run through a padlock connected to the item (though small padlocks can be easily destroyed). Often, thieves are in a hurry; if presented with troublesome cables they will cut them without examining what they are.

The unit can be powered from the 13.8v available from most home alarm systems. Check the rating of your burglar alarm's auxiliary power circuit to ensure its maximum current will not be exceeded. In standby mode the receiver draws ~1.2mA, rising to 2mA+Siren Current when the alarm is triggered. With an R3 of 100 Ω, the transmitter requires an average of 40mA (at 9V). If the output is connected to a relay with the normally closed connections wired into the alarms tamper loop, triggering the alarm will set off the main alarm bell. A normally open key switch should be wired in parallel with the N.C. contacts so the unit can be easily switched out of the system for servicing, etc.

Battery Backed-up Power Supply

Alternatively, this useful battery-backed power supply could be used. This circuit is useful in any application where power is required even when mains failures occur.

The circuit is a straightforward power supply using a standard 78M (500mA) voltage re.g.ulator. The basic re.g.ulator output voltage is raised (by VR1 and R1) to the float voltage of sealed lead-acid battery, B1. Either a 6v or 12v battery can be used. If a 6v battery is used, a 5v re.g.ulator (78M05) should be used and VR1 adjusted to give an output voltage of ~6.8v. For a 12v battery, use a 12v (78M12) re.g.ulator and adjust VR1 to give an output of 13.8v. D1 protects the re.g.ulator from reverse voltages.

Construction

Construction is simple; as always, take care with connections to the mains. If a 6v battery is used, a 9v, 0.8A transformer will be required. A 15V,0.8A transformer will be required for a 12V battery. Transformers with these ratings are not readily available. Instead, a transformer with two 4.5V, 0.8A secondaries, connected in series can be used for the 6V battery. For the 12V battery, a transformer with two 15V, 0.4A (NOTE: a transformer with 15-0-15 tappings will not do) secondaries, connected in parallel, can be used. Be sure to connect the secondaries correctly, as shown in Figure 8.

Place the circuit in an earthed metal case. Bolt the re.g.ulator to the case (using insulating washers) so the case will act as a heat-sink.

Testing

Test the case is connected to the earth pin of the plug (and that live and neutral are not!). Before connecting the battery, plug the unit in and adjust VR1 to give the correct output voltage (6.8V for a 6V battery and 13.8V for a 12V battery).

Basic Alarm

If you have an existing battery-backed power source, this simple, yet effective method of alarming items can be used. The unit is fixed inside the item to be protected, with its power supplied from outside. Disconnecting the external power triggers the alarm. If the alarm went off inside the house it may not be heard, and the thief may try to stop it. To try to prevent this, the alarm does not sound until a preset time (currently ~40 seconds) after the power is removed. The alarm aims to frighten the 'smash and grab' burglar, or at least draw attention to her/him. It will do little to prevent those that specialise in complete house clearances.

How It Works

In normal use, the external power supply holds relay RL1 on. Cutting the power to RL1 causes the relay to open. Once the relay has opened, reapplying power will not reactivate it (due to the wiring of the relay contact). Power is cut in one of three ways: (i) removing external power; (ii) tilting the unit too far causes tilt switch SW1 to open (optional); (iii) closing a normally open switch (optional). SW1 can be replaced by a shorting link if not required. If the N.O. sensor (such as a vibration sensor) is not required, TR1 and R1 can be removed, and a link placed between where the collector and emitter were.

When the relay opens, power is supplied to the alarm circuit from an internal battery. IC1 is a 555 wired as a monostable, it is triggered when power is applied. The output will remain high for approximately 1.1*C1*R2. When the output of IC1 goes low, TR2 is activated, sounding the siren. The transistor specified for TR2 is a Darlington PNP transistor, which happened to be handy at the time. A cheaper PNP power transistor can be used (e.g. TIP32) if R4 is reduced accordingly.

SW3 is normally closed, opening it will turn off the alarm

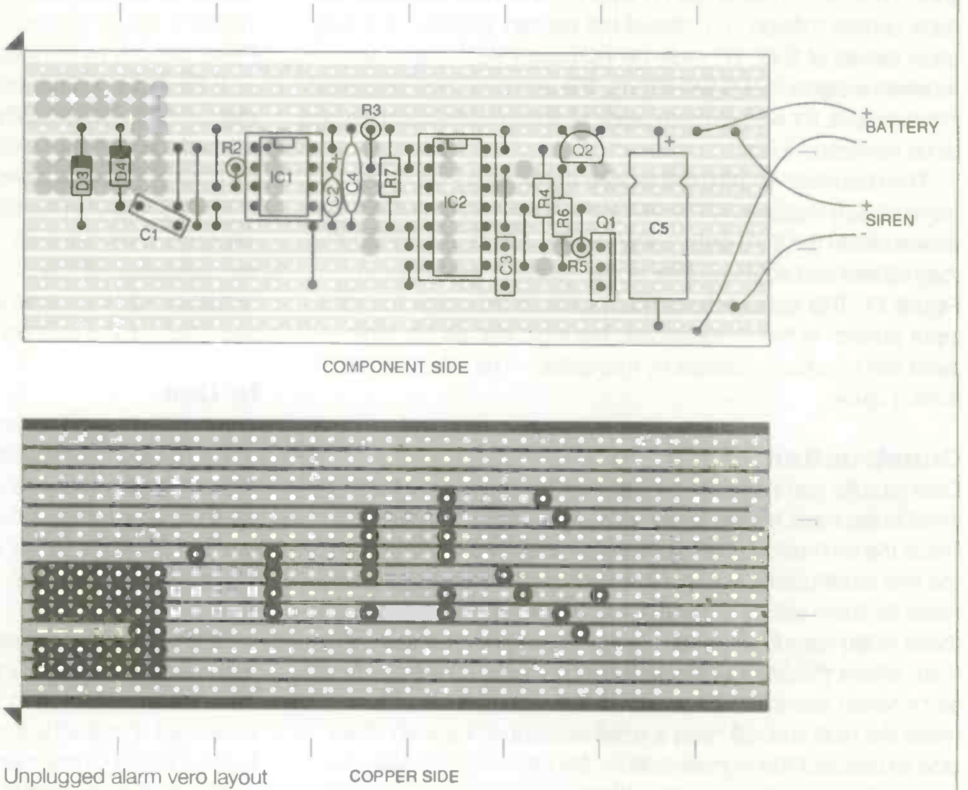


Fig 2. Unplugged alarm vero layout

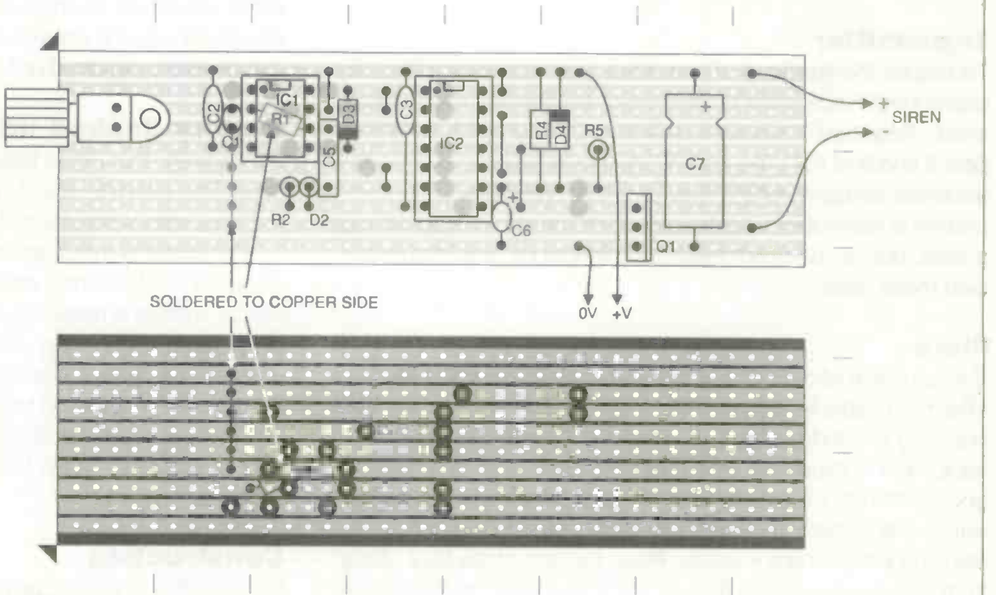


Fig 3. Fibre optic alarm receiver Vero layout

section. A keyswitch, or a hidden switch should be used for SW3. SW2 shorts out the relay contacts, allowing the relay to be activated by the external power supply. The relay will remain active when SW2 is released. A hidden push button or reed-switch could be used for SW2. Alternatively, a socket could be used; inserting a plug with two pins shorted would reset the alarm.

Construction

RL1 is a single-pole change-over relay; the coil rating required will depend on the external supply. Most SPCO relays will suffice. Reed relays are small and generally have the highest coil resistances, but are often expensive, and have low current ratings. The prototype used a relay extracted from some old equipment. Alternatively, the unit can be used without an external power supply if a SPCO reed-switch is used with an external magnet.

A partial stripboard layout is shown in Figure 1. Wiring of the relay will depend on the type chosen.

Batteries

The unit draws zero current from the internal battery when in standby mode. Alkaline batteries should be used to power the unit as they have a five-year shelf-life. A PP3 is probably the best type to use. Duracell batteries are guaranteed leak proof, claim to be able to supply loads of up to 2A, and have a capacity of ~0.5Ah. Note that the output voltage of the battery has fallen to 4.8V by the end of its life. Lithium batteries have a longer shelf-life, but cannot supply high currents.

Sounders

The type of sounder chosen will depend on space available, supply voltage, and budget. Small piezo sirens, drawing 100mA to 300mA are very effective and cost from £4 to £10. Smaller piezo sounders can be purchased; they have high outputs, but are very directional. The circuits in this article assume that no more than 2A will be drawn by the siren.

Experiment with various positions for the siren if possible as this will greatly affect its final output. For example, mounting the siren behind holes in the case will allow greater output than mounting the siren inside a sealed box. With this, and the following internal alarm, be careful not to obstruct any vital cooling slots, moving mechanisms, etc. A spare drive bay on a PC would be an ideal place for an alarm.

UNPLUGGED

Externally connected units are fine, but require extra wires and can be annoying in some situations. A device that could be placed inside the item to be protected and which required no extra external connections would be easier to live with. Vibration sensors, tilt switches, reed switches, etc can be used to detect theft. Such methods make movement for cleaning difficult and can be triggered by everyday knocks.

As many valuable items remain plugged in permanently (PCs, hi-fis, VCRs, etc.), the obvious way to check the item has not gone far is to check it is plugged into the mains. However, sensing the presence of mains voltage is not sufficient. Though power cuts are rare, they do occur. The alarm must be able to tell if it is plugged in and the power has failed, or if someone has unplugged it.

Many mains powered devices have a low DC resistance. For example a transformer coil may have a resistance of 100 Ω. When the mains fails, this alarm measures the resistance across its live and neutral pins. If there is an infinite resistance, the alarm will be set off. A low resistance implies the unit is still connected to the mains, so the alarm is not triggered. For this unit to work there must be another item plugged into the same mains circuit that does not have this alarm fitted and that has a low D.C. resistance (e.g. a clock-radio).

Circuit Operation

Figure 7 shows the unplugged alarm circuit. During a mains failure, the protected item must be disconnected from the incoming mains lead (otherwise its resistance would be measured). RL1 is a 4PCO relay with a 240VAC coil and 240VAC contacts. When the mains is applied the relay is switched on by the ne.g.ative part of the cycle via D1. D1 prevents the resistance of RL1's coil being measured, it is switched out when the relay is activated. The activation of RL1 also supplies power to the protected item and disconnects the sensing circuit.

Measuring the resistance between two wires is straightforward. Due to the finite switching time of the relay, the sensing circuit may have +-120V at its input. An input circuit that can protect the sensing circuit from high voltages, yet has an infinite D.C. resistance across the mains, and little resistance to the DC sensing current, is required. Diodes D2, D3, D4, and resistor R1 form the input circuit. D2 half wave rectifies the mains voltage, leaving the ne.g.ative part of the each mains

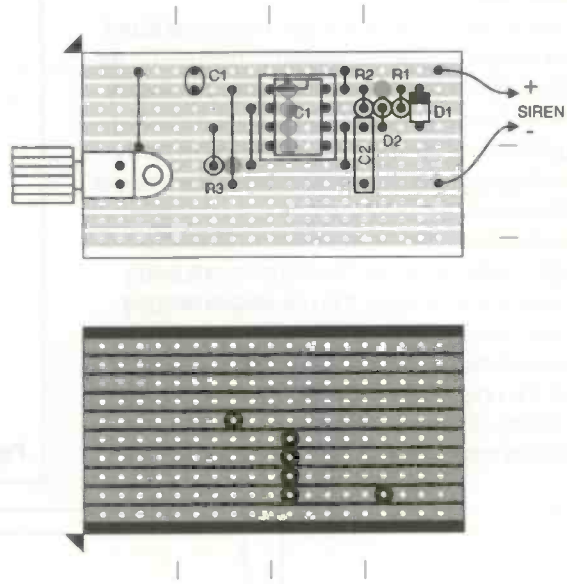


Fig 4. Fibre optic alarm transmitter Vero layout

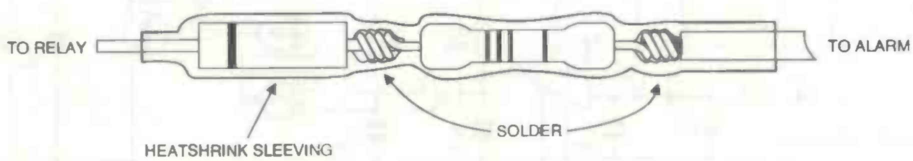


Fig 5. D2 and R1 assembly

cycle. Potentials of 0V to -120V are now present. D3 effectively shorts any ne.g.ative voltage to neutral. R1 limits the input current. The voltage at the cathode of D3 still has some ne.g.ative components due to the voltage drop across D3. D4 reduces any ne.g.ative component to a level that IC1's inputs can stand.

The resistance between live and neutral is measured by R1, R2 and IC1. If live and neutral are connected, a small current (microamps) will flow through R2 and R1 to neutral. This produces a potential difference between pins 2 and 3 of comparitor IC1, causing the output (pin 7) to go low. Notice the arrangement of input diodes allows current to flow from the sensing circuit, while not causing any current to flow between the live and neutral lines. The high value of R1 (1M***OHM***) is acceptable as the sensing circuit is very sensitive.

If the circuit is unplugged, the potential between pins 2 and 3 of IC1 will be equal, causing the output of IC1 to float. In this state, C2 is charged via R3. As the voltage rises, the NAND gate output (IC2 pin 3) will go low, setting the latch formed by two NAND gates. The time delay is required to prevent false alarms when power is reapplied after a power cut. With the present values for C2 and R3 the alarm trigger pulse must be >1 second long. Such a long delay would give a thief, who knew about the alarm, ample time to remove the plug and short out the pins. It is possible that a 1µ F capacitor would be large enough to prevent false alarms after power cuts.

The output of the latch goes high when the alarm is triggered, activating the siren. So that plugging the unit back in will not reset the alarm, TR2 is switched on to 'short out' the relay contact. R4 and C3 ensure the latch is in the reset state when power is applied. Reset the alarm by removing and reapplying the power. S1 is a 250V surge suppressor that protects the unit from large voltage spikes.

Construction

Due to the use of mains voltage, this circuit is not recommended for inexperienced constructors. As the ne.g.ative connection of the battery is directly connected to neutral, the whole circuit (including the battery case) should be insulated from earth, preferably placed in its own earthed metal case, or insulated case.

Assemble the circuit as shown in Figure 2. Though connections can be made by soldering directly to the relay pins, it is not recommended. Use of a relay holder with screw connections produces a neater, safer, unit. It also increases the size of the unit, however, consumer goods often have plenty of room inside. Figure 13 shows how to connect the recommended relay and holder.

Diode D1 should be covered in heat-shrink sleeving and attached as shown. So 240VAC mains is not connected directly to the stripboard, D2 and R1 should be assembled as shown in Figure 5. The diode end is connected to the relay, and the wire end connected to the stripboard. Though 'less dangerous' than the live end, the wire end of the assembly should still be treated with respect. Sleeving should be placed on the leads of the surge suppressor.

The relay must have a coil that can cope with 240VAC, and contacts with the correct current rating for the load. Relay RS353-146 was used for the prototype with holder RS403-257. It has a 230VAC coil and 5A, 250VAC contacts, which should be okay for most applications. It also has a test button that allows the relay contacts to be changed over when power is absent.

Testing

Before connecting the alarm to the mains or the item to be protected, double check the connections. If the relay has a test button it can be used to check the power-on connects are correct. Connect the pins of the mains plug with a piece of wire (DO NOT CONNECT TO MAINS!) and connect the battery. The siren should be off; it will be activated approximately one second after the wire has been removed.

Plug the unit into a two-way adaptor plug, also plug in something with a low (less than 1M Ω) D.C. resistance, such a radio or power supply. Connect the battery and wait for a second; the unit should not go off. Plug the adaptor into a switched socket, then switch the mains power on. The relay will activate, supplying power to the protected item. Unplugging the alarm from the adaptor should set the alarm off after a second.

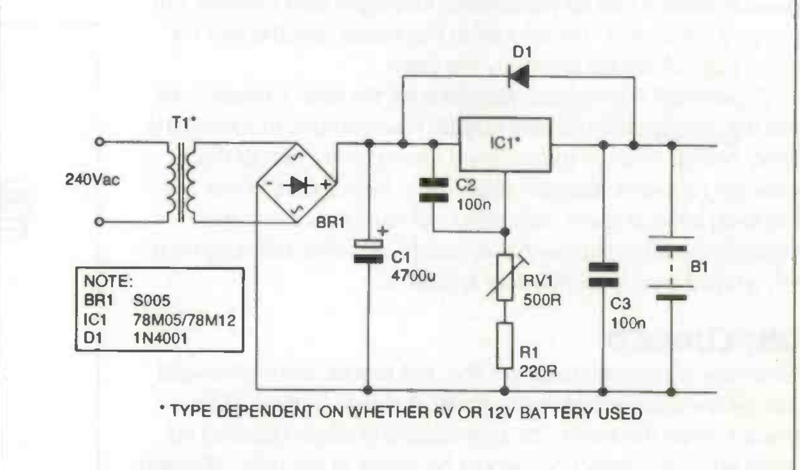


Fig 6. Battery backup PSU circuit

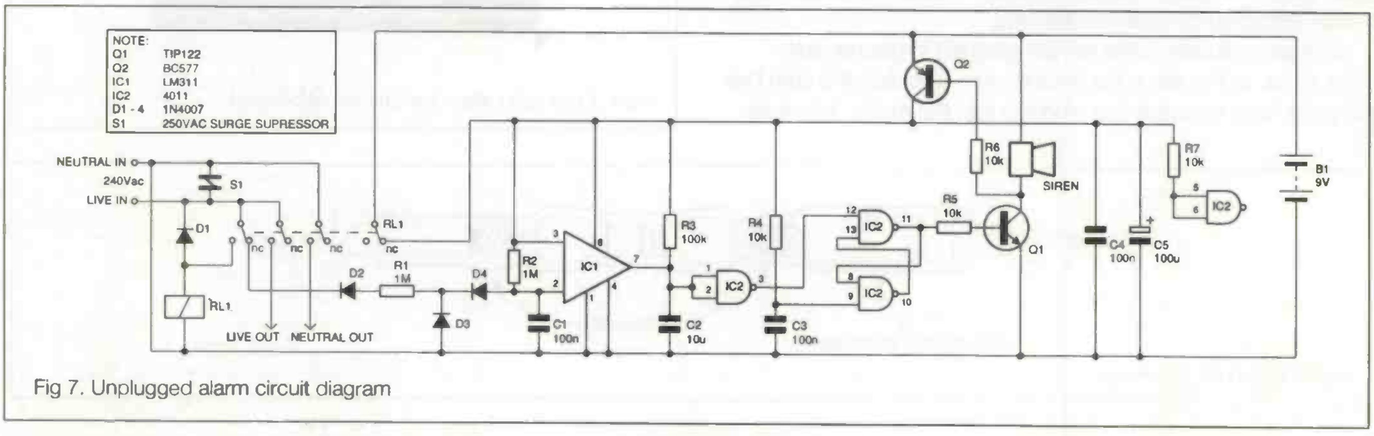


Fig 7. Unplugged alarm circuit diagram

Installation and Use

The comments made previously about batteries and sirens also apply here. Ensure that no live connections are accessible from the outside, e.g. through ventilation slots. An external keyswitch can be used to disable the alarm.

Modifications

Although the circuits presented here are working projects in their own right, they are intended to be a source of inspiration to be expanded on or mixed and matched to provide the functionality required. Variations will make the circuits more secure and more alarming (!) for the thief.

COMPONENTS LIST

Basic Anti Theft Alarm
Resistors

- R1,R3,R4 — 10k
- R2 — 820k

Capacitors
- C1 — 47uF Elect.
- C2 — 47uF Tant.
- C3 — 100nF Poly.

Semiconductors
- D1 — 1N4001
- D2 — 1N4148
- TR1 — BC548
- TR2 — TIP127
- IC1 — 555

Misc.
- RL1 — SPCO [SEE TEXT]
- SW1 — Optional mercury tilt switch
- SW2 — Normally open reset switch (e.g.. use a link in plug [See text])
- SW3 — Alarm on/off switch (e.g.. SPST keyswitch)
- B1 — 9v Alkaline battery

Siren, optional normally open sensors (e.g.. vibration sensor), battery connector, external power supply.

Unplugged Alarm
- Resistors
- R1,R2 — 1M high voltage
- R3 — 100k
- R4-7 — 10k

COMPONENTS LIST

Capacitors
- C1,C3 — 100nF 100v Poly Layer.
- C2 — 10uF 35v Tant.
- C4 — 100nF Ceramic
- C5 — 100uF 35v Elect.

Semiconductors
- D1-4 — 1N4007
- TR1 — TIP122
- TR2 — BC577
- S1 — 250VAC Surge supressor
- IC1 — LM311
- IC2 — 4011

Misc.
- B1 — 9v Alkaline.
- RL1 — 240VAC coil, 4PCO 240V contacts

(e.g.. RS 353-146, for

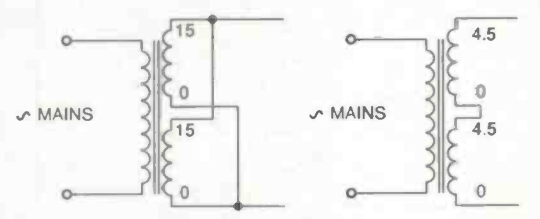


Fig 8. Connection of secondaries

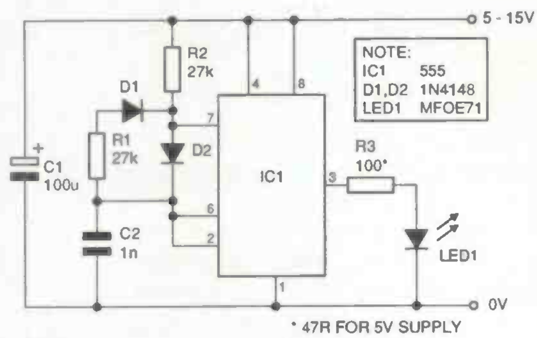


Fig 9.Fibre optic transmitter circuit

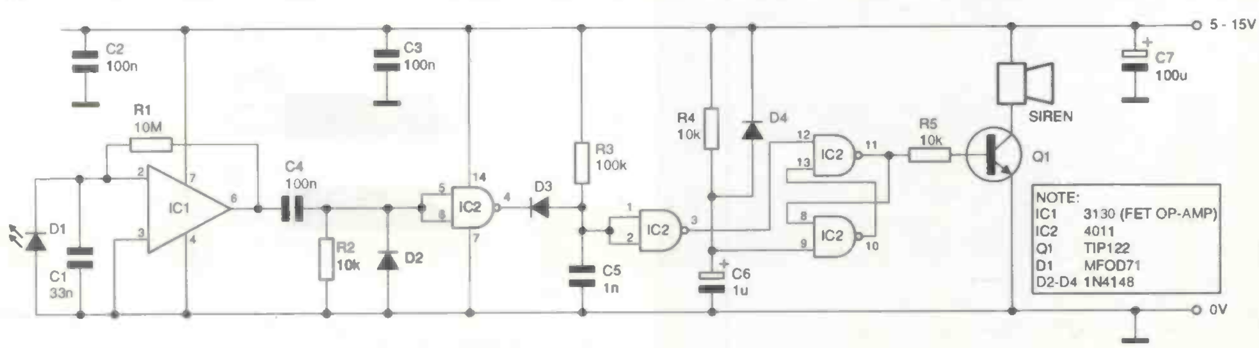


Fig 10. Fibre optic receiver circuit

COMPONENTS LIST

Fibre Optic Alarm Component List
Transmitter

- Resistors
- R1,R2 27k
- R3 100R, (47R for 5v supply)

Capacitors
- C1 100uF 35v Elect.
- C2 1nF Poly layer

Semiconductors
- D1,D2 1N4148
- LD1 MFOE71 (Fibre Optic Emitter - Maplin)
- IC1 555

Misc.
Nylon bolt to fix emmiter. Fibre optic cable.

- Receiver
- Resistors
- R1 0M
- R2,R4,R5 0k
- R3 00k

Capacitors
- C1 33nF Ceramic
- C2,C3 100nF Ceramic
- C4 100nF Poly layer
- C5 1nF Polystyrene
- C6 1uF Tant.
- C7 100uF 35v Elect.

Semiconductors
- D1 MFOD71
- D2-4 1N4148
- TR1 TIP122
- IC1 3130 (fet op-amp)
- IC2 4011 (4x2ip NAND)

Misc.
- Nylon bolt to fix receiver. Siren (up to 2 Amps).

Battery Backed Power Supply
- Resistors
- R1 220R
- VR1 500R Multi-turn

Capacitors
- C1 4700uF 35v Elect.
- C2,C3 100nF 63v Poly

Semiconductors
- BR1 S005 (2A bridge rectifier)
- D1 1N4001
- IC1 78M05 (for 6v battery), 78M12 (for
- 2v battery) [SEE TEXT]

Misc.
- B1 6v, 1Ah or 12v,1.2 Ah Sealed Lead
- Acid Battery [SEE TEXT]
- T1 9v, 0.8A(or 2x4.5v, 0.8A, coils in series) for 6v battery,

15v 0.8A (or 2x15v, 0.4A, in parallel) for 12v battery [SEE TEXT]

Metal case, heat sink (can use case), spade connectors for battery, mains cable, etc.

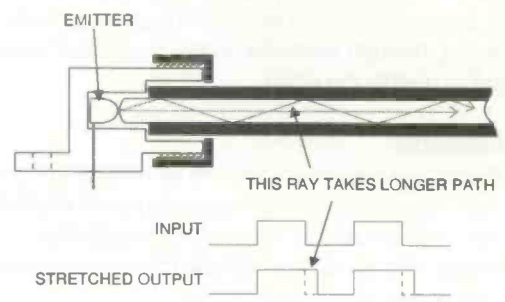


Fig 11. Fibre optic ray pathsd

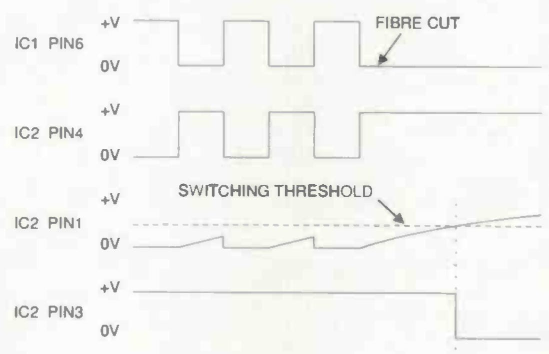


Fig 12. Optical loop alarm waveforms

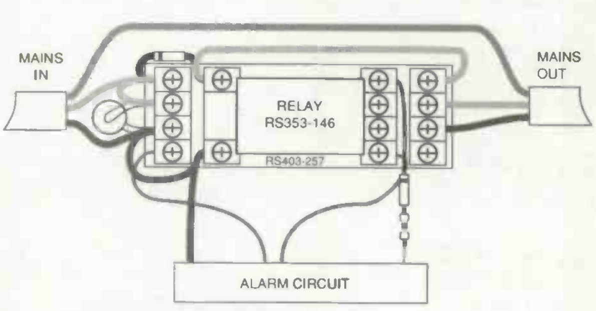


Fig 13. Relay connections

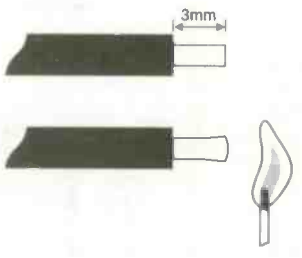


Fig 14. Preparing the fibre optic cable

The ETI 80188 single board Computer

PART 2

A powerful and highly versatile 16bit processor system designed by Richard Grodzik for which software can be developed directly on any IBM PC

Last month we looked at building the 80188 SBC, and showed how this versatile board can be used for a wide range of applications. Part of this versatility can be attributed to the fact that it is software compatible with the family of processor chips used in the IBM PC. This means that software can be directly developed and tested on the PC and then downloaded onto the 80188 SBC, thereby making software development for the SBC much easier and quicker. It also means that software can be developed using the enormous range of software development tools which are available on the PC.

Programming the SBC.

Since no monitor ROM exists for the board, the user is forced to program the operating system, which is by far the best way to achieve complete control of the system, with no buried layers of software as in pre-written operating systems.

To facilitate the user, several small programs have been written to initialise various parts of the SBC - the user ports, printer port, serial port, interrupt system and counter/timers. All of the software examples, fully commented and assembled are available, together with the A86 assembler, on a 3 1/2 inch floppy from the author.

The A86 assembler is lightning quick and source code written in ASCII should have the MSDOS extension ASM. To assemble type

```
A86 FILENAME.ASM
```

An object code file FILENAME.BIN, 2048 bytes in length will be produced which is then downloaded via the serial or parallel port to the EPROM emulator. The whole process takes a couple of seconds. Using an EPROM emulator that connects to the parallel port of the PC, a typical download instruction would be:

```
COPY FILENAME.BIN LPT1
```

Individual code bytes may be changed without reassembly by using the MSDOS resident debugger - DEBUG. To disassemble the object code file the command U500 will produce a listing. The following are a list of useful DEBUG commands:

Debug is invoked by entering:

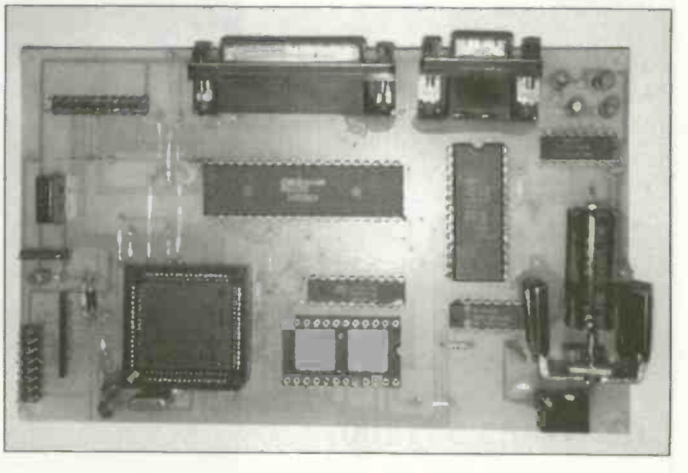
```
DEBUG FILENAME.BIN **ENTER**
```

Common debug commands:

RCX Displays the number of bytes in the file.i.e. 0800H (2K)
W Will write the file to disc with any modifications made under DEBUG.
Q Leaves DEBUG.
E {address} Changes a selected byte. Pressing the space bar will cause the display of each byte of the file. The byte displayed can then be over-written by a different value. Pressing the enter key will leave the file editor.
T Executes instruction and displays register values.
U Unassembles memory contents.
D Dumps the hex contents of the file.
A Enters the DEBUG assembler. Assembly language programs can be entered line by line. Escape to DEBUG by pressing the enter key. Note that labels are not recognised by this assembler. It is useful, however, in that small routines can be entered and tested.

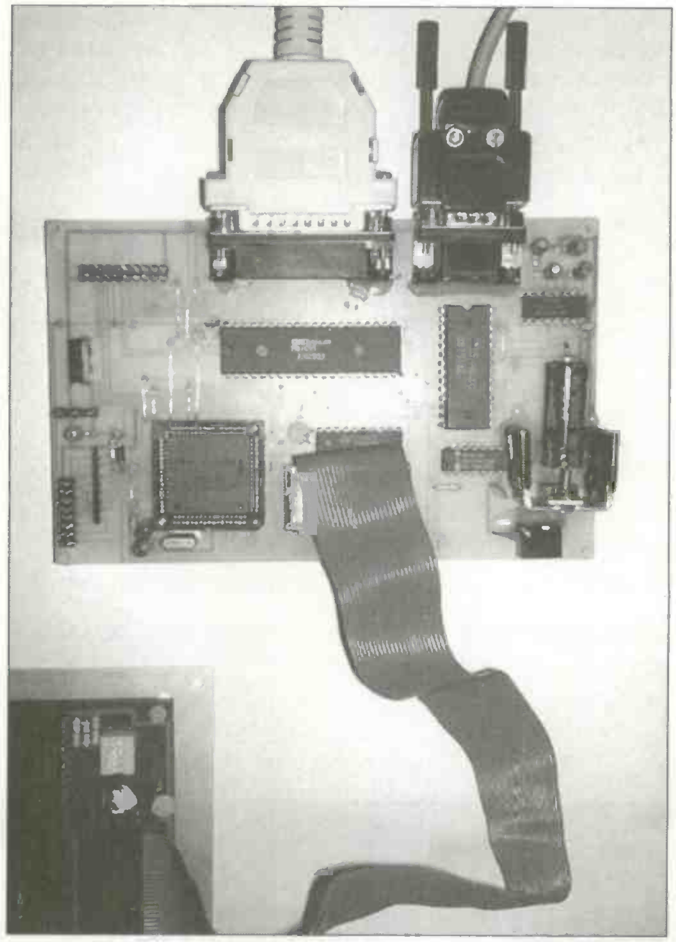
Programming the chip selects.

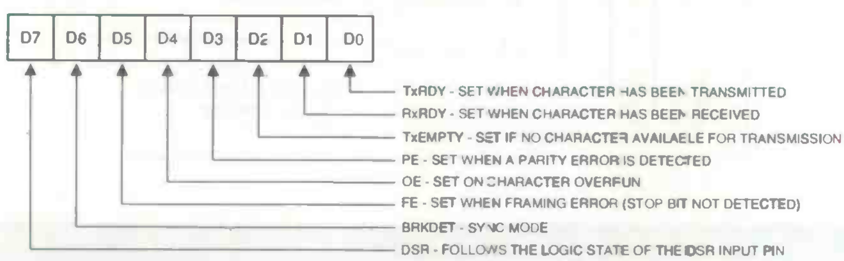
Altogether, the 80188 can accommodate 1 MByte of memory and 64 KBytes of I/O space. On reset, only the upper memory chip select is initialised and this for only a 1 Kbyte boundary (memory area 0FFC00 - 0FFFFF). To enable other chip select areas, i.e. low memory and to provide a greater addressing range, an internal block of 16 bit registers inside the 80188



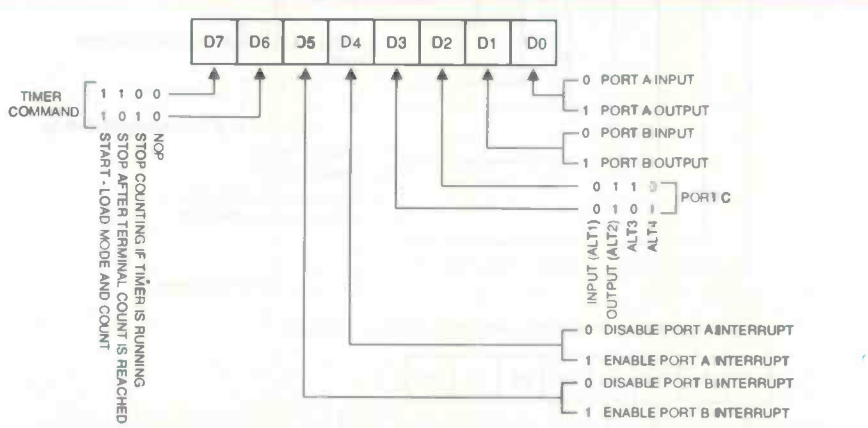
need to be programmed. The following registers and contents should suffice as a starting point for most readers. Included are register values for 32 KByte EPROM and RAM areas. Note that these internal registers are mapped in I/O space and there the OUT programming instruction is used.

```
;CS.ASM

     LMCS  EQU  0FFA2H    ; LOW MEMORY CHIP
                          ; SELECT REGISTER
                            ADDRESS

     LCS1  =   038H       ; RAM SIZE 1K
     LCS8  =   01F8H      ; RAM SIZE 8K
     LCS32 =   07F8H      ; RAM SIZE 32K

     UMCS  EQU 0FFA0H     ; UPPER MEMORY CHIP
                            SELECT REGISTER

                          ; ADDRESS

     UCS2  = 0FFB8H       ; ROM SIZE 2K
     UCS8  = 0FE38H       ; ROM SIZE 8K
     UCS32 = 0F838H       ; ROM SIZE 32K
                          ; default size 1K

;E.G.
     MOV DX,LMCS          ; PROGRAM LOWER MEMORY
                            CHIP SELECT
     MOV AX,LCS1          ; FOR 1K BYTE RAM
     OUT DX,AX            ; ADDRESS 00000 -
                            003FF
     MOV DX,UMCS          ; PROGRAM UPPER MEMORY
                            CHIP SELECT
        MOV AX,UCS2         ; FOR 2K BYTE EPROM
        OUT DX,AX           ; ADDRESS 0FF800 -
                              0FFFFF
```





USART status flag register



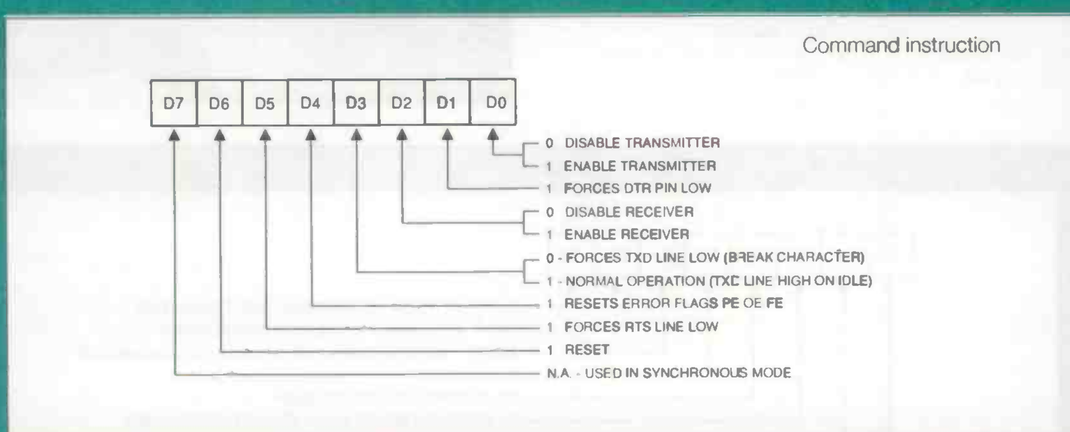
Command register bit assignment

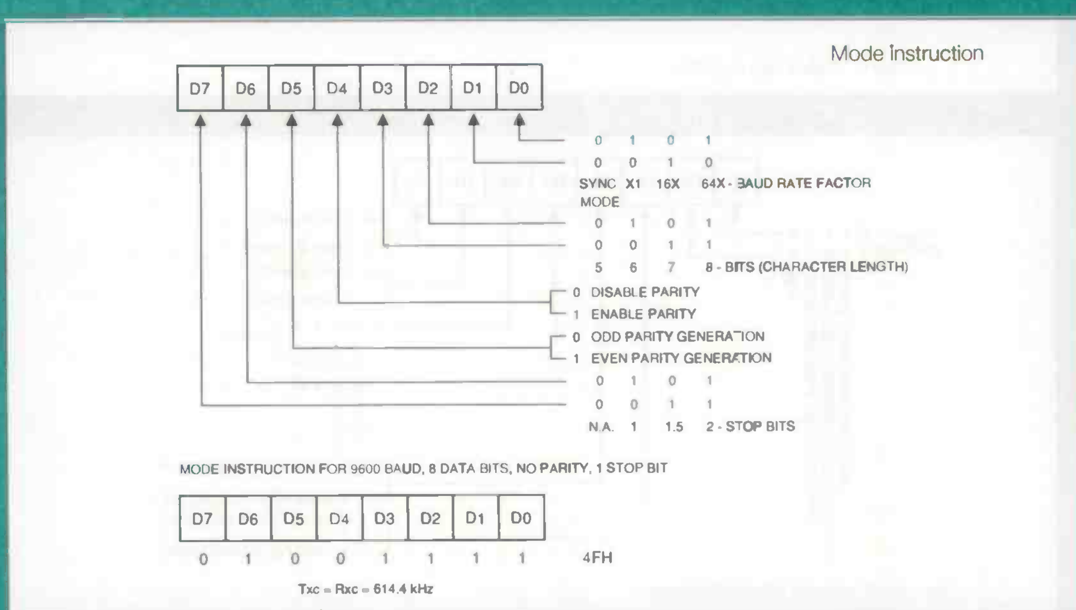
```
A Model source code program (MODEL.ASM) is
shown below:
;MODEL.ASM
CODE SEGMENT
ASSUME CS:CODE

ORG 0

ORG 0400H
        LMCS  EQU  0FFA2H ; LMCS REGISTER
        LCS    =   038H   ; LMCS VALUE,MEMORY
                            RAM SIZE=1K
        MOV DX,LMCS       ; PROGRAM LOW MEMORY
                            CHIP SELECT
        MOV AX,LCS        ; FOR 1K BYTE RAM
        OUT DX,AX         ; ADDRESS 00000 -
                            003FF
        MOV SP,0FFH       ; INITIALISE STACK
                            POINTER
                          ; TO TOP OF RAM

;USER CODE GOES HERE

ORG 07F0H                 ; RESET VECTOR FFFF0

JMP 0FFC0:0000            ; START EXECUTION AT
                            SYSTEM
                          ; ADDRESS FFC00H
                          ; EPROM ADDRESS
                            0400H

ORG 0800H                 ; File size=2048 (2
                            Kbytes)

CODE ENDS
END
```

The ORG 0800H statement causes a 2 KByte object file to be created which is the EPROM area of the SBC.A JMP instruction is placed at EPROM physical address 7F0H (System address FFFF0H) - the reset address vector of the 80188 which is generated on switch-on or reset. Program execution begins at EPROM address 0400H (System address FFC00H). Note that only 1 KByte of this area is actually used, so only the top half of the EPROM area is used. If a larger EPROM area is required, then instructions to program the UMCS register must be placed at the RESET vector.16 bytes of space FFFF0 -FFFFF are sufficient to accommodate these instruction, followed by a JMP instruction to the start of the larger EPROM area.

For simplicity, all the programming examples details in the text assume the default Rom area i.e. 1K, so that the 80188's UMCS register does not have to be programmed.

For readers who possess Microsoft's 'MASM' Assembler, a model program is given. (M_ASM.ASM) Note that different instructions required at the reset vector (07F0), for this source code to assemble correctly. The MASM assembler itself doesn't





provide Romable code for a target SBC and the following batch program must be run to produce pure binary (object code) - FILENAME.COM

```
;8088.BAT
ECHO ASSEMBLE AND LINK %1
IF NOT EXIST %1.ASM GOTO END
MASM %1,%1,%1;
IF ERRORLEVEL 1 GOTO END
LINK %1,%1,%1;
IF NOT EXIST %1.EXE GOTO END
EXE2BIN %1.EXE %1.COM
ECHO OFF
ERASE %1.EXE
ERASE %1.OBJ
:END
```

Ensure that the following Files are resident in the Directory you are using for program development:
()Masm.COM
()Link.EXE
()EXE2BIN.EXE

The EXE2BIN.EXE file will be found in the DOS Directory. To assemble a source program (FILENAME.ASM), enter 8088 FILENAME, with no extension. The batch file will run, producing a listing (FILENAME.LST) and 2 Kbytes of code. Then it should be just a matter of downloading the FILENAME.COM file to the EPROM emulator.

```
;M_ASM.ASM

              PAGE ,132
CODE SEGMENT
ASSUME CS:CODE
ORG 0

ORG 0400H

;USER CODE GOES HERE

ORG 07F0H                        ;Reset vector
FFFF0H
JMP FAR PTR BOOT                 ;Jump to start
                                 of operating
                                 system
                                 ;at FFC00H

ORG 0800H                        ;File size=2048
                                 (2 Kbytes)
CODE ENDS


CODEBOOT SEGMENT AT 0FFC0H       ;START OF
                                 OPERATING SYSTEM
ASSUME CS:CODEBOOT               ;AT ADDRESS
                                 FFC0:0000  =
                                 FFC00H


ORG 000H
BOOT PROC FAR
BOOT ENDP

CODEBOOT ENDS
END
```

```
Alternatively, the following procedure will
assemble source code to binary code:

A86 FILENAME.ASM FILENAME.OBJ
LINK FILENAME
EXE2BIN FILENAME
```

An object code file (FILENAME.BIN) of 2048 bytes will be assembled. Check with the MSDOS DIR command to ensure that the correct files have been produced.

Programming the parallel ports

The 8155 port i.c. is described as a R.I.O.T. device containing Ram,I/O and a Timer. The 80188 SBC uses the 8155 to provide a total of 22 TTL I/O lines. Port A lines PA0-PA7 are reserved for the printer interface, together with port C lines PC1 and PC2. The remainder of the port C lines and Port B (PB0-PB7) are available to the user.

The command register of the 8155 is located at address 0100H in the memory space of the 80188. Writing to this register configure the ports as output or inputs. Programming of this register is accomplished by writing the control byte taken from the table below:

```
COMMAND  EQU 0100H          ;8155 Command

Register address
I/O = X                     ;Control byte

MOV DI,COMMAND              ;Write control byte
                             to 8155
MOV AL,I/O                  ;command register.
MOV [DI],AL
```

where X is the value to configure the ports taken from the table below:

PORT C	PORT B	PORT A	X
OUTPUT	OUTPUT	OUTPUT	0FH
OUTPUT	OUTPUT	INPUT	0EH
OUTPUT	INPUT	OUTPUT	0DH
OUTPUT	INPUT	INPUT	0CH
INPUT	OUTPUT	OUTPUT	03H
INPUT	OUTPUT	INPUT	02H
INPUT	INPUT	OUTPUT	01H
INPUT	INPUT	INPUT	00H

Once the command register is loaded, it is a simple matter to send data to or from port A (address 0101H), port B (address 0102H) or port C (address 0103H). For example:

```
PORTB EQU 0102H
VALUE = 055H


            ;Send 055H to port B
MOV DI,PORTB
MOV AL,VALUE
MOV [DI],AL
```

Note that the 8155 PIO is not mapped in IO space but occupies the memory space 0000 to 00FFH, and therefore the IN and OUT instructions cannot be used. The reason for this is that the PIO's internal 256 bytes of RAM have to be addressed by the LCS pin which is mapped in memory space and therefore shares the same memory area as the IO command register and ports.

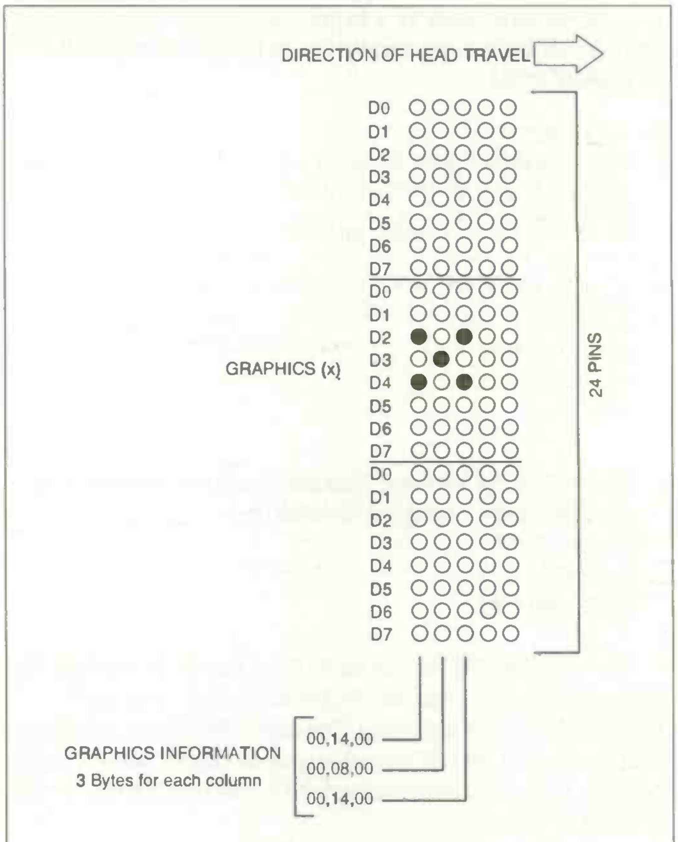
The following program configures Port B as an output and inverts the port lines every second.

```
;SECOND.ASM

CODE SEGMENT
ASSUME CS:CODE

ORG 0                             ;EPROM ADDRESS
0000

ORG 0400H                         ;EPROM ADDRESS
400H,START OF CODE
```

```
     LMCS   EQU   0FFA2H            ;LMCS REGISTER
     LCS    =     038H              ;LMCS
                                     VALUE,MEMORY
                                     RAM SIZE=1K

     MOV DX,LMCS                    ;PROGRAM LOWER
                                     MEMORY CHIP
                                     SELECT
     MQV AL,LCS                     ;FOR 1K BYTE
                                     RAM
     OUT DX,AX                      ;ADDRESS 00000
                                     - 003FF

     MOV SP,0FFH                    ;INITIALISE
                                     STACK POINTER
                                    ;TO TOP OF RAM

     ;INVERT PORT B LINES AT 1 SECOND
     INTERVALS

     PORTCOMMAND EQU 0100H          ;8155 PORT
                                     COMMAND
                                     REGISTER
     PORTB       EQU 0102H          ;PORT B ADDRESS
     MODE         = 3               ;PORTS A AND B
                                     OUTPUTS

     MOV DI,PORTCOMMAND             ;PROGRAM 8155
                                     COMMAND
                                     REGISTER
     MOV AL,MODE
     MOV  [DI],AL

     MOV AL,055H                    ;INVERT
                                     ALTERNATE LINES

     MOV DI,PORTB                   ;COMPLEMENT
                                     PORT B LINES
INVERT:XOR AL,0FFH                  ;AT 1 SECOND
                                     INTERVALS
     MOV [DI],AL

     CALL SECOND                    ;1 SECOND DELAY
     JMP INVERT                     ;REPEAT FOREVER

SECOND PROC NEAR

     MOV BX,0             ;MILLISECOND COUNTER
NEXT:MOV CX,0C8H          ;1 MILLISECOND DELAY
MILLISECOND:LOOP MILLISECOND
     INC BX
     CMP BX,03E8H         ;X 1000 = 1 SECOND
     JNZ NEXT
     RET

SECOND ENDP

ORG 07F0H                           ;RESET VECTOR
FFFF0

JMP 0FFC0:0000

ORG 0800H                           ;File size=2048
(2 Kbytes) CODE
ENDS
END
```

Handshaking-strobed output

A strobed I/O operation provides a means for transferring data to or from a specified port in conjunction with strobes or 'handshake' signals. This handshaking is especially required when data has to be sent to a printer since, without handshake, data would be lost if the printer was switched off or out of paper. The 8155 has this facility whereby a positive control of data transfer between the system processor and an external peripheral device can be effected. Port A is used as an 8 bit data port carrying the ASCII data of the text to be printed, whereas two control lines of port C affect the handshake process. Programming the 8155 command register for handshake mode provides three type of control lines for handling the 'handshaking' operations. These lines are STROBE (an active low input), BUFF (an active high output) and INTR(an active high interrupt line).



Printer operation

Bits 2 and 3 of the Command word define the function of Port C. For handshaking, ALT3 or ALT4 mode is used. IN ALT3 mode Port C lines serve the following functions:

```
PC2=STROBE INPUT ACTIVE LOW (pin 39)
PC1=BUFF OUTPUT,ACTIVE HIGH (pin 38)
PC0=INTERRUPT OUTPUT,ACTIVE HIGH (pin 37) (not
used)

PORT A=OUTPUT (pins 21-28)
```

Using a handshake operation also improves the efficiency of the system, since the throughput of data must be matched to the receiving capability of the external device. If too slow, efficiency is degraded, since time is wasted by the external device waiting for data. On the other hand, if too fast, data may be lost if the external device is too slow to accept data. By handshake control, data is written to the external device at peak efficiency and data cannot be lost.

When WRITE handshaking, the 80188 writes data to the output port (Port A), where it is latched in the port register. The 8155 generates a 'data ready' signal on its BUFF (Buffer full) line (PC1) to indicate that data is available for the external device (printer) from Port A. The external peripheral device takes the STROBE line (PC2) low to acknowledge it has received data. In addition, an interrupt signal is issued from PC0. Further data can now be written by the 80188 to Port A for reading by the peripheral device. This cycle is repeated, allowing the controlled output of data.

Interfacing a printer

The write handshaking facilitles offered by the 8155 are ideally suited for the outputting of data by the SBC to a printer. The standard IBM printer interface, commonly known as the 'Centronics' interface, is the standard used by many dot- matrix and bubble-jet parallel printers. The diagram shows the interface connections between the 8155 and the printer, for users who wish to make up their own leads. As stated, the PC printer lead may be used with no modifications.

Description of Centronics Interface

()STROBE(input):This line is normally high; it is taken low to signal to the printer that data is available.
()Data lines D0-D7(input):Carry ASCII data to the printer.
()BUSY(output):Normally high. Goes low to indicate printer can receive data.
()INIT(input):Normally high. Taken low to reset printer and to clear printer buffer.
()AUTOFEED(input):when low, paper to be fed one line after printing.
Additional output lines give printer status information. These lines may be connected to simple buffered L.E.D's to provide printer status.
()ACKNOWLEDGE(output): goes low to indicate printer has received data.
()PE(output):High to indicate printer out of paper.
()SELECT(output):High to indicate printer off-line.
()ERROR(output):Low to indicate printer out of paper, off-line or in error state.

The following program (MESSAGE.ASM) configures the 8155 so that the 80188 can output data to a printer from port A. Procedure INITIALISE loads the command register for handshake mode of operation. Procedure SEND_MESSAGE causes an ASCII character to be written to port A. The 8155 BUFF line (PC1)is taken low, signalling to the printer via the printer STROBE line that data is available. The printer reads the ASCII data and prints it. The printer's BUSY line goes low, signalling the 8155 on pin 39 that it is ready for more data.

Procedure HANDSHAKE controls the printing of data by polling the status of the interrupt flag in the command register. This will go high to signify that a STROBE active low signal has been received from the printer (printer line BUSY), and that the printer is ready for further data. This cycle Is repeated until the entire message is printed, at which time a carriage return and line feed control character is issued and the whole process is repeated.

Note that all chip select programming must be accomplished at the beginning of the program, and also that the stack pointer must also be initialised, since calling a procedure will invoke the stack. Likewise, prior to calling a procedure, the relevant chip enable lines must already have been programmed.

```
;MESSAGE.ASM
CODE SEGMENT
ASSUME CS:CODE

ORG 0

ORG 0400H

        LMCS EQU 0FFA2H             ;LOW MEMORY CHIP
                                     SELECT
        LCS = 038H
        PORTCOMMAND EQU 0100H       ;8155 COMMAND
                                     REGISTER ADDRESS
        MODE = 015H                 ;HANDSHAKE MODE -
        PORT A OUTPUT,
                                    ;PORT C LINES
                                     HANDSHAKE
        PORTA EQU 0101H             ;PORT A ADDRESS

                                    ;MAIN PROGRAM

        MOV SP,0FFH                 ;INITIALISE STACK
                                     POINTER

        MOV DX,LMCS                 ;INITIALISE 8155
                                     RAM AND PORTS CHIP
        MOV AL,LCS                  ;SELECT
        OUT DX,AL

          CALL INITIALISE
CYCLE:    CALL SEND_MESSAGE
          JMP CYCLE                 ;REPEAT FOREVER

INITIALISE PROC NEAR

        MOV DI,PORTCOMMAND          ;INITIALISE 8155
                                     FOR HANDSHAKE MODE
        MOV AL,MODE
        MOV [DI],AL

        RET

INITIALISE ENDP
```

Future Add-on modules:

(a) 3 channel touch switch.
(b) Serial A to D converter.
(c) D to A converter - 4 to 20 mA loop.
(d) 16 key Matrixed keyboard.
(e) Stepper motor controller.
(f) Multiplexed LED display.

;ROMTEST.ASM

```
CODE SEGMENT
ASSUME CS:CODE
ORG 0

ORG 07F0H                            ;RESET VECTOR
FFFF0H

JMP 0FFFFH:0000                      ;CYCLE AT
ADDRESS FFFF0H

ORG 0800H                            ;FILE SIZE=2048
(2 KBYTES)
CODE ENDS
END
```

```
SEND_MESSAGE PROC NEAR
MOV BX,OFFSET MESSAGE-0400H   ; POINT TO START
                              OF MESSAGE

NEXT:   MOV AL,CS:[BX]        ; GET ASCII
                              CHARACTER
        CMP AL,'$'            ; IF $,END OF
                              MESSAGE
        JZ DONE

        MOV DI,PORTA          ; SEND CHARACTER
                              TO PRINTER
        MOV [DI],AL           ; VIA PORT A
        CALL HANDSHAKE        ; CHARACTER
                              RECEIVED?
        INC BX                ; NEXT CHARACTER
        JMP NEXT
DONE:   RET

SEND_MESSAGE ENDP

HANDSHAKE PROC NEAR

        MOV CX,0FFH           ; DELAY
DELAY:LOOP DELAY

STROBE: MOV SI,PORTCOMMAND    ; POLL 8155 STATUS
                              REGISTER
        MOV AX,[SI]
        AND AL,1
        JZ STROBE             ; EXIT IF
                              CHARACTER SENT
        RET
HANDSHAKE ENDP

MESSAGE:    DB 0DH            ; RETURN
            DB 0AH            ; LINEFEED
            DB 'RG 80188 EMBEDDED CONTROL
                              COMPUTER'
            DB '$'            ; END OF MESSAGE
                              CHARACTER

ORG 07F0H                     ; RESET VECTOR
                              FFFF0H

JMP 0FFC0H:0000               ; JUMP TO START OF
                              OPERATING SYSTEM
AT FFC00

ORG 0800H                     ; FILE SIZE=2048
                              (2 KBYTES)
CODE ENDS
END
```

Printing graphics

24 pin dot matrix and bubble-jet printers are capable of printing graphics to a high resolution. All printers respond to control codes, which consist of the ESC character (ASCII 1B), followed by an additional code which is translated by the printer electronics to control the print head, print carriage and also so configure the printer for reception of graphics data. To set graphics mode, 1B 2A is sent to the printer, followed by a series of bytes which define the dots that make up the image to be printed. The diagram shows how these dot patterns are calculated.

```
;CROSS.ASM

CODE SEGMENT
ASSUME CS:CODE
ORG 0

ORG 0400H

     LMCS EQU 0FFA2H
     LCS = 038H
     PORTCOMMAND EQU 0100H
     MODE = 015H
     PORTA EQU 0101H

     MOV SP,0FFH              ; INITIALISE STACK
                              POINTER
     MOV DX,LMCS              ; INITIALISE RAM
                              CHIP SELECT
     MOV AL,LCS
     OUT DX,AL

     MOV DI,PORTCOMMAND       ; INITIALISE 8155
                              FOR HANDSHAKE
                              MODE
    MOV AL,MODE
     MOV [DI],AL
CYCLE:
     MOV BX,OFFSET
     MESSAGE-0400H            ; POINT TO START
                              OF MESSAGE

NEXT:MOV AL,CS:[BX]           ; GET ASCII
                              CHARACTER
     CMP AL,'$'               ; IF $,END OF
                              MESSAGE
     JZ DONE

     MOV DI,PORTA             ; SEND CHARACTER
                              TO PRINTER
     MOV [DI],AL              ; VIA PORT A
     CALL HANDSHAKE           ; CHARACTER
                              RECEIVED?
     INC BX                   ; NEXT CHARACTER
     JMP NEXT
DONE:

     JMP CYCLE

HANDSHAKE PROC NEAR

     MOV CX,01FFH             ; DELAY
DELAY:LOOP DELAY
STROBE: MOV SI,PORTCOMMAND    ; POLL 8155 STATUS
                              REGISTER
        MOV AX,[SI]
        AND AL,1
        JZ STROBE             ; EXIT IF
                              CHARACTER SENT
        RET

HANDSHAKE ENDP

MESSAGE:    DB 01bh,02ah,027h,3,0
            DB 0,014H,0       ; DEFINE DOT
                              PATTERN 'X'
            DB 0,8,0
            DB 0,014H,0
            DB
            DB '$'            ; END OF MESSAGE
                              CHARACTER
ORG 07F0H                     ; RESET VECTOR
                              FFFF0H
JMP 0FFC0H:0000               ; JUMP TO START OF
                              OPERATING SYSTEM
AT FFC00

ORG 0800H                     ; FILE SIZE=2048
                              (2 KBYTES)
CODE ENDS
END
```

The software mentioned in this article can be obtained from the author. Send a cheque or P.O. for £12.50 to:
Mr Richard Grodzik, 53 Chelmsford Rd, Bradford BD3 8QN.

Next Month...

we will continue our look at programming and using the ETI 80188 single board computer.

ACTIVE GUITAR

Dimitri Danyuk and George Pilko

Some of the most important functions in sound reinforcement systems are performed by low-level preamplifiers. They must amplify signals from millivolt level with a minimum amount of electronic noise and hum. Considering a guitar magnetic pickup as a signal source, the input impedance specification is of particular importance.

The output impedance of guitar pickups can vary by a factor of 40:1 over the audio band. The d.c. output resistance of pickups lies in the range 3 - 15kΩ and their inductance is around 2 - 10H. Before a signal enters the amplifier input, it has been passed through a long shielded cable. Cable capacitance and pickup inductance form a parallel resonant circuit which shifts the pickup resonance several octaves lower.

The guitar signal is amplified by an overdriven amplifier to achieve the required sound. This reduces the signal dynamic range so interference such as hum, clicks and pops produced by the long cable become evident. A possible solution is to use a noise gate, but the gate's switching effects are audible.

This article describes an active front-end circuit which allows one to properly interface a magnetic pickup and combo amplifier. Rejection of unwanted signals and increase in the output dynamic range produces marked improvement in performance.

Usually, the active electronics circuit consists of a battery driven, op-amp based voltage follower placed inside the guitar [1]. This is not very convenient since the user needs to be aware of the battery state. An advantage of the proposed circuit is that it shares the same cable and jacks and is ready to operate when the combo amplifier is turned on.

The circuit diagram of the amplifier minus the power supply is shown in Figs 1 and 2. It is based on the authors' previously published circuit [2]. This has been redesigned to achieve the lowest signal to noise level and to increase the amount of control. The guitar unit is a common source stage with transistor Q1 and employs passive, noiseless equalisation to produce 'Presence' (switch 52) and 'Middle cut' (switch 51) effects.

Both controls being combined with a certain degree of overdrive in combo amplifier implements interesting artistic effects. If the pickup has a pronounced middle frequency 'voice', one can

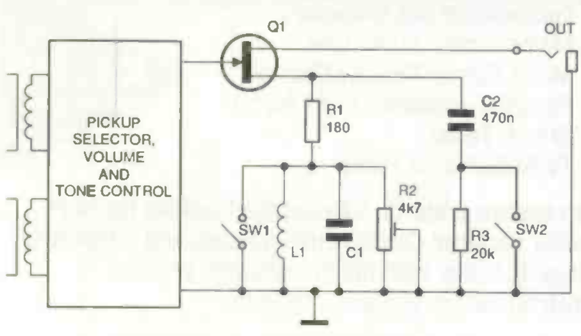


Fig. 1 Active electronics: guitar unit

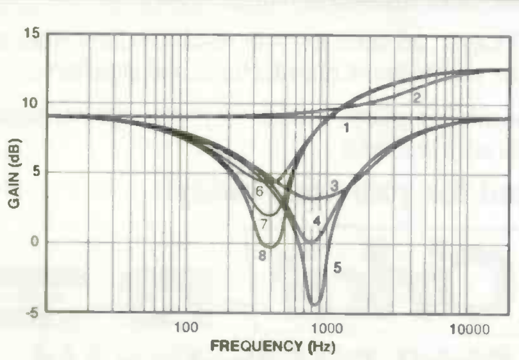
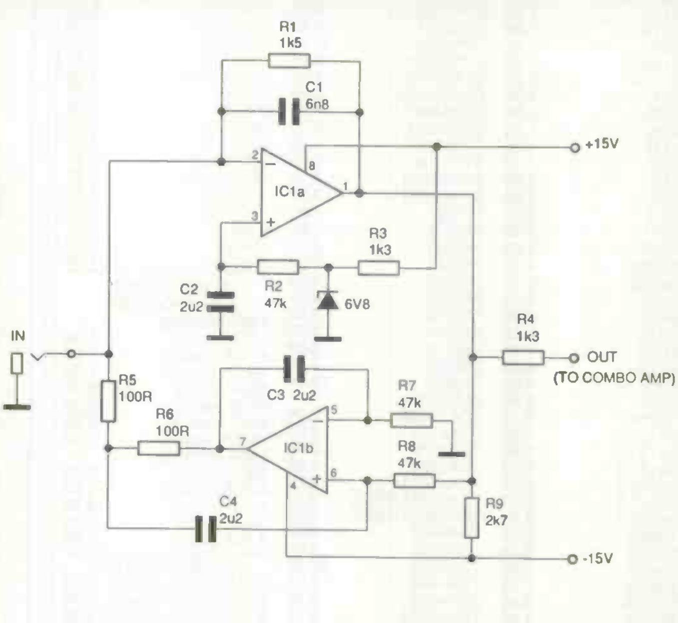


Fig. 2 Active electronics: combo amplifier unit



FFig. 3 Set of frequency responses for the active guitar electronics: curve 1 - switch S1 is closed and S2 is opened, curve 2 - both switches are closed ('Presence' effect is enabled), curves 3-5 - both switches are opened ('Middle cut' effect is enabled), curves 6-8 - switch S1 is opened and S2 is closed (both effects are enabled). Curves 3,6 - R2 = 510 Ω, curves 4, 7 - R2 = 1kΩ, curves 5, 8 - R2 = 2.2 kΩ.

ELECTRONICS

change the components C1 and L1 to muffle it. For example, with the DiMarzio GH-1201 humbucking pickup, it was found C1 = 0.22 μF and L1 = 0.2 H. The set of measured frequency responses with these elements is given in Fig.3.

Transistor Q1 is a 2N4416, 2N5270, 2N5459 or similar, preferably low-noise type, with I dss ~ 10mA and V (p) gs ~ - 3 V. The pinch-off voltage V (p)gs must exceed the peak output of the pickup being used to prevent clipping in common source stage. The quiescent drain current is set by resistor R1 and should be equal or slightly higher than half of the drain current saturation value I dss.

The combo amplifier unit consists of a current-to-voltage converter with d.c. servo loop built around IC1 (5532). The input of the unit becomes a virtual earth and the interference which originated in the cable vanished. The non-inverting integrator IC1b implements a multi-loop feedback via C3 and C4. The integrator output impedance at audio frequencies is much higher than R1 thus the noise contribution of IC1a is negligible. The unit was placed inside Marshall 2100 JCM900 valve amplifier and fed from the amplifier filament supply through a simple voltage regulator. As the overall gain is nearly equal to 3, the peak output from the unit reaches a few volts and allows the input valve to be overdriven.

The guitar unit and combo amplifier unit are interconnected with a conventional shielded cable and 1/4 inch jacks. The circuit works with cable length up to 300 feet and is also very handy for piezo-electric pickups.

References

- E. Meinel, Elektrogitarren (VEB Verlag Technik, Berlin 1987), pp. 83 - 84, 136 - 142
- D. Danyuk and G. Pilko, "Active Guitar Electronics," Electronics Australia, May 1994, p. 65

PC Clinic

This month PC Clinic looks at the PC serial communications port, how it works, how to repair and upgrade it and how to check for faults

Most PCs will have at least one COM port as standard, some may have as many as four. They are used to allow the PC to communicate with a range of different peripherals, such as modems, printers, plotters etc.

The COM port is a serial port, which means that the data is transferred along a single wire one bit at a time. But since the PC does not work with data in serial form but instead uses data in parallel eight bit bytes, it is necessary for the system to have some means of converting parallel data into serial data. To do this, the PC uses an UART, or Universal Asynchronous Receiver Transmitter.

On modern systems the UART will probably be on the motherboard, but in older systems it will be on a plug-in adapter card, and this will still be the case where more than one COM port is installed in the system. Many older adapters will use the 8-bit 8250 UART, more modern systems will use the 16-bit 16450 UART, which provides users with a considerable improvement in performance over the 8250 based circuits.

The 8250 was used by IBM in the original PC and XT machines, it has rather a severe bug in it that causes a spurious random interrupt to be generated by the 8250 at the end of an access. But the designers of the PC wrote the PC and XT ROM BIOS so that it anticipated at least one of these bugs. This means that if you replace the 8250 chip with an 8250A which does not have the bugs then your system will not work properly because BIOS is expecting the bugs; the result is random lockups. (if you do need to replace this chip use either an 8250 or an 8250B)

Fortunately, neither the 16450 or the 16550A have this interrupt bug, and the AT ROM BIOS was written without any of the 8250 bug correction routines found in the PC and XT. This means that an old serial card using the 8250 will not work properly on an AT. Similarly, the newer 16450/50 based serial I/O boards will not work properly on old PC and XT machines since such machines expect the bug to be present.

IBM replaced the 8250 with the faster 16450 (note: if you want to run OS/2 then your system has to use this chip or the faster 16550) and it is found in all AT systems. The 16450 was, in turn, replaced by the 16550 but this chip also has bugs which prevent its FIFO buffer from being used. Any system with a 16550 can be upgraded to overcome these problems by simply replacing the 16550 with a 16550A.

The most modern use the 16550A UART which, because it has a 16bit FIFO buffer, offers the best performance of any currently available serial communications chip. This buffering allows the UART to handle more data before having to be serviced by the CPU, thus reducing the processor overheads. This can be very important in multitasking environments such as Windows, and it also allows data transfer at much higher rates, which is particularly important when using a high speed modem.

This means that it can be a very good idea to make sure that your system is using a 16550A UART. If the adapter card uses a 16450 then one can simply replace the 16450 chip with a 16550A, since they are pin-compatible. These chips are often socket-mounted which makes replacement easy. If it is not, then take great care when unsoldering the old chip not to damage any of the tracks or the plating on the holes. In fact, you may well find it easier to cut all the pins on the old chip with side cutters before attempting to unsolder them, this makes them much easier to remove. In either case, always discharge any static before handling the board and the chips.

However, it should be noted that, if the processor is fairly slow, in particular if it is a 4.77MHz 8088 based system, then it will probably not be able to run communications at higher speeds. Even on a 286 based system one can lose characters with a serial port running at 19200 or higher, particularly when the system is also making heavy use of extended memory such as a RAM disk or cache. In such situations it can help to reduce the size of the sectors or the transfer block size.

If you are using Windows, you will need to update the entries in the SYSTEM.INI file after you have changed from the 16450 to the 16550 UART. This will enable Windows to make full use of the extra features of the 16550. Some additional lines will need to be added to the [386Enh] section, thus:

```
COM1FIFO=On
COM1Buffer=0
COM2FIFO=On
COM2Buffer=0
```

Installing a new I/O adapter card.

When installing a new I/O adapter card it is necessary to assign the ports the correct I/O base address so that they do not conflict with other ports and other adapter cards. The COM ports on a PC have standard I/O addresses and IRQ designations, these are as follows:

COM Port	I/O Base Address	IRQ
COM1	03F8	4
COM2	02F8	3
COM3	03E8	4
COM4	02E8	3

You will probably have to set the correct I/O base address on the card for the desired COM port number. This is usually achieved by setting jumpers on the card; the documentation will usually show how to set these jumpers.

COM port line designations

The COM port on a PC conforms to the RS232 standard. This that it can communicate serially over distances, up to 500ft. The RS232 specification is a physical standard covering the permissible connectors, the pin designation on those connectors, the control lines and the way that the data is transmitted, the voltage levels etc.

The signal coming from a COM port will be in the range +3volts to +12volts represents a 'logic 1', whilst a signal in the range -3 volts to -12volts represents a 'logic 0'. With a minimum output voltage swing of $\pm$ 5volts when loaded with the nominal 5kohm input resistance of an RS232 receiver. The slew rate of the transmitter is limited to less than 30V/us, this limits the baud rate to about 19200.

It should be noted that the maximum baud rate can be traded for cable length; the shorter the cable the higher the baud rate, and vice versa. The factors which govern this are, cable load capacitance, slew rate of the driver under high capacative loading, and the receiver's threshold and hysteresis. When determining the maximum cable length, bear in mind that the load capacitance of the cable should not exceed 2500pf.

Detecting Serial ports with DEBUG

If one can not tell which I/O port addresses the system is using then a simple solution is to use DEBUG to locate them. To do this simply run DEBUG (you will probably find it in your DOS directory). Then type the following line terminated by pressing Enter:

```
d40:0
```

This will cause DEBUG to display the hex values of all the active I/O port addresses, as shown in the following example line:

```
0040:0000   F8 03  00 00  00 00  00 00  BC 03
            COM1   COM2   COM3   COM4   LPT1
```

here COM1 is at address 03F8hex and LPT1 at 03BC hex.

Testing serial ports

In order to test your serial port you will need to perform what is known as a loopback test, which essentially feeds the output back into the input and checks for errors. For this you will need a special loopback connector to suit the type of connector plug on your machine. If necessary, these can be purchased at a fairly modest cost from most specialist PC equipment suppliers, but are invariably included with the diagnostic software needed to perform a proper loopback test.

Norton Utilities Version 7 includes both diagnostic utilities and optional plugs. If you already have plugs then there are a number of shareware programs which can perform loopback tests, programs such as Modem Doctor. They are all quite simple to use; one simply unplugs existing cables from the serial ports and replaces them with a loopback plug, then runs the software. This will then automatically analyse the serial port and display its findings.

Next Month...

PC Clinic will be looking at the heart of multimedia systems, CD-ROM drives and sound cards.

OPTO-

Robert Penfold looks at a technique for adding gain control to public address systems

Massive variations in the output level from a microphone is a familiar problem for those who supervise the use of public address (PA) systems and tape recording equipment. The problem is due more to a lack of expertise on the part of many users, rather than any technical limitation of the microphones. Some users insist on shouting into the microphone at point-blank range, while others seem to suffer from microphone shyness. Some equipment has a built-in automatic gain control circuit which largely compensates for the inevitable variations in the input level. With units that do not have this facility it is not usually too difficult to use an external compressor between the microphone and the main piece of equipment (PA amplifier, tape deck, or whatever).

The basic function of a compressor is to provide reduced gain if the input signal exceeds a certain threshold level. The higher the input level goes above the threshold level, the greater the reduction in gain. The compression gives a virtually constant output level despite wide variations in the signal level from the microphone. Satisfactory results should always be obtained unless the signal from the microphone is totally inadequate.

The "compressor" name is derived from the fact that the dynamic range of the processed signal is compressed, with a 40dB variation in the input signal giving perhaps a 20dB change at the output. In some applications this compression of the dynamic levels is undesirable, but is preferable to the alternatives of overloading and consequent distortion, or an inadequate signal level. Bear in mind though, that it is often best not to rely too heavily on compression to get an appropriate output level. Results are generally best if only a modest amount of compression is normally used, with larger amounts only being used as a result of some inept microphone work.

This microphone compressor is designed for use with a low impedance dynamic or electret microphone. It provides an output signal that can be set anywhere between about 3500mV and 2.8 volts peak-to-peak. The unit should therefore be connected between the microphone and a high level input of the main equipment ("Aux", "Tuner", etc.). The compression characteristic is very good, with a 34dB increase above the compression threshold giving an increase of under 6dB in the output level. The noise and distortion performance of the circuit are also very good.

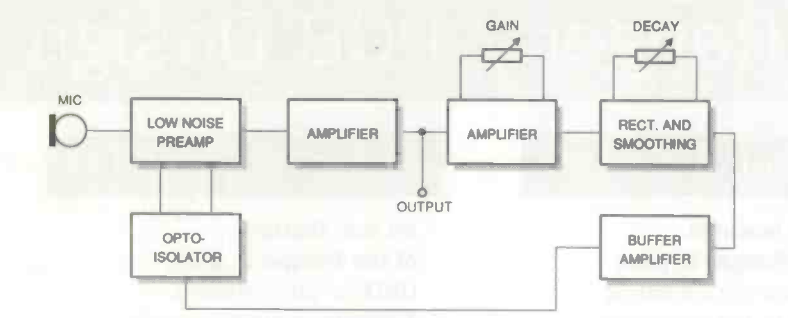


Fig 1. The microphone compressor block diagram

Opto-Resistor

Audio control circuits such as compressors and expanders are mostly based on some form of voltage controlled resistance. Unfortunately, the ideal voltage controlled resistor has yet to be produced. Practical voltage controlled resistances tend to fall well short of theoretical perfection in two main areas. One is simply a lack of isolation between the control voltage and the controlled resistance. This often places severe restrictions on the ways in which the resistance can be used, and it also tends to produce some odd control voltage requirements. The other main problem is a lack of linearity through the resistance, which in most cases does not act as a true resistance at

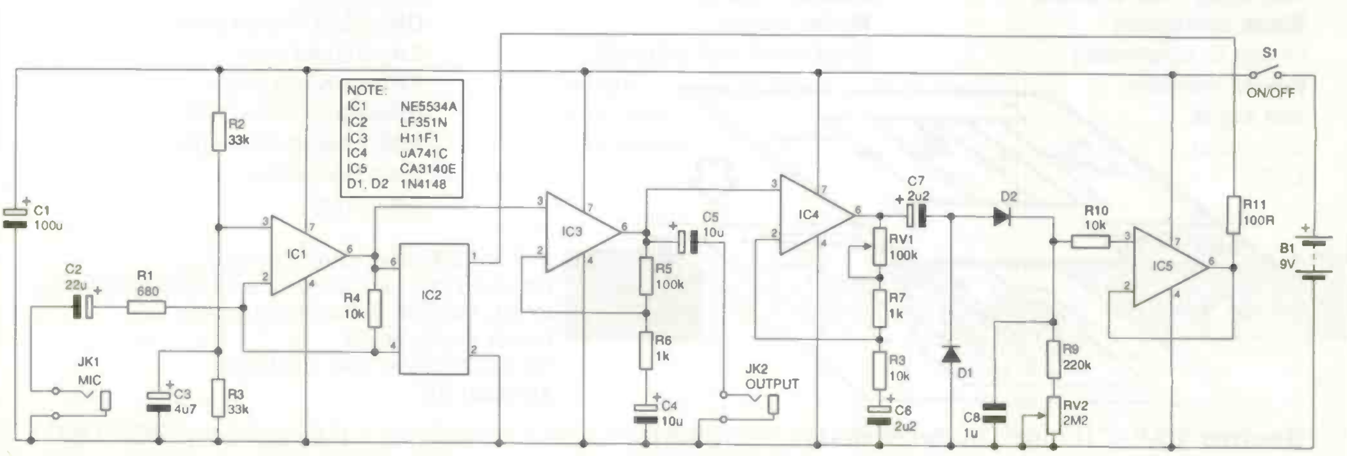


Fig 2. The microphone compressor circuit diagram

COMPRESSOR

all. With semiconductor devices such as bipolar transistors and f.e.t.s, the applied voltage does not produce proportional changes in the current flow. In general, linearity is actually quite good with low applied voltages, but it soon starts to deteriorate with higher voltages. A higher voltage often means an actual potential of only about 100mv or even less.

In my experience, one of the best forms of voltage-controlled resistor is an opto-isolator which consists of the usual LED on the input side, and a cadmium sulphide photo- resistor on the output side. The raw control characteristic of the LED is not very convenient, but where necessary it is easily modified to produce a more amenable characteristic. On the output side the cadmium sulphide cell offers something close to perfection. It provides pure resistance even when the applied voltage is quite high, and as it is electrically isolated from the input section of the device, its resistance can be placed at any desired point in the circuit. The only slight problem with this arrangement is that a cadmium sulphide photocell is not particularly fast in operation. However, it is rapid enough for use in most audio control applications.

There is a practical difficulty with this type of opto- isolator, and this is simply a lack of availability in the U.K. At one time it was quite easy to improvise a home-made equivalent from an ordinary 5 millimetre LED and a cadmium sulphide cell. This approach is still possible, but is made difficult by the limited range of cadmium sulphide cells currently available. In fact, the only widely available photo-resistors are the ORP12, and near equivalents to this component.

Modern technology provides an alternative but similar approach to the problem in the form of the H11F1 opto-isolator. This has the usual infra-red LED on the input side, plus what is effectively a Jfet on the output side. There is no gate connection on the photo-f.e.t. though, and the only way of controlling what could be loosely termed the drain-to-source resistance is via the LED. This gives a voltage controlled resistor that can be used anywhere in the audio circuit, but it is not a true resistor. In order to obtain really good linearity the voltage across the resistor must be kept below plus and minus 50 millivolts. In many applications, this is not a major problem, and the noise level of the opto-isolator seems to be low enough to avoid problems with excessive background "hiss". In fact, the noise level of the resistance provided by the isolator seems to be very low indeed, and is comparable to an ordinary resistor.

How It Works

The block diagram of Fig.1 shows the basic make up of the microphone compressor. The signal from the microphone is fed to a low noise preamplifier, and then to the output via another amplifier. The combined voltage gain of this two stage amplifier is very high, and is actually well over 60dB (1000 times). Although the input signal from the microphone may be no more than about one millivolt peak-to-peak, the output level is more like one volt peak-to-peak, which is sufficient to drive a high level input on most amplifiers, tape recorders, etc.

The f.e.t. at the output of the opto-isolator is used in the negative feedback circuit of the preamplifier stage. Under standby conditions there is no input current to the LED, and the resistance through the f.e.t. is extremely high. In fact it is at least 300 megohms, which is high enough to ensure that it has no significant effect on the level of feedback. However, by applying a current to the opto-Isolator's LED, it is possible to increase the amount of negative feedback applied to the preamplifier stage, which decreases its voltage gain. A reduction in gain of well over 30dB can be achieved.

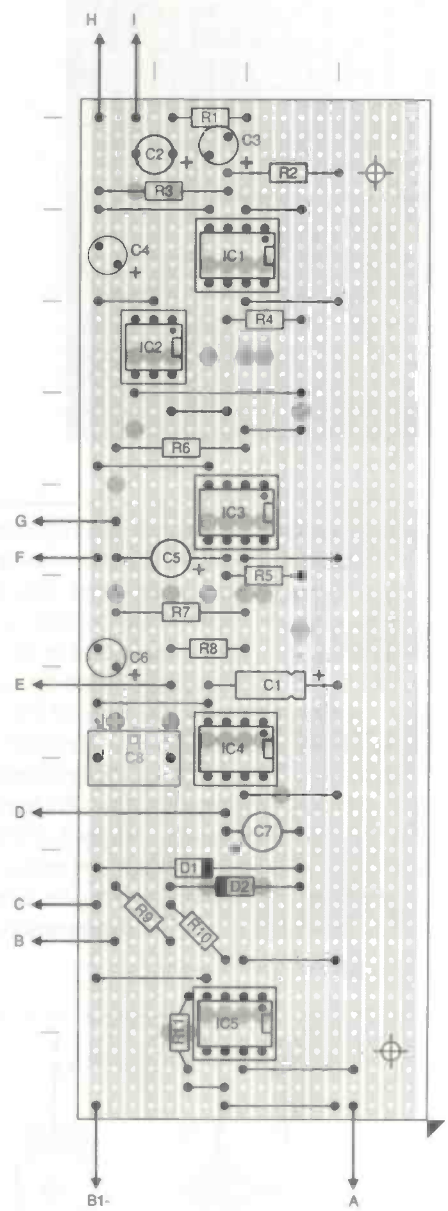


Fig 3. the stripboard component layout (board measures 55 holes by 18 strips)

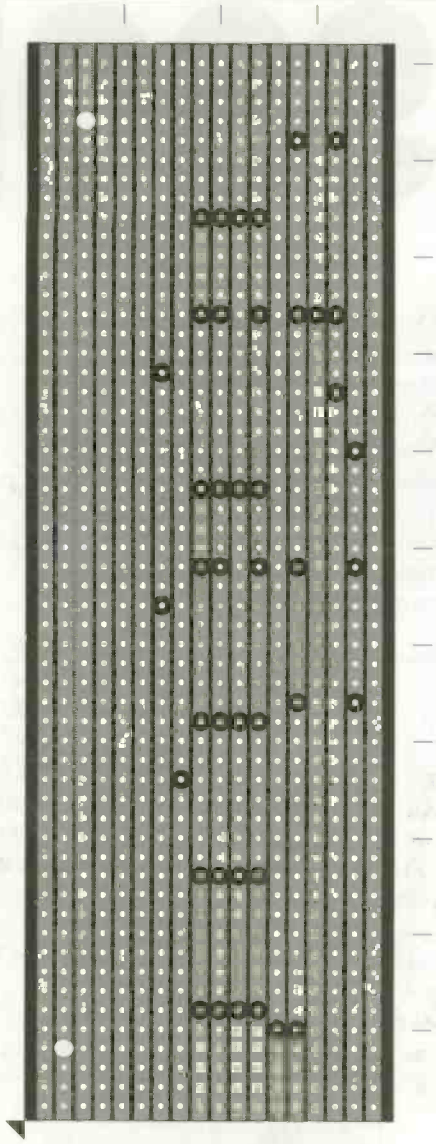


Fig 4. Underside of the stripboard panel

In order to obtain a compressor action it is merely necessary to amplify some of the output of the unit, and then feed this amplified signal to a smoothing and rectifier circuit. The output from the rectifier circuit drives the opto-isolator's LED via a buffer stage. This positive voltage is roughly proportional to the amplitude of the input signal. Due to voltage drops through the rectifier circuit, plus the forward threshold voltage of the LED itself, the input signal has to reach significant proportions before the LED starts to switch on. Once this threshold level has been reached, increasing the input level results in the LED lighting up, and the gain of the preamplifier reducing. This gives a form of negative feedback action, with any increase in the output level being tamed by a reduction in the preamplifier's gain. Some increase in the output level does occur, but this increase is only a fraction of the rise in the input level.

The voltage gain of the amplifier that drives the rectifier and smoothing circuit is adjustable. This control sets the compression threshold level. The higher the gain of this amplifier, the lower the output level that is needed to produce a given amount of compression. In other words, this control is used to set the maximum output level from the unit.

The decay time of the smoothing circuit is also adjustable. A fast attack time must be used so that the circuit responds rapidly to high input levels, preventing them from producing clipping at the output. The attack time must be much longer in order to prevent self modulation, and strong distortion on the output signal. In practice a very short decay time is often undesirable as it results in rapid changes in gain, which might be very obvious due to the accompanying changes in the background noise level. A very long decay time is undesirable as it can result in the occasional loud but brief noise holding down the gain for many seconds. The decay time has to be something of a compromise, and the ideal setting for the gain control will depend on the precise circumstances in which the unit is used.

The Circuit

Fig.2 shows the full circuit diagram for the microphone preamplifier. The preamplifier is a simple inverting mode circuit based on IC1. As a very low signal level is being handled, a very low noise device is used for IC1. The circuit will work using an ordinary operational amplifier in the IC1 position, but with a reduction in the signal to noise ratio of about 20dB. R1 and R4 are the negative feedback resistors, and these set the gain and input impedance at about 15 times and 680 ohms respectively. Good results should be obtained with most low impedance microphones using a value of 680 ohms for R1, but with some 200 ohm types it might be better to reduce R1 to about 330 ohms. This gives a lower input impedance and a small boost in gain. IC2 is the opto-isolator and it has its f.e.t. connected in parallel with R4. The output of IC1 is coupled to a non- inverting mode amplifier based on IC3. This has its voltage gain set at about 100 times by R5 and R6.

IC4 is used in the amplifier that drives the smoothing and rectifier circuit. Its closed loop voltage gain can be varied from a little over unity to about 11 times by means of VR1, which is the threshold level control. The rectifier circuit is a simple half-wave type based on D1 and D2. C8 is the smoothing capacitor, and VR2 is the decay control. The decay time is approximately 2.5 seconds with VR2 at maximum resistance, reducing to a little over 200 milliseconds with VR2 at minimum resistance. IC5 acts as the buffer amplifier at the output of the smoothing circuit, and it drives the LED in IC2 via current limiting resistor R11. IC5's PMOS input stage ensures that there is no significant loading on the smoothing circuit.

The current consumption of the circuit is about 9 milliamps under quiescent conditions, but it is several milliamps more than this at high compression levels (due to the current flow into IC2's LED). A fairly high capacity battery should therefore be used, such as six HP7 size cells in a holder.

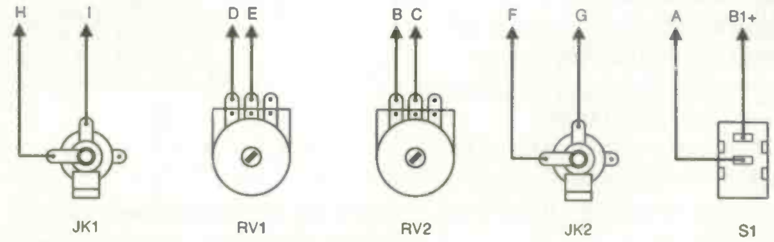


Fig 5. Details of the hard wiring

Construction

The stripboard layout for the microphone compressor is shown in Fig.3 (component side) and Fig.4 (copper side). The board measures 55 holes by 18 copper strips. Start by cutting out a board of the correct size using a hacksaw, and then make the breaks in the copper strips. These can be made using the special tool, or a hand held twist drill bit of about 5 millimetres in diameter. Either way, make quite sure that the strips are broken across their full width. Also drill the two 3.3 millimetre diameter mounting holes at this stage. These will take either metric M3 or 6BA screws.

Next fit the components and link-wires. Note that the CA3140E used for IC5 has a PMOS input stage, and that it therefore requires the usual anti-static handling precautions. In particular, use a holder for this component. In fact, I would recommend the use of holders for all five integrated circuits, especially IC2 which is not a particularly cheap component. Single-sided solder pins are fitted to the board at the points where the connections to off-board components will be made. Details of this hard wiring are provided in Fig.5 (which should be used in conjunction with Fig.3).

In Use

The unit connects between the microphone and a high level input of the main equipment. A good quality screened lead should be used to carry the connection from the compressor to the main unit. The compressor is almost certainly functioning correctly if VR1 enables the maximum output level to be controlled. Also, a loud noise (tapping the microphone for instance) should cause a slight reduction in the background noise level. The noise level should return to normal over a period that can be controlled via VR2.

VR1 must be set to provide an output level that is appropriate for the main piece of equipment. In many cases the main unit will have a gain control that enables a wide range of maximum input levels to be accommodated. If this should be the case, simply give VR1 a roughly central setting, and then adjust the gain control of the main unit in the normal way. The best setting for VR2 must be found by trial and error and, to a large extent, this is a subjective matter.

PARTS LIST

Resistors (0.25 watt 5% carbon film)

- R1 680R
- R2,R3 33k
- R4,R8,R10 10k
- R5 100k
- R6,R7 1k
- R9 220k
- R11 100R

Potentiometers

- VR1 100k lin carbon
- VR2 2M2 lin carbon

Capacitors

- C1 100u 10V radial elect
- C2 22u 16V radial elect
- C3 4u7 50V radial elect
- C4,C5 10u 25V radial elect
- C6,C7 2u2 50V radial elect
- C8 1u polyester

Semiconductors

- IC1 NE5534A
- IC2 H11F1
- IC3 LF351N
- IC4 uA741C
- IC5 CA3140E
- D1,D2 1N4148

Miscellaneous

- S1 SPST min toggle
- B1 9 volt (6 x HP7 in holder)
- JK1,JK2 3.5mm jack socket

Case

0.1 inch pich stripboard, 55 holes by 18 strips
Battery connector (PP3 type)
Control knob (2 off)
8 pin DIL
IC holder (5 off)
Wire, solder, etc.

RAYDOR

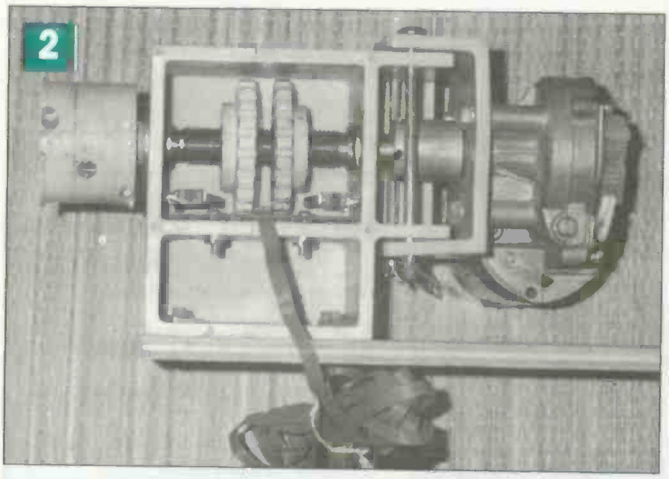
A PATENTED REMOTE CONTROLLED AUTOMATIC GARAGE DOOR OPENER

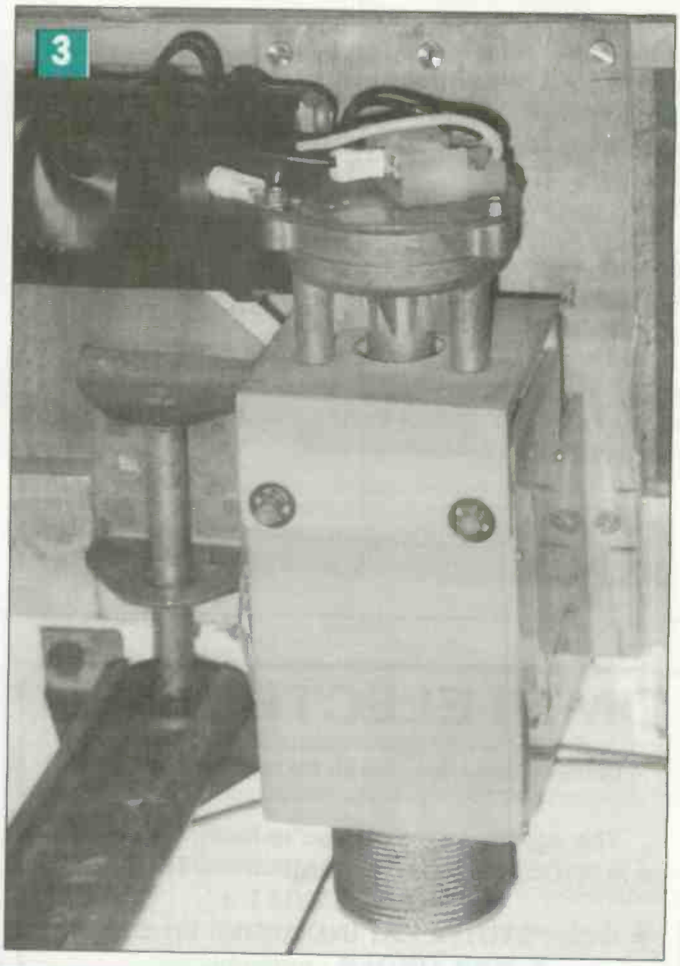
Designed by Pat Alley

There are several benefits from owning an automatic garage door opener (AGDO). Convenience, security, no back strain and less exposure to inclement weather are the more obvious ones. Also when selling your house you not only get your money back but it is a valuable attraction in pulling in potential buyers. The disadvantages are the up-front costs of around £300 plus £100 for fitting. Double this if you have a double garage with two single doors.

Brief history of Raydor

The ideas for Raydor stemmed from a cable-operated AGDO I patented more than a decade ago. At that time the motor drum unit was affixed to the ceiling or garage wall and a well-known company developed it and manufactured quite a few thousand of them. They were well made and robust and many are still going strong today but the final version did prove to be rather involved to install. On my retirement, I decided to investigate means of simplifying the installation but to retain the low-cost





1 - Door closed. Motor/drum unit fitted via its wooden baseboard on the left-hand side of the door immediately under the door roller wheel. It can be seen here that, with the door fully closed, winding cable 2 (on the outside of the drum) has a minimum of at least two complete residual turns to relieve strain on its nipple. The positive motor connector from the control box can be seen plugged to the spade terminal terminating the motor's red wire and the negative connector is entrapped under one of nuts holding down the gear lid.

2 - Door fully open. 700mm long baseboard is bolted to the rear of the metal track. In this particular installation, the door stop is on the other metal tack (out of sight). Spring chord 2, pinchblock 2 and endstop 2 are mounted on the baseboard co-acting with cable 2 wound round the drum. In the background cable 1 can be seen passing over the pulley and passing through endstop 1, both screwed to the door jamb, with spring chord 1 attached to the loop formed at the end of cable 1.

3 - View of motor/drum unit with lid removed, ready to be screwed to door via its wooden baseboard. In this version the microswitch PCB is bolted to the frame but whichever way it is fitted MS2 is always closest to the motor.

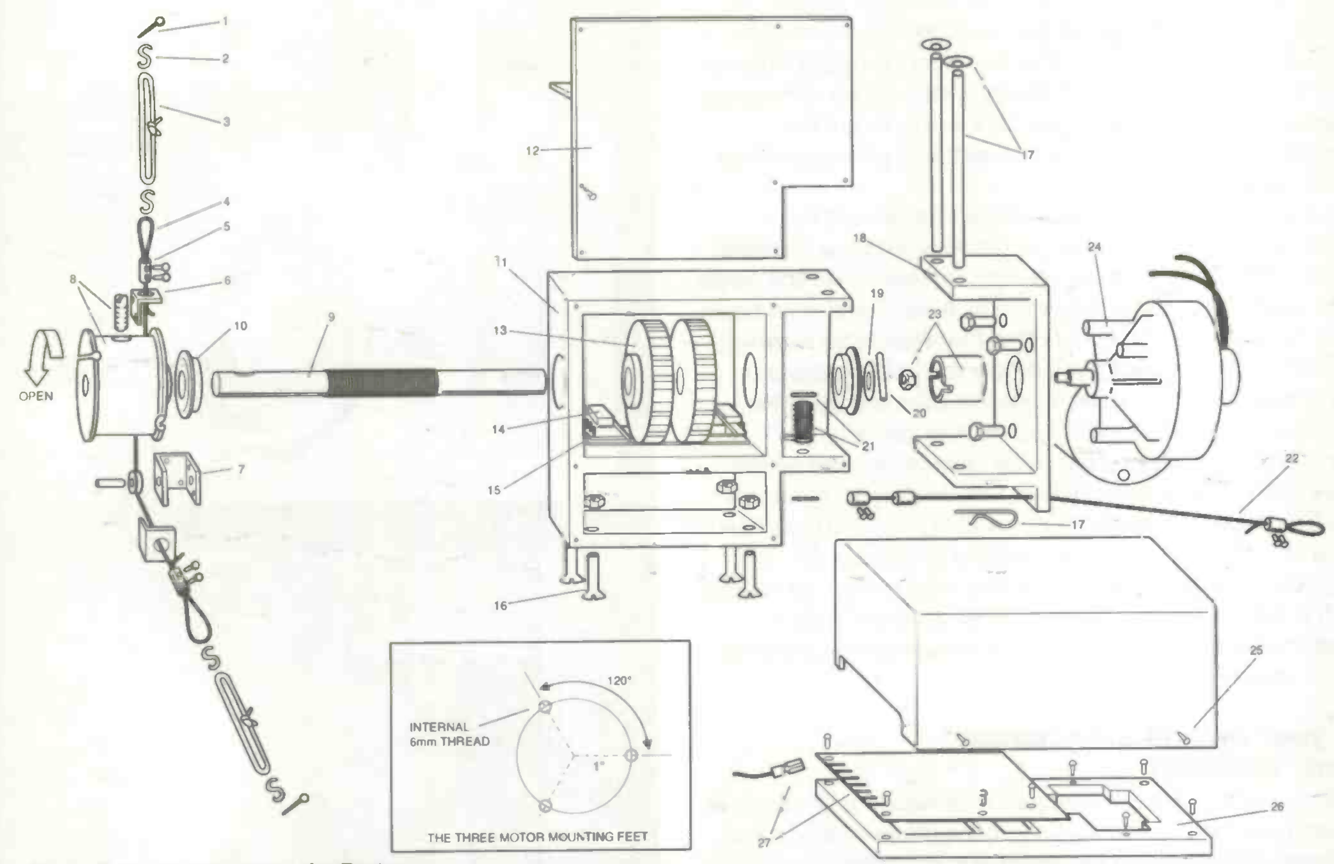


Fig 1. Exploded diagram of a Rador

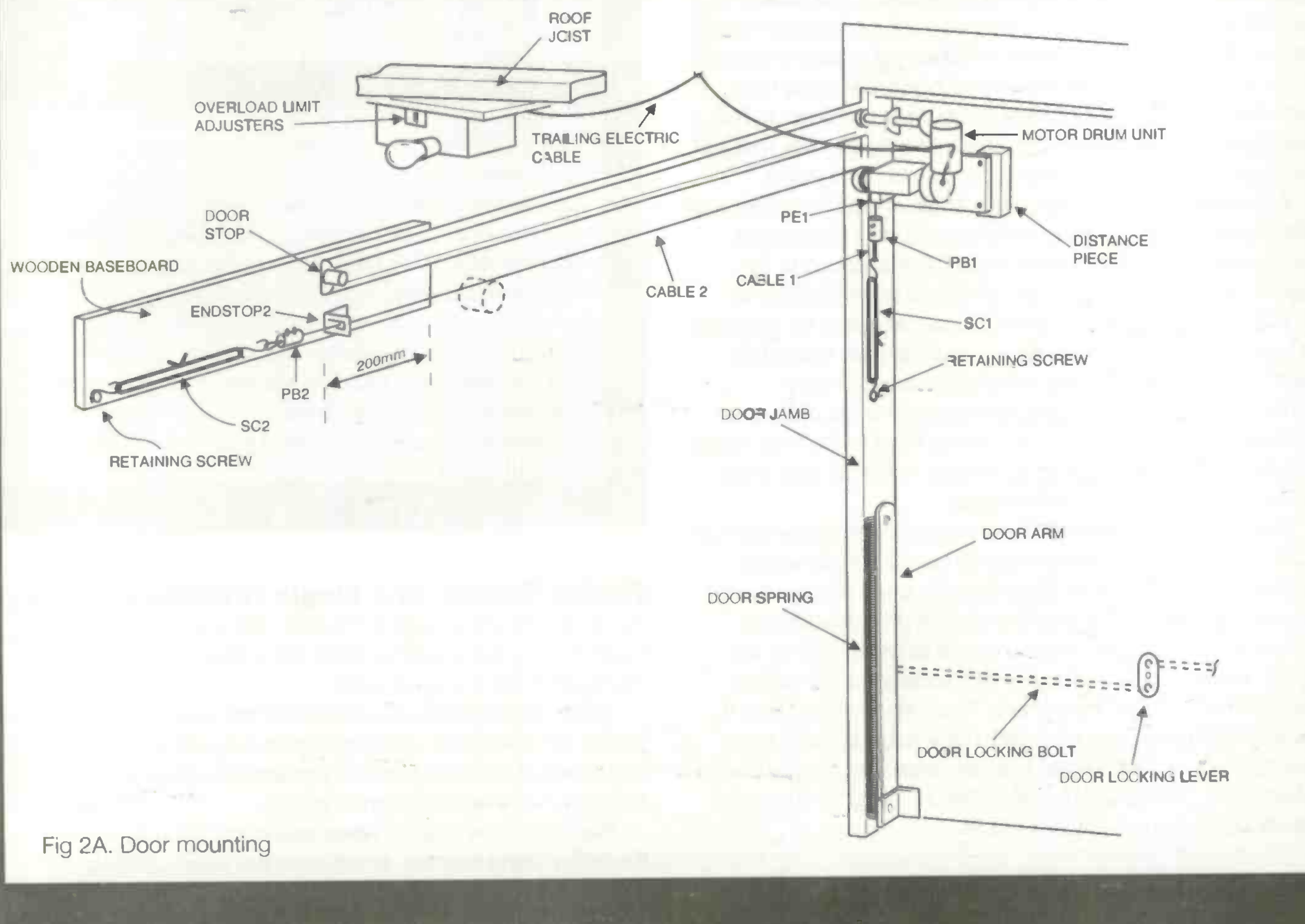


Fig 2A. Door mounting

cable operation, which by now was well proven.

An idea finally surfaced to mount the motor drum unit on the door itself and the first two prototypes of Raydor are still operating my own two single garage doors. Operation of the door is now from one side rather than from the centre. This not only simplifies installation but effects greater economy by taking advantage of the door's existing structure to mount the operating mechanism and, for this reason, is principally aimed at the single door.

would mention that I have patented Raydor and its Felectronics so if there are any companies out there interested in commercialising it, please contact me. Meanwhile, any reader who would like to make one or two on a non-commercial basis may derive satisfaction from putting their skills to good use and saving money, more still if you supply your own windscreen wiper motor which provides the motive force and by far the most expensive component. Such motors can often be purchased second-hand from a car breaker for a few pounds. For those who lack the workshop facilities to make the rest of the Raydor units, I have produced a kit of parts and units listed in table 1, together with prices inclusive of carriage. An exploded diagram of Raydor is shown in fig.1 which will be dealt with in more detail later. Some of these parts are made in urethane plastic and produced from moulds used to make my latest prototypes.

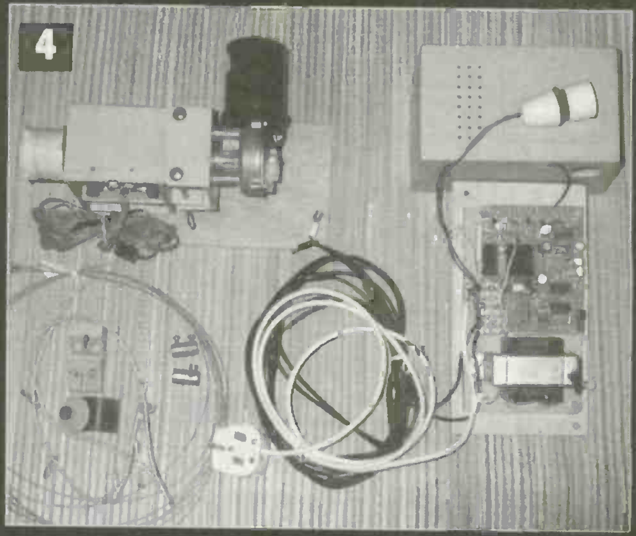
Is your up and over garage door suitable?

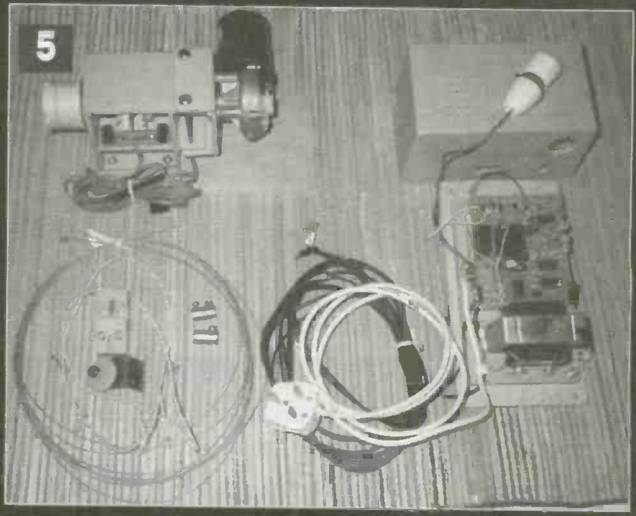
First you need to know the difference between the two types of up-and-over doors presently used in the UK, one being called the retractable door and the other being called the canopy door.

A retractable door is one that is capable of being fully raised and lowered by a horizontal force exerted on the top of the door. Such doors come in various guises but most have a pivoted arm attached to a counterbalancing spring down either side of the door, with a small wheel attached to each top corner of the door running in their respective horizontal metal track. From outside, the handle is near the bottom of the door. The retractable door is capable of being automated by any make of commercial AGDO and is widely used around the world.

A canopy door is one that has a small wheel fitted either side of the door, about one third of the way up from the bottom, each running in its own vertical metal track attached to its respective door jamb. To open, it first has to be significantly rotated about these wheels before it can be raised by exerting a vertical force, allowing the wheels to run up their respective track. A vertical force is also needed to lower the door. Counterbalancing on older models was by means of weights but, more recently, by a long coil spring fitted to the lintel inside the garage. The canopy door is peculiar to the UK with a few exported to some European countries.

Given the multi-directional forces complicates automation. A commercial "bow" arm accessory can be employed with a standard AGDO. This is a large metal structure shaped like a bow and bolted to the rear of the door to provide a vertical component to the essentially horizontal force exerted by an AGDO. It costs about £50 but is less successful with some manufacturers' doors than others. Thus, the moral is clear. If you are buying a garage door with automation in mind, buy a retractable door. Having said this, for those who already have a canopy door, Raydor has been adapted to automate one and this will be described in a later article.





4 and 5 - Varying views of all the main components of Raydor. The two winding cables surround the two pinchblocks and two spring chords with the two endstops and pulley in the centre. Rolled up and attached to the microswitch PCB on the motor/drum unit is the ribbon cable. Attached to the terminal blocks on the main PCB are the two motor cables, main cable and a short blue lead to the light socket which, when assembled, will be screwed into the hole at the side of the control box lid. In this instance, to ensure the light and overload adjusters face towards the rear of the garage, the base of the control box has been screwed to a wooden baseboard ready to span two ceiling joists which, in this garage, run front to rear.

Fitting Raydor to a single retractable door

Some abbreviations used in the text:- PE = pulley/endstop, PB = pinchblock, SC = spring chord, DN = disc nut, MS = microswitch, POF = push-on-fit.

Whilst all retractable doors work on the same principle, each model can have small variations which may call for minor alterations of measurements or installation so be sure to read sections 1 - 21 before attempting to fit.

Raydor can be fitted to either side of the door. Apart from the motor being inverted, which does not affect operation, automation from one side is virtually a mirror image of the other side. However, one benefit of installing on the left-hand side (as shown in all drawings) is that the winding cables come off the top of the drum affording an extra 50mm head clearance.

All wooden baseboards (supplied by the installer) should be about 18mm thick in order to take the screws. Blockboard is preferred but not essential. In many of the figures, some items (e.g. the motor) are not shown in order to maintain clarity.

The existing door locking bolts should be left permanently retracted so as not to impede movement of the door.

1. Raydor is not a cure for a badly fitted door!

Lubricate door pivot joints and wheel bearings and ensure all screws are tight. The door should have adequate clearance within its frame with no tendency to rub when raised from the side. A properly counterbalanced door normally remains stationery whatever position it is left in; except, when nearly closed, the door has a natural tendency to close itself as the springs go over-centre of their arms.

To stimulate Raydor's operation, tie a length of string to one of the door roller wheel bracket shafts, then, standing near the rear of the garage, pull the door open. Better still, become an instant expert by pulling the string with a spring balance (fig. 2b) and note the maximum reading. This not only provides a datum but eliminates any guesswork by numerically quantifying an improvement (or deterioration) following any spring or other adjustment you may make. The maximum force occurs when opening the door. Typical values are 5 - 15kg and should not normally exceed about 20kg (44lb). The benefits of any preparatory work cannot be overstressed and will pay dividends in long and trouble free operation.

2. How Raydor works (See Figs. 1 and 2)

Door opening time is about 10 - 12 seconds. Triggering Raydor by pressing the push switch in the garage or the radio transmitter (Tx) button, rotates the motor clockwise (as viewed from its motor). Initially, spring chord SC2 stretches until pinchblock PB2 abuts endstop 2 and simultaneously SC1 relaxes. This movement occurs within the first fraction of a second after which the door is pulled open along its tracks as the drum winds on to cable 2 and winds off cable 1. Meanwhile two disc nuts, DN1 and 2 (fig.1), both prevented from rotating by a projection on the lid, move axially along the motor/drum shaft (toward the motor) until, when the door is fully open, DN2 depresses the lever of MS2 to stop the motor. Note that the control box light illuminates from the time the door starts to open.

Triggering the system once more causes the motor to rotate in the reverse direction. Initially SC1 stretches until PB1 abuts endstop 1 and simultaneously SC2 relaxes, after which the door is pulled closed along its tracks as the drum winds on to cable 1 and off cable 2. Meanwhile, the captive disc nuts move axially in the reverse direction until, when the door is closed, DN1 depresses the lever of MS1 to stop the motor. The light will extinguish after a further three minutes giving time to exit the garage. Note that it is the endstops which bear the door load on opening and closing. The SCs are there simply to keep tension on their respective cable when winding-off the drum.

3. Safety devices

Whilst the door is opening, pressing the push switch or radio Tx button again (or, if the door is obstructed, a self-generated overload signal) will stop the motor. The motor can be restarted from the push switch or Tx. If the door is closing, pressing the switch or Tx button (or, should the door be obstructed, a self generated overload signal) will stop the motor momentarily then automatically reverse it to re-open the door. Another safety device prevents the motor running continuously for more than about 25 seconds. Note that when pressing the Tx button, sweep it in an arc to avoid radio dead spots. Ensure the door is fully open and has stopped before driving into or out of the garage.

4. Fit the motor/drum unit to door (Fig.2)

In all cases, the drum shaft will be horizontal and parallel to the door. Mounting the motor/drum unit will depend on whether the door is wood or metal and the position of any strengthening struts. In all cases, a wooden baseboard will make the job easier and the drum unit should be attached to a 250mm x 125mm baseboard using the four 5mm x 30mm nuts and bolts provided, with equal clearance top and bottom and outer edge of the casing in line with one edge of the baseboard (Fig. 2c).

Now position the drum unit on the rear of the door with the baseboard abutting the bottom of the roller wheel bracket and aligned with the outer edge of the door weather strip so that the drum overhangs clear of the door. Mark the baseboard in four places coincident with the centre line of the door return and the door strut. Drill the baseboard with 4.5mm holes and metal door with 3mm clearance holes before screwing down with No.8 x 25mm self-tapping screws. If necessary, lengthen the baseboard to span between the door return and any door strut

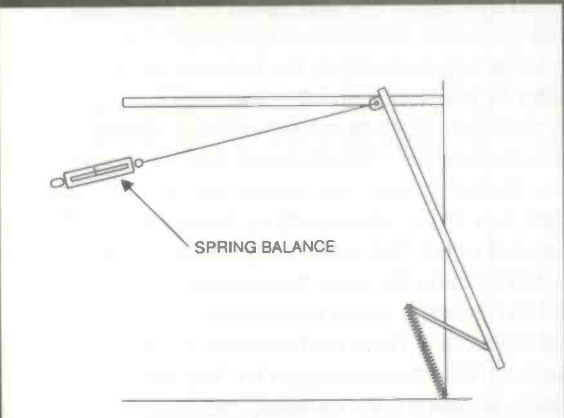


Fig 2B. Measuring door counter balance

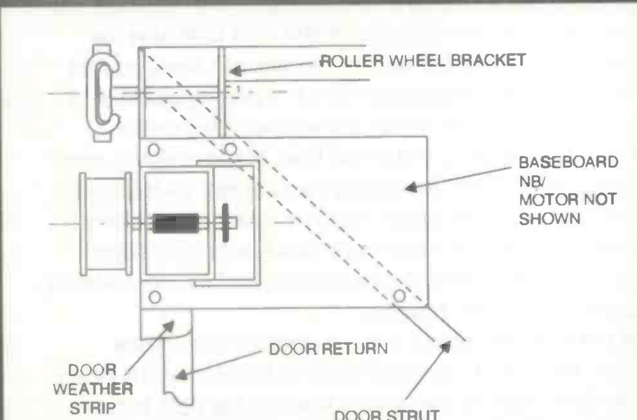
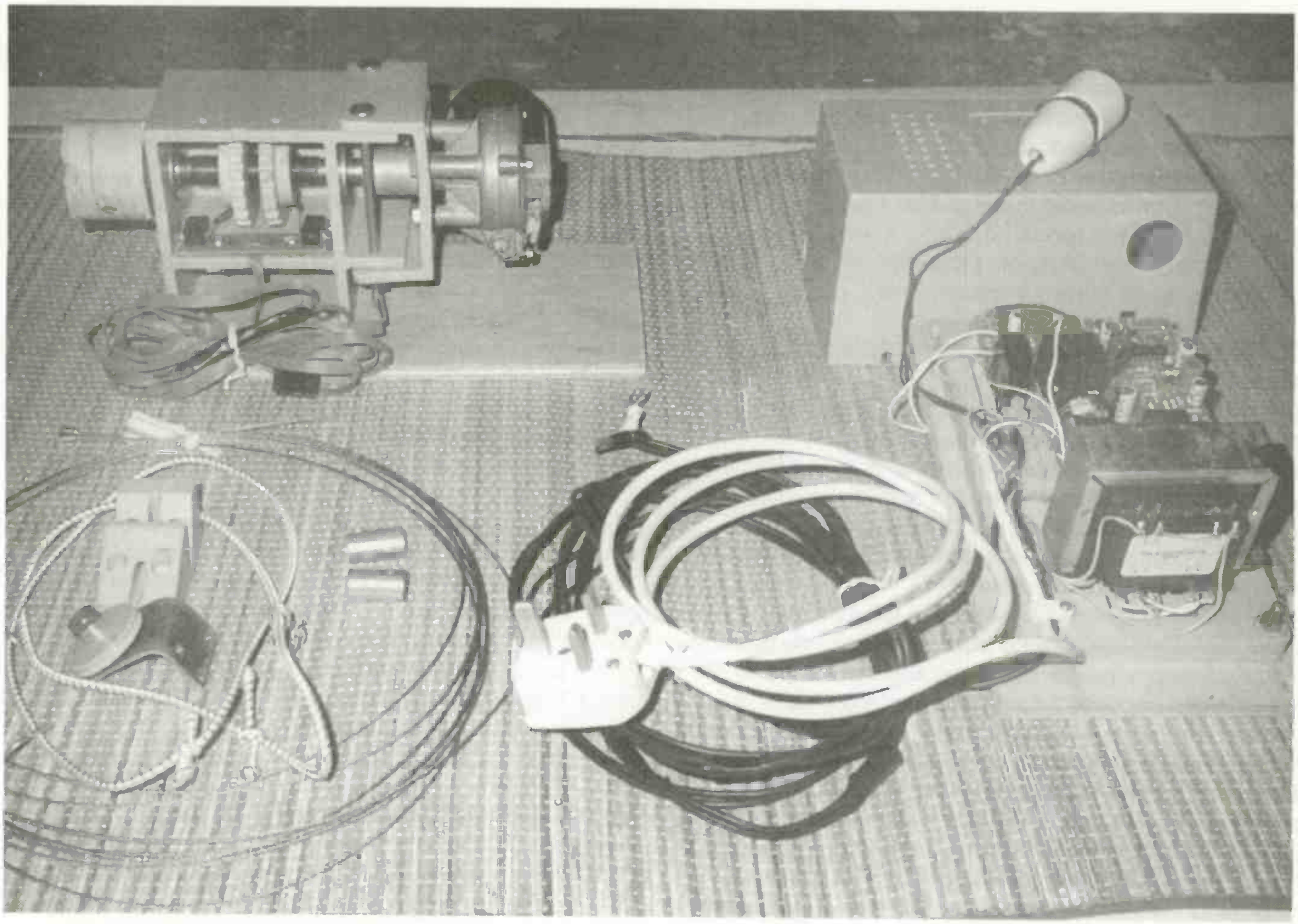


Fig 2C. Fiting motor/drum unit todoor



provided or alternatively (see fig. 2a) screw the baseboard to a wooden distance piece of suitable thickness with two No. 8 x 30mm screws then from outside the garage drill two 4.5mm holes in the door coincident with the centreline of the distance piece and tighten down using two further No.8 x 30mm screws. If the inside of the door is ribbed, profile the distance piece accordingly.

5. Fit metal track baseboard and associated parts

The baseboard bolted to the rear of the metal track can be ordinary planed and prepared Yellow Deal 18mm thick, about 700mm long and at least 100mm wide if fitted on the left-hand side, or 150mm wide if fitted on the right-hand side of the door. Align the top of the baseboard with the top of the metal rail, drill two 5mm holes then bolt together. In the front hole, use the 5mm x 30mm bolt supplied with its countersunk head against the inside of the metal track to prevent it impeding passage of the door roller wheel, with its nut and washer fitted on the outside of the baseboard. In the rear hole, fit your existing door stop with its nut and bolt, increasing the hole size as required. (Note that it is imperative a door stop is installed. This is simply a bolt projecting from the metal track which acts as a safety device by physically impeding overrun of one of the door wheels which could have drastic results.)

Open the door and screw down endstop 2 with its slot aligned with the rear of the metal track and the top of the drum (fig.2d), or the bottom of the drum if fitted on the right-hand side. Note that if the metal track baseboard is too wide it may obstruct the drum, in which case saw off the front bottom corner as appropriate. Now mark the drum surface 10mm from the outside edge. Call this mark "A". Referring to fig.2e and fig.2f, screw the pulley/endstop PE1 to the door jamb using the two No.6 x 30mm posidrive screws provided, so that the top of the pulley aligns with both mark 'A' and the top of the drum (bottom of the drum if fitted on the right-hand side).

NB. To avoid any confusion, a separate pulley and endstop 1 can be used, the distance between them being immaterial so long as the endstop on the door jamb aligns with the pulley. Alternatively, a combined pulley/endstop (PE1) can be used.

6. Fit control box

The control box can be fitted anywhere convenient provided the trailing electrical cable (which only carries low voltage) is not strained by normal movement of the door. To keep this cable high, out of the way and ensure minimum droop, the preferred position of the control box is screwed to a ceiling joist (or depending on their orientation, a baseboard spanning two ceiling joists) approximately in line with and as far to the rear of the motor as the motor and MS cable allow, using No.8 x 30mm screws in opposite corners of the control box base. The lightbulb (suggest 60 - 100W) should face rearwards. Ensure that you are able to reach the control box overload limit adjusters at all times. Loosely clamp the motor's black cables to a ceiling joist with a T&E cable clamp, about halfway between the control box and the door, then connect one lead to the motor's red (positive) spade terminal and entrap the hook terminal of the other black lead underneath one of the three nuts holding down the motor gear lid. This earths the motor's metal body to mains earth for safety. Now route the MS wires via the same ceiling clamp back to the control box and plug the IDC connector into its DIL socket on the main PCB. Following a few test runs the trailing cables can be tidied up with a few loops of black adhesive tape.

7. Fit winding cables 1 and 2

SC1 and SC2 are identical and are quickly formed by doubling over and tying their free ends together in a knot so that each are 150mm long unexpanded before attaching their two S hooks. Attach cable 1 to the inside edge of the drum via its nipple and spirally wind on sufficient close turns up to mark 'A'. Note that Cable 1 disengages from top of drum (bottom of drum if fitted to right-hand side of door). Ensure you wind the cable consistent with the drum rotating clockwise (as viewed from the motor) to open the door. Temporarily stick last turns of cable down to the drum with adhesive tape to ensure coils will not unwind. Then continue by threading cable 1 over the pulley and through the hole of endstop 1, twice through PB1 to form a loop about 50mm long then back through endstop 1 before tightening down the two PB1 screws with the top of PB1 25mm from the bottom of endstop 1. Finally, hook cable 1 onto SC1 retaining screw. Ideally, with the door closed, the No. 8 x 25mm countersunk retaining screws should be positioned so that both SC1 and SC2 (not counting their S hooks) are stretched to about 300mm.

Attach cable 2 to the outside edge of the drum via its nipple, then spirally wind up to and in the opposite direction to cable 1 so as to completely fill the single layered bobbin, cable 2 disengaging the drum from the top (bottom of drum if fitted to right-hand side of door). Now remove and re-apply adhesive tape to temporarily secure cable 2. Thread cable 2 through endstop 2, twice through PB2 to form a loop about 50mm long then back through endstop 2 before tightening down the two PB2 screws with PB2 about 25mm from the rear of endstop 2, finally hooking cable 2 onto its retaining screw. Remove adhesive tape from drum. Eventually excess cable 1 and 2 can be cropped off but leave a generous excess to cater for adjustments in the future.

8. Essential notes and tips

1. The simplest method of cropping a wire cable is with the guillotine cutters on the outside hinge of a pair of pliers (fig. 2g). To then whip the end of the cable, tightly wrap a 10mm length of Sellotape around the end and twist it in the same direction as its component wires (fig. 2h).
2. After attaching a wire cable to the drum by its nipple, take it the long way round the drum to avoid kinking (fig. 2i). If, at any time, you do accidentally kink a cable, carefully bend the cable itself to remove the kink.
3. At the fully open and fully closed door position, cables 1 and 2 respectively should have at least two full turns left on the drum. These residual turns help to relieve strain on the nipple.
4. The way the cables wind is worth mentioning. As the drum rotates, the winding-on cable immediately takes up the space left by the winding-off cable and this prevents miswinding. Alignment is not critical but obviously becomes more so when the drum is within a few inches of pulley 1 or endstop 2.
6. Although plastic urethane is a khaki colour it can be painted a different colour should you desire, after giving any glossy surface a very light sanding.

9. Fitting the radio Rx and garage push switch

The radio Rx which receives its power from the control box should be fitted high up in the garage with its short aerial wire left dangling (an article describing the construction of a suitable radio TX/RX will appear in a later issue). The radio Tx requires a 9 volt battery. Screw down the internal garage push switch in a convenient position (suggest close to the side entrance if the garage has one) running the two 7/0.2mm equipment wires to the sockets marked PUSH SW and V+ on the PCB.

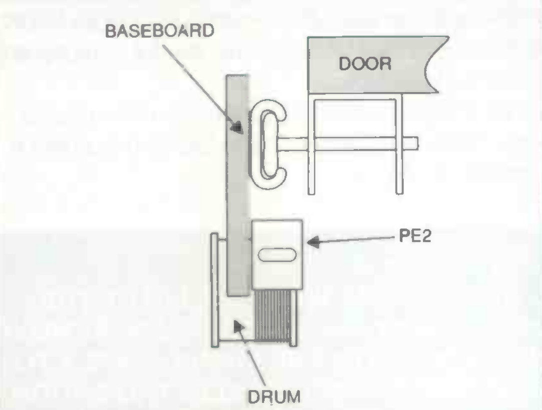


Fig 2D. Drum attachments to baseboard

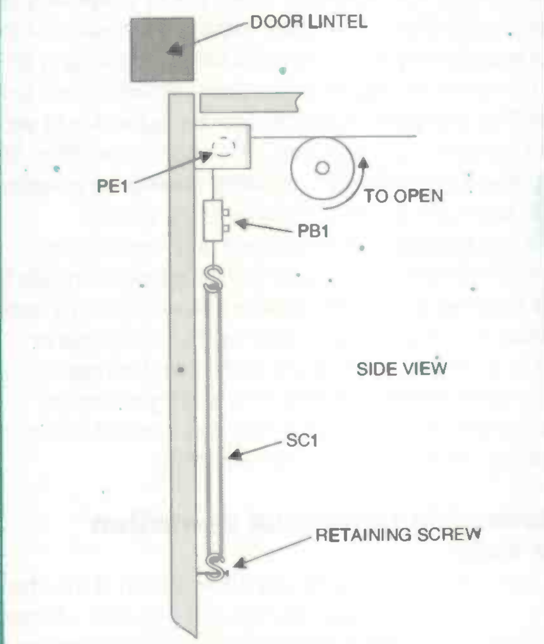


Fig 2E. Track to baseboard attachment

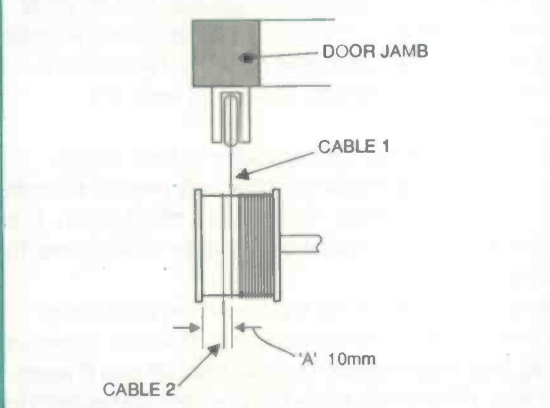


Fig 2F. Pulley drum alignment

10. Test automatic operation of the door

1. Remove the lid and rotate DN1 until you hear the barely audible click as it operates MS1. Position DN2 close to DN1. Refit the lid temporarily with one screw (the full complement is four No. 2 x 8mm screws).
2. Give a last minute check then connect a mains plug to control box mains lead using a 2 amp fuse and plug into a suitable mains receptacle.

BEFORE REMOVING THE LID OF THE CONTROL BOX FOR ANY REASON, REMOVE THE PLUG FROM THE MAINS SUPPLY TO AVOID ANY CHANCE OF ELECTROCUTION.

3. Trigger door operation and, when the door is fully open, switch off at the mains to stop the motor. Remove the lid and rotate DN2 until it operates MS2. Re-fit the lid temporarily and now operate the door a few times, refining the position of the DNs (no need to switch off the mains for this), arranging for DN1 to stop the motor on closure of the door with PB1 close to its endstop. This effectively locks the door because should an attempt be made to push it open, PB1 abuts its endstop. (NB. For even greater security I am presently developing a separate door lock which will be described in a future article).
4. After a few operations the individual door opening and closing overload limit control pots can be adjusted. Initially these will have been set to their mid position. Now reduce by about 15 degrees at a time until such time as the door stops or reverses in mid cycle or refuses to start, then turn back clockwise to the previous setting. This setting allows the minimum obstruction to stop the door but to avoid erratic operation do not aim for maximum sensitivity.

11. Reversion to manual operation of the door

In case of a power failure or for any other reason, it may be necessary to revert to manual operation. To do this, withdraw the "R" clip from the upper pivot pin hole and withdraw the top pivot pin from the frame assembly. This causes the motor to pivot downwards and disengage the motor drive. The door can now be opened and closed by hand, the cables winding on and off the drum as normal.

To re-instate automatic operation, close the door and rotate the drum a few degrees sufficient to position PB1 its usual distance from endstop 1, at which point the slot in the motor drive will align with the drum shaft drive pin. Re-insert the top pivot pin and "R" clip. The DNs should not need any adjustment.

For those without a second entrance to their garage, reversion to manual operation will obviously need to be carried out from outside the garage. This entails a modification. First remove the door locking bolts from the door locking lever then proceeding as follows:

1. Using a drill, convert the top hole in the pivot frame furthest from the door, into an open-ended slot as shown in the inset to fig.1 (urethane plastic is a soft material and is easily drilled). Drill a 1.5mm hole in the top pivot pin 25mm from the uncapped end. Connect the short pin to the end of the release cable 22 with a small pinchblock (the reason for the pin is that, unlike the cable, it cannot be squashed and therefore retracts more easily), thread on a second pinchblock close to it, drill a 2mm hole in the pivot frame and thread the flexible metal cable through it as illustrated in fig.1. Using a third pinchblock, the free end of the cable is now affixed to the inside door locking lever of the redundant outside door handle. From now on, the

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	19	Push-on-fit (POF)	1
	20	Drum shaft drive pin	1
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	22	Outside release cable	1
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door handle should be kept permanently locked.

2. To assemble, push the top pivot pin through the outside hole of the main frame, insert the pin 21, slide spring 21 onto the bottom of the pivot pin, close the pivot frame, push the pivot pin through the co-incident holes in the main frame and pivot frame then insert the release cable steel pin through the bottom hole of the pivot pin. Now position the second pinchblock so that when the release cable is pulled and its steel pin just clears the pivot pin hole, the second pinchblock abuts the 2mm hole in the pivot frame. Finally, adjust the third pinchblock so that the release cable is reasonably taut.

3. The release mechanism is now ready to be used. From outside the garage, unlock the door handle and turn it. This will retract the cable's steel pin, allowing the spring to retract the pivot pin. Normally, the weight and leverage of the motor will pivot it out of engagement but if not then the second pinchblock abutting and rotating the pivot frame will, at which point the door can be opened manually by hand.

12. Assembling the motor/drum unit (Refer to fig.1)

For those who used the motor supplied, the motor/drum unit will come already assembled. Do not attempt to remove the drive block from the motor.

For those who wish to purchase the drum unit but supply their own windscreen wiper motor, fit this to the pivot frame using three 6mm bolts. The spacing of the three 6mm bolt fixing feet shown in fig.1 (bottom centre) is virtually standard for all windscreen wiper motors. The usual output shaft is about 10 - 15mm long with either a 6mm or 8mm thread. The end of the simple drive block you construct should be screwed onto the shaft and the free end should extend no more than 28mm from the inside surface of the pivot frame (if it does, you will have to use spacers under the motor's fixing feet). The free end of the drive block should have diametrically opposed slots which can be filed to just greater than the diameter of the drum shaft drive pin (1/8" diameter Selok pin) and about the same depth.

Ensure the drive block will not unwind when the motor is reversed. One way of achieving this is to have two diametrically opposed grub screws mounted in the drive block which can be tightened down onto the motor's output shaft and/or use an adhesive such as Loctite adhesive 290. The drum unit will come already assembled except the position of the POF and drum will need to be finalised once you have fitted the motor and pivot frame to the main frame using the two pivot pins. With the drive pin fully engaged with the slotted drive block, push the POF up against its bearing then tighten down the drum grub screw, the object being to minimise any end play on the drum shaft. Ensure that the grubscrew is tightened down on the flat filed on the drum shaft, if necessary using a file to extend the flat.

In all cases, dismantling the motor drum unit down to its component parts only takes a few minutes. Remove the two pivot frame from the main frame. (Note the pivot frame and main frame should be reassembled the same way. If you are unsure, look for the polarising grooves on the pivot frame and main frame). Undo the drum grub screw and slide off the drum. Remove outside bearing and unscrew the DNs. If necessary, the Selok drive pin 20 can be drifted out of its hole allowing the 1/2" POF 19 and other bearing to be removed. The POF can normally be re-used but if it is damaged buy a new one for a few pence from a local engineering tool shop.

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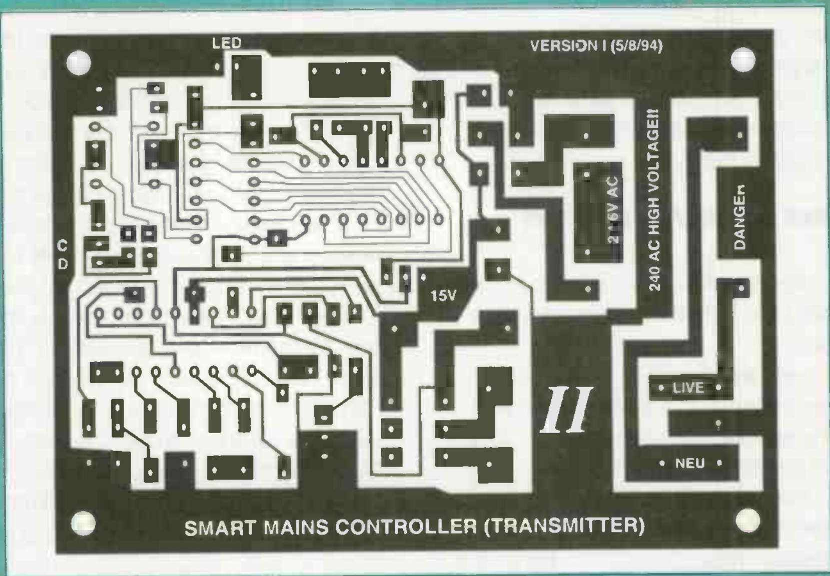

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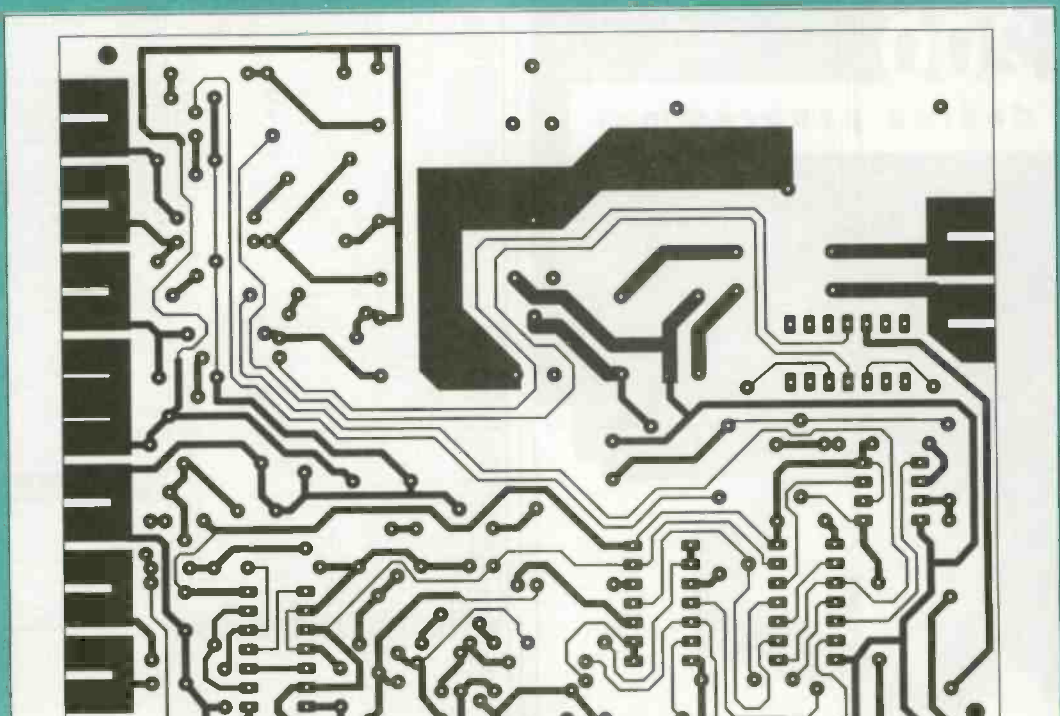

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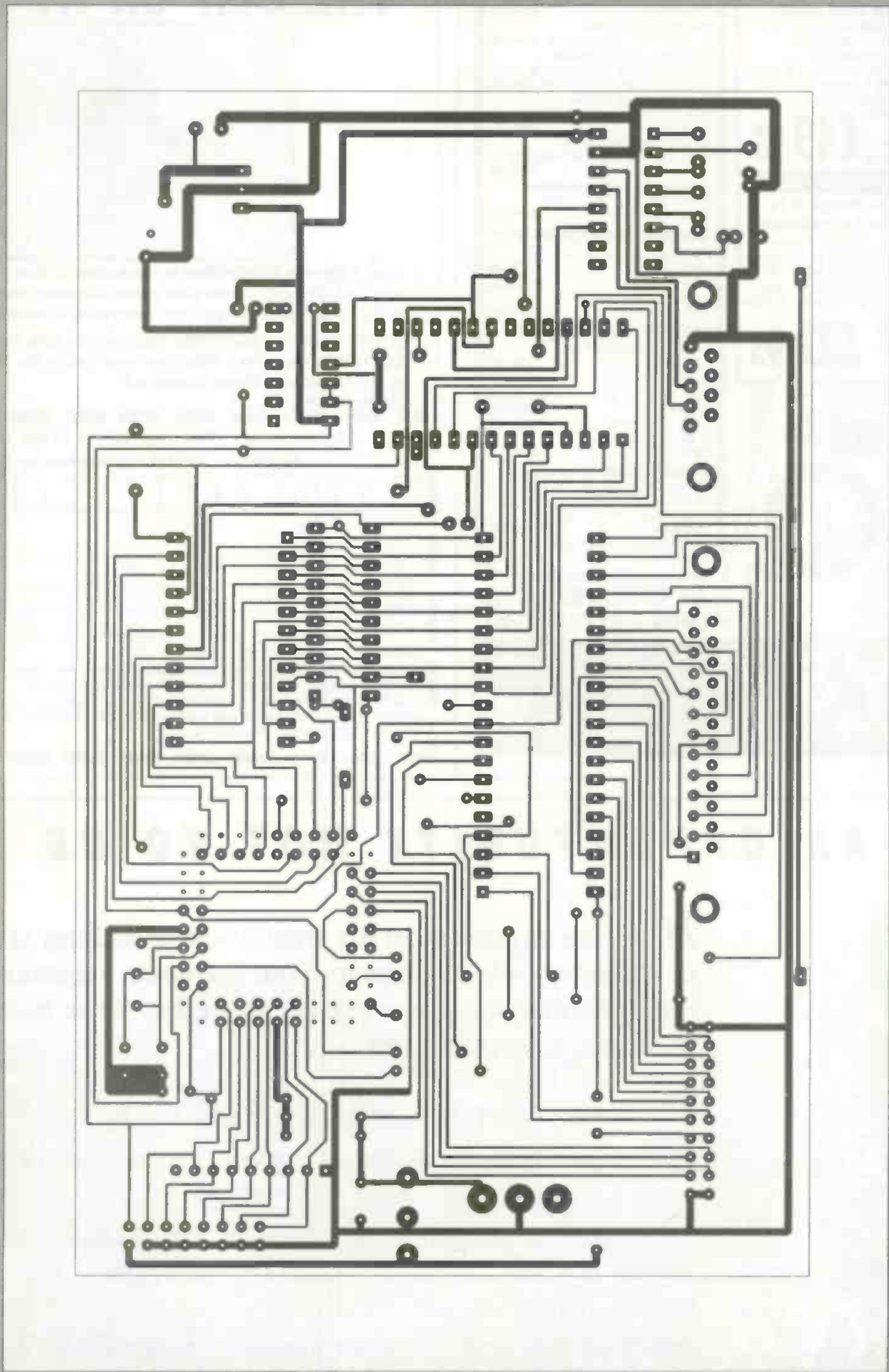

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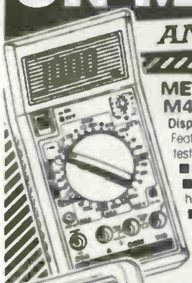

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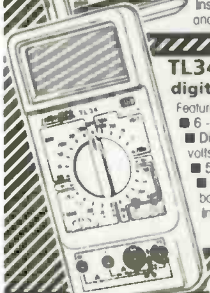

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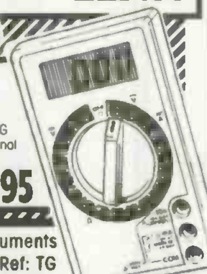

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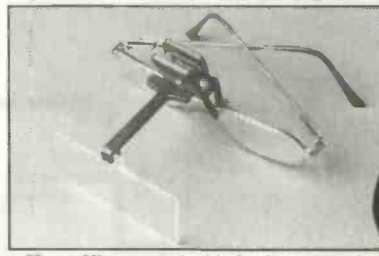

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Open Forum

There is an old tale about two gruff, hard-nosed businessmen of the old school who decide to see what this science lark can do for their business. So they hire a graduate straight out of University, put him in a little room at the back of the building, and give him a small amount of assorted scientific equipment bought cheap as a job lot.

The first day that their 'boffin' arrives for work, the two businessmen go down to the pub for their usual pint and pie. On their way back one says to the other "Let's pop in on the boffin and see what he has invented for us" to which the other replies, "Best wait until tomorrow, by then he will have invented something much bigger and better".

It is a humorous tale which, like many humorous tales, has a familiar truthful ring to it. Scientists and technologists who are employed in industry are expected to deliver new, innovative ideas which their employers can tum into profitable new products, or at the very least improve existing products or enable them to be made cheaper.

The problem is that innovation is not a commodity which can be bought by the pound; it is instead the product of rare flashes of intuition. You cannot put a scientist or engineer Into a lab and tell him to invent somethlng totally different. If you tell him to improve something in a specific way then he will probably do it.

The thing is that innovation, of whatever sort, is an entirely different intellectual process from targeted research or development. By its very nature, genuine innovation tends to be a rather erratic process which often leads in entirely different directions to those currently being pursued by the innovator.

Bearing this in mind. why is it that Britain has such a good record for innovation? Even the Japanese Govemment in a recent publication accepted this, stating that nearly half of all the major commercial Innovations of this century have been made in Britain. Yet on the other hand we have all too often been singularly poor at actually developing and exploiting these innovations.

In my opinion, the answer to this question must lie not in any intellectual or educational advantage but in a cultural and intellectual difference which favours innovation at the expense of directed research and development.

An advantage which has come about through the relaxed attitudes of universities and the British tradition of the amateur. Both of these favour serendipitous innovation as opposed to the rigid, disciplined activity of directed research and development.

The tradition in British universities has been to allow researchers to pursue their own ideas rather than being channelled into a specific line of work by a dominant department head or by a commercial contract. It is an approach which does not necessarily produce disciplined team oriented researchers but it does tend to produce individuals capable of original innovative ideas.

The same applies to that marvellous British tradition of the informed amateur, of which most of ETI's readers are examples. Without any commercial forces driving them to develop ideas such individuals are in a position to follow their own fancies; they do what they do because it is fun, not because it makes money, usually the exact opposite. For these reasons they too are likely to develop innovative ideas.

If my hypothesis is true then Britaln is in danger of losing its talent for innovation. The informed amateur is all too often a dying breed. He is ridiculed in the popular media and made into a comic figure. Younger generations are now faced with a wide range of competing interests that distract them from taking up a serious hobby, and devoting the time and resources to it that are necessary.

The same goes for the relaxed attitude in universities. There is now enormous pressure on students to get good qualifications with the emphasis that going to university equates with getting a well paid job. There is a declining emphasis on the concept that one goes to university because one wants to study a particular subject and expand the field of human knowledge and ability. There is also pressure on the universities which are now all too often expected to take on commercial work in order to generate necessary funds.

The result is that the general populace in this country are now a lot better educated, and the standard of directed research and development work has improved no end. We only have to look at the enormous Improvements in product design which has taken place over the lest 20 years. But at the same time, are we in danger of also losing the cultural basis which has produced so many innovators?

Next.Month...

In the March 1995 issue of ETI we will be starting a new premier project by Robin Abbot to build a laser tag game. We will also be publishing Part Three of Richard Grodzik's ETI 80188 single board computer project, and looking further at using and programming the board.

There will be two projects which should be of interest to computer owners; the first of these has been designed by Jason Sharp and is an Amstrad PCW I/O port which should be of interest to the considerable number of people who still own this popular machine. The second is Part Two of a project by Dr Pei An to build a PC based smart mains control system.

From Tim Parker there is a project to build a garden shed security alarm. Whilst from Douglas Clarkeson there is an interesting project on the measurement of light. Pat Alley will also conclude his project to build an automatic garage door opener.

Next month we will examine the current and future use of electronics in aviation, whilst PC Clinic will look at audio adapters.

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