SECURITY · ROBOTICS · AUDIO

No. 59

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ELECTRONICS

The Maplin Magazine

Britain's Best Selling Electronics Magazine

Virgin Atlantic Competition

See Inside...

Build your own Soldering Station and save money!

Satellite TV

New series starts this issue!

How to protect your home from theft

Discover the secrets of circuit board manufacturing

'Short Circuit' the way to controlling a robot from your PC

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EDITORIAL

Hello again and welcome to this month's feast of electronics, technology, news and information. In response to the huge number of requests for particular projects and features, I am pleased to include in this issue many of things that you, the readers, have asked for.

Ready-built temperature controlled soldering iron stations are expensive to buy, but once you've used one you will not want to use just any old iron again. The Soldering Iron Station project combines high performance, ease of construction, safety and low cost – what a recipe!

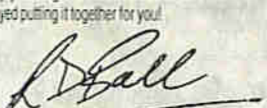
Every day it seems the media inform us of the rising crime rate, increasing insurance premiums and the state of our society. Now, more that ever, is a good time to improve the security of your home or business. Commercially installed alarm systems are expensive, but installing a system yourself has many advantages. Not only is it cheaper, but the way you install the system will be completely unique. You may think that alarm systems are difficult to install, but this is not the case, our in-depth article explains every step!

Satellite TV is very much at the forefront of today's entertainment scene. A new series starting this issue deals with many aspects of satellite TV, explaining the 'how's and why's' of current and new developments in this fascinating, fast moving field. Part one deals with the concepts of satellite communication and includes rare photographs of inaugural satellite TV transmissions.

New to our team of regular contributors is Ian Poole, he kicks off with a series on the history of amateur radio.

We all owe so much to the work of the early pioneers (much of it unfunded) who paved the way for the technological developments in radio, communications and electronics technology that we take for granted today.

So until next month, all that remains for me to say is I hope that you enjoy reading this issue as much as the 'team' and I have enjoyed putting it together for you!



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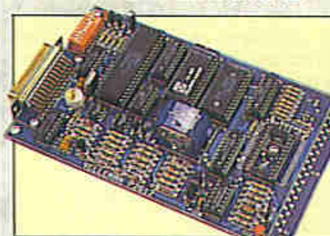
PROJECTS



FEATURES

REGULARS

Prices shown in this issue include VAT at 17·5% (except items marked NV which are rated at 0%) and are valid between 2nd October 1992 and 28th February 1993.

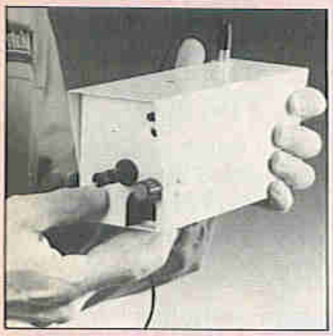
NEWS Report

IT Supports Mickey Mouse

If you are thinking of visiting the new Euro Disney, near Paris, watch out for the lighting. Philips have supplied no less than 135,000 lamps, 33,000 luminaries as well as equipping electronic products throughout the theme parks. Apart from supplying over 5,000 hotel rooms with advanced TV sets, Philips has a display of wide-screen TV sets as well as CD-Interactive products. Also the main parade light show is a Philips enterprise.

Also, IBM can hardly be missed at Euro Disney. The IBM 'Star Tours' is an inter-galactic adventure which takes place aboard a robot-piloted race through space. Thanks to the synchronising of a stunning film, spectacular special effects and the virtually limitless actual motion of the simulator, you can feel what you see! (If it's anything like the Disney World 'Star Tours' you'll be in for a real treat – Ed.)

Radio Mousetrap



Rentokil, experts in pest elimination, have announced a mouse trap aptly named 'Mouse Alert', that will hoodwink even the wisest rodent. Not only does the device catch your mouse but it informs you of the fact.

The basis of Mouse Alert is a series of strategically sited, metal boxes each fitted with two miniature infra-red break-beam detectors and a radio transmitter. When a mouse enters and breaks both beams the transmitter passes word to a central control unit and swiftly closes the trap's doors. On receiving a signal, the control unit – which can serve over two hundred traps – provides both visual and audio alarms and automatically dials a sequence of telephone pager numbers. Once alerted, the pest control technician attends the scene, switches off the alarm, removes the mouse into a special container for humane disposal off-site and resets the trap.

Intended for high risk premises where the damage or contamination caused by even one mouse would be catastrophic; pharmaceutical factories, air and rail traffic control centres, banks, insurance offices and computer hardware manufacturers are already benefiting. Similarly vulnerable are food producers who by using the trap will have evidence to demonstrate the due diligence required by The Food Safety Act 1990.

Non-toxic bait is used so there is no risk of contamination. Labour intensive inspections are also eliminated and the system provides round the clock protection, 365 days a year – the results are clear, no poison, no expensive wiring, no inspections and no mice.

Not the Colour of Money

Just in case you thought you would be on a winner thanks to the new colour photocopiers, one Japanese supplier has introduced a method which will prevent the mass production of banknotes. The system is programmed with the designs of banknotes so that they stubbornly refuse to cooperate in reproduction.

Fuzzy Searches

There is no need to perform sequential searches any more, the MS160 non-numeric co-processor is a parallel VLSI-integrated circuit for fuzzy information retrieval and pattern recognition. Operating at a frequency of 20MHz, it is capable of sustaining a browsing rate of 160 Megabytes per second.

Most database systems rely on hierarchical structures and systematic searches. Fuzzy queries, where each attribute has low selectively, pose severe performance problems to conventional systems.

The MS160 is an ideal disc controller component. It may drastically reduce the need for transferring data via buses to the host computer, simply by restricting data to positively requested items only.

An eight bit host interface allows connection with any host microprocessor. Alternatively, mounted on an expansion card the device offers the possibility of immense speed for personal computers and work-stations.

Produced by international electronics company Microway, the chip is manufactured in Norway.

Shocking Result from Electrical Safety Survey

A report just published by Livingston Hire reveals that an amazing 70% of small to medium size companies have no knowledge of the Electricity at Work Regulations 1989 with regard to the testing of portable appliances. In one case, a company director, himself a qualified electrical engineer, suggested that the Regulations had been invented to catch him out!

Plastic LED

A new American company, Uniax devoted to the research and development of polymer conductors, announced last month that they are one step away from being able to commercially fabricate a plastic light-emitting diode.

Besides offering all the benefits of their traditional semiconductors counterparts, plastic LEDs are formed from polymers which are more suited to manufacturing processes. Chemically tunable to any part of the visual light spectrum, the plastic LEDs are expected to find their way into consumer products that require curved displays. Already, green, red and yellow devices have been demonstrated, with blue and more exotic colours to follow.

The problem which Uniax now face is to find a suitable material from which to construct the electrodes. Critical to the performance of the diode, the electrode must be robust, chemically stable and have a good transfer characteristic. At the moment Uniax are stuck between metal electrodes that are chemically stable, but have low efficiencies, and unstable metals that produce good results.

Once the electrode problem is resolved, Uniax expect it to take a further two years before the plastic LEDs are commercially available.

New 7·5ns PLD

The first 7·5ns 22V10 Bipolar Programmable Logic Device (PLD) is now available from Texas Instruments. The TIBAL22V10-7 is designed to meet the critical performance, reliability, price and availability requirements of today's end equipment designers and manufacturers.

The most attractive benefits to Bipolar technology is its proven reliability, familiarity and good noise-immunity.

The device enables fast address decoding and pipe-line controller functions to be carried out in a single package for processors operating in the 50MHz range. Interfacing well with processors and peripherals alike, it is ideal for system applications using cache memory.

While the majority of the PLD market is moving towards CMOS devices, Texas Instruments stand apart, committed to provide Bipolar users with cost effective devices.

You Have Been Warned

B-Sky-B TV are reminding prospective purchasers not to buy the many BSB systems on sale in the UK. These units will only receive B-Sky-B's channels until the end of the year, after which transmission will cease. It seems that unsuspecting customers are paying anything up to £150 for the equipment and, in many cases, are not being made aware of the system's limitations. B-Sky-B and 'Electronics' warn "Don't be conned – play it safe and go for an Astra-compatible system." In fact the DTI have now issued a statement that no further broadcasts will take place from the Marcopolo satellite once B-Sky-B programmes cease to be broadcast from it at the end of the year.

Following the revelations last month of prying 'scan fans', who allegedly taped a Royal mobile phone conversation, The Radio Society of Great Britain – the representatives of the 'hams' – has called the activities 'disgusting'. But relief is at hand. Already the police are experimenting with scrambled or coded radio transmissions while cellular is going digital – a notoriously difficult medium to intercept.

BT Climbs Down

Faced with the might of the industry regulator Oftel, BT has agreed to the proposed new tariff structure of pegging prices to 7·5% below inflation. The users are pleased, the industry is pleased and in all probability so is BT who had been threatened with the Monopolies and Merger Commission if agreement had not been reached. For the private user, savings of around £6 can be expected on the bill. In addition, the cost of connection has been reduced from £152.79 to £99 with the low user rebate scheme being extended.

Fibre Optic Splicer

The cost of laying a fibre optic cable has always been dominated by the time and precision required in termination and joining links together. Whilst the transmission specification and qualities are far superior to those of a copper cable, the price of installation and subsequent maintenance is often prohibitively expensive.

Fujikura Europe Limited have now made a bid to reduce the cost of linking lengths of fibre optic cable. Available in two models, their FSM-05S and FSM-05R cater for either single core or multiple four fibre splicing. Boasting a typical junction loss of between 0·05 and 0·15dB, dependent of the type of fibre, both units include a mechanical proof test function enabling the stability of a junction to be examined before electrical tests are undertaken. Being palmtop devices, both are lightweight and allow up to 120 fusion splices to be made from a single one hour battery charge.

Flashing Orange

Sanyo Electric has produced the world's first semiconductor laser to emit orange light. This will, theoretically, allow the amount of music or data stored on an optical disk to be increased – the unit produces an orange laser beam with a wavelength of 615nm at room temperature.

Whether the development will be of any interest to Sony is not known, but the company has now firmly stated that their MDP-650 Dual System Disk Player will be launched this month. The unit will replay both PAL and NTSC disks, a large number of which already exist in the UK.

Philips are also releasing four new titles to its entertaining range of software for Compact Disk Interactive – the new CD-based home entertainment system. The new disks which include 'The World of Gambling', and 'Backgammon' brings the UK CD-I catalogue up to 36 titles with prices ranging between £15 and £40.

Meanwhile Philips has admitted a hitch in its launch of the Digital Compact Cassette (DCC) deck. Apparently more time is needed to ensure that volume production runs meet quality targets. One possible problem area is believed to be the overheating of components.

Taking a Lifetime

Now Vodafone has joined in the low use cellular network market. Following the launch of CellNet's Lifetime, Vodafone has announced LowCall (as in low usage rather than low cost). Essentially, the new service offers a lower renting fee but higher call charges. Equipment prices will be about £200 and connection charges £25 with a monthly fee of £15. The bad news is that call charges will run out at 50p per minute peak time and 25p off-peak. The break-even point seems to be that if you make more than one call a day, you would be better off on the standard cellular tariffs. Both CellNet and Vodafone are well aware that the proposed Personal Communications Networks will be on the UK scene mid-'93 as will the GSM digital cellular network, and therefore it is necessary to capture as much of the market as possible before that time.

Audio Interface for Mobile Phones

In September we reported that Austrian firm Asic Mega Systems had developed a CMOS integrated circuit that combined all the features of a telephone on a single chip. Not wishing to be out-done, Texas Instruments has now launched a device to do almost the same for cordless and cellular telephones. The integrated circuit operates from a single 5V supply providing ease of design in voice band communication systems.

The TCM320AC36/7 Voice Band Audio Processor is designed to perform transmit and receive PCM/Linear transcoding together with appropriate filtering. Although targeted at cellular and cordless telephones the device can function in a multitude of systems including PABX and data acquisition systems using a digital signal processor.

The Voice Band Audio Processors interface directly to an electret microphone, piezo speaker and digital signal processor. The gain of the earpiece and microphone interface can be set by single resistors – thereby simplifying circuit design. The sampling rate and bandpass filter characteristics are altered by changing the frequency of the master clock. As a result, the device can pass special control frequencies such as the Supervisory Audio Tones that other devices may not be able to handle.

Manufactured in the Texas Instruments Advanced LinEPIC CMOS process technology, the TCM320AC36/7 is available in a 20-pin plastic DIL package.

Disturbed Power Pyschiatrist

Cetronic has introduced a new power unit which monitors the power line continually, providing a printed record of all potentially damaging power disturbances. This allows the operator to quickly differentiate power-related problems from equipment failures and negates valuable time chasing problems that do not exist. Details, Tel: 0920 871 077.

Quest for Speed

Intel is planning to keep ahead of the microprocessor market by releasing a new 486, with a processor speed of 66MHz chip, double that of its predecessor. Intel claims that personal computers built around the superior device will run applications an average 70% faster. One manufacturer who would agree is Compaq, who ahead of the crowd have already announced the availability of their 486–66MHz versions of the Deskpro/I and Deskpro/M range of personal computers.

It's a High Tech World

Three of the world's leading semiconductor companies – Siemens AG, IBM and Toshiba have formed an alliance that will result in advanced semiconductor devices for the end of this decade and into the next century. The three companies will cooperate in the development of a 256Mbit dynamic random access memory (DRAM) and its production process. This sophisticated submicron technology will be a basis for production of future generations of highly dense chips. The group will also focus on the process technology for fabricating features a mere 0·25μm wide – 400 times narrower than a human hair.

Not to be outdone, AT&T reports that its new optical storage technique can store not one but two entire copies of War & Peace in a disk area no bigger than the head of a pin.

Gizza Guinn

Rad Data Communications has staked its 'claim to fame' by having 'The Worlds Smallest Modem' listed in The Guinness Book of Records. According to the daily industry bible, Computergram, the modem is used for connecting asynchronous terminals to host computers. The units measure 2·4 x 1·2 x 0·8in. with a maximum speed of 19,200 BAUD.

Waterproof Computing

Fujitsu engineers have developed a waterproof, portable word processor which apparently can be used in the ocean at depths of up to 100 feet. The idea is that notes can be made, data checked or communicated with other divers. It has a pressure-resistant case made of clear acrylic resin, and features waterproof keys connected with rubber tubes. But whether it will catch on in the typing pool is another matter.

Don't Hold Your Breath for HDTV

All, is not plain sailing for high definition TV manufacturers. In the States, the system will not now go on sale at the planned launch date, 1995. Instead, lower resolution wide screen TVs will be available in order to keep down costs.

Closer to home, royalty problems have broken out over copyright issues. This covers most of the 400 hours of HDTV recorded at Expo 92, in Seville, Spain. But even closer to home, NTL, the company which has taken over the former role of the Independent Broadcasting Authority, has made a breakthrough in digital TV transmission. The system helps cram more channels into the available UHF bandwidth: signal processing ensures that only changes in the picture are transmitted with the digital signal being separated into 432 sub-signals, with its own low-power carrier.

IBM Goes Shopping

IBM and Sears Roebuck, the mega sized US retailing organisation, are merging their data networking operations into a new IBM controlled company, Advantis. The joint venture will provide private line networking services for current IBM and Sears customers. It will have access to 5,500 cities in 92 countries serving over 9,000 customers and facilities for over one million users. The move will disappoint BT who were hoping to form a global facilities management operation with such a US partner.

Twice as Mice as One

US development company Logitech have produced a mouse-shaped mouse for the Apple Macintosh computer. So what's new! This particular mouse is mouse-shaped with a pointed nose and *two* buttons to stand in for ears – Mac users can relax, both buttons serve the same purpose!

Meanwhile what could be the best behaved microcomputer mouse has been bred by Honeywell. Their new X-Y axially inclined transducer mouse, incorporates a self-cleaning feature, does not require special surfaces for operation and can operate at any angle, even upside down. Details, Tel: 0344-424555.

BT has the Connection

BT is making it easier for the three million households in the UK still without a telephone to get the service by spreading the cost of the connection charge. From this month, BT will allow new residential customers to spread the cost of connection over five instalments. BT has also introduced for deaf people, 'Typetalk', a telephone/text service which allows the relaying to and from text users throughout the UK to hearing people world-wide. Up to 1,700 people are already registered with Typetalk and it is expected that this number will grow to 5,000 by March '93.

Diary Dates

Until 31 October. 'Friendly Invasion', RAF Museum, Hendon. Tel: 081-205 9191.

Until January '93. The Irn-Bru Pop Video Exhibition. MOMI, South Bank, London. Tel: 071-815 1339.

5 to 9 October. SICOB (business equipment), Paris. Tel: 071-221 3660.

6 to 8 October. VOICE '92 (Computer telephony and voice automation), Olympia, London. Tel: 081-877 9007.

6 to 8 October. Exclusively Tools, Wembley, London. Tel: 081-868 4466.

20 October to 1 November. British International Motor Show, NEC, Birmingham, Tel: 0483-222888.

28 to 31 October. Apple Expo '92/ The MAC-User Show Olympia, London. Tel: 071-404 4844.

19 to 22 November. Computer Shopper Show, Olympia, London. Tel: 071-373 8141.

5 December. All Formats Computer Fair, Motorcycle Museum, Birmingham. Tel: 0608 662212.

Please send details of events for inclusion in 'Diary Dates' to: The Editor, 'Electronics – The Maplin Magazine', P.O. Box 3, Rayleigh, Essex, SS6 8LR.

The History of Amateur Radio

Part 1

by Ian Poole (G3YWX)

Amateur radio is a hobby that has existed since the beginning of radio itself, having its roots in those people who enjoyed experimenting with communications over the new medium. Since the earliest pioneering days, many millions of people have found the same fascination and today the hobby is still thriving all over the world – amateur radio is a truly international hobby!

Many changes have occurred since amateur radio first began. Early equipment used coherers as the basis of the receiving apparatus. Soon coherers gave way to valves which, in their turn, had to bow to the invention of the transistor – and later, the integrated circuit. Through all of these changes, amateur radio has played a major role in helping to push back the frontiers of technology. It was through the experimentation of radio amateurs that the value of the short-wave bands was discovered. Amateurs also helped to pave the way for short-wave broadcasting to start. Today, they are still at the forefront of technology in many areas; a notable example is that of packet radio networks. These networks, set up wholly by amateurs, have influenced the design of commercial systems.

The story of how amateur radio developed over the years is fascinating. To begin, it is necessary to go back to the days when the very basic concepts of radio were being postulated.

Foundations Laid

Ideas concerning the possibility of a wire-less medium that could be used for communication were put forward originally by James Clerk Maxwell, a brilliant theoretical physicist. Maxwell set out his electromagnetic theory in several papers which culminated in 1873 with the publication of a book called "A Treatise on Electricity and Magnetism". However, he never gave a practical demonstration of his theories.

Like so many discoveries, it is difficult to attribute radio to just one person. This is true of the first demonstration of electromagnetic waves, as several people were involved. One was Professor D.E. Hughes, who built a spark generator in his house and was able to detect the sparks over 400 yards away. Unfortunately, he did not link the effect with Maxwell's electromagnetic wave theory.

In the end, a German scientist Heinrich Hertz made the practical discovery of these waves. He performed a number of experiments proving their existence beyond doubt. In his most famous experiment, Hertz placed two coils of the same size a few metres apart. Each loop had a spark gap in it, and when a spark was made to cross the gap in the first coil he showed that a similar but smaller spark jumped the gap in the second coil.

The results of the Hertz experiments were published in many journals, and he was widely attributed with having discovered these waves. As a result, electromagnetic waves were originally called Hertzian waves.

Good Publicity

Although the original discoveries were made by scientists, it did not take long for public awareness to be awakened. Many reports appeared in the scientific journals about this new form of communication, and it did not take long for the popular press to follow suit.

The popular press were helped a great deal by a number of scientists and businessmen. One was Marconi himself, who foresaw the great potential of this new medium and set up his own company. However, to stimulate public awareness – which would help him obtain sufficient financial backing – he set up a number of demonstrations. These were designed to catch the public eye and receive maximum impact. In 1898 he used wireless (as it

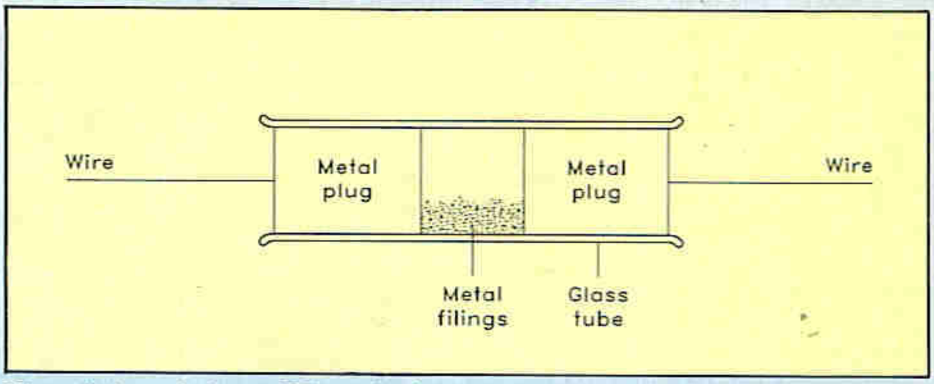


Figure 1. An early form of Marconi coherer.

Other scientists became more interested in this new phenomenon and started to perform experiments. This gave rise to a number of improvements, and many new inventions. One, the 'coherer' (shown in Figure 1), was conceived by Professor Onesti. He demonstrated that iron filings placed in a glass tube with electrodes at either end could be made to stick together, or 'cohere', when a high voltage was placed across the electrodes. Once the filings had cohered they were able to pass an electric current, which could be used to complete a second circuit. A further step was taken when Professor Branley found that the iron filings would cohere in the vicinity of an electrical discharge. Finally, Oliver Lodge used this discovery to detect Hertzian waves, managing to receive signals over a distance of about 150 yards. The circuit of a typical coherer-based receiver is shown in Figure 2.

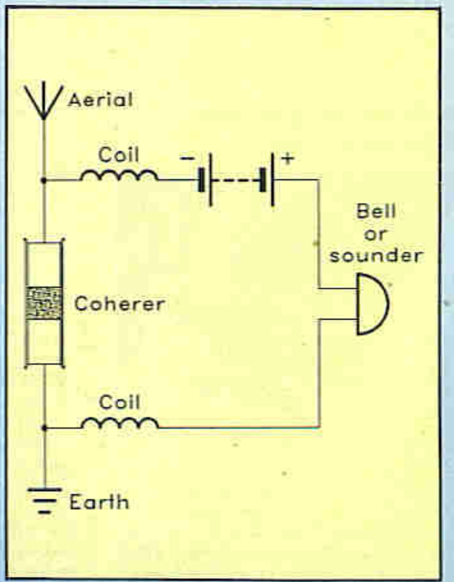


Figure 2. Circuit diagram of a receiver based on a coherer.

was then called because it had no wires between the two stations) to report on the Kingstown Regatta for a Dublin newspaper. A year later, he made the first international contact by communicating between a station at the South Foreland lighthouse and another located at Wimereux near Bologne – a distance of about 50km.

Amateur Experimenters

With the large amount of publicity which was being given to wireless, public awareness grew very rapidly. As a result people started to become interested in building their own receiving and transmitting apparatus. This was perfectly legal at this time because no licences were needed!

Soon, articles began to appear in periodicals detailing how apparatus could be made. In January 1898 a magazine called "The Model Engineer and Amateur Electrician" included an article which gave details of experiments for amateurs. In it there were details of basic transmitting and receiving apparatus. Books also started to appear; one called "Wireless Telegraphy and Hertzian Waves" by S. Bottone, published just after the turn of the century, gave a comprehensive explanation of the subject as well as detailing how the necessary apparatus could be constructed. Typically, a coherer could be made from a glass tube, some iron filings, two copper wires, and a couple of corks for either end of the tube. Descriptions of transmitting apparatus were also included.

Licences Issued

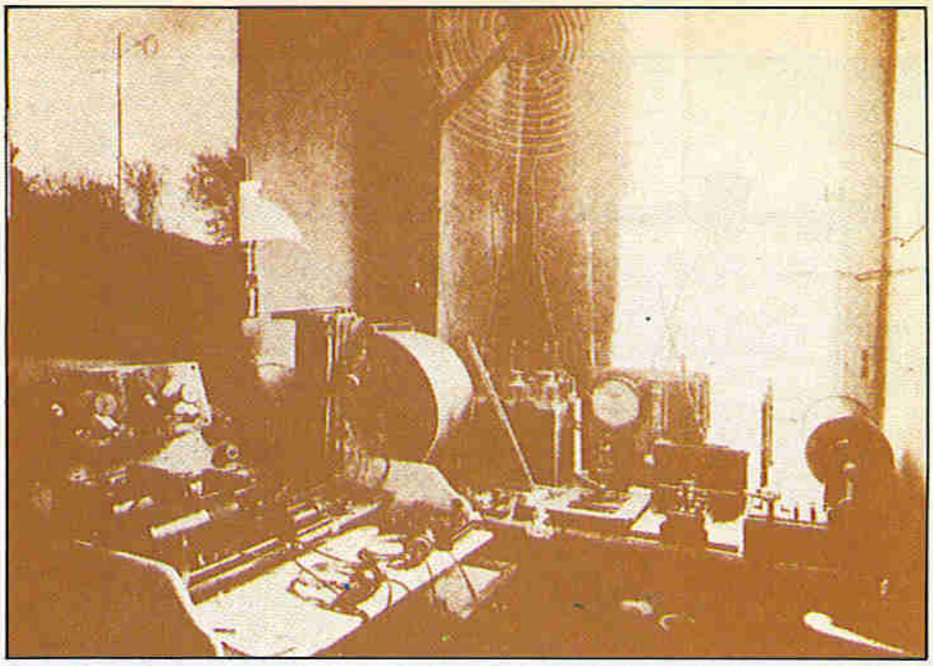
It did not take long for radio to catch on – both professional users and amateur experimenters were using the airwaves increasingly. As a result, it became obvious that some form of regulation was necessary, and on 15th August 1904 the first Wireless Telegraphy Act became law.

The Act was wide-ranging in its implication. For amateur experimenters it meant that licences were required, although no fee had to be paid. Fortunately the Post Master General who administered the Act, applied the terms of it favourably to experimenters. Despite this, however, the terms of the Act were quite strict, and limited the operation and experimentation possible by these early stations.

Some of the licences were issued to people who had a professional interest in the subject, but many were given to people who were real amateurs and had a great enthusiasm for the subject. They needed such enthusiasm, because all the components had to be made out of raw materials – there were no Maplin stores then!

Parliament was obviously interested and concerned about the issuing of experimental licences in view of possible security risks and in 1906, it requested that the Post Master General give a summary of all the licence applications that had been received to date. The document is very interesting because it is possible to see the names of those to whom licences had been given. One of the most famous is that of Ambrose Fleming, the inventor of the diode valve and consultant to Marconi. It is also possible to see that stations were being set up in many parts of the country.

Although just over 60 licences had been granted by this time, interest was growing and the rate at which licences were issued started to increase.



W. K. Alford's 200 metre station (TXK), dated 1913 – no valves here! The 25W spark transmitter was powered by a 26V accumulator, which was itself charged by a 35V 12A dynamo. The aerial was a 48 foot long four-wire cage, while the receiving apparatus was a crystal set using a 'Perikon' point- contact detector. Out of interest, TXK was in operation at the time of the Titanic disaster, and was able to make out the names of the survivors that night.

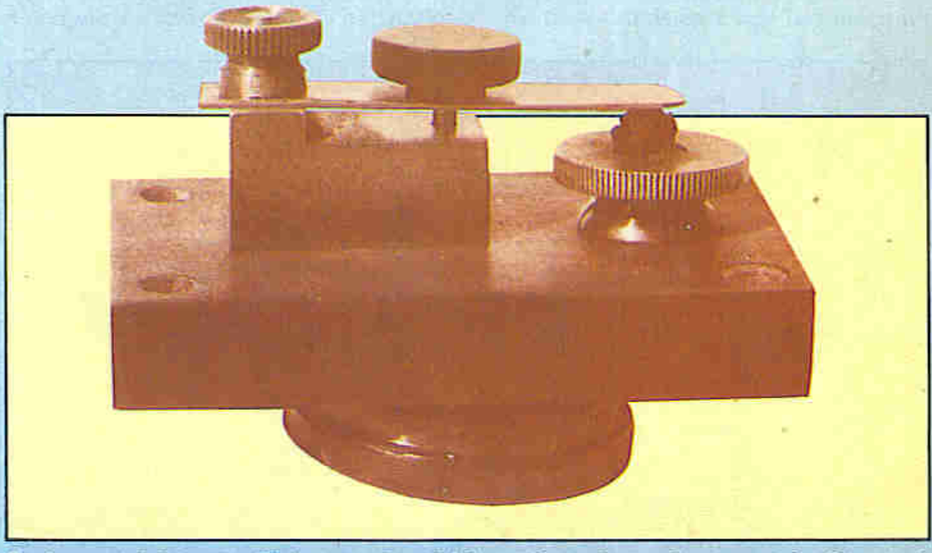
Callsigns

When the first licences were issued in 1904, there was no requirement for stations to be able to identify themselves in any standard way. However, as time passed, the number of experimental stations increased and the Post Master General found it necessary to introduce the use of callsigns, or 'call signals' as they were first termed, for easier identification of stations. The new system was introduced in May 1910, when all licence holders received a letter giving them their new three-letter callsign. The letter also mentioned that the callsign should be used at the beginning and end of each transmission, together with the callsign of the station with whom they were in contact.

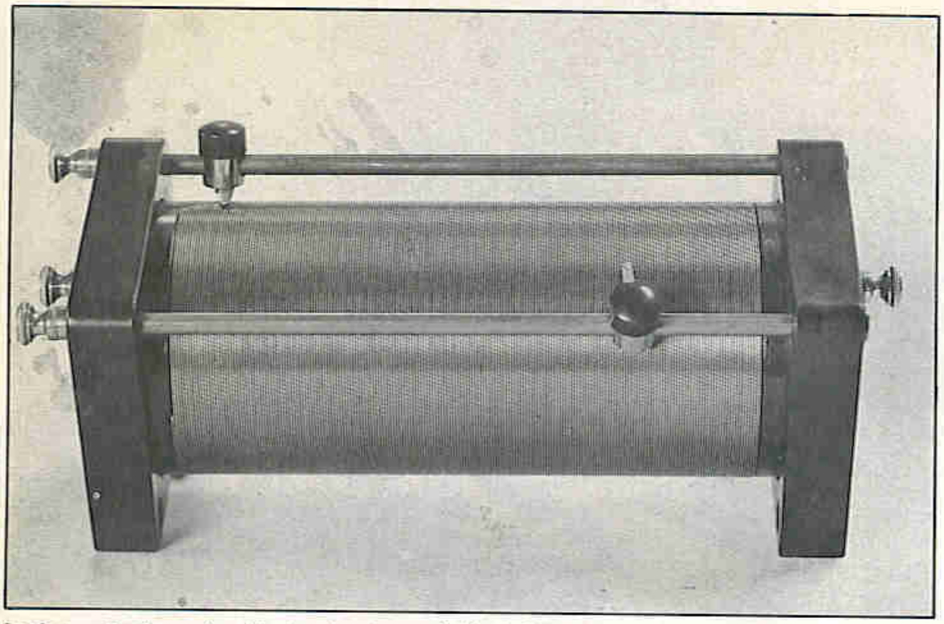
The callsigns did not appear to be issued in any strict order. Often they contained the initials of the licensee, but in all cases the callsign contained the letter X for experimental.

Equipment Used

Since the introduction of the first licences, there had been a number of major improvements in the technology



Early crystal detector. This example, which used a carborundum crystal with a steel blade, was part of a Army Mark 3 receiver during the First World War.



In the early days of radio, tuning by variable inductor was common since variable capacitors were more difficult to make! The example shown has two movable taps, and was known as a 'jigger'.

which was used. Originally, coherers were the only form of detector, but then in 1904 Ambrose Fleming invented the diode. This was followed in 1906 by an American, de Forest, who invented the triode. However, the most important advance for the amateur experimenter was the crystal detector, which gave a cheap and efficient method of detecting signals; valves were, at the time, horrendously expensive. A number of different types of these detectors were used. Early types used two crystals, but these gave way to more sensitive single crystal point-contact detectors, which were fondly referred to as "Cat's Whiskers".

Tuning in a receiver was generally accomplished using a variable inductor. Although capacitors (or 'condensers' as they were then called) could be used, they were more difficult to make in a variable form.

Transmitters invariably used spark gaps; the circuit diagram of such a transmitter is shown in Figure 3. The most common way of generating the high voltage required was to use an induction coil and a mechanism which broke the circuit periodically. Components from the primitive car ignition systems of the day were often used, as they could be bought relatively easily. The high voltage from the coil was then connected across the spark gap. Typically, a spark gap consisted of two brass spheres placed about half an inch apart. One of the major problems encountered when using such devices was the large amount of audible noise that they generated. To reduce this, many amateurs enclosed their spark gaps.

With the spark generated, the output was connected to the tuned circuit so that all the energy could be concentrated around a particular wavelength. This, in turn, was connected to the aerial. Often the connection was made directly with no series capacitance in circuit, with the result that the high voltage from the induction coil would appear directly on the aerial. Accordingly aerials had to be very well insulated and care had to be taken not to touch them.

The tuned circuits in the transmitters were grand affairs. The coils were often ten or more inches in diameter and often wound on beautifully finished formers. Tuning was again accomplished using taps on the coils but sometimes variable condensers were employed. In view of the high voltages used, these condensers were large, they often employed meshed plates which could be moved in and out to vary the capacitance.

Aerial designs were quite varied and some just consisted of large quantities of wire raised as high as possible into the air, but others followed more standard structures. One favoured aerial had a multi-wire top, as shown in Figure 4, and because of its shape it was called a 'flat top'. Another popular design consisted of a cage of six wires with a hexagonal supporting hoop at either end.

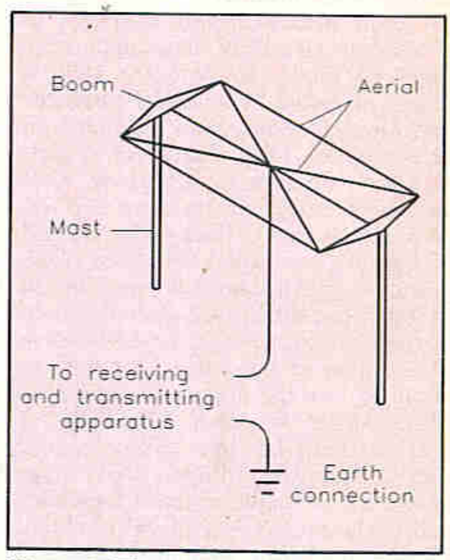


Figure 4. 'Flat-top' aerial.

Operating

Communications by amateur experimenters were comparatively limited. One reason was, there were not nearly as many stations active as there are today. In addition to this many of them were only able to use powers up to about 25 watts. With this sort of power and the very basic equipment which they used, it was only possible to reach distances of about ten miles. Some stations were able to use more power, often up to about 150 watts and they could reach other stations further afield. Even then, maximum distances of only 100 miles or so could be reached.

There was little control on the wavelengths which were used, but most amateur activity was confined to wavelengths between approx. 100 and 600 metres. Within this band most operation seems to have occurred around a wavelength of 200 metres.

Morse Code was used almost exclusively, some operators would have been very proficient in using it because it was widely used for land telegraph systems. However, it is interesting to note some advice given to those newcomers using the code. "It is suggested

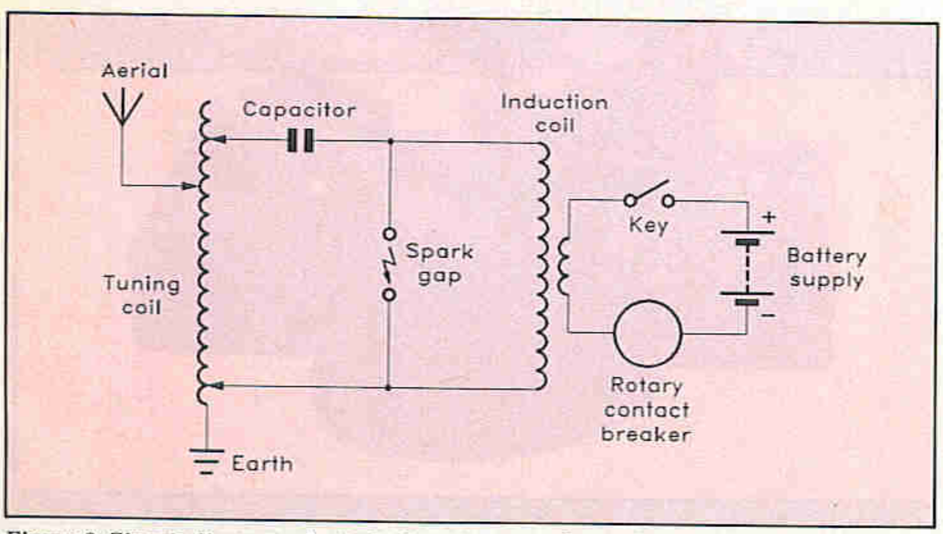
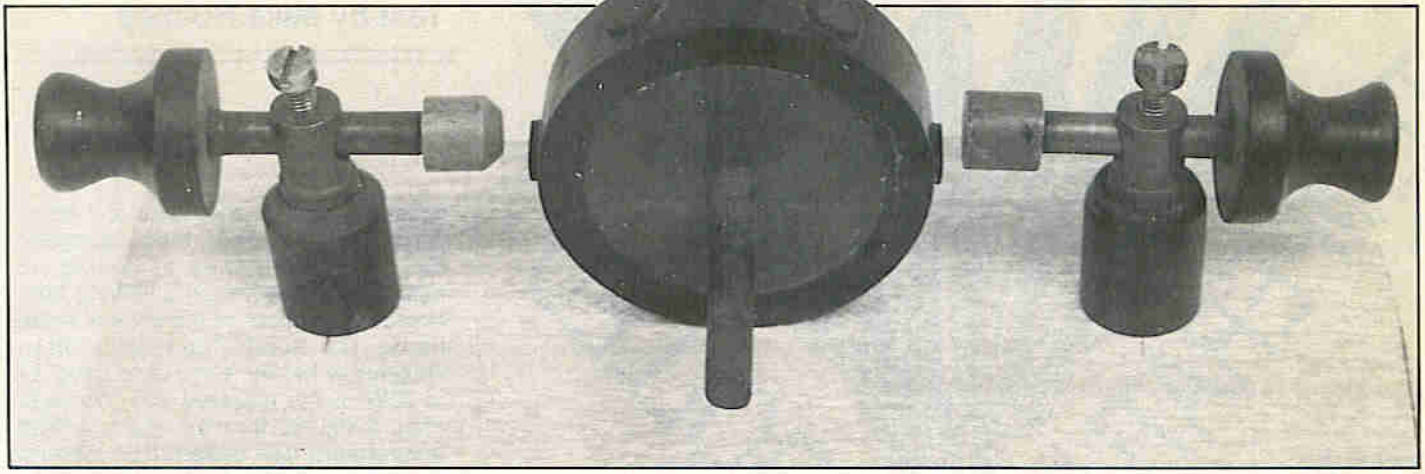
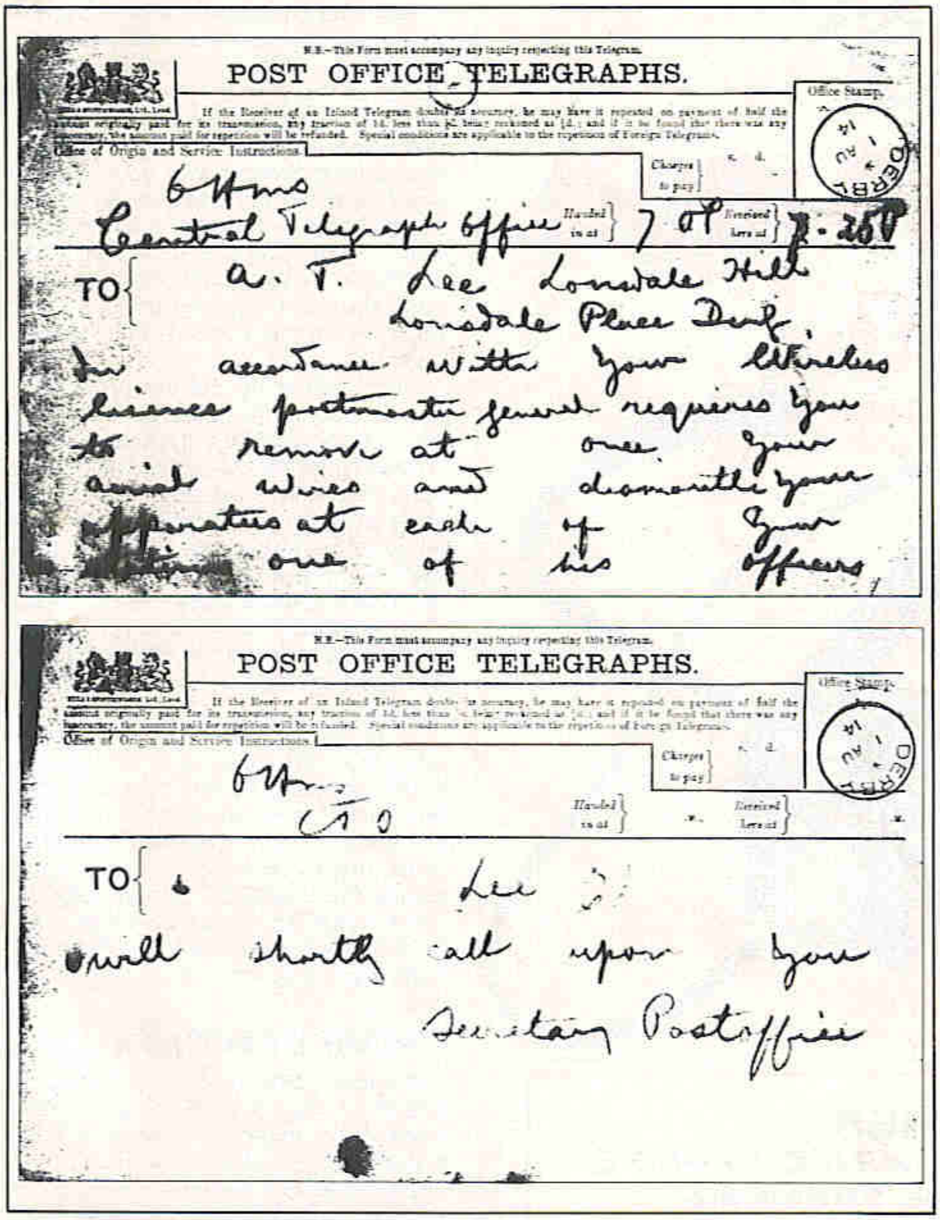


Figure 3. Circuit diagram of a typical amateur spark transmitter.



Rotary spark gap, as constructed and used by Birmingham amateur A. E. Vick (WVX) in 1912. It was used with his 10W (input power) 100 metre transmitter.



POST OFFICE TELEGRAPHS.

Office of Origin and Service Instructions: 6 Hms Central Telegraph Office

Handed in at: 7 0P

Received here at: 7.25P

TO { A. T. Lee Lonsdale Hill Lonsdale Place Derby

In accordance with your Wireless licence postmaster general requires you to remove at once your aerial wires and dismantle your apparatus at each of your [illegible] one of his officers

POST OFFICE TELEGRAPHS.

Office of Origin and Service Instructions: 6 Hms CTO

TO { Lee

will shortly call upon you

Secretary Postoffice

The Post Office telegram sent to all registered amateurs at the outbreak of the First World War. The operators had to close down their stations and dismantle their equipment for removal.

that the receiving operator should write down, in properly spaced dots and dashes, all that he receives, interpreting it at leisure when the signals have ceased. Any hesitation while the signals for letters are hunted for in a book will lead to hopeless confusion."

(Extract from Wireless Telegraphy for Amateurs, by R.P. Howgrave-Graham).

Rise and Fall

During 1913, the number of applications for experimental licences increased dramatically. In 1912 there were about 250 licences in force, this number almost quadrupling in 1913 to just under 1000. The next year it rose to about 1600.

Unfortunately this level of activity was not to last for long. Tension was rising in Europe, and on July 28th 1914 Austria declared war on Serbia. Concern was expressed in a number of quarters about the security risk of having wireless transmitting stations around the country which were not under strict government control. Accordingly on 1st August, a few days before Britain declared war on Germany, all experimental licences were suspended. The licensees were instructed to dismantle their equipment ready for inspection by Post Office staff. Most licensees had their equipment removed but some were able to keep theirs, provided that it remained dismantled. However, in 1915 it was decided that all equipment should be removed into the custody of the Post Office for the duration of the war.

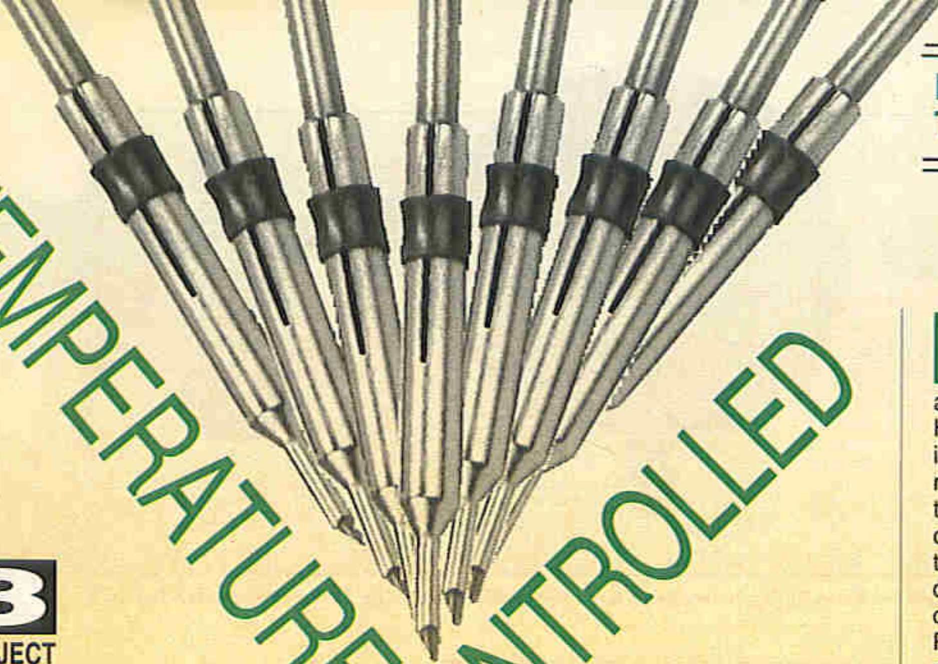
This measure was necessary because of the mounting public concern about wireless equipment being used by German spies. In fact, the authorities received a large number of reports about people who were thought to be passing secrets to Germany using their wireless equipment.

During The War

Although the war silenced all amateur activity, it did not dull the inventive spirit of the amateur experimenter. Many of those who held licences were able to use their expertise towards the war effort. Even though wireless was still in its infancy, the experience offered by amateur experimenters was valuable. Wireless communications were starting to prove their worth and they were used increasingly as the war progressed.

Acknowledgments

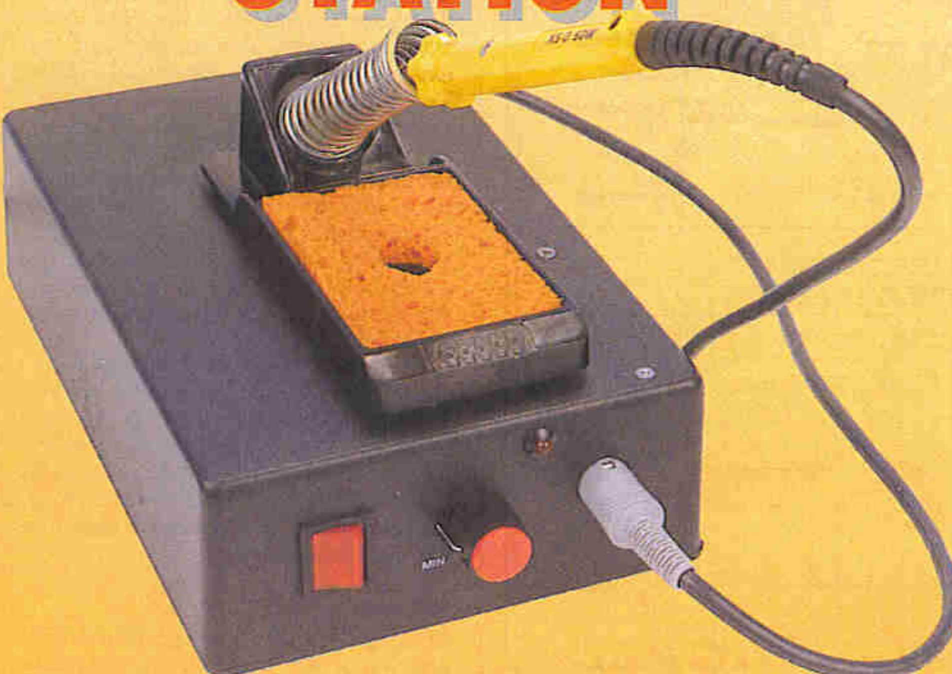
Acknowledgments are due to Mr G. R. Jessop and the Radio Society of Great Britain for the loan of valuable archive material, some of which is reproduced here.



TEMPERATURE CONTROLLED SOLDERING IRON STATION

3
PROJECT RATING

Design by Alan Williamson
Text by Mike Holmes



FEATURES
* Temperature Range 70°C to 450°C
* Minimal Noise Emission
* Negligible Element Leakage Current
* LED Indication of Heating

APPLICATIONS
* Precision Soldering
* Thermal Fault Location
* Pyro-graphic Pen

Professional engineers and home hobbyists alike, both appreciate the usefulness of having an adjustable temperature soldering iron. However, because of the price of these items, the home hobbyist is often resigned to having a 'standard issue' 17 to 25W mains powered iron. Although often adequate for most tasks, a fixed temperature iron suffers from several drawbacks. It may be too hot for delicate soldering operations involving thin PCB tracks, signal diodes and small polystyrene capacitors for example, or, at the other extreme, not powerful enough to solder something onto a piece of brass or tin-plate more than two inches square. Not least is the fact that you are invariably dragging a 240V mains lead around with you as well, which is easily damaged by laying the hot iron on it by mistake. It also follows that a mains level electromagnetic field is emitted by the iron's coiled element and induced voltages are present in the tip, even if it is connected to mains earth.

The Soldering Station presented here is ideal for hobbyists on a budget, who cannot afford the expensive ready built units. Whilst the actual low voltage irons used with these are not that much more expensive that equivalent mains powered versions, the solder station itself can cost as much as £80 or more for a temperature controlled version. This kit version offers a considerable saving and includes the 50W XSD iron as used with the TCSU-D Solder Station.

The temperature of the iron can be adjusted over a range from 70°C to 450°C, making the unit very versatile and having more applications than just soldering, for example a pyro-graphic pen, and even a controllable heat source for checking 'thermal faults' in semiconductors, i.e., a transistor may work perfectly well when cold, but may malfunction only when warm.

Circuit Description

The circuit diagram of the controller is shown in Figure 1. IC1 is a low frequency DC amplifier, using an OP-07 instrumentation grade op-amp IC, the upper frequency response of which is –3dB at 15Hz which will provide good rejection against any radiated 50Hz hum picked up in the iron's temperature sense return wire. The iron has a thermocouple sensor generating its own DC signal, and the gain of the op-amp is set at x300 (approximately 49·5dB). This value was determined by the output voltage of the thermocouple which, when the soldering iron is at maximum temperature, equals the reference volt-

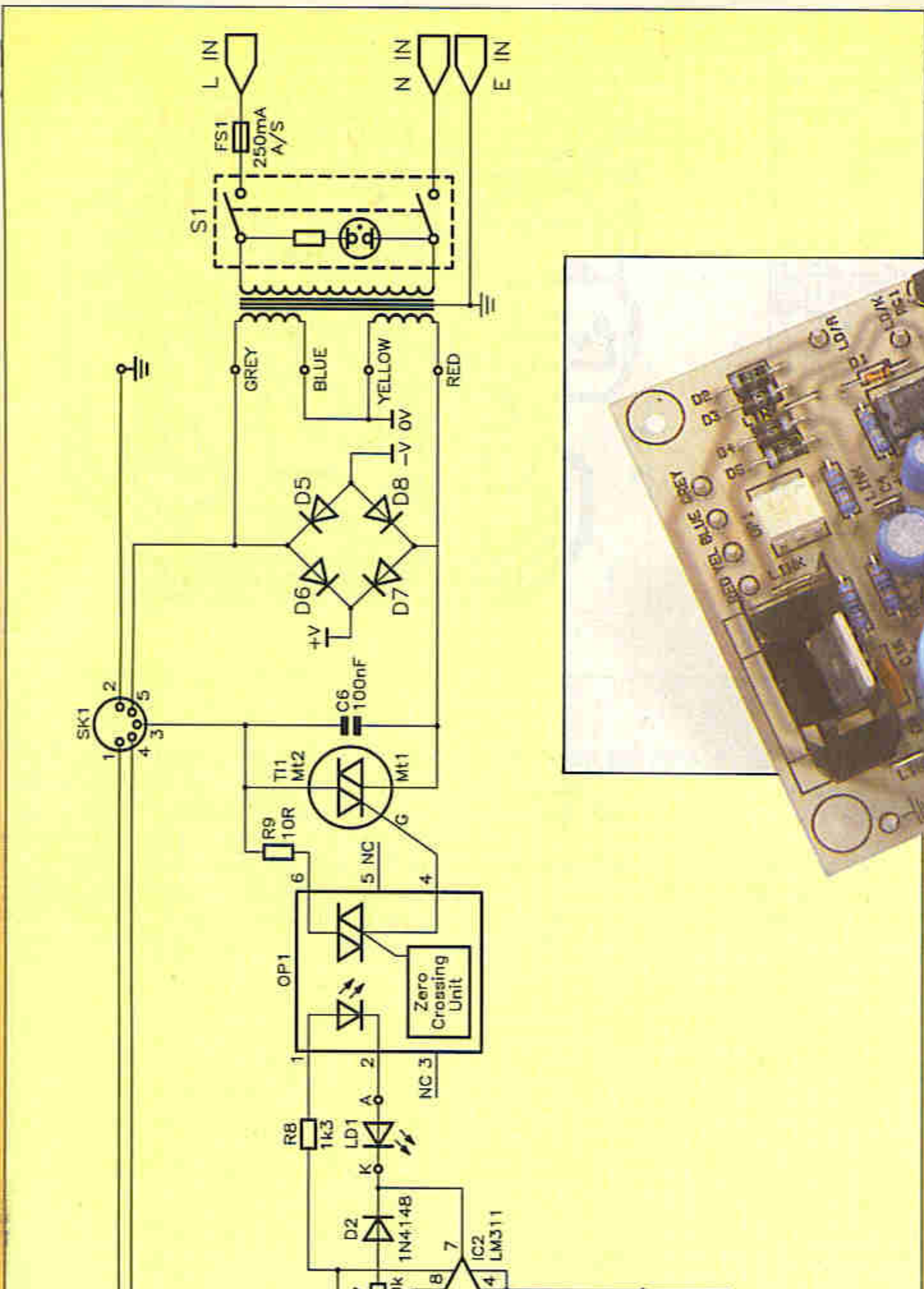
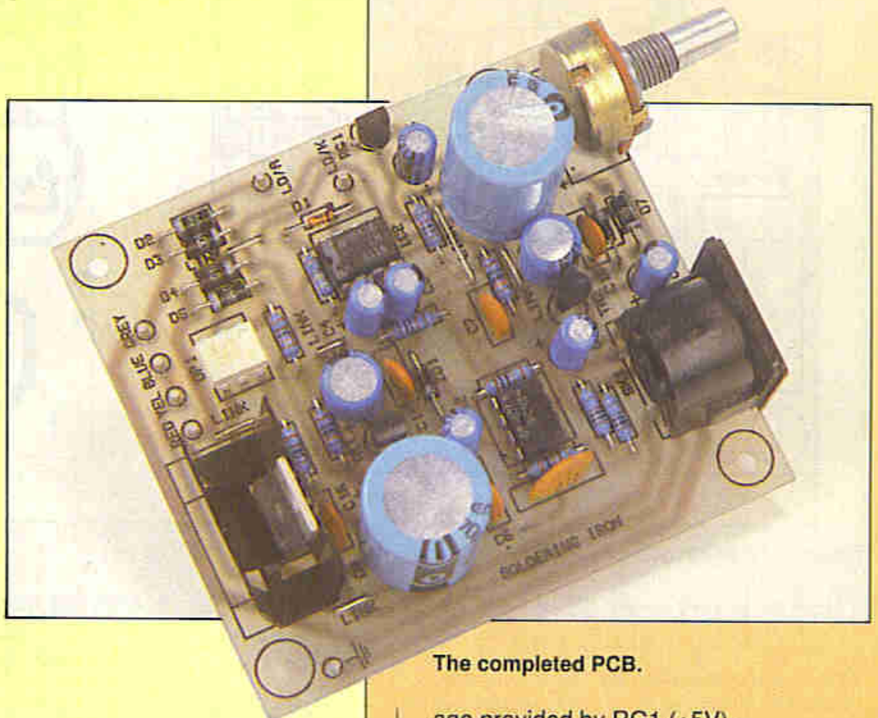


Figure 1. Circuit diagram.



The completed PCB.

age provided by RG1 (+5V).

IC2 is a comparator with a small amount of hysteresis provided by R7 and D1. The comparator monitors the output voltage of IC1 and compares it with the reference voltage at the wiper of VR1 (the temperature control), diode D1 is used to set the minimum temperature. When the voltage at the inverting (–) input of IC2 is higher than the voltage of the non-inverting (+) input, the output of IC2 will be low, illuminating both LD1 *and* the opto-coupler device LED (OP1). This will activate the opto-coupler's zero crossing detector and triac, which in turn will operate the high current triac TI1, providing power for the soldering iron element.

As the soldering iron element heats up, the output voltage of its thermocouple will increase, until eventually the output voltage of IC1 will be higher than that of the reference voltage from VR1, causing the comparator output to change state and turn off the opto device. LD1 will only illuminate when the soldering iron is being heated, directly indicating when power is applied to the iron.

A zero-crossing opto-coupler was used, so that there will be no switching noise in the connecting lead of the iron. Also a toroidal transformer is used to keep mains frequency fields to a minimum on the work bench. The iron is powered directly by 24V AC from the transformer, while rectifiers D5 to D6 provide DC for the controlling electronics. The opto-coupler must be used because, being in the AC line, triac TI1 is constantly changing in polarity relative to the DC supply and hence the controller circuit. It must be noted that other irons of this type are NOT suitable for use with this controller, as they more often than not have different connections and specifications!

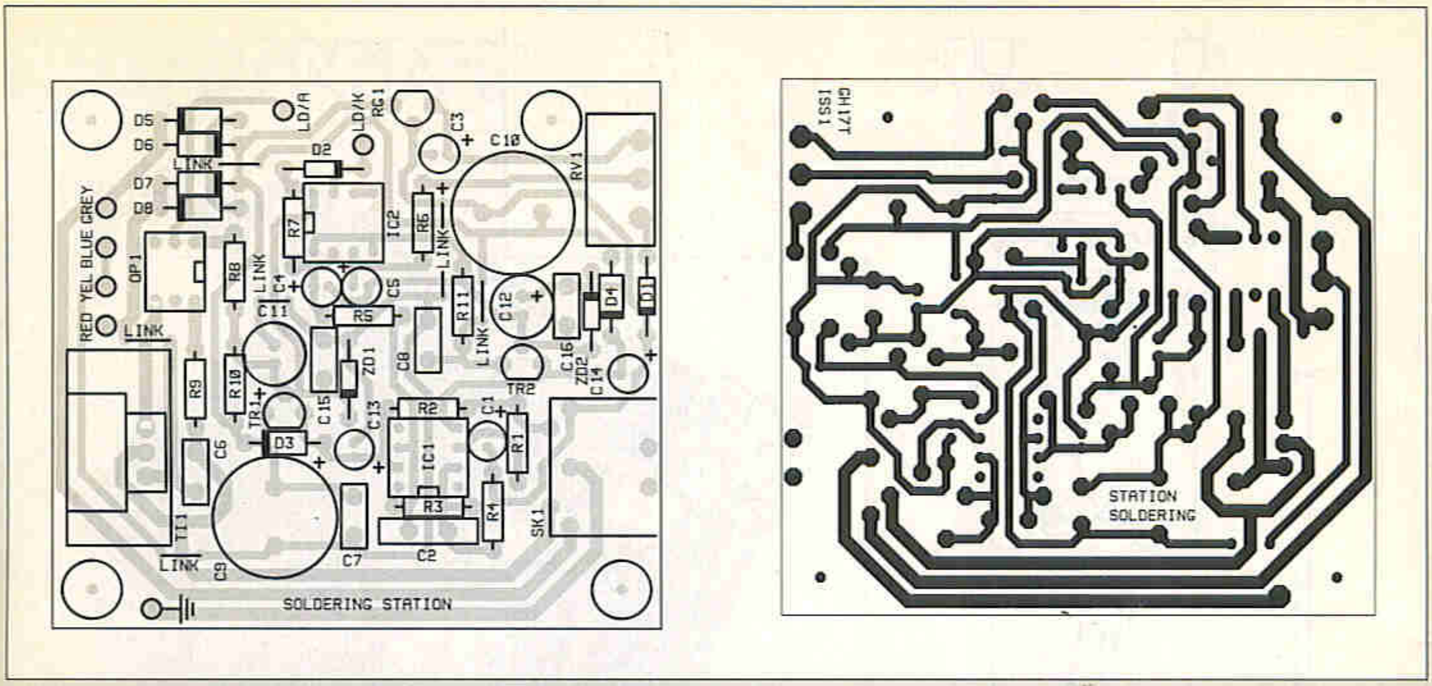


Figure 2. PCB legend and track.

Construction

Referring to the PCB layout (Figure 2), begin construction by inserting the PCB pins followed by the resistors, but do not fit VR1 yet. Use the off-cuts from the resistors for the wire links. Next, fit the diodes (but *not* LD1 yet), followed by TR1, TR2, RG1 and then the capacitors. Double check the polarity of each component before soldering! Both the ICs and the opto-coupler OP1 can be installed next, but please note that IC sockets have specifically *not* been provided in the kit, so check and recheck that the ICs are in the correct position with the correct orientation. The dot or notch at the end of the package must be adjacent to the marker on the legend.

Clip the heatsink onto the triac TI1, then fit both as a single assembly to the PCB, followed by the DIN socket SK1.

The spindle of the potentiometer VR1 requires the shaft shortening by 10mm and the panel location lug removing, as can be seen in Figure 3. You can then finish off the PCB by fitting VR1 and thoroughly cleaning the PCB using a suitable solvent. Don't forget to check for poor solder joints and bridges and rectify as necessary before going any further.

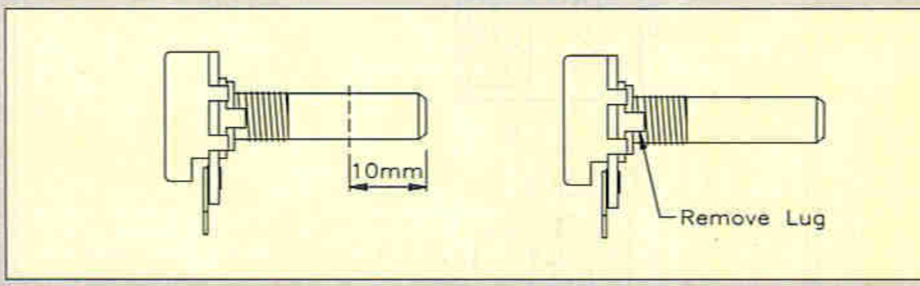
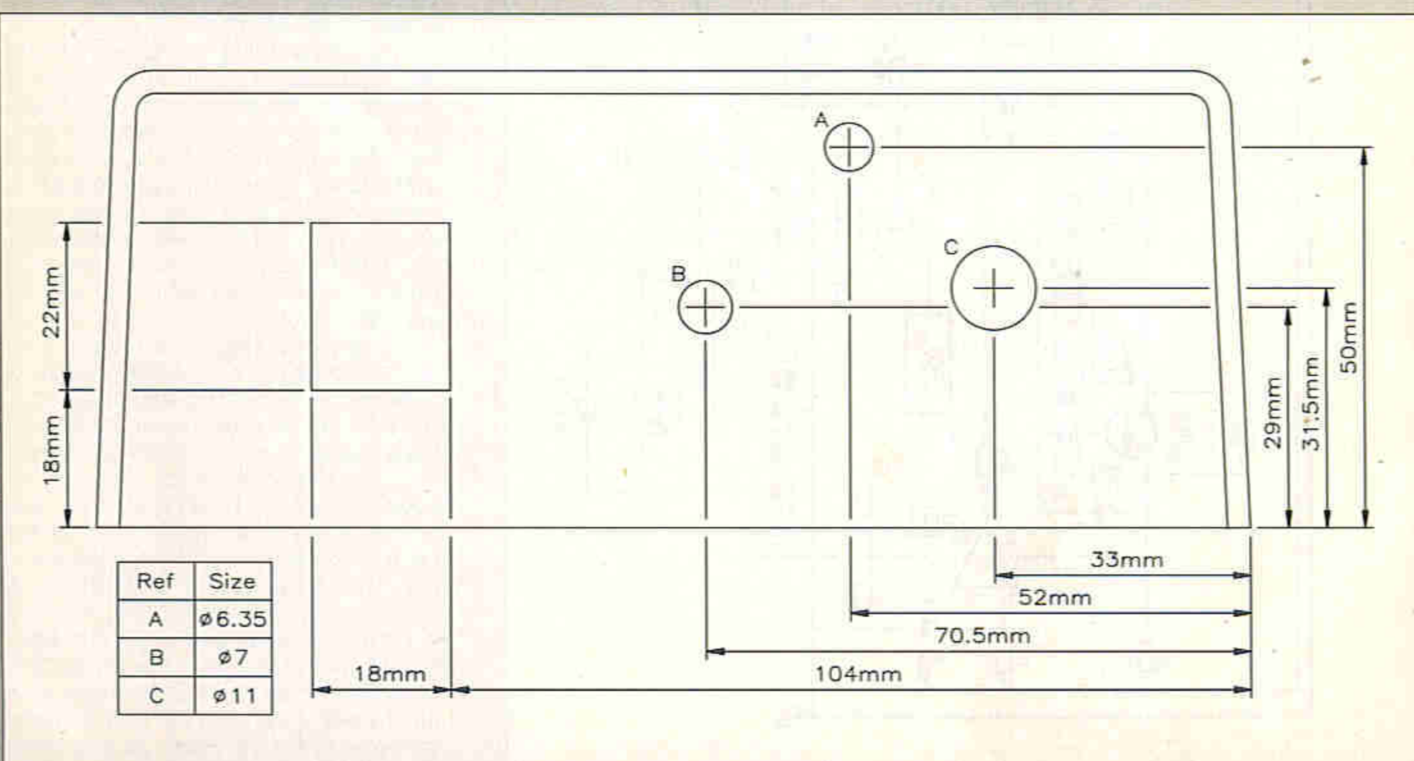


Figure 3. Modifying potentiometer VR1.



Ref	Size
A	ø6.35
B	ø7
C	ø11

Figure 4. Box front drilling details.

Drill,cut and file all the holes required in the ABS box, and countersink the holes for the M3 screws. The drilling details can be seen in Figures 4, 5 and 6.

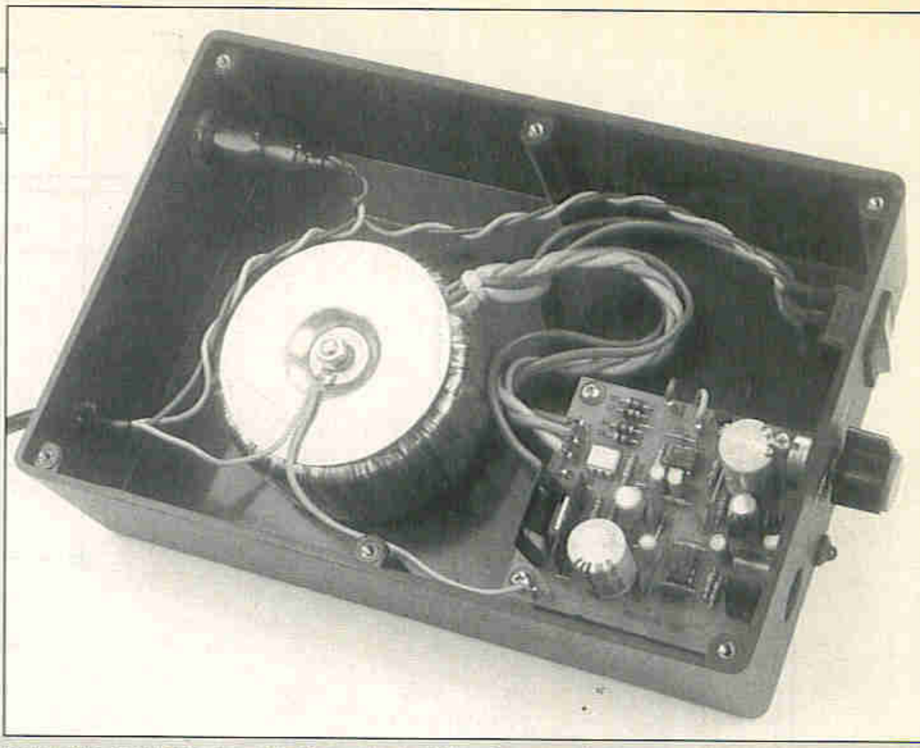
Final Assembly

First of all, trim the LED leads to 5mm, first making note that the longer of the two leads is the anode. Cut off a 10cm length of the mains cable and strip off the outer insulation; solder the brown lead to the LED anode and the blue lead to the cathode – also denoted by the flat on the package – the LED can then be inserted into the bezel and then installed into the box.

After fitting the countersunk screws and threaded spacers into the box, the PCB can then be mounted on top of the spacers and secured in place using the M3 x 6mm screws with shakeproof washers; then fit the potentiometer with nut and washer.

Next, fit the mains transformer as shown in Figure 7. An M5 solder tag is required to be fitted over the transformer bolt and its fixing hole will need filing out to size. Then trim off 50cm of outer insulation from the mains lead and fit the lead into the box complete with the strain relief grommet. Insert the fuse holder and wire it up as shown in Figure 8, and don't forget the fuse holder insulation boot!

Cut the heatshrink sleeving provided into four equal lengths; slide a piece over the mains cable live (brown) and neutral (blue) leads, and also each of the transformer's primary mains lead (coded orange). Feed the mains lead and transformer primary leads out through the switch cutout and solder them to the rocker switch as also shown in Figure 8. Note that the transformer leads are connected to the terminals in the *centre* of the rocker switch.



Inside the Soldering Iron Station prior to fitting the case bottom.

Slide the heatshrink sleeving over the switch terminals and shrink it, using a heat source such as a gas flame, cigarette lighter, hot air gun etc. (but carefully!), then you can push the switch into the cutout to secure it in place.

Solder the mains cable earth lead to the M4 solder tag mounted on the transformer bolt. The earth pin on the PCB may also be connected to the M4 solder tag if so desired, but please note that this is *optional;* the function of this earth pin on the PCB is to discharge any static build-up via the soldering iron bit.

The transformer secondary leads can then be soldered to the PCB pins according to their colour codes as printed on the PCB and also shown in Figure 8. Now double check all the wiring thoroughly, and when you are quite happy that no short circuits can occur and that all the wiring is correct, insert the fuse into the fuse holder.

Screw the base onto the box, and stick the self adhesive rubber feet onto the base and fit the knob onto the potentio meter shaft.

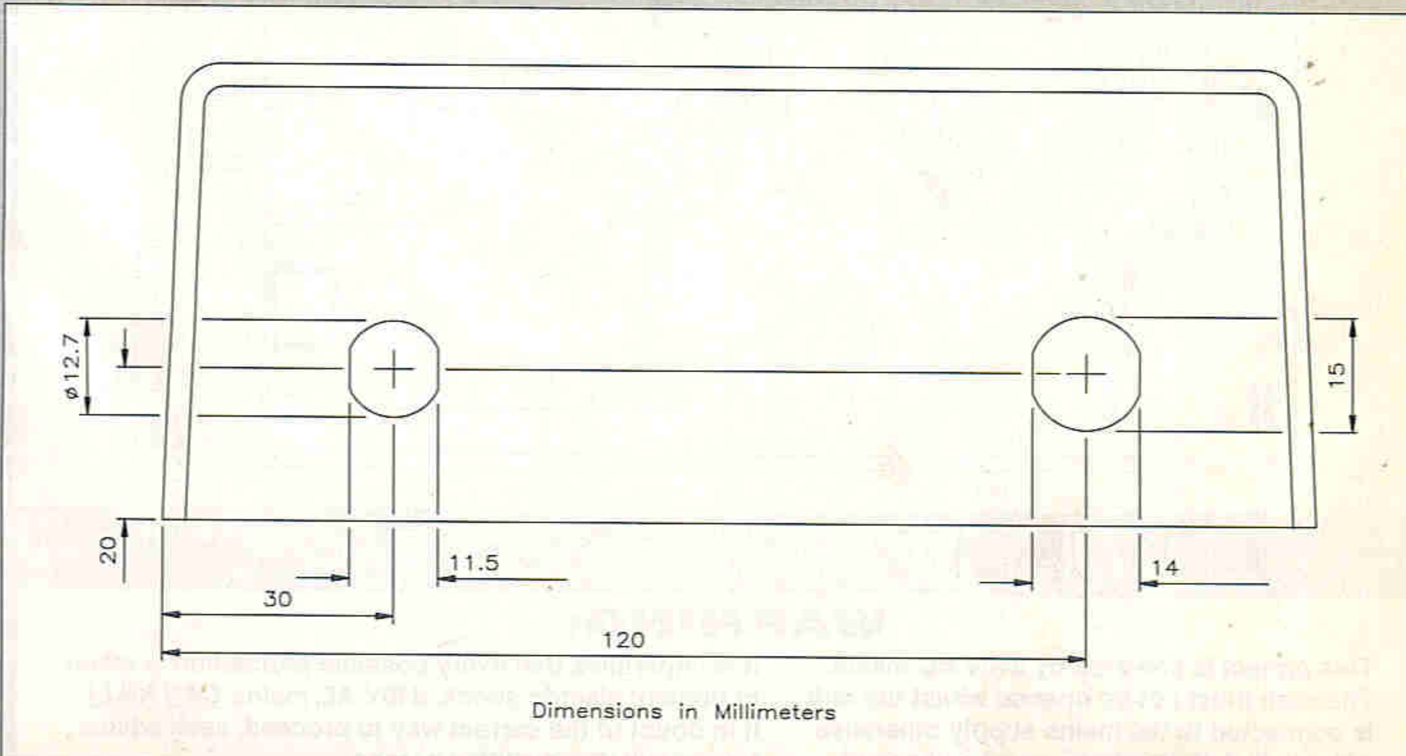


Figure 5. Box rear drilling details.

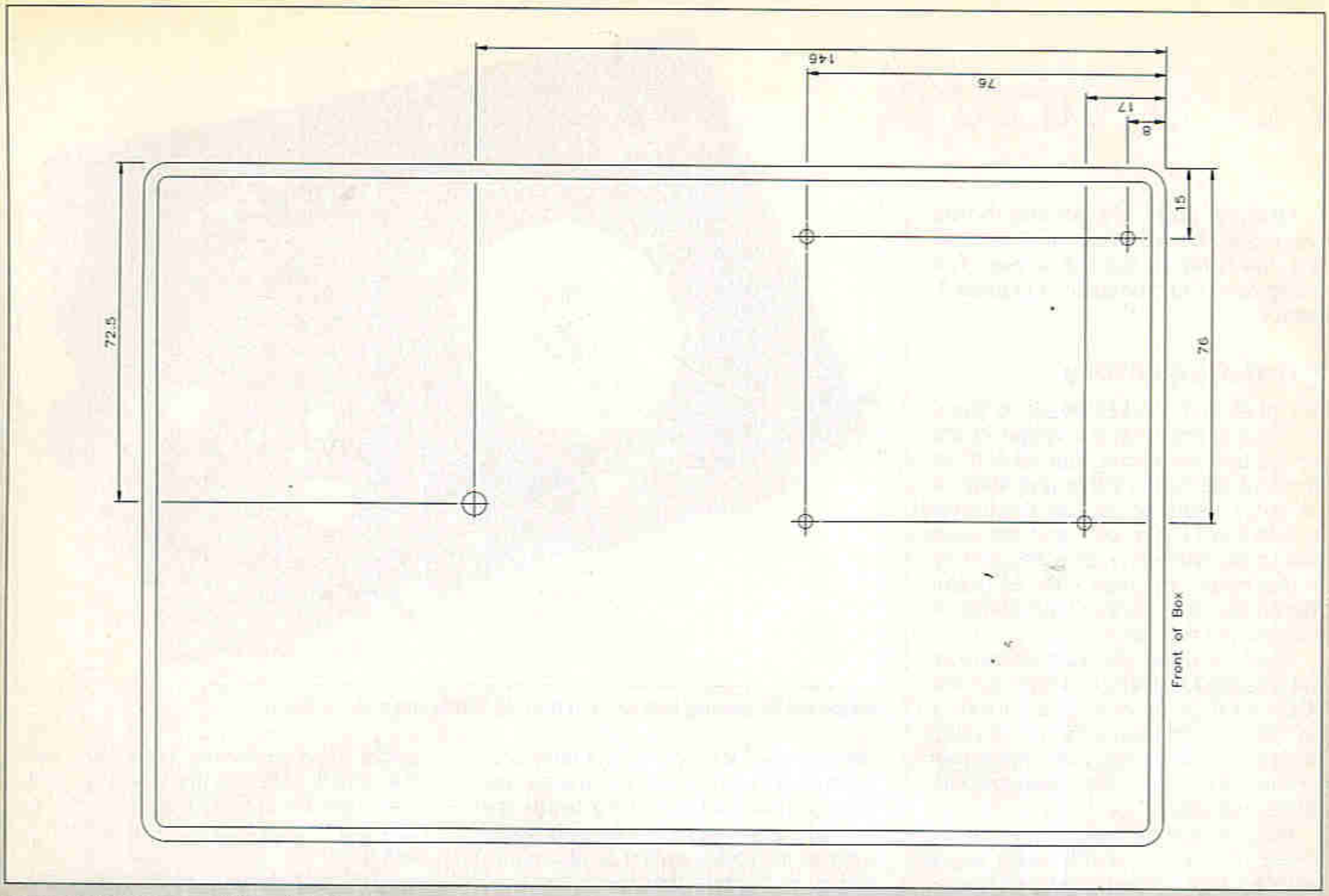


Figure 6. Box interior drilling details.

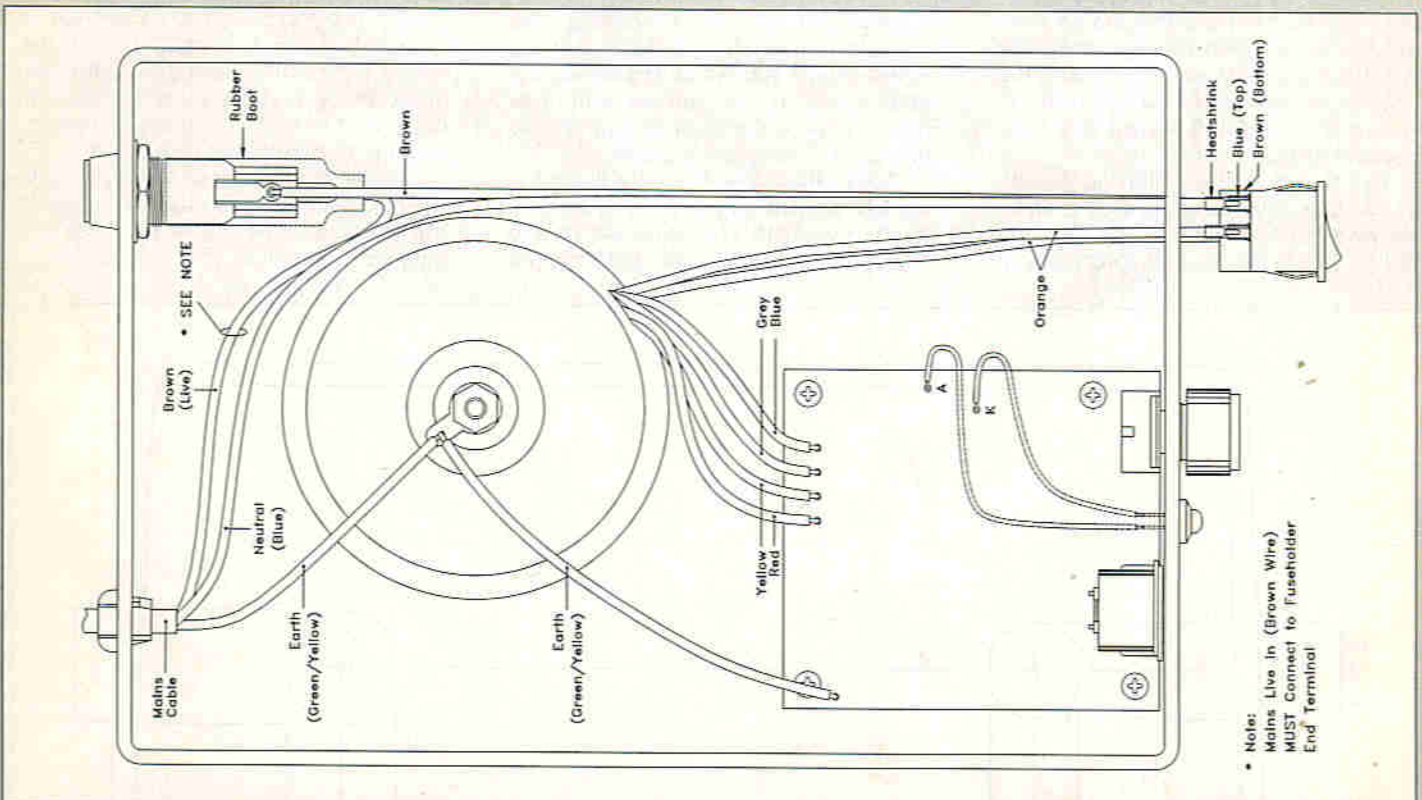


Figure 7. Complete wiring diagram.

WARNING:

This project is powered by 240V AC mains. The case must not be opened whilst the unit is connected to the mains supply otherwise potentially lethal voltage may be exposed.

It is imperative that every possible precaution is taken to prevent electric shock. 240V AC mains *CAN KILL!* If in doubt of the correct way to proceed, seek advice from a suitably qualified person.

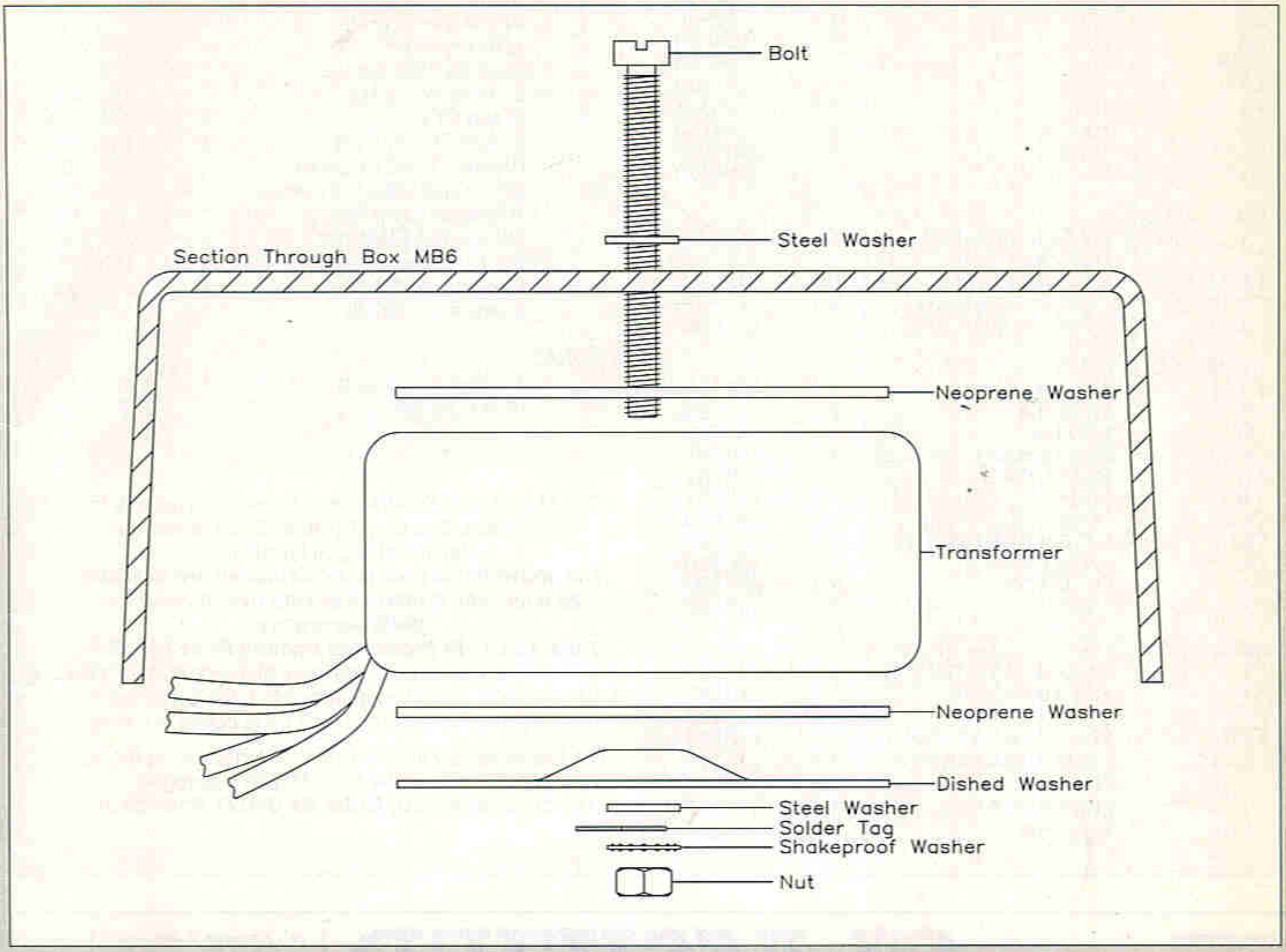
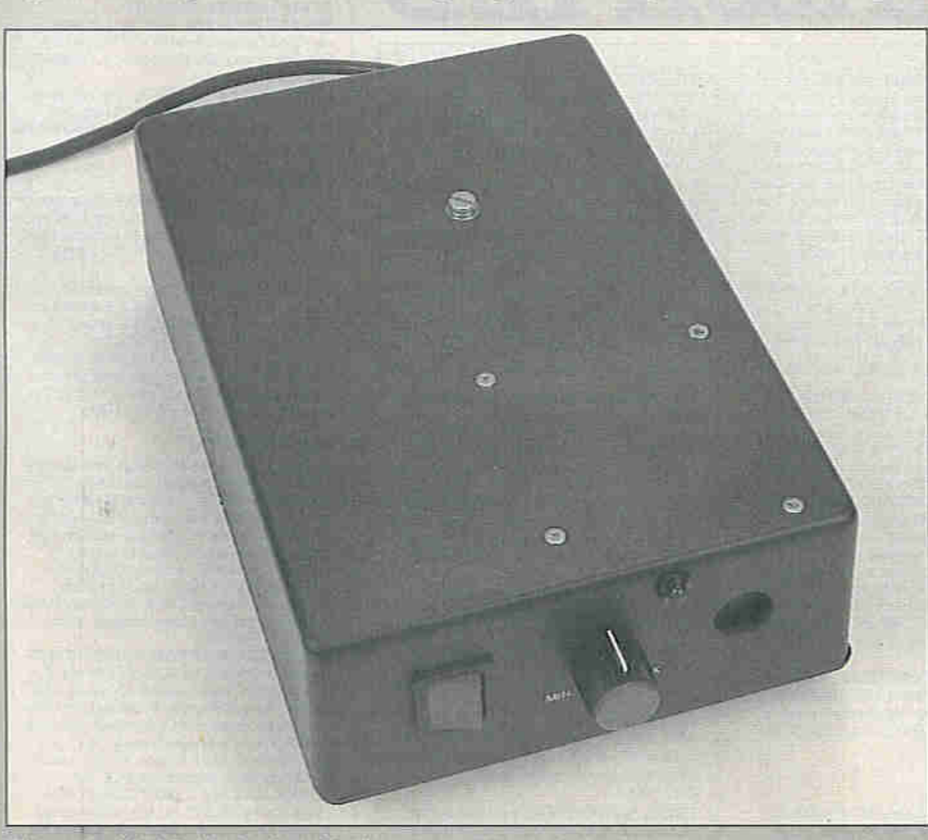


Figure 8. Mounting the transformer not forgetting the solder tag.



The assembled Soldering Iron Station.

Last but not least, connect a 13A mains plug *fitted with a 2 amp fuse* to the mains lead.

Switching On

The soldering iron temperature controller is now ready for use. Plug the 50W XSD soldering iron into the controller and turn the control knob fully anti-clockwise. Insert the mains plug into a 13A outlet and turn 'ON' the rocker switch. The switch should illuminate and the LED should also illuminate for a few seconds, the LED will then extinguish when the iron has reached the pre-set minimum temperature. Turn the control knob clockwise (the LED will re-illuminate as the iron begins to heat up) to approximately the 1 o'clock position, this is the temperature setting where solder will begin to melt. Apply solder to the tip of the iron bit to tin it, which must be done fairly quickly before the bit begins to oxidise. If the control knob is advanced even further clockwise, the LED will then re-illuminate until the new temperature is reached.

You can now begin using your new Solder Station!

SOLDERING STATION PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1,4	1k	2	(M1K)
R2	1M	1	(M1M)
R3	300k	1	(M300K)
R5,6	10k	2	(M10K)
R7	470k	1	(M470K)
R8	1k3	1	(M1K3)
R9	10Ω	1	(M10R)
R10,11	130Ω	2	(M130R)
RV1	Pot Lin 1k	1	(JM69A)

CAPACITORS

C1,3,4,5,13,14	PC Elect 10µF 50V	6	(FF04E)
C2	Disc 220nF 25V	1	(JL02C)
C6,7,8,15,16	Disc 100nF 50V	5	(BX03D)
C9,10	PC Elect 470µF 63V	2	(FF59P)
C11,12	PC Elect 100µF 25V	2	(FF11M)

SEMICONDUCTORS

D1,2	1N4148	2	(QL80B)
D3–8	1N4001	6	(QL73Q)
LD1	LED Red	1	(WL27E)
OP1	Zero Crossing Opto-triac	1	(RA56L)
TI1	BTA08–600B	1	(UK54J)
TR1	BC337	1	(QB68Y)
TR2	BC327	1	(QB66W)
ZD1,2	BZY88C12/BZX55C12	2	(QH16S)
RG1	µA78L05AWC	1	(QL26D)
IC1	OP–07CNB	1	(RA73Q)
IC2	LM311N	1	(QY09K)

MISCELLANEOUS

T1	Toroidal 50VA 12V	1	(YK15R)
S1	Red Neon Switch	1	(KU99H)
SK1	PC DIN Skt 5-pin A	1	(YX91Y)
FS1	Fuse 1 1/4 in. A/S 250mA	1	(UK00A)
	1 1/4 in. Clickcatch F/H	1	(FA39N)
	Min Mains Black	2m	(XR01B)
	LED Clip 5mm	1	(YY40T)
	Isotag M5	1 Pkt	(LR62S)
	Pin 2141	1 Pkt	(FL21X)
	Knob RN18 Red	1	(FD67X)
	SR Grommet 5R2	1	(LR48C)
	ABS Box MB6	1	(YN39N)
	Stick-on Feet Square	1 Pkt	(FD75S)
	50 Watt Iron XSD	1	(FT12N)
	Stand ST4	1	(FR20W)
	Solder Station PCB	1	(GH17T)
	Clip-on T0220 Heatsink	1	(FG52G)
	M3x10mm C/sk Pozi Screw	1 Pkt	(LR57M)
	M3x6mm Steel Screw	1 Pkt	(JY21X)
	M3 Isoshake Washer	1 Pkt	(BF44X)
	M3 Threaded Spacer	1 Pkt	(FG38R)
	Constructors' Guide	1	(XH79L)
	Instruction Leaflet	1	(XT90X)

OPTIONAL

	13 Amp Plug Nylon	1	(RW67X)
	Plug Fuse 2A	1	(HQ31J)

The Maplin 'Get-You-Working' Service is available for this project. See Constructors' Guide or current Maplin catalogue for details.

The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LT13P (Soldering Station) Price £59.95 D

Please Note: where 'package' quantities are stated in the Parts List (e.g. packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new item (which is not included in the kit) is not shown in the 1993 Maplin Catalogue. (Solder Station PCB) **Order As GH17T Price £2.35**

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AMSTRAD CPC6128 (Disc), colour monitor, monitor – TV converter. 43 boxed games, joystick, user instructions, computer and monitor desk. Excellent condition £99. Tel: (0702) 201700 (Southend-on-Sea).

SILVER REED COLOUR PEN GRAPH EB50, mains adaptor, parallel interface to CP compatible, operating manual etc. In good condition. £8 o.n.o. Tel: (0392) 75896 (Exeter).

VARIOUS

GIANT CLEAR OUT! Long list of unused components including ICs, Capacitors, Resistors, some in large quantities. All at bargain prices. Send S.A.E. for list. M. J. Dean, Blenheim, Walton Lane, Bosham, Chichester, West Sussex, PO18 8QF.

NEW COMPONENTS. Clearing workshop – need more space. Assorted resistors, capacitors, diodes, ICs, etc. £10 per bag inclusive of postage/packing. Mr D. J. Brown, 2 Glentworth Avenue, Whitmore Park, Coventry, West Midlands, CV6 2HW.

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OSCILLOSCOPE. Telequipment D75. 20MHz Dual Trace Dual Sweep, Delay & Time multiplier in good working order, £100. Thander function generator, 0·2 – 20MHz. Excellent condition £60 o.v.n.o. Tel: (0432) 625483 (evenings).

ATARI 520STFM, 4800 synth kit, Toshiba 5·25in. drives, ZX81 (16k), Acorn Atom, Atari 800, Freq. synthesiser 80–160MHz, 'Sodeco' pulse counters, used EPROMS, valves, valve voltmeter, much more! Tel: Mike, (0604) 755785.

LABGEAR UHF/VHF PAL COLOUR BAR GENERATOR. Type CM6052 and Sony Video Camera Selector HVS2000P. Price £20 each. Tel: (0628) 26305 (Maidenhead).

CROTECH 3030 15MHz single trace oscilloscope £50. Microprofessor MPF-1B (Z80) training system plus applications board £50. K. P. Edwards, 19 The Square, Tatsfield, Kent, TN16 2AS.

ADVANCE ELECTRONICS DIGITAL MULTIMETER. Model DMM3 – 25 ranges C/W manual. £30 o.n.o. Saft rechargeable nickel cadmium cells. Type V040KH – 1·2 Volts 40A HR for sale. £5 each or offers for total quantity of 40. Tel: (0274) 593382.

COSSOR CDU150 OSCILLOSCOPE. 35MHz Bandwidth, Dual Beam, Delayed Sweep. Supplied with full service manual and circuit diagrams. Unit recently calibrated (July 1992). Chopping oscillator requires slight attention, however, unit works perfectly in CH1, CH2. Add and Alt modes, hence ridiculously low asking price of £50 (+ £20 p&p and insurance or buyer arranges collection). Tel: (0389) 58523 (Dumbarton).

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1·5m OR 1·8m PRIME-FOCUS SATELLITE DISH with polar mount and stand. Must be cheap and in South-East Essex area. Any condition as long as it's still parabolic! Also front control flap and remote control unit for PANASONIC TC2232 colour TV. Contact Martin on (0702) 554155 ext. 282 (office hours).

ANY INFO. and help on Radio Shack TRS80; diagrams, manuals, discs, etc. Will refund costs. D Kurtz, 17 Acresfield, Adlington, PR7 4JZ.

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CIRCUIT OR PCB track diagram for an AMTRON UK677 Power Supply. Will re-imburse any cost incurred. Write to: R. Norvill, 131 Stanshawe Crescent, Yate, Bristol, BS17 4EG.

I HAVE A SONY PS-LX5 turntable but no instructions or wiring diagrams. Can anyone help? Will buy, beg or borrow! All reasonable costs met. Tel: David, (0978) 758313.

FOR ATARI ST: Hand scanner, hard drive, floppy drive. Also MSX computer. Tel: (0323) 500910.

DEAD OR ALIVE SINCLAIR MICROVISION TVs (must be early type, i.e. 'Torch' shaped using 4 x HP7 batteries). Sensible price paid, plus postage. Tel: (0323) 460147 (Eastbourne).

DESPERATELY WANTED... Any 2nd hand cheap fax machine. Any type as long as it works, I don't mind. Tel: Simeon, (0884) 840203 (after hours).

MUSICAL

TECHNICS AX7 SYNTH with on board, seq, etc. Mint condition. Home use only. Cost over £900, sell £375. Seon Smyth, 12 Bethecar Road, Harrow, Middlesex, HA1 1SF. Tel: (081) 863 7368.

ELECTRONIC ORGAN components clearout – keyboards, stop tabs, etc. S.A.E. for list to: Fred Wright, 23 Merrion Close, Moorside, Sunderland, Tyne & Wear, SR3 2QP.

ELECTRONIC ORGAN. Elka Minuet 99 with tutorial Lessons, 2 keyboards, bass pedals, rhythm accompaniment, roll top. Walnut veneered. Offers! Tel: (081) 500 6526.

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THE BRITISH AMATEUR ELECTRONICS CLUB (founded in 1966), for all interested in electronics. Four newsletters a year, help for members and more! UK subscription £8 a year (Junior members £4, overseas members £13.50). For further details send S.A.E. to: The Secretary, Mr. J. S. Hind, 7 Carlyle Road, West Bridgford, Nottingham NG2 7NS.

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ACROSS THE BOARD

A Look at PCB Manufacturing

by Martin Pipe

Most electronics enthusiasts commonly make their PCBs by drawing their track layout designs onto a copper-clad board with an insoluble ink pen, etch-resistant transfers or tape. The prepared board is then normally left to stand in some ferric chloride solution. The ferric chloride attacks the exposed copper, and if all goes well you remove your finished PCB from the tank, which by then will contain a rather murky solution of copper and iron, amongst other things. After washing the PCB, out comes the faithful PCB drill and the holes are drilled in the etched pads for the component leads. A final clean, and a rub with an abrasive later, the PCB is ready for populating and soldering. This is the method that I used in the past and the boards, more often than not, used to end up in a rather grotty state! For example, the amount of copper forming a particular track would be rather inconsistent along its length; a fact, no doubt, related to the fact that the so-called 'insoluble' ink had washed away. Or was it because the boards had been left in the ice-cream container (sorry, etching tank!) for too long? Despite this, Maplin's Versatronics PCB development system uses a (somewhat more advanced) variant of this system, with excellent results – see 'Projecting Ahead', the first part of this series.

For the amateur, and indeed for small-scale professional batches and prototype projects, a rather better method is to prepare the design on clear plastic film using transfers and black crepe tape. The finished design is placed (I stress, the correct way up/around!) in an ultra-violet light box followed, face-down, by a piece of pre-sensitised copper-clad board of the appropriate size. After a period of exposure time proportional to the size of the design, the board is immersed in some kind of container (all right then, an ice-cream tub!) containing developer. This solution, normally aqueous sodium hydroxide, removes any of the photo-resist that was exposed to ultra-violet light – i.e. that not originally covered by the design artwork, and hence no part of the PCB track layout. The unwanted photo-resist, after exposure to the developer for an appropriate period of time, is very soft and can be washed off with running water. After washing, the board is etched with ferric chloride solution, washed and drilled in the normal way. Using this system, much better boards can be obtained – and this is why it is a standard method of producing prototypes.

Introducing PMS

When you buy a Maplin kit, you will no doubt wonder why the boards included are of such good quality. This is because our PCB suppliers are used to supplying industrial and professional equipment manufacturers, and have to maintain high standards in order to remain competitive. A large proportion of Maplin's boards are supplied by Photomechanical Services (PMS), a company employing 35 people at its base in Rayleigh, Essex. Demonstrating its commitment to quality, PMS is seeking to gain accreditation to BS5750. PCBs supplied with the more complex Maplin kits tend to be of the double-sided, plated through-hole (PTH) variety, and the purpose of this article is to describe the manufacture of this type of PCB. Briefly, with a PTH board the layers of the board are electrically linked together by 'through-holes', which are drilled through the PCB and metallised using ingenious processes. For Maplin PCBs, there are only two layers – the bottom and top sides of the

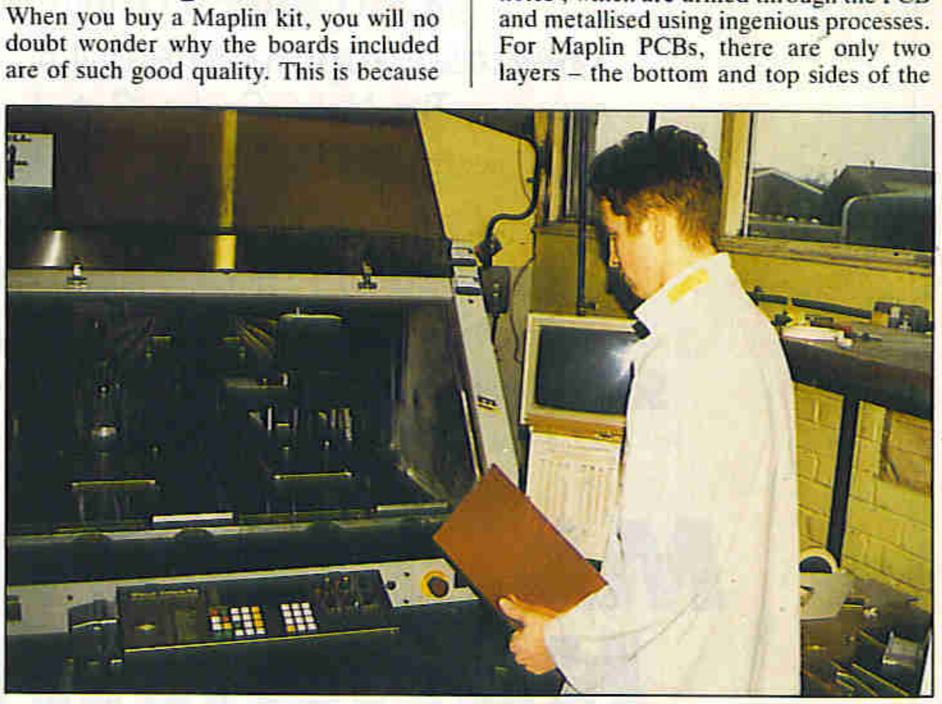


Photo 1. One of the five CNC drilling/routing machines that PMS uses. Just above the control panel of this Wessel CompacTrol machine, you can see the tool bay; the machine can be programmed to change bits automatically.

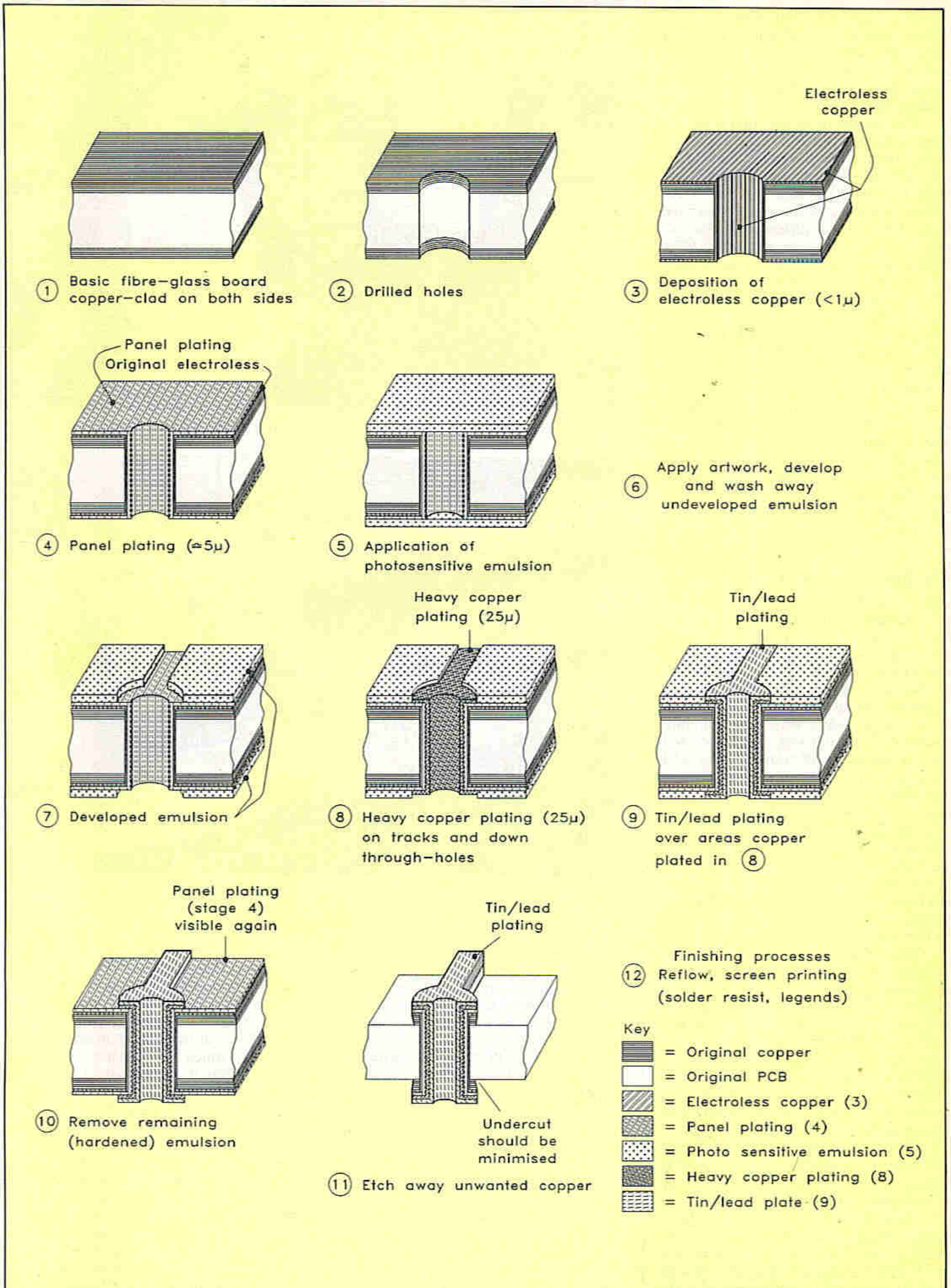


Figure 1. The various stages that take place during the manufacture of a PTH PCB.

board. However, in certain applications where space is at a premium (e.g. laptop PCs, camcorders, military/avionics equipment), multi-layer boards are used. Here, additional track layers are 'sandwiched' in the board material.

It is interesting to note that while the basic principles used in industrial PTH board production (i.e. the removal of unwanted conductive material) are essentially the same as those put into effect when you make a PCB at home, there are some fundamental differences. For example, in the case of industrial PTH PCB manufacture, drilling the PCB takes place BEFORE any etching! The story of PTH PCBs is very interesting, and involves a large number of processes. If any of these go wrong, the PCB (or more commonly, a batch of PCBs) has to be discarded or re-worked – an expensive course of action. The timing of each particular process is critical – as with the amateur/semi-professional methods already outlined. However, when PCB manufacture is your business, a 'right first time' policy must be adopted wherever possible. Figure 1 shows the various stages that the tracks and through-holes of a PTH board go through.

Drilling by Numbers

After ordering and inspection, the sheets of PCB material (referred to at this early stage as 'blanks' for obvious reasons) are stored in a rack. Their next fate? A trip to the drilling shop. PMS have 5 Computer Numerical-Controlled (CNC) drilling machines, one of which is shown in Photo 1. These machines have a bewildering variety of bits and tools, which are used for drilling holes of various sizes and routing them out (the latter refers to the removal of unwanted material from a hole – a matter of critical importance as you will later discover). The machines can automatically change the tool being used; the head 'fetches' the bit from a bay at the front of the machine. It really is impressive to watch these expensive pieces of hardware (typical cost £50,000 to £100,000 each) in action!

And this is where the Maplin intervention comes in. Your favourite electronics company supplies CAD-generated computer data, presented in industry-standard Excellon and Gerber formats, to PMS. The Excellon files are used to derive the programs that drive the CNC drilling machines. The Gerber files, however, are used to control the photo-plotter responsible for generating the master artworks.

If the PCB is the first of a new batch (for example, a Maplin kit whose details are to be published two months, or so, henceforth), then a 'test board' is produced. This is then inspected, and any changes to the drilling program are made. If all is OK, then batch drilling of the PCBs can commence. Test boards are used to check the effectiveness of each different production process – 'guinea pigs' if you like! For example, test boards

Photo 2. Here we see the Bohan pinning machine, which is used to drill the alignment reference holes.

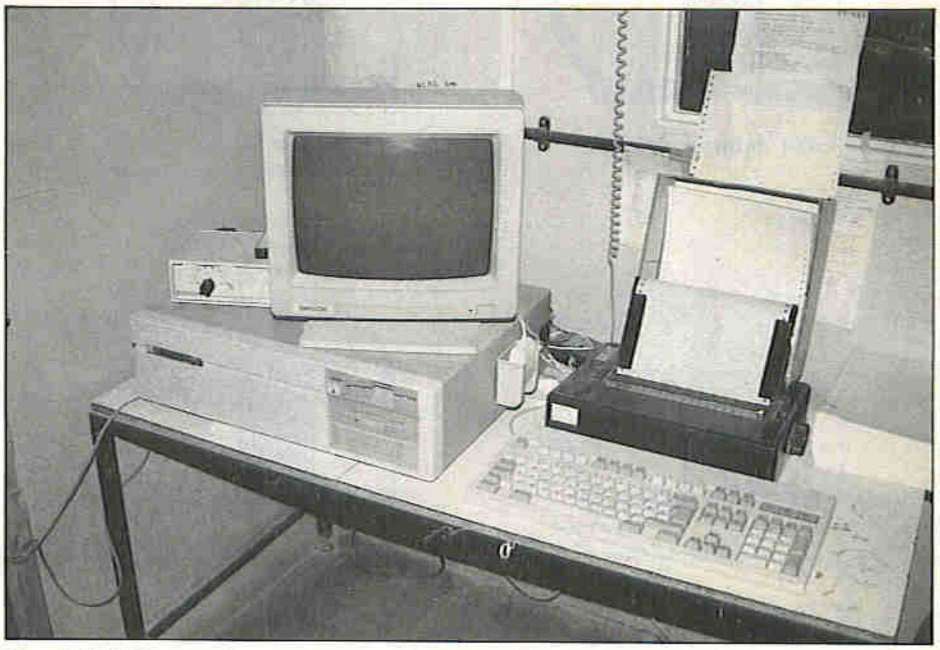


Photo 3. The PC now used for the co-ordination and storage of drilling programs. Replacing the bulky, slow and unreliable cassettes, it has a 120Mb hard disk for storing the most used drilling programs.

are used to determine plating current.

Before the main drilling operation can take place, the boards must have reference holes drilled in them; a task fulfilled by the machine shown in Photo 2. Such reference holes are necessary for lining up the artwork, and to ensure that side one of the PCB lines up with side two. Imagine the chaos that would be caused, at this stage, by a registration error of a mere millimetre! Yes, those reference holes are put down to micron accuracy. As you can see, two of these holes are used for each blank.

After a 'first run', followed by another inspection designed to detect any production problems, the blanks are normally drilled three-deep, entry and exit boards being placed on top of and below the stack, respectively. This is done to protect the finish of the top and bottom boards. Each blank (i.e. each PCB) is around 1·5mm thick, and the entry and exit boards are 0·8 and 1·5mm thick respectively. Thus, on an average job, the drill has to cope with a bundle of material around 6·8mm thick. That may not sound a lot, but when you bear in mind the number of highly accurately bored holes drilled in each blank, and the speed at which the machine works, it starts defying the imagination!

The five drills are linked to the 386-based PC shown in Photo 3. With its 120 megabyte hard disc, this machine is responsible for keeping track of a vast number of jobs. Originally, CNC drilling programs were stored on ordinary audio cassette tapes – those that you and I would listen to music on! Due to slow speed, limited storage capacity and the problems of indexing a vast library of the things, the PC-based system was introduced – and the company hasn't looked back since!

Another inspection stage follows

drilling. Problems, such as blunt drills and missed holes, are discovered by the team of eagle-eyed inspectors employed by this department.

Electroless Plating

After drilling comes the first plating process, but not before a thorough clean that includes a certain degree of mechanical abrasion, followed by a five bath immersion sequence. These five baths include a potassium permanganate 'de-smear', which removes any resin from the holes (this resin is used, in the manufacture of the original blanks, to bond the glass fibres together), a micro-etchant (ammonium persulphate) that exposes the pure surface copper, and various intermediary cleaners and chemical neutralisers. Decontamination of such ferocity is needed to rid the boards of such nasties as finger grease, dust and oxide – all of which will inhibit subsequent stages to some capacity or other. The initial plating procedure, which deposits a layer of 'electroless' copper on each board and through each hole, is unique to the production of PTH PCBs. The purpose of applying this thin (less than 1 micron) layer of copper is to act as a 'base' for further electroplating. This seemingly long-winded approach is the only real practical manner in which you can plate a non-metallic object *viz* the fibreglass surface of the hole, the initial electroless plating being achieved by means of some pretty clever chemistry. Basically, a solution containing a form of the metal palladium is introduced into the plating bath. This palladium 'colloid' is absorbed into the walls of the hole, and acts as a surface upon which plating can take place. In a separate reaction, hydrogen associated with the palladium attracts the copper, the overall result being a deposit of this metal. This process is entirely chemical; thus the term 'electroless'. After the electroless plating comes the real thing – an electroplating process known as 'panel plating' adds around 5 microns of plating to the delicate layer of electroless copper. With the CNC drills costing many tens of thousands of pounds each, industrial PCB manufacture doesn't come cheap! To this must be added the enormous cost of the plating baths (one set for each plating stage) and the not insignificant electricity bills incurred in running them! Photo 4 shows the electroless plating bath, while the electroplating section is captured in Photo 5.

This stage is a critical one for the inspectors – they must look for any problems and trouble-shoot any that do occur; so much could go wrong at this stage that could affect the proper plating of the batch (contaminated copper, incorrect dip time, build-up plating current too weak etc.). Similar meticulous care is exercised over all subsequent plating stages – as already mentioned, the use of test boards is very common.

After electroless/panel plating, washing and inspection, the boards are

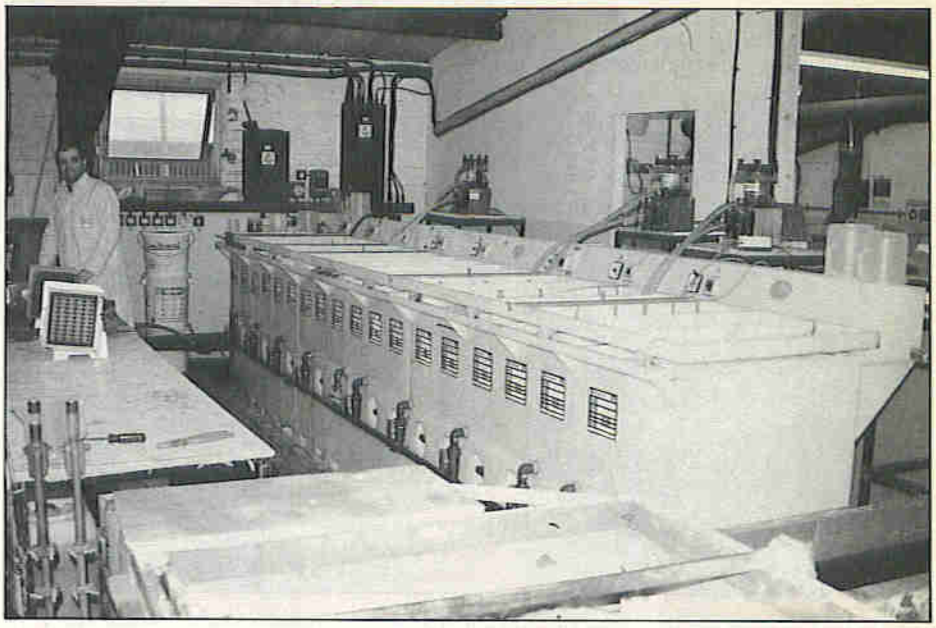


Photo 4. The electroless plating area.

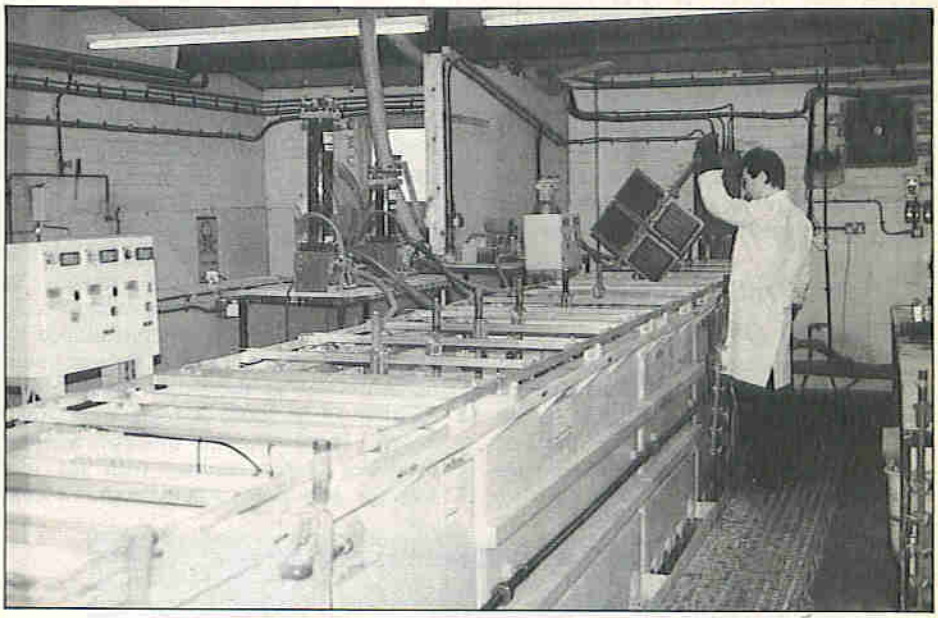


Photo 5. The electroplating baths. Different compartments are used for various degrees of plating and type of metal to be plated. Those catered for include copper, tin/lead, and gold (for edge connectors, etc).

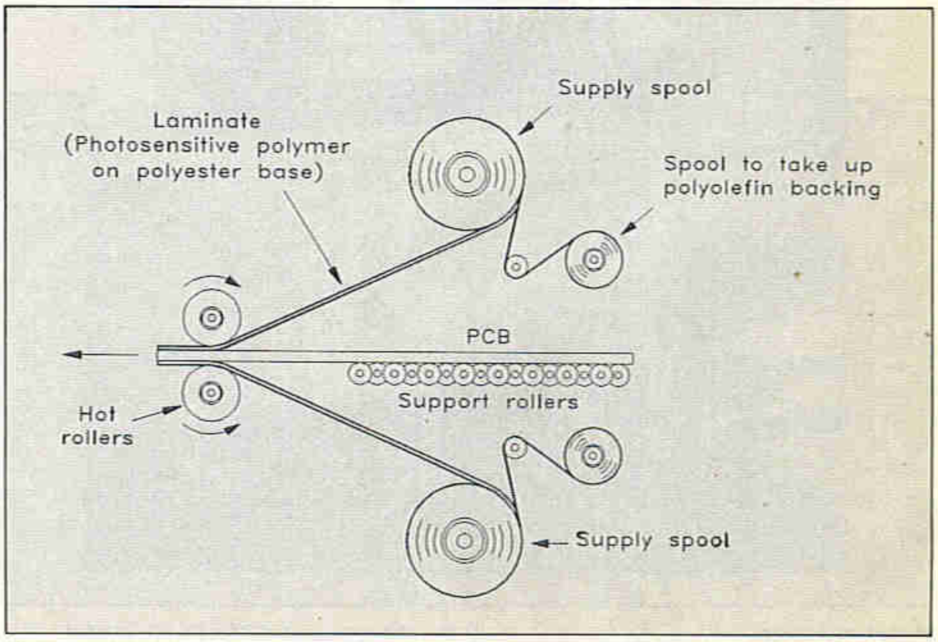


Figure 2. This diagram illustrates how a photolaminating machine works.

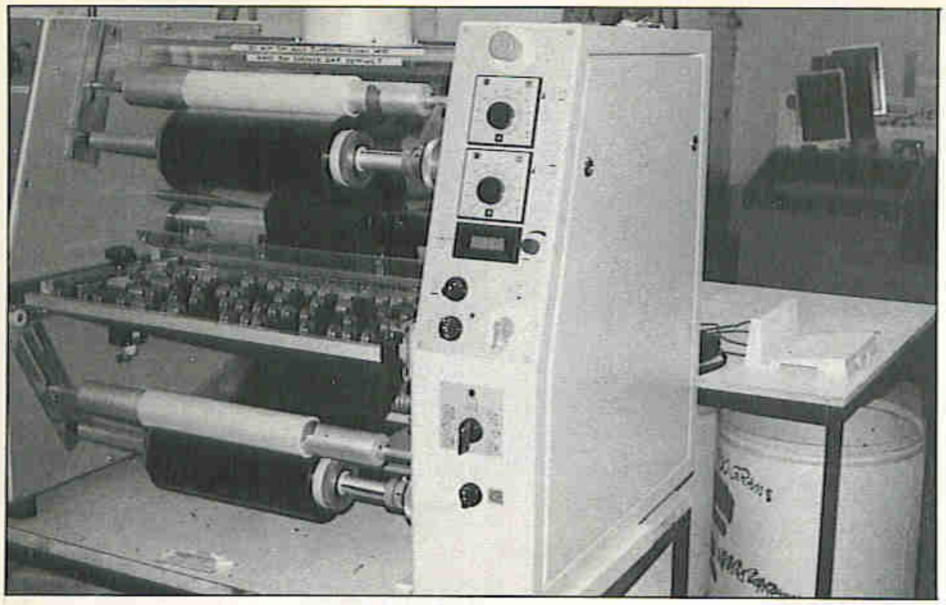


Photo 6. The laminating machine, whose job in life is to apply the photosensitive emulsion to both sides of the board. See Figure 2 to see how it works.

'photolaminated'. This refers to the application of a photosensitive material, to both sides of the board, by hot rollers – see Figure 2. The room in which this, and other photosensitive materials are handled, is characterised by garish yellow lighting! This yellow glow, however, is not reflected in Photo 6, which shows the machine responsible for lamination.

(Ultra-Violet) Lights, Cameras, Action!

The next stage is one which bears at least a little resemblance to the UV light-box treatment, mentioned towards the beginning of the article. However, in terms of complexity it is like comparing chalk with cheese!

The Gerber files, supplied by Maplin, provide information to control a laser photo-plotter, for the creation of the artwork. The designs for each PCB layer are produced on clear film, with the same dimensions as the PCB itself (i.e. at a 1:1 scale). These layers include alignment marks, top and bottom track designs and the component identification legend. Originally, an electromechanical plotter would produce scaled-up images, a photographic process being used to scale the image, and the errors introduced by the plotter, down. Several images could be combined on the single film, so that multiple PCBs could be made on a single board. However, the modern method produces better results, with far less wastage and time requirement, several first-generation images being used to produce multiple board artwork. Basically, a laser photo-plotter works along the same lines as the increasingly common laser printer, but with a much higher definition. In professional circles, the artwork used to generate the PCB track designs are known as 'phototools'. Of course, each set of films has to be scrutinised very carefully before being used, otherwise errors (caused by dust, hairs, smudges, incorrect track layout and so on) will introduce recurring problems later on.

When the finalised phototools are accurately aligned (by means of the reference holes) with the laminated boards, exposure can begin. If the photosensitive emulsion is exposed to UV light it develops, going hard and insoluble (to etchant as well as water!). Normally, it is soft and can be washed off. You may be excused, if still thinking in terms of home-constructed PCBs, that the phototool will have a 'negative' image; i.e. all areas except the required track pattern are completely opaque. However, this is not the case. Confused? Read on and find out! In the meantime, feast your eyes on Photo 7, which shows the machine in charge of administering controlled amounts of UV light.

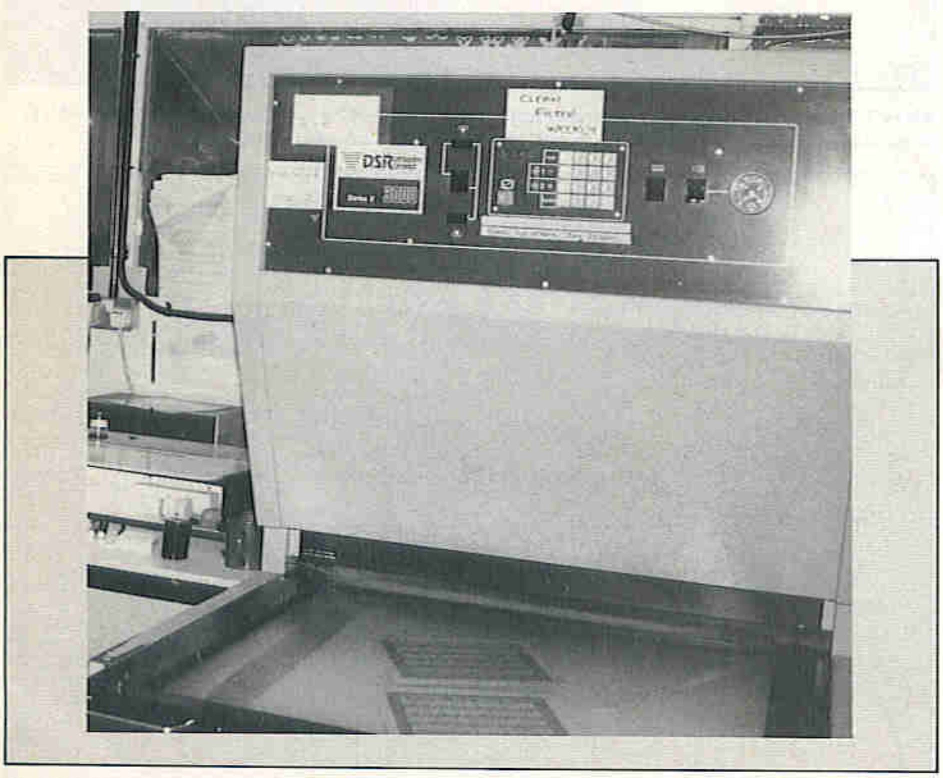


Photo 7. This machine is responsible for exposing both sides of the phototool-clad boards to controlled amounts of ultra-violet light.

Plating Away

Following a bath, in which the undeveloped emulsion is washed off, another plating stage is waiting for our unsuspecting PCBs. Remember that the tracks were not exposed to UV light, and thus the emulsion here was washed off. Conversely, the unwanted areas *around* the tracks are still protected – from the 25 microns of copper electroplating that will be applied to the exposed tracks and through-holes. The main, though by no means only, ingredient of a plating bath is copper sulphate solution, which will stir fond memories of your high school science lessons in most of you – oh happy days! Then, you probably tried to electroplate your pencil sharpener cathode (or whatever metal object came to hand) with the limited amount of copper that you could get off the two pence piece, or old halfpenny if you predated decimalisation, being used as an anode. Basically the same set-up is used – the only main difference is the scale. The PCB acts as the cathode, and there are two anodes corresponding to each side of the board. The anodes are copper bars, and are held in little cotton bags to collect the sludge of impurities that will collect in them as a result of electrolysis. Ah yes, and the DC supply is somewhat more potent than the cycle lamp battery that you probably used in your childhood! This heavy plating takes place in one of the tanks shown in Photo 5. The workings of the plating tank are illustrated in Figure 3.

At this stage we have an (almost) finished board. But how is the unwanted copper removed without etching away at the tracks? The answer is highly ingenious, as you will find out. The boards

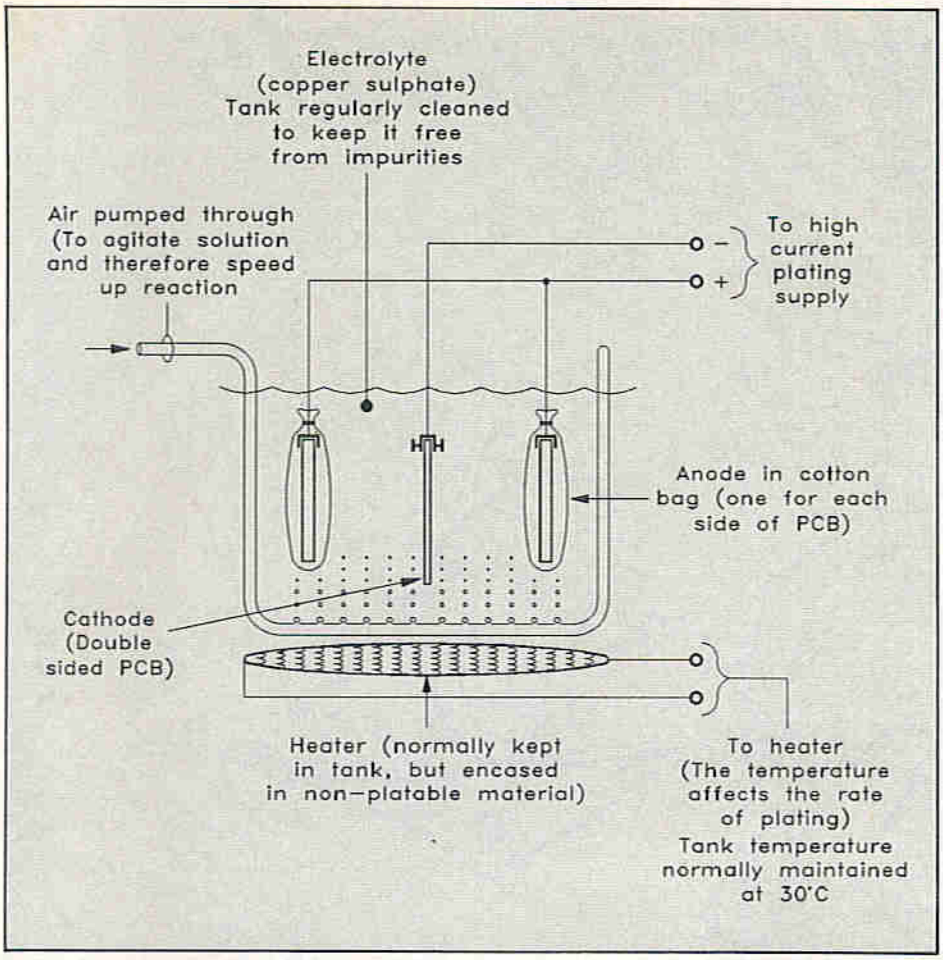


Figure 3. The components of an industrial plating tank.

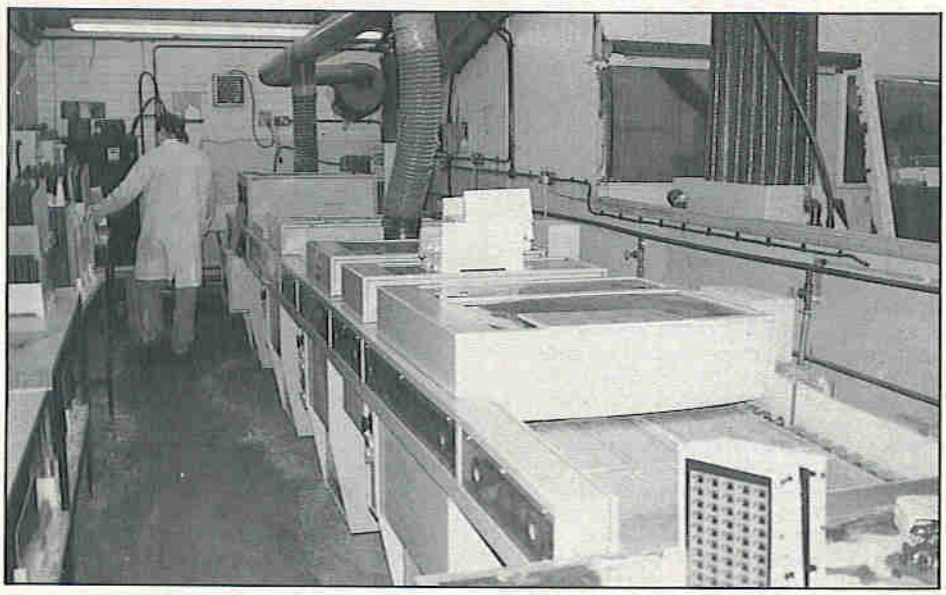


Photo 8. Here we see the etching tanks, which remove the unwanted copper from the PCBs with ammonium persulphate. Because ammonia gas is produced, a ventilation unit is employed (as can be seen from the picture), which disposes of the noxious gas in the most environmentally friendly way possible.

are tin-lead plated, using the same principles used for copper plating, in yet another of the plating tanks visible in Photo 5. Instead of copper sulphate, the electrolyte is a solution of tin and lead fluoroborates, while tin/lead anodes are used instead of copper bars. After a wash, the tracks (and through holes) of the PCBs take on a rather dullish metallic sheen – similar to that of a dry solder joint, which is hardly surprising since solder is a tin/lead alloy!

Etching Out a Living

At this stage, the remaining (developed) emulsion can be stripped away. This will lay bare the unwanted copper, which is then etched away with ammonium persulphate, in the etching tanks that can be seen in Photo 8. And the clever thing is that the tracks, under their coating of tin/lead, remain unaffected. However, if the boards remain in the etchant for too long, 'undercut' may result. Here, the sides of the tracks (which are unprotected by tin/lead) may be attacked. Correct timing, determined by the use of test boards, stops this from happening to a noticeable degree. Remember that there are many factors that affect the length of time that a batch of PCBs should spend in the etching tank, such as ambient temperature, the degree of agitation, concentration of etchant and board surface area. In etching, as in many of the stages of PCB manufacture, no two jobs (even 'identical' ones) are the same!

The final step in producing a usable board is to 'reflow' the PCB. Here, the PCB is placed on a slow-moving conveyor under a source of infra-red radiation, and the tin/lead is melted. On cooling though, the tin/lead reconstitutes itself into the shiny coating that is immediately recognisable on the superb boards supplied with Maplin kits.

The story does not end here. Most kit-builders would be disappointed, and somewhat bewildered, without those helpful component identification legend and solder-resist layers. Generally these layers are screen-printed onto the board (see Photo 9), before being cured with ultra-violet light. The templates for the screens are produced from artwork derived from the aforementioned Gerber files.

After the solder resist and legend have been applied, final inspection takes place and if all are OK, the board is divided into the individual PCBs by means of a scoring machine (see Photo 10) which cuts separation grooves into PCB material. Final division of the boards is left to the customer because automatic component insertion machines and mass soldering techniques are normally used for medium to large scale production, and it is more cost effective to deal with several panels of PCBs, rather than a large number of loose boards.

Post-Production Changes

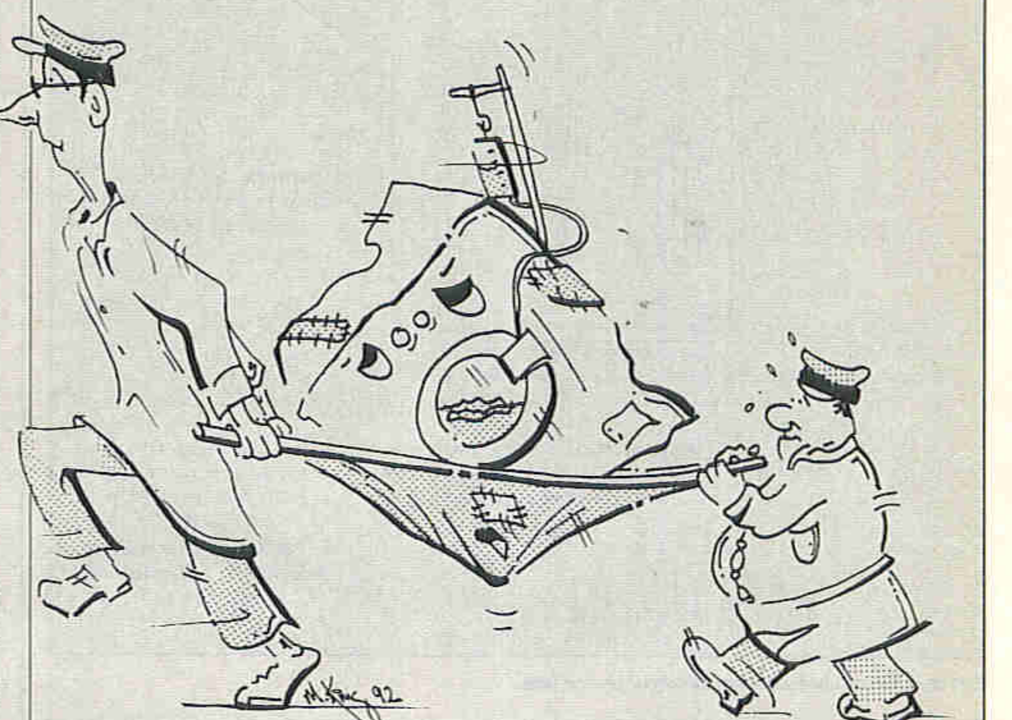
As we have discussed, inspection is a very important process. Four people are employed by PMS in this section alone. Despite the increasing automation of other aspects of the work (drilling and so on), here is an activity that depends wholly on the sight and judgement of people, aided only with bench magnifiers. Careful inspection at each stage will stop any potential problems from becoming real ones. The inspection department also houses an interesting piece of equipment for the small-scale re-work of boards. The TX250L 'Track Repair Station', shown with operator in Photo 11, is useful in situations where customers want slight modifications made to their PCBs – due to revisions in circuit design, for example. However, this course of action is taken only as a last resort – it is rather expensive in terms of person-hours! The machine works by electrically fusing metal tape between the points to be connected. As was graphically demonstrated during my visit, the join is very strong (strong enough to lift the track

Continued on page 39.

Stray Signals

by Point Contact

During the bombing in the earlier stages of the Second World War, a popular slogan was "Britain can take it." During the post-war export drive this changed to "Britain can make it," and so we could. We still can, but imported goods flood in nonetheless. Part of the reason (gripe time coming up) is that the quality of British products is not always what one would hope for, or expect. In particular, many U.K. products are not just of inferior manufacture, but actually poor by design. Take the example of our last washing machine, it lasted just three months longer than the extended five year guarantee cover which fortunately for us, we decided not to take out.



The first sign of impending doom was when, for no apparent reason, the machine started to fill to a higher and higher level until it began overflowing. Replacing a ¼in. push-on connector, which had come loose from its tag, only seemed to effect a temporary improvement, so we were left with the wash programs which *didn't* overflow. One day shortly after this, it failed to take in any water at all: the temperature sensor decided that the 'water' was not as hot as required for that particular wash cycle, and turned on the water heater element. Fortunately Mrs. P.C. happened to go into the laundry-room at that moment and noticed an orange glow showing through the glass front door of the machine, so we were able to rapidly rescue the clothes, which were hot but not harmed. But, compared with a friend of our daughter we were very lucky – her washing machine, having suffered a similar fault, actually caught fire. In view of the obvious danger of fire, you would think that a back-up sensor would be fitted, to detect the absence of water even if the normal sensor said the level was OK, but that is unfortunately not the case!

Another example of bad design is the bayonet lampholder, made in thermo-setting plastic, as manufactured to BS5042. You can buy this at any hardware shop; indeed you may find it difficult to get hold of any other sort of lampholder. But, with monotonous regularity, the shade retaining ring jams, making it very difficult to remove the shade for cleaning. Worse still, as you try to turn the shade ring, the top cover of the lampholder unscrews instead, exposing the electrical connections. This fault has been known about and complained about for years, but nothing has been done about it. My advice is; look around for a shop that stocks the old-fashioned brass lampholders. Brass is a reliable, dimensionally stable material so you shouldn't have any trouble.

For a third example of bad design, take the IEE's lapel badge. This looks very smart when it is the right way up, but unfortunately it is retained by a single stalk onto which locks a spring boss behind the lapel. The single hole fixing means that it is free to rotate and I can vouch that it is seldom if ever the right way up. By contrast is the very simple pin fixing used by the lapel badge sported by regular blood donors – nothing could be simpler and it always stays the right way up.

Sorry about that; three gripes are surely more than enough for one day, so onto other matters. You may have gathered from reading these columns that, far from living an uneventful life, Mrs. P.C. is one of those people to whom things happen. Only a couple of months ago she surprised a burglar in broad daylight trying to break in – of course he wasn't the only one surprised. And then a fortnight ago she was chatting, while swimming alongside a friend at an over 50's session at the new municipal swimming pool, when suddenly, they came up on a man treading water, he cried out "I've got a pain," put his hand over his heart, went bright pink and disappeared beneath the surface. Mrs. P.C. grabbed him, but being out of her depth, was pulled under. When they came up she called out for the lifeguards (who are always on duty), they arrived just as Mrs. P.C. and the gent came up for the second time. Fortunately, it was only a minor heart attack and the gent was soon released from hospital. However, the affair – apart from leaving Mrs. P.C. a little jittery – had a sequel which could have led to an embarrassing misunderstanding, but I'll tell you about that on another occasion.

Talking of misunderstandings, an interesting one nearly deprived the P.C. household of electric light and power recently. We had a period insurance savings policy which had reached maturity, so Mrs. P.C. went into the Halifax to cancel the direct debit. This was duly carried out, but what we didn't know was that the girl behind the counter had accidentally cancelled the *next* direct debit down the list as well. I don't know whether the terminal's operating system does not allow a cancellation to be reversed, and the item reinstated, or whether the young lady didn't know how to do it, but in fact she just entered a new direct debit with the same reference number, operative from the same day – no problem surely? But no, a direct debit having been cancelled, the computer system automatically issued a letter to the payee informing them of the cancellation. But what about the replacement direct debit, one may ask? Unlike a standing order, which is paid by the bank willy-nilly, a direct debit payment is only made when the payee asks for it. The payee can only ask for the money if he knows the direct debit has been set up, and this information is forwarded by the bank in the form of the authorisation signed by the customer. As, in this case, the Electricity Board had not been informed of the existence of the 'new' direct debit (with the same reference number) the P.C. household was then just a customer in arrears. Wonderful things, computers.

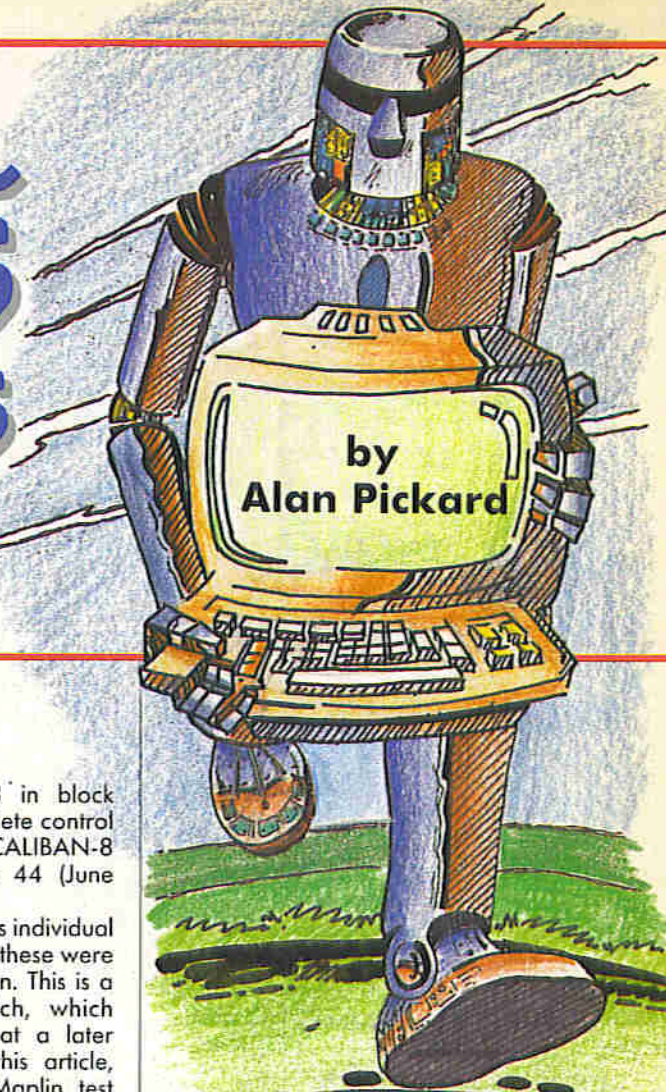
Yours sincerely,

Point Contact

The opinions expressed by the author are not necessarily those of the publisher or the editor.

PRACTICAL ROBOTICS TECHNIQUES

A PC UPDATE



The three-part series 'Practical Robotics Techniques', which appeared in Issues 42 to 44 of 'Electronics', was written with 8-bit micros in mind. Because of the limitations of the BBC machine (featured throughout the series) which offers only an 8-bit user port, and the increasing presence of IBM-compatible PCs as control computers, this article is an update on the previous series so far as it describes interfacing to a IBM PC compatible computer.

A suitable expansion card for a PC is the Maplin 24-line Programmable I/O Card, which was featured in issue No. 43 of 'Electronics'. This item is available as a kit from Maplin.

This article describes how the 24-line Programmable I/O Card enables the 8-bit robot vehicle CALIBAN-8 to be driven from a PC, and how its operation can be extended via the 16 additional I/O lines.

Robot Vehicle Specification

Figure 1 shows CALIBAN-8 in block diagram form, while the complete control circuit is given in Figure 2. CALIBAN-8 was fully described in Issue 44 (June 1991) of 'Electronics'.

In the earlier series, various individual test circuits were tried out, and these were built up into a complete design. This is a useful step-by-step approach, which avoids multiple fault-finding at a later stage. For the purpose of this article, however, I have used the Maplin test circuit which is simply a ULN2803A 8-channel Darlington driver device, an 8-resistor SIL package, and eight rectangular LEDs. This test circuit can be used, via a 37-way D socket, to check firstly PC port lines PA0 to PA7, followed by PB0 to PB7, and then PC0 to PC7. Alternatively, three test boards or a 24-channel test board could be constructed. The usefulness of such a board should not be underestimated as it is a far more convenient preliminary test device than a robot which moves or bleeps unexpectedly (and/or uncontrollably!). The output codes responsible for CALIBAN-8's actions are shown in Table 1. The test circuit is covered in the original article on the PIO card.

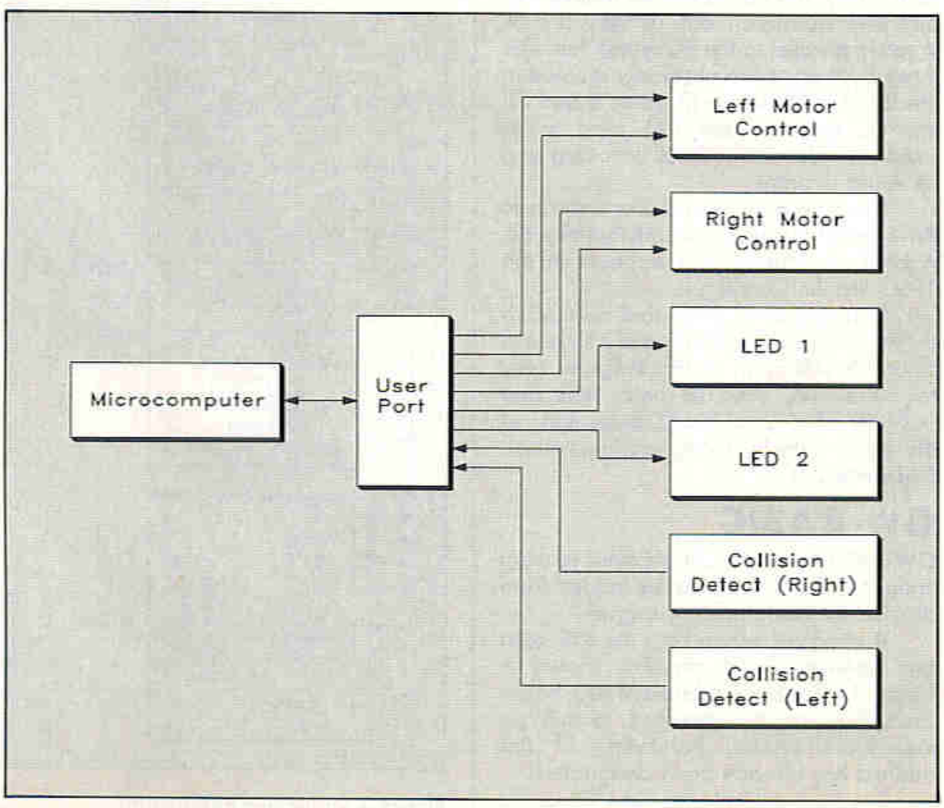


Figure 1. Block diagram of robot vehicle system.

PORT A 7 6 5 4 3 2 1 0	HEX	ACTION
0 0 0 0 0 0 0 0	00	REVERSE
0 0 0 0 1 1 1 1	0F	FORWARD
0 0 0 0 0 1 0 1	05	STOP
0 0 0 0 0 0 1 1	03	RIGHT (F)
0 0 0 0 0 1 1 1	07	RIGHT (S)
0 0 0 0 1 1 0 0	0C	LEFT (F)
0 0 0 0 1 1 0 1	0D	LEFT (S)
0 0 0 1 0 1 0 1	15	LED 1 ON
0 0 1 0 0 1 0 1	25	LED 2 ON
0 0 1 1 0 1 0 1	35	LED 1 & 2 ON
0 0 0 0 0 1 0 1	05	LEDS OFF

Table 1. Useful output codes for CALIBAN-8.

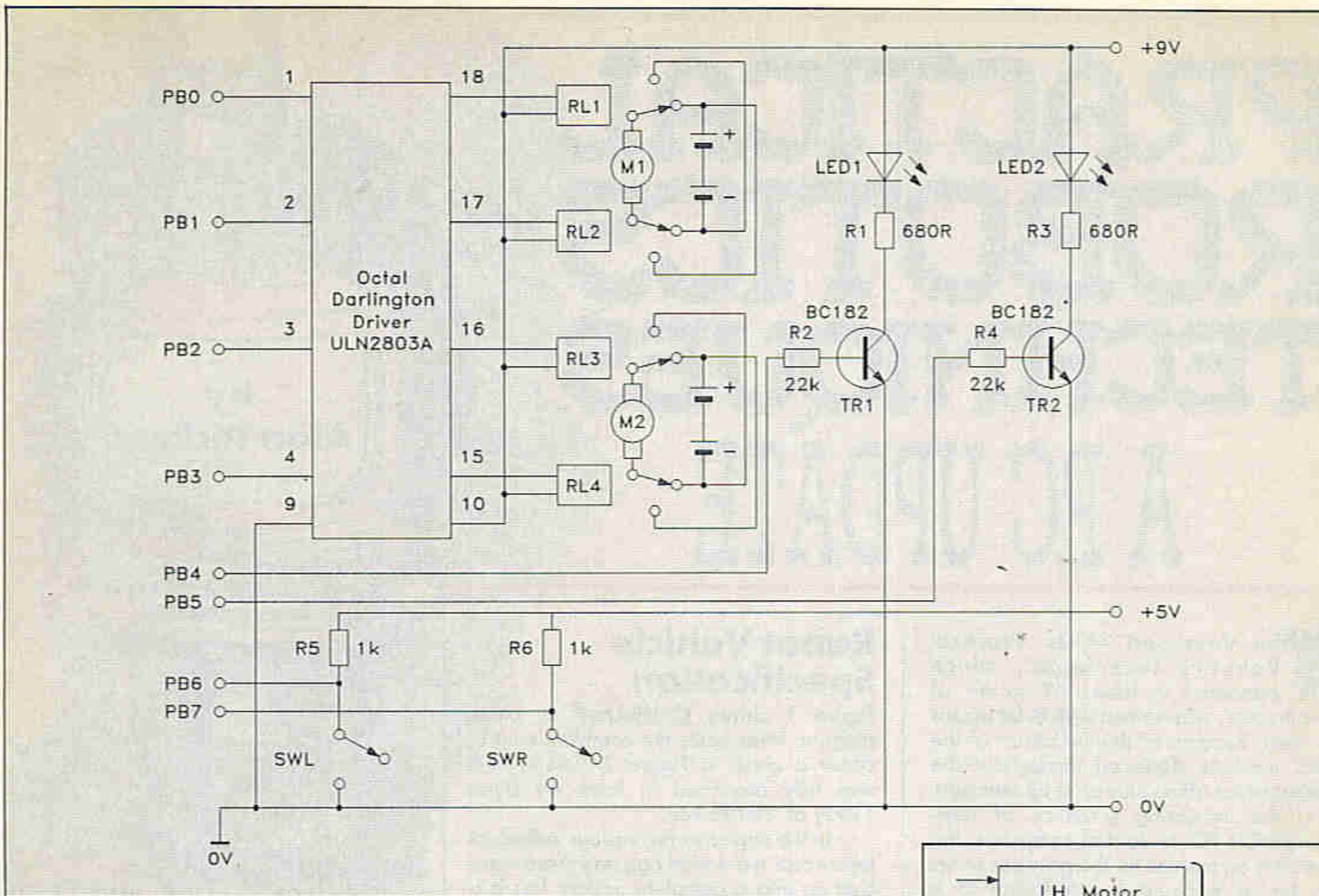


Figure 2. Full control circuit of CALIBAN-8.

Suggested I/O Expansion

A 24-bit I/O card obviously provides a further 16 lines of input or output which can considerably extend the functions of the original 8-bit vehicle by the use of, for example, more individual function LEDs, additional collision detect switches, etc. Perhaps the best application of them is to introduce additional sensors, for such areas as ultrasonics, gas, temperature, and light.

This 'conversion' article is intended to describe how the CALIBAN-8 vehicle or similar device can be connected to a PC and tested with simple GW-BASIC programs. The incorporation of other sensors or output devices is left to the individual user, but an example of a possible system utilising all 24 I/O lines is shown in the block diagram of Figure 3.

PC as Control Computer

Although the PC is a business-orientated machine normally associated with the running of wordprocessors, spreadsheets and a variety of programming languages (including GW-BASIC, C, PASCAL), etc., it is often used on the bench as a control computer, or as an extension to a piece of test equipment. Indeed, several manufacturers produce IEEE-488 interface cards; the memory map of the PC was designed to take this interface standard into consideration.

A typical PC has a number of parallel ports; usually up to three (LPT1, etc.), and up to four serial ports (COM1, etc.). The I/O card is used as an independent port.

Maplin I/O Card

The 24-bit I/O card is positioned in one of the expansion slots in the PC and, as can be seen in Figure 4, it sits astride the address bus (A0 to A9) and the data bus (D0 to D7). The board can be placed into any free expansion slot, as they are all wired in parallel to the PC system bus. The three 8-bit ports are physically situated in the 8255A PPI device (Ports A, B and C); the PC accesses the I/O card in its expansion slot via address decoding and enabling circuitry.

Full details of this card are given in the original article, as already mentioned. A brief description also appears in the 1993 Maplin Catalogue.

Connection of the robot vehicle to the PC via the 24-line I/O card is shown in Figure 5. Although in this diagram only ten wires are used (8 data lines and +5V/0V, for one port), extension of the basic vehicle wiring could produce CALIBAN-24!

GW-BASIC

GW-BASIC is a BASIC interpreter running under MS-DOS, and must be loaded from disk before entering this program.

A program which tests the I/O card and connected test circuit is shown in Listing 1. The base address 0300 hex is used, but can be changed to suit an individual's system, particularly if this address has already been designated.

The base address for the I/O card is 300 hex. Line 20 puts the data value 80

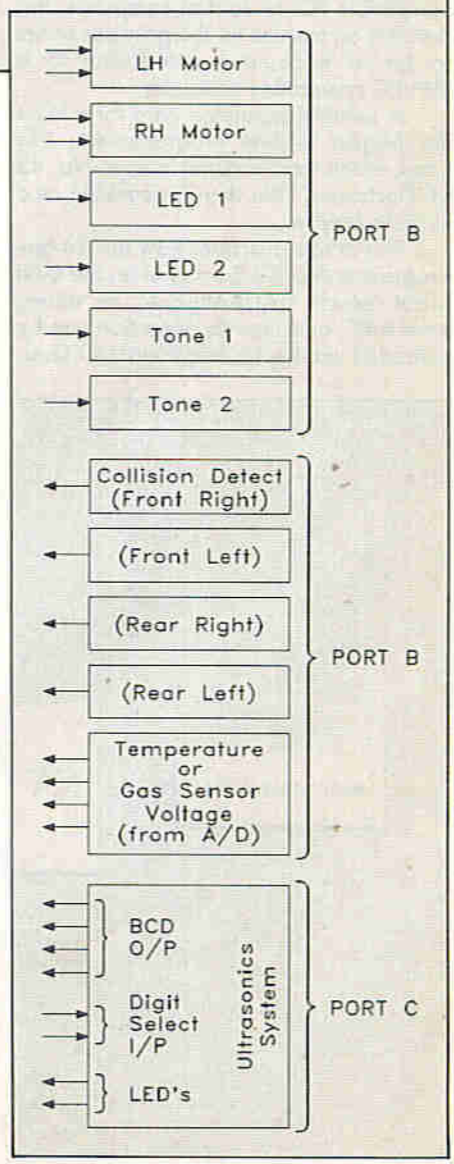


Figure 3. Suggested expansion/ modification of robot vehicle specification.

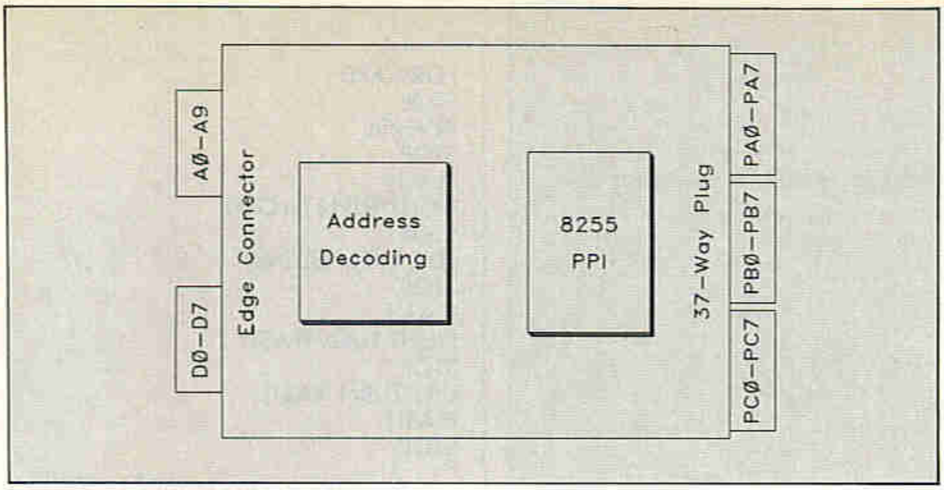


Figure 4. Block diagram of PC I/O card.

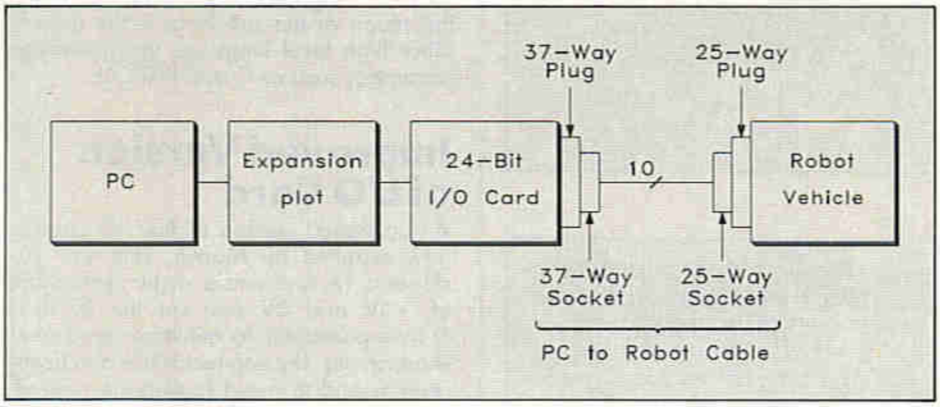


Figure 5. PC to robot vehicle connection via 24-bit I/O card.

							A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
0300H =	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
							SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8		
															Register Select Bits (Mode) on 8255 Pins 8 & 9	

Table 2. I/O card address/switch settings.

A1	A0	ADDRESS				CONTENTS	FUNCTION
1	1	0	3	0	3	&H80	MODE 0, CONTROL WORD 0 – PORT A, B & C AS OUTPUT
0	0	0	3	0	0	&HFF	SET PORT A TO ALL 1s
0	1	0	3	0	1	&HFF	SET PORT B TO ALL 1s
1	0	0	3	0	2	&HFF	SET PORT C TO ALL 1s

Table 3. 8255 programming details.

hex (128 decimal) into address 303 hex, which configures the 8255 in Mode 0 (control word = 0), setting Ports A, B and C as outputs. The 8255 data sheet gives details of other modes, which would provide alternative input/output combinations. Lines 30, 40 and 50 output &HFF (1111 1111 binary) to Ports A, B and C. Lines 80 to 100 change the output to 00 hex (0000 0000 binary), and lines 140 to 150 provide a time delay subroutine which can easily be altered if required.

Details showing the inter-relationship of address lines and DIL switch settings on the I/O card are shown in Table 2.

Table 3 explains the significance of the address bits A0 and A1. When they are both set to 1, the mode can be set up in the 8255 device and in this case, the control word 80 hex (128 decimal) is set up via the data bus (D0 to D7). Further details are given in the 8255 data sheet.

Test Programs

The basic test program has already been described. Other useful test programs for 'exercising' the robot are Listings 2 to 5:

Listing 2 is a straightforward adaptation of the test board program, using codes from Table 1 to provide robot motion.

Listing 3 is an extension of Listing 2, providing forward and reverse movement.

```
10  BASEADD%=&H300
20  OUT BASEADD%+3,128
30  OUT BASEADD%,&HFF
40  OUT BASEADD%+1,&HFF
50  OUT BASEADD%+2,&HFF
60  PRINT "LOGIC 1"
70  GOSUB 140
80  OUT BASEADD%,0
90  OUT .BASEADD%+1,0
100 OUT BASEADD%+2,0
110 PRINT "LOGIC 0"
120 GOSUB 140
130 GOTO 30
140 FOR I=1 TO 2000
150 NEXT I
160 RETURN
```

Listing 1. I/O test card program.

```
10  REM CALIBAN TEST 1
20  REM
30  BASEADD%=&H300
40  OUT BASEADD%+3,128
50  REM
60  REM STOP-FORWARD LOOP
70  REM
80  OUT BASEADD%,&H5
90  PRINT "STOP"
100 GOSUB 160
110 OUT BASEADD%,&HF
120 PRINT "FORWARD"
130 GOSUB 160
140 GOTO 80
150 REM
160 FOR X=1 TO 5000
170 NEXT X
180 RETURN
```

Listing 2. Stop-Forward loop.

Listing 4, when run, should make the LEDs flash sequentially.

Listing 5 is a possible collision detection program which sets up Port C (PC4 to PC7) as input lines by changing the BASEADD%+3 address contents to 136 (line 40). The robot moves forward (line 60) until a collision occurs. This is tested by inspecting BASEADD%+2 (Port C) on bit 6 (decimal value 64) and bit 7 (decimal value 128). If a logic 0 is detected on either PC6 or PC7, a collision is detected and appropriate action (reverse movement) is taken. The cycle then continues. The original test board is not suitable as two (input) switches are required on PC6 and PC7. In addition, PC4 and PC5 will also be set as inputs. Suitable test circuits are shown in the PIO constructional article, and the previous robotics series.

The experimenter can produce further test or functional programs based on the above listings, perhaps using them as modules. The following sequence could, for example, be converted into a suitable program:

```
10 REM CALIBAN TEST 2
20 REM
30 BASEADD%=&H300
40 OUT BASEADD%+3,128
50 REM
60 REM STOP-FORWARD-STOP-REVERSE LOOP
70 REM
80 OUT BASEADD%,&H5
90 PRINT "STOP"
100 GOSUB 500
110 OUT BASEADD%,&HF
120 PRINT "FORWARD"
130 GOSUB 500
140 OUT BASEADD%,&H5
150 PRINT "STOP"
160 GOSUB 500
170 OUT BASEADD%,&H0
180 PRINT "REVERSE"
190 GOSUB 500
200 GOTO 80
210 REM
500 FOR X=1 TO 5000
510 NEXT X
520 RETURN
```

Listing 3. Stop-Forward-Stop-Reverse loop.

```
10 REM CALIBAN TEST 3
20 REM
30 BASEADD%=&H300
40 OUT BASEADD%+3,128
50 REM
60 REM LED FLASHING
70 REM
80 OUT BASEADD%,&H5
90 PRINT "ROBOT IS STATIONERY!"
100 GOSUB 500
110 OUT BASEADD%,&H15
120 PRINT "LED1 ON"
130 GOSUB 500
140 OUT BASEADD%,&H5
150 PRINT "LED1 OFF"
160 GOSUB 500
170 OUT BASEADD%,&H25
180 PRINT "LED2 ON"
190 GOSUB 500
200 OUT BASEADD%,&H5
210 PRINT "LED2 OFF"
220 GOSUB 500
230 OUT BASEADD%,&H35
240 PRINT "LED1&2 ON"
250 GOSUB 500
260 OUT BASEADD%,&H5
270 PRINT "LEDS OFF"
280 GOTO 110
290 REM
500 FOR X=1 TO 5000
510 NEXT X
520 RETURN
```

Listing 4. LED flasher.

```
10 REM CALIBAN TEST 4
20 REM
30 BASEADD%=&H300
40 OUT BASEADD%+3,136
50 REM
55 REM COLLISION DETECTION
56 REM
60 OUT BASEADD%,&HF
70 PRINT "FORWARD"
80 REM
90 DAT%=INP(BASEADD%+2)
100 IF DAT% AND  64 =   0 THEN GOTO 150
110 IF DAT% AND 128 =   0 THEN GOTO 150
120 IF DAT% AND  64 =  64 THEN GOTO 130
130 IF DAT% AND 128 = 128 THEN GOTO 60
140 REM
150 OUT BASEADD%,&H0
160 PRINT "REVERSE"
170 REM
180 FOR X=1 TO 5000
190 NEXT X
200 REM
210 GOTO 60
```

Listing 5. Collision detection.

FORWARD
STOP
REVERSE
STOP
FLASH
RIGHT TURN (SLOW)
STOP
LEFT TURN (SLOW)
STOP
FLASH
RIGHT TURN (FAST)
STOP
LEFT TURN (FAST)
FLASH
STOP

Assembly language (8086, 80286, 80386) programs could also be written for controlling the robot, but this is beyond the scope of this article as is the use of other high level language programming languages such as C and PASCAL.

Improved Version of I/O Card

An upgraded version of the I/O card is now supplied by Maplin. This now includes a 1A fuse and a larger separation of +5V and 0V pins on the 37-way D-type connector to minimise accidental short circuits. The connector has also been repositioned to avoid fouling the case of some 'less than 100% IBM-compatible' PCs.

References

1. Practial Robotics Techniques, 'Electronics' Issues 42 to 44.
2. 24-line Programmable I/O Card for IBM PC and Compatibles, 'Electronics' Issue 43.
3. Intel 8255A Programmable Peripheral Interface Data Sheet

Parts List

LP12N	IBM Expansion Kit	£21.95
XK97F	8255 Leaflet	80p
XA42V*	'Electronics' Issue 42	£1.45
XA43W*	'Electronics' Issue 43	£1.45
XA44X*	'Electronics' Issue 44	£1.45

(*These are required if you do not already have copies!) Construction details for the IBM Expansion Kit, in the form of the updated Maplin Magazine article from issue 43 are provided with the kit. This also includes a parts list for the test circuit.

Further Reading

The following books may be useful in connection with experimental work undertaken along the lines of the material in this article:

WT32K	IBM PC Assembly Language and Programming	£19.95
WT35Q	Assembly Language Subroutines for the 8086	£19.95
WT54J	GW-BASIC for Beginners	£17.45

MAPLIN'S TOP TWENTY KITS

POSITION			DESCRIPTION OF KIT	ORDER AS	PRICE	DETAILS IN		
1.	(5)		MOSFET Amplifier	LP56L	£20.95	Magazine	41	(XA41U)
2.	(1)		TDA7052 Kit	LP16S	£ 4.95	Magazine	37	(XA37S)
3.	(4)		L200 Data File	LP69A	£ 4.75	Magazine	46	(XA46A)
4.	(2)		1 300 Timer	LP30H	£ 4.95	Magazine	38	(XA38R)
5.	(8)		IBM Expansion Sys	LP12N	£21.95	Magazine	43	(XA43C)
6.	(3)		Live Wire Detector	LK63T	£ 4.75	Magazine	48	(XA48C)
7.	(6)		Car Battery Monitor	LK42V	£ 9.25	Magazine	37	(XA37S)
8.	(9)		Vehicle Intruder Alarm	LP65V	£11.25	Magazine	46	(XA46A)
9.	(7)		Courtesy Light Extender	LP66W	£ 2.95	Magazine	44	(XA44X)
10.	(-)	NEW ENTRY	RS232/TTL Converter	LM75S	£10.75	Magazine	31	(XA31J)
11.	(18)		PWM Motor Driver	LK54J	£10.75	Best of Book	3	(XC03D)
12.	(15)		Low Cost Alarm	LP72P	£16.95	Magazine	45	(XA45Y)
13.	(13)		MSM6322 Data File	LP58N	£12.95	Magazine	44	(XA44X)
14.	(-)	RE ENTRY	TDA2822 Stereo Amp	LP03D	£ 7.95	Magazine	34	(XA34M)
15.	(10)		LM386 Power Amplifier	LM76H	£ 4.60	Magazine	29	(XA29G)
16.	(16)		LM353 8W Amplifier	LW36P	£ 7.95	Catalogue	'93	(CA10L)
17.	(17)		Partylite	LW93B	£12.45	Catalogue	'93	(CA10L)
18.	(20)		Rec Playback	LM80B	£31.45	Magazine	30	(XA30H)
19.	(12)		Mini Metal Detector	LM35Q	£ 7.25	Magazine	48	(XA48C)
20.	(19)		15W Amplifier	YQ43W	£ 7.95	Catalogue	'93	(CA10L)

Over 150 other kits also available. All kits supplied with instructions.
The descriptions are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate project book, magazine or catalogue mentioned in the list above.

NEXT issue

In next month's super festive issue of 'Electronics – the Maplin Magazine', there are some really great projects and features for you to get your teeth into! The December issue is on sale 6th November, available from Maplin's regional stores and newsagents countrywide, and of course by subscription (see page 30 for details). To whet your appetite, here's just a taster of some of the goodies on offer:

VINTAGE RADIO

A new series in which Geoff Arnold, delves into the nostalgic world of vintage wireless collecting. As he reveals in the first part, this hobby may be a lot more popular than you think – encompassing military, professional and recording equipment in addition to the old 'steam radio' set cherished by so many people. Included throughout the series are beautiful photographs of the sets themselves, all of which have far more character than modern equipment – and that's not just because the

majority employ valves as their active devices! If the article fires your enthusiasm, practical guidelines on starting your own collection are given.

CO-PROCESSORS

Co-processors are designed to complement the popular Intel microprocessors, as used in the industry-standard IBM PCs and their clones. They speed up maths-intensive operations (CAD, spreadsheets, etc.) considerably – as they should; after all, they don't come cheap! But which one is best for your needs? Frank Booty comes up with the answers, with some courtroom drama thrown in for good measure, in this special feature.

BOB'S MINI CIRCUITS

Robert Penfold, by popular demand, is back with five circuit designs for you to build or experiment with. There's a field strength meter for radio-controlled models, a sensitive flash slave for the amateur photographer, and no less than three projects for the electronically-inclined musician; tremolo, dynamic tremelo and 'wah-wah' effects units are all waiting to be built in the December issue!

MUSEUM OF THE MOVING IMAGE

This is probably one of the most original, entertaining and lively museums in London. Intrepid 'Out and About' reporter Alan Simpson takes a look behind the scenes, and finds out what makes MOMI tick. And that's not all – six lucky readers can win free double tickets to sample the delights for themselves!

SATELLITE TV SYSTEMS

We all know that Christmas TV, ahem, is not what it used to be. To get away from the 50th showing of that James Bond film, and those other tedious repeats, set your televisual aspirations skyward towards the Clarke Belt. A look at this article will tell you 'what you're missing' – and there's a lot more to it than B-Sky-B!

FROST INDICATOR

An appropriate project for the time of year! This little circuit can be installed in a car to provide warning, via an LED, of potentially icy roads – the cause of so many motor accidents each year. But its use is not limited to winter; the Frost Indicator could also be of great benefit in your freezer when summer reaches us once again. The temperature sensor is a precision thermistor, and can be installed wherever monitoring is required.

FEST-O-METER

This year's fun Christmas project is the Fest-o-meter. Place your thumb on the 'thumb park' and see how many LEDs you can light up – are you a Scrooge or a Cracker? The Fest-o-meter, an ideal stocking filler, relies on the resistance of the skin, which varies with its moisture content, to complete a circuit. Its usefulness may outlive the festive season as it can be employed as a lie detector – liars supposedly sweat more!

RADIO ASTRONOMY

Douglas Clarkson goes into some depth about this fascinating subject which, to the general public, is synonymous with Jodrell Bank. The history and principles of radio astronomy, along with the important discoveries made with its help, are all outlined. Such discoveries include quasars, pulsars, and even background radiation dating back to the Big Bang. And, as you've by no doubt guessed, the Cheshire-based Jodrell Bank complex plays an important part in the story.

PRECISION STEREO VU-METER

MODULAR MIXING SYSTEM

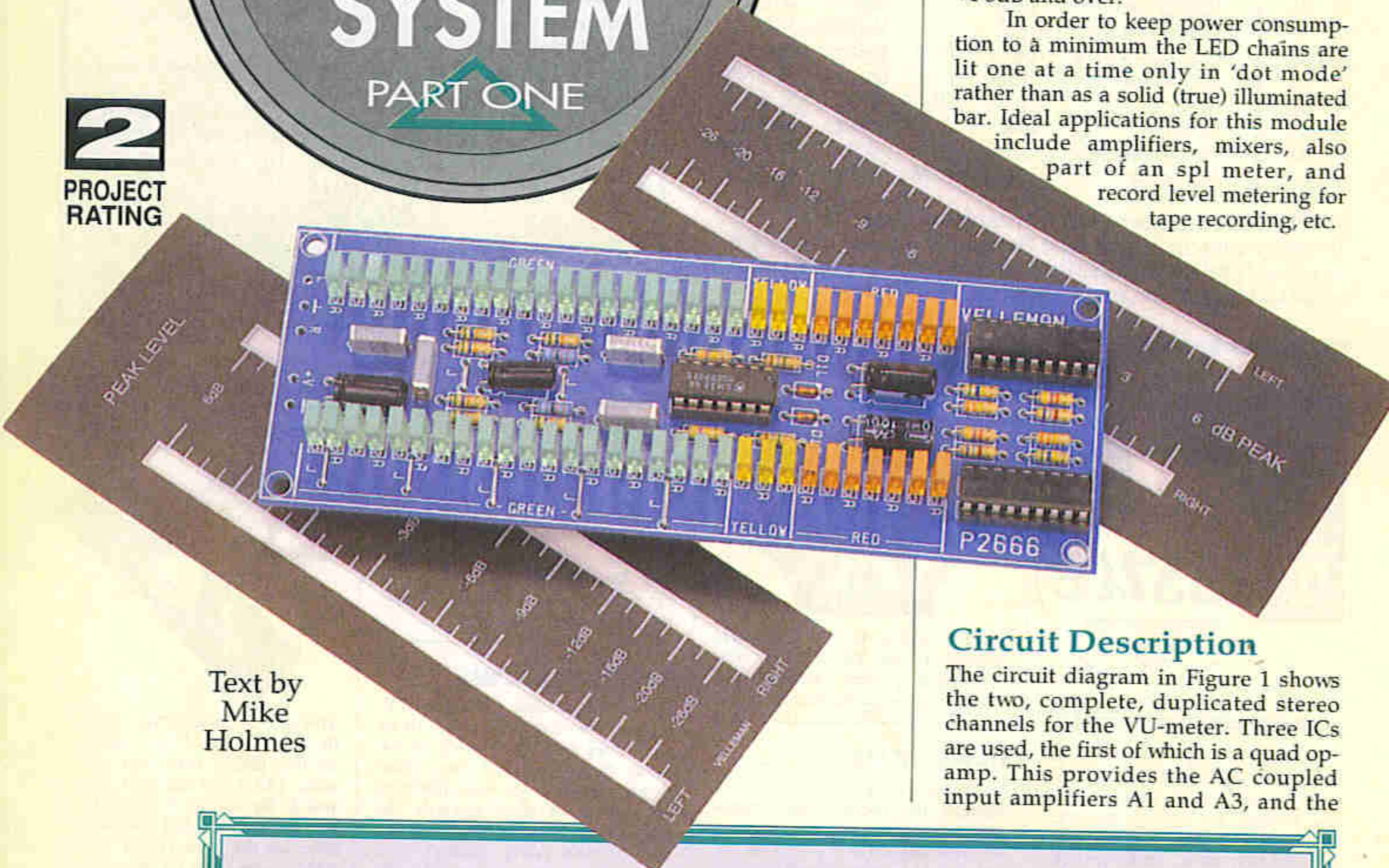
PART ONE

2 PROJECT RATING

This VU-meter combines both a high precision and large scale readout in a compact size; the finished module is only 149 x 55mm in size. The module is intended to be used as a building block as part of the series of audio mixer modules currently shown in the Velleman Kits section of the 1993 Maplin Catalogue, but this doesn't mean that it cannot be utilised in some other stereo audio application.

In use, the strength of a stereo signal is indicated over a range of −26dB to +6dB using 30 rectangular LEDs. The scale is dB-linear over the range −6dB to +6dB, each LED corresponding to 0·75dB (16 used over this range). The whole display is 105mm (4⅛") in length providing a generous viewing area, and interpretation of the display is made easier through the use of three LED colours; green from −26dB up to −1·5dB, yellow for −0·75 to + 0·75dB (i.e., in the region of 0db), and red for +1·5dB and over.

In order to keep power consumption to a minimum the LED chains are lit one at a time only in 'dot mode' rather than as a solid (true) illuminated bar. Ideal applications for this module include amplifiers, mixers, also part of an spl meter, and record level metering for tape recording, etc.



Text by Mike Holmes

Circuit Description

The circuit diagram in Figure 1 shows the two, complete, duplicated stereo channels for the VU-meter. Three ICs are used, the first of which is a quad op-amp. This provides the AC coupled input amplifiers A1 and A3, and the

FEATURES

* −26dB to +6dB Scale * 30 LEDs Per Scale
* LEDs Illuminate in Dot Mode
* Three Colour Scale, Green below −1·5dB, Yellow −0·75dB to +0·75dB, Red above +1·5dB
* Input Sensitivity 150 or 775mV
* Power Requirements 12 or 15V DC @ 50mA

APPLICATIONS

* Amplifiers * Record Level Metering
* Mixers * Tape Recording

Specification

Scale graduation:	−26dB to +6dB in 30 steps dB-linear from −6dB to +6dB
Input impedance:	56k
Input sensitivity:	150 or 775mV for 0dB, alterable
Power requirement:	12 to 15V DC @ 50mA, regulated

gain of these is determined by the value of R2L and R2R. The sensitivity of the meter depends both on the supply voltage level and the value of R2. For this reason a regulated supply must be used. The lower the supply voltage, or the larger the value of R2, then the greater the sensitivity of the meter. Four different values of resistors are provided in the kit for R2. For example, if 91k is chosen, then the meter will register 0dB for an input of 775mV RMS given a supply level of 12V DC, as indicated in the table below, which also shows the other values required for matching supply voltages and input levels to 0dB:

R2 Values		
Supply voltage:	12V	15V
0dB = 150mV RMS:	470k	510k
0dB = 775mV RMS:	91k	100k

The values 91k and 510k are high tolerance metal film types; the remaining two are 5% metal film as are all the other resistors. If the module is to be used with one of the modular mixing panels then the value of R2 needs to be 100k. Should you need another scale of sensitivity or a supply voltage between 12 and 15V DC, then there are one or two options open. You can either temporarily fit a preset potentiometer in the R2 position (of a value between 500k to 1M, say) and find the final value (after trimming to the required level using a test signal of the required amplitude) by measurement, and substitute a fixed resistor of the (nearest) required value.

Alternatively R2 can be kept to a maximum value (use the 510k resistors for instance), and the input preceded by 10k preset attenuators as shown in Figure 3. In either case it is advisable, after having found the required adjustment, to replace the trimmers with fixed resistors or combinations of resistors. Only by using identical components in both channels can you be sure of maintaining a sensitivity difference between channels of less than 0·5dB.

Amplifiers A1 and A2 are also inverting providing 'virtual earth' inputs, meaning that the input impedance is entirely determined by R1. The non-inverting inputs of the op-amps are tied to VREF, which is maintained at half the total supply level by R10 and R11 and decoupled to ground by C5.

The second stage, using A2 or A4, also contained in IC1, is a 'peak picker', the function of which is to pick out the positive transient peaks of the signal and hold the charge on C3. The result of this is that the LED display has a fast rise time with a slow decay; this

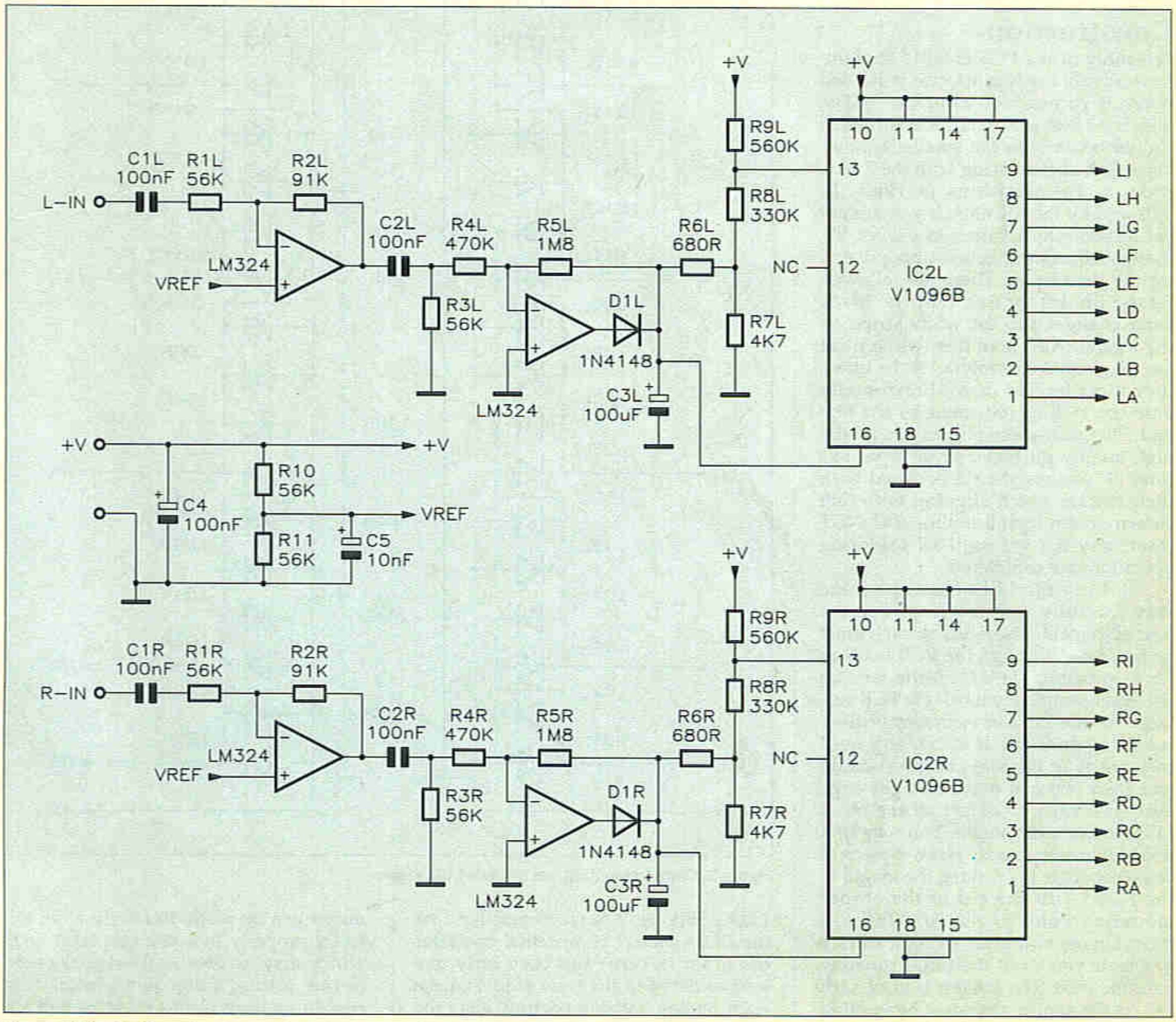


Figure 1. Circuit diagram.

ensures that peak levels are more accurately monitored. Diode D1 prevents C3 discharging via the amplifier's output, leaving a slow discharge path via R6 and R7. R5, the main part of the amplifier's feedback network, is given a high value to minimise the effect of current drain from C3. Note that diode D1 is also part of the negative feedback loop of the amplifier in order to compensate for the forward voltage drop across D1's junction. This ensures accuracy at the minimum sensitivity of the meter, which would otherwise be inaccurate due to the need for an input signal to overcome the forward voltage drop across D1 before registering on the scale. Interestingly, the bias reference for this stage is at 0V or earth potential, so that the amplifier is only able to produce positive going half cycles to charge C3.

IC2L and IC2R are complete voltage to bargraph display drivers containing all the necessary amplifiers, comparators and voltage references, and the manner in which the LED displays are connected is illustrated in Figure 2. It can be seen that the LEDs are connected in alternate, back-to-back pairs and the driver IC uses only nine lines to illuminate each of the thirty LEDs in turn.

Construction

Assembly of the PCB is fairly straightforward, although some care is needed when it comes to fitting the LEDs, which are best left till last. Construction should begin with the smaller components first, commencing with the 7 wire links at the positions marked 'J', followed by the resistors. If you are not yet certain which values to use for R2, these positions can be left unpopulated for the time being. These are followed by the diodes, noting that the black band is aligned to the white stripe on the legend. Also note that, while there are four radial electrolytics to be fitted, they must be laid down horizontally onto the PCB as indicated by the legend. The non-electrolytics are of the high quality polyester layer type. The three IC sockets should be fitted with their marker notch aligning with that shown on the legend outline. DO NOT insert any ICs yet until all soldering operations are completed.

Fitting the LEDs must be done very carefully in order to preserve a neat alignment. The leads of each must be be passed through the PCB holes as far as possible, until the little tabs on the leads completely touch the PCB surface. Fit one LED in each corner first, soldering only one lead initially until they are all at the same height (14mm), and then you can use a straight edge such as a ruler to adjust all the other LEDs to the same height. You may find it useful to temporarily screw a piece of wood, or angle bead along the length of the PCB (with the aid of the corner mounting holes provided); this will provide you with a flat, straight surface to enable you to fit the LEDs squarely onto the PCB. The longest lead of each LED is the anode, and must be inserted into the hole marked 'A' in each of the

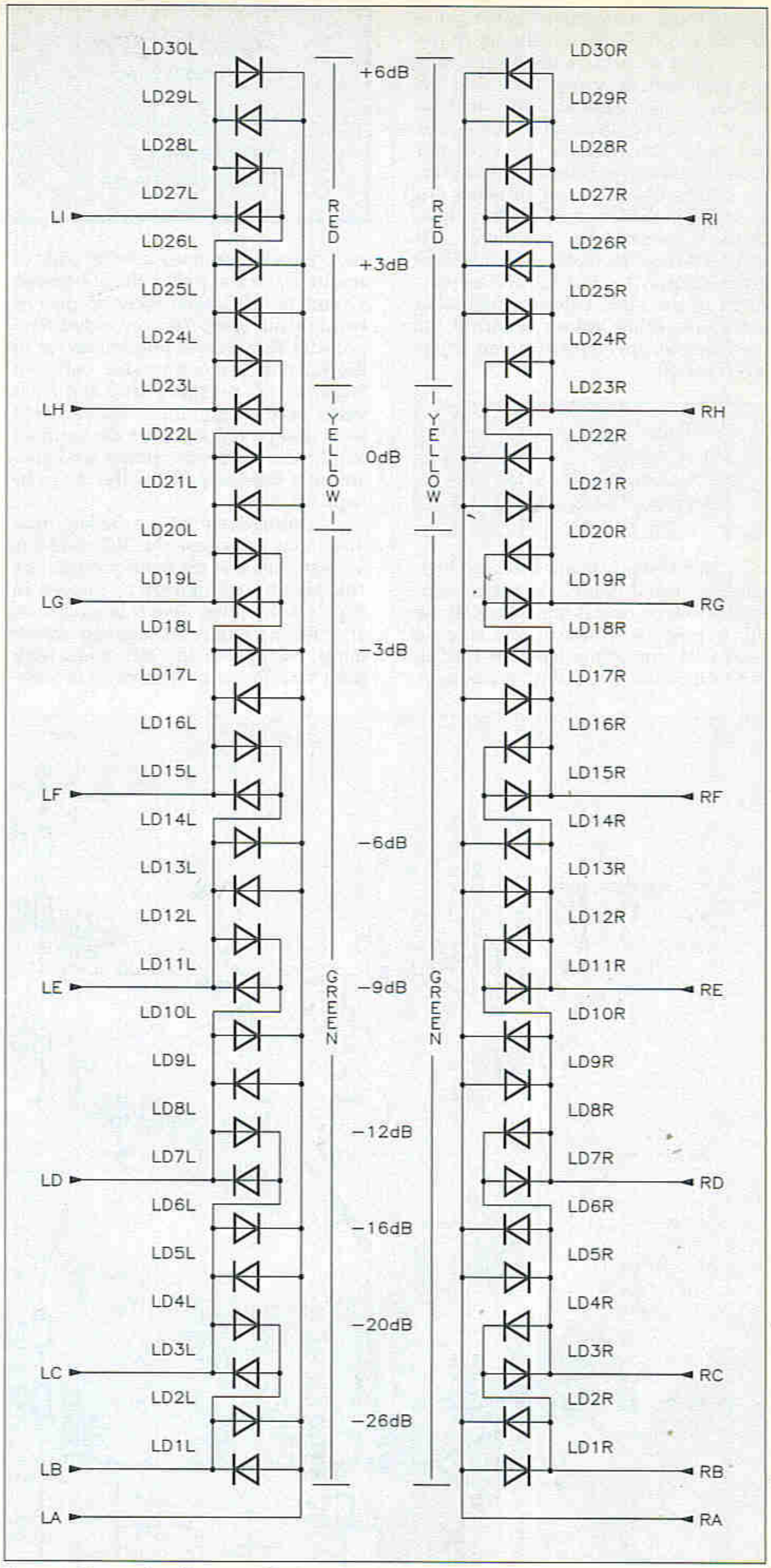


Figure 2. Connection diagram of both LED arrays.

LED positions. It is recommended that the LEDs should be installed one after the other in turn, and then only one lead soldered to the track side, and the leads remain untrimmed, until all of the LEDs are in place. Then fine adjustments can be made to finally align all LEDs properly in a straight, level line, which may involve re-flowing the soldered joints, once completed the remaining leads can be soldered and all leads trimmed with side cutters. The positions of the different LED colour groups are shown on the PCB. Note that while the 'RED' LEDs appear to be orange (in orange packages), they do in fact emit red light.

Connections

Connection wires can then be soldered to the supply and input points. It is not recommended that PCB pins are used, on account of the fact that these may foul the front panel when finally installed, resulting in short circuits. If the signal wires are long it may be necessary to use screened cable if the sensitivity is high. In most cases however, (including that of installation in the Modular Mixing Panel) it shouldn't be necessary. After these wires have been attached, the ICs can be safely inserted into their respective sockets. IC1, an LM324 or equivalent, is placed in the IC1 position with its orientation marker notch towards diodes D1L and D1R (aligned with the IC socket notch). Similarly IC2R (U1096B) at bottom right has its notch facing the LEDs, while IC2L at top right has its notch facing outwards towards the PCB edge.

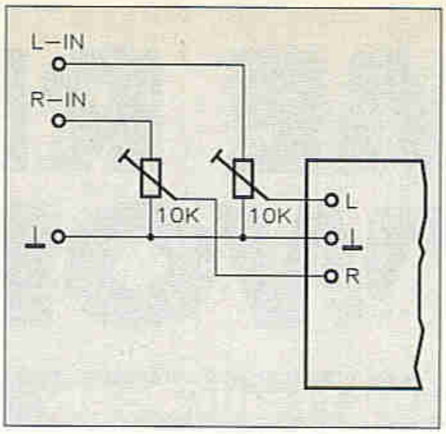
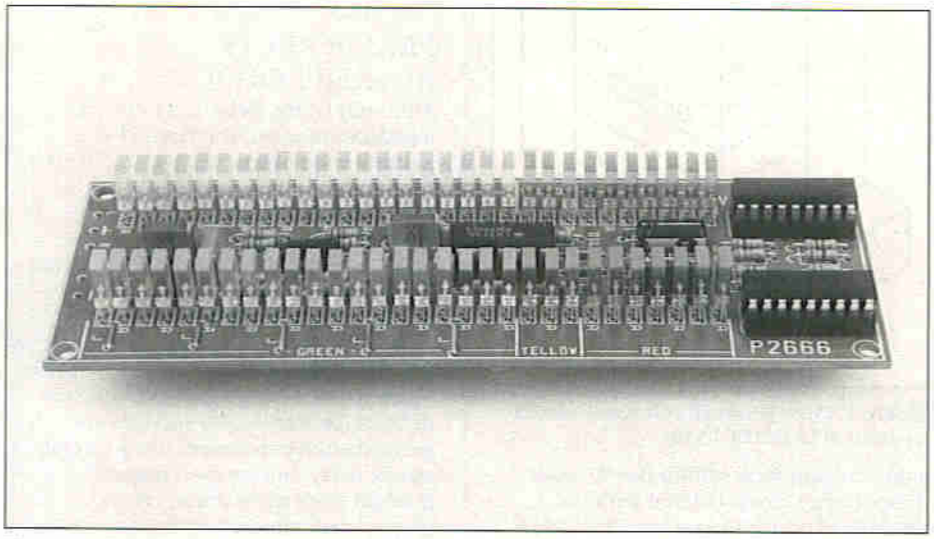


Figure 3. How to connect an input attenuator.

A STABILISED DC supply of 12V minimum to 15V maximum should be connected to points '+V' and earth (upside-down 'T' symbol) on the board, and the supply current is approximately 50mA.

Thanks to its relatively high input impedance of 56k, the VU-meter can be connected to almost all signal sources, but the input must never exceed 3V RMS or possible damage to IC1 may result. However, if the signal level is high, then use 10k attenuator presets before the inputs, as shown in Figure 3.



The assembled VU-Meter.

Mechanical Considerations

If the module is going to be used with the Professional Modular Mixing Panel then this panel includes a calibrated dB scale and the VU-meter will go straight in. If, however, you wish to use the meter in your own project or for other purposes, then it is thoughtfully provided with a choice of two calibrated, plastic scales with white lettering on a matt black background. One is used for vertical mounting while the other is designed for horizontal use. Either of these will require a front panel cut-out of at least 115 x 35mm, over the front of which the plastic scale must be glued with a suitable water based adhesive, otherwise damage will be done to the rear of the scale if a solvent glue is used. This is because the scales are screen-printed on the rear and a solvent could dissolve the ink. Alternatively double-sided tape, such as carpet tape, could be used. The VU-meter PCB can be mounted on the rear of such a front panel with the aid of four 14mm, M3 mounting pillars if your panel is at least 1mm or more thick. If thinner, then plain washers can be used under each pillar to effectively increase the height. If this is not done properly the LEDs may protrude through the front panel and prevent the plastic scale seating flatly onto the panel. At the same time you don't want the LEDs to be too far behind the scale, as its rectangular windows are diffused and will blur the display.

Suitable spacers such as the threaded FG38R (pack of ten), with countersunk head M3 x 6mm screws (BF36P), since the plastic scale will cover the screw heads which must be flush with the panel surface.

PRECISION STEREO VU-METER PARTS LIST

RESISTORS: All 5% Metal Film (Unless specified)		
R1R/L,R3R/L, R10,11	56k	6
R2R/L	91k 1% Metal Film or	2
	100k or	2
	470k or	2
	510k 1% Metal Film	2
R4R/L	470k	2
R5R/L	1M8	2
R6R/L	680Ω	2
R7R/L	4k7	2
R8R/L	330k	2
R9R/L	560k	2
CAPACITORS		
C1R/L,C2R/L	100nF Polylayer	4
C3R/L,C4	100µ F 25V Radial Elect	3
C5	10µ F 50V Radial Elect	1
SEMICONDUCTORS		
D1R/L	1N4148 or 1N914	2

IC1	LM324 or equivalent	1
IC2R/L	U1096B	2
LD1-20R/L	Rectangular LED Green	40
LD21-23R/L	Rectangular LED Yellow	6
LD24-30R/L	Rectangular LED Red	14
MISCELLANEOUS		
	14-Pin DIL IC Socket	1
	18-Pin DIL IC Socket	2
	PCB	1
	Leaflet	1

The Maplin 'Get-You-Working' Service is available for this project, see current Maplin Catalogue for details.
The above items are available in kit form only.
Order As VE35Q (VU-Meter Kit) Price £39.95.
Please Note: Some parts, which are specific to this project (e.g., PCB), are not available separately.

FRAME RELAY NETWORKS

by Frank Booty

There is a 'new' networking technology, known as 'Frame Relay' which overcomes many of the deficiencies of X.25, in particular those of through-put. Frame Relay is a network access standard, and thus has an affinity to X.25. But it follows the principle that data is transmitted over a network as a complete block of information of any length, rather than made up of fixed, predimensioned data packets. But there are other important differences between Frame Relay and X.25. In the latter, the data link layer (which is equivalent to the OSI layer two) provides for reliable data transfer across the data link between the terminal (DTE) and the network (DCE), and implements 'Link Access Procedure Balanced' (LAPB) communication, which is a subset of the ISO 'High Level Data Link Control' (HDLC). Addressing, routing, multiplexing and demultiplexing and other functions in X.25 are accomplished at the network layer (OSI layer three).

Frame Relay implements addressing and multiplexing at the data link layer. This is accomplished by the use of LAPF, a version of the ISDN link access protocol LAPD (the Link Access Protocol used over the D channel is emerging as a standard for high-speed packet networks). LAPF provides logical channel identification and multiplexing demultiplexing, in addition to the link layer functionality provided by LAPB. Frame relay operates wholly within the data link layer and provides statistical multiplexing of different users' data streams.

These data streams are called 'Data Link Connections' (DLCs). Each DLC is assigned an 'Identifier' (called a DLCI) at the time a call is established, and frames carry this DLCI throughout the call. The scope of the DLCI is normally limited to a single physical link. A typical virtual circuit will span a number of network links,each with a different DLCI mapped to the virtual circuit.

Currently, Frame Relay networks operate with 'Permanent Virtual Circuits' (PVCs), which are set up for point-to-point connections across the network. In order to set up a 'Switched Virtual Circuit' (SVC) across a network, the value of the DLCI and other associated parameters will be negotiated for each link in the network during the set-up of the call, by means of 'C-plane' procedures (see Figure 1). The C-plane, or Control Plane's, protocols relate to the establishment and control of calls,

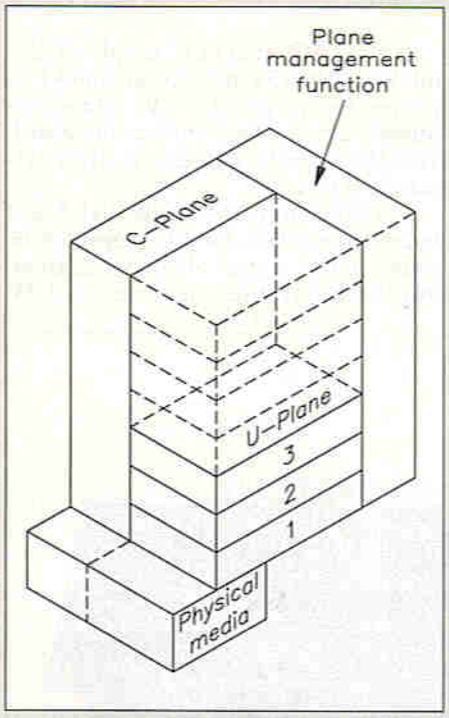


Figure 1. ISDN protocol reference model as defined in CCITT I.320.

whereas protocols within the 'U-plane' (User Plane) are associated with the transfer of user information. The Q.933 standard is intended to enable end-to-end SVC functionality.

Essentially, Frame Relay provides a multiplexed service that focuses on transporting variable length frames from one end of the network to the other as quickly and simply as possible. Frame Relay standards (outlined in I.233) define the following set of core functions in layer 2 that the network will offer: frame delimiting, alignment and transparency; frame multiplexing and demultiplexing using the DLCI; inspection of the frame to ensure that it consists of an integer number of octets prior to zero bit insertion or following zero bit extraction; inspection of the frame to ensure that it is neither too long nor too short; and detection of transmission errors (no correction procedures).

Figure 2 shows the user/network interface protocol reference model showing the interaction of the C-plane and U-plane standards.

FRAME RELAY BEARER SERVICES

Although Frame Relay is a network interface standard, the Frame Relay packet mode bearer service standards have been defined, and public Frame Relay services, ranging from 64k-bit/s to 2·048M-bit/s, are becoming available. Once implemented in networks, Frame Relay will be a connection-orientated service which preserves the order of frames, does not duplicate frames and has a very low probability of frame loss. The 'Quality Of Service' (QOS) parameters defined for frame relay services are: performance parameters (through-put, transit delay, information integrity, residual error rate); frame errors (duplicated frames, frames delivered out of sequence, lost frames, mal-delivered frames); virtual circuit performance parameters (switched virtual circuit establishment delay, switched virtual circuit call establishment failure, premature disconnect, switched virtual circuit clearing failure).

As well as these functions, Frame Relay service functions in the U-plane provide for the acknowledged transport of frames, detection and recovery from

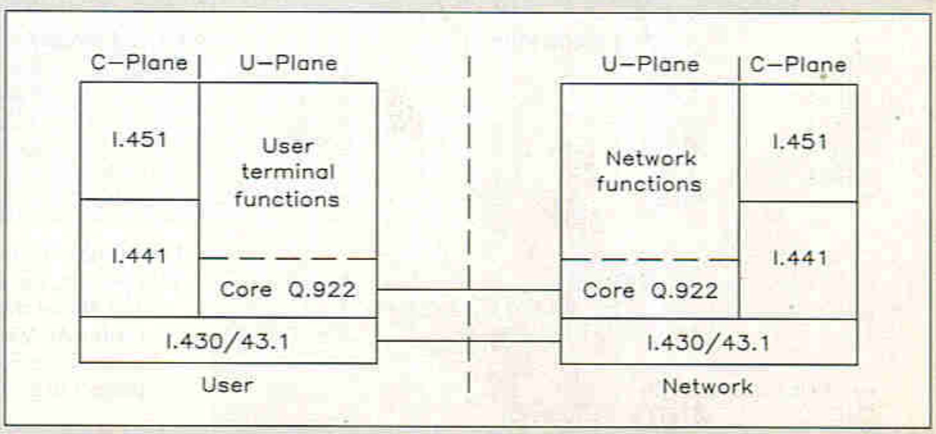


Figure 2. Frame Relay user/network interface protocol architecture.

transmission, format and operational error, detection and recovery of lost or duplicated frames and flow control.

Frame relay does not offer error recovery within terms of the standard. The standard does, however, allow for end-to-end checking by the end system entities at the data link layer, and also by higher layer U-plane functions in the end system application entities. Figure 3 shows the Frame Relay protocol layers.

The major advantages of Frame Relay over X.25 are simplicity (there's no complex network layer software) and speed (hardware switching). The disadvantages are the necessity for error recovery to be provided by higher layer procedures outside the network (although this is a less significant factor in the era of low error rate digital circuits), and the need for congestion control procedures.

In summary, Frame Relay is a technology which is being deployed for private and public data networks which require faster through-put and lower delays than X.25 can provide. Figure 4 shows the differences between Frame Relay and X.25. The benefits of Frame Relay include higher network through-put, lower delays, possibility of economical hardware implementation in silicon, protocol transparency, relatively simple software conversion for changing equipment from X.25 to Frame Relay, and Frame Relay offers a migration path to ATM (Asynchronous Transfer Mode).

APPLICATIONS

One of the most useful applications for Frame Relay is LAN interconnection. The benefits include high-speed connectivity, lower delays and no compromises on full connectivity. Of course, such a network may be private or public. Although Frame Relay was developed primarily for wide area data network applications, this technology can also be used for voice traffic. In practice, to ensure the low delay necessary for speech clarity, shorter frames are employed and voice traffic is given higher priority. This type of implementation enables true integration of voice and data.

In many ways the development of Frame Relay has been the opposite of that of ISDN. Whereas ISDN has been waiting in the wings for years and is *still* not readily available to most users, Frame Relay products were available almost before the technology had been fully defined. Some problems with the initial Frame Relay specification are only now being addressed by the Frame Relay Forum, which is agreeing standards in advance of their formal ratification by the standards body ANSI.

Despite the fact that the standard is still being refined, however, manufacturers are integrating Frame Relay into their products at an ever faster rate. The main reason is that Frame Relay is an interim technology, with a limited life span. As it is accepted that it will be superseded by ISDN, suppliers are hoping to get as much mileage out of it as possible and are pushing ahead as fast as they can. While Frame Relay was primarily developed because of the hole left by the non-availability of ISDN, it is the threat of ISDN looming in the background which is giving rise to the activity.

FUTURE IMPLEMENTATION OF FRAME RELAY

The transience of the technology was highlighted by BT North America, when the ExpressLANE public Frame Relay service was launched in the US late in 1991. BT published a four stage strategy covering the move from X.25 to

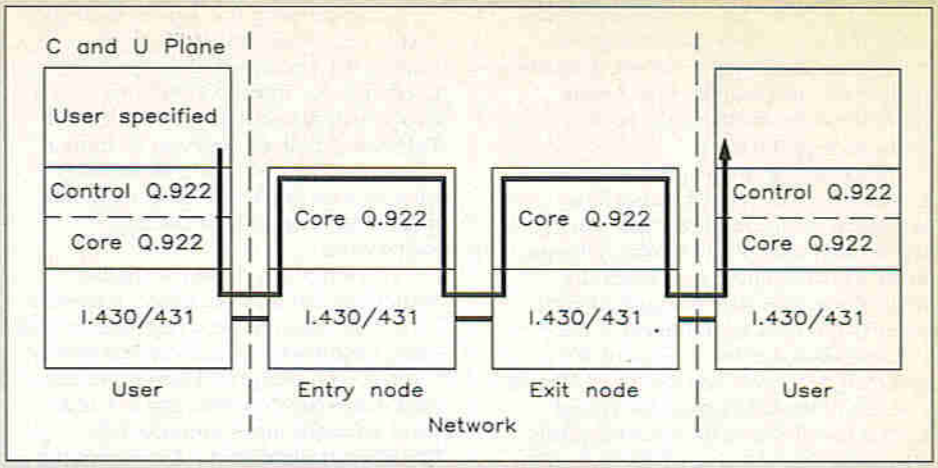


Figure 3. Frame Relay protocol layers.

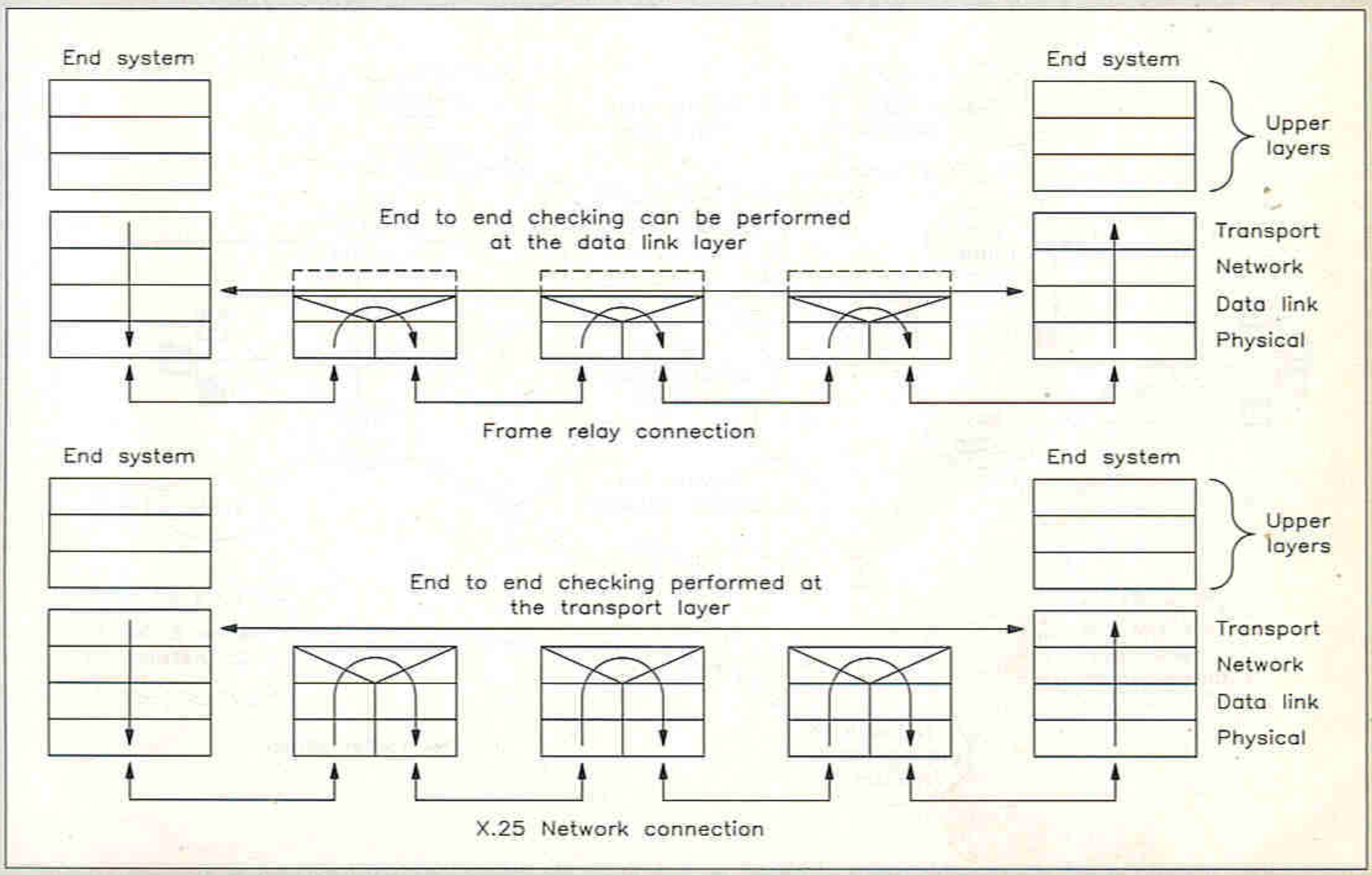


Figure 4. Frame Relay and X.25 error checking procedures.

Broadband ISDN, taking in Frame Relay along the way. While the strategy was mainly designed to give users a migration path, it also emphasised how Frame Relay is a short term answer to an immediate problem.

Stage one of the plan involved the launching of the hybrid Frame Relay service, transporting both X.25 packet traffic and Frame Relay traffic. A Frame Relay software interface statistically multiplexes user data to allow a Frame Relay based LAN interconnect service.

Stage two, set for the end of 1992 and early 1993, will see Switched Virtual Circuits replacing Permanent Virtual Circuit based Frame Relay connections. BT claims this will give a fully fledged dynamic Frame Relay service. Stage three, in 1994, will introduce a broadband backbone which will enable data to be switched at T3/E3 speeds. Finally stage four, expected to be in place in 1995, will see the migration to Broadband ISDN, with ATM architecture.

COMPATIBILITY

In addition both manufacturers and suppliers have been working hard to demonstrate that Frame Relay does work as it is supposed to, which has involved many demonstrations of how the technology works and particularly, that it works across different suppliers' products. This latter point is a key concern. With so many people working independently to develop products which conform to a non-established standard, it begs the question of compatibility problems if different products were used together. To prove the case, the latter part of 1991 and beyond saw unprecedented levels of co-operation between erstwhile competitors.

A display of faith in the technology was to be seen in late 1991 at the Interop '91 exhibition in San Jose, California. Six Interop exhibitors, two public Frame Relay networks and Telecom '91 all got together to form a 1·544M-bit/s T1 network, connecting Interop with the Telecom show taking place simultaneously in Geneva, Switzerland.

Three of the exhibitors, Digital, StrataCom and Sync Research, formed a backbone network between their booths using StrataCom IPX networking systems. Cisco, CompuServe and SynOptics also linked into the network, and live links were arranged into CompuServe's FRAMEnet public Frame Relay network from the CompuServe booth. Geneva was linked in from the StrataCom stand over the WilTel WilPak public Frame Relay network, using WilPak and WorldCom domestic and international circuits, to WilPak, WorldCom's Geneva based service using its domestic and international service.

The TMA show, held in Brighton in late November every year, also saw suppliers demonstrating the versatility of the technology. BBN Communications claimed a UK first with what was hailed as the first UK demonstration of multimedia applications utilising Frame Relay, X.25 and high-speed bandwidth management.

Manufacturers have also been working to broaden the range of applications which Frame Relay can support. Two companies, FastComm and Dowty, have shown systems capable of transporting voice connections over Frame Relay. FastComm got round any problems using Critical Information Rate technology, which reserves bandwidth to ensure a minimum of traffic gets through. If this minimum of traffic cannot be passed because of the high incidence of data traffic, the data is buffered until the voice traffic has been passed.

The system pioneered by Dowty – launched at the TMA show – uses a new networking architecture, FPX 2000, which can be used to carry two classes of voice traffic (see Figure 5). That suppliers should be evolving different solutions for the same problems is typical of the way Frame Relay is developing. It is not just in the development of the technology that suppliers are differing, but also in how it should be implemented. The main differences have been in the optimum speeds at which the services should be run and how those services should be tariffed.

In the US, which has set the pace, BT North America commissioned Ernst and Young to analyse potential customer requirements. The conclusion was that, for most of the LAN interconnect market, customer access speeds of 56/64k-bit/s and transmission speeds of 256k-bit/s would be satisfactory. Other suppliers with competing services however, differ. CompuServe introduced a service with access speeds of up to 1·024M-bit/s. The company felt that, since the major benefit of Frame Relay is the increased through-put levels, users will want to take advantage of this as much as possible by opting for the highest available speeds.

AT & T has also gone for higher transmission speeds, although access speeds are to be offered at initially 56/64k-bit/s. Its InterSpan service will run at up to 1·536k-bit/s, again because it feels that speed is the major priority for users considering Frame Relay.

The decisions in the US do seem to

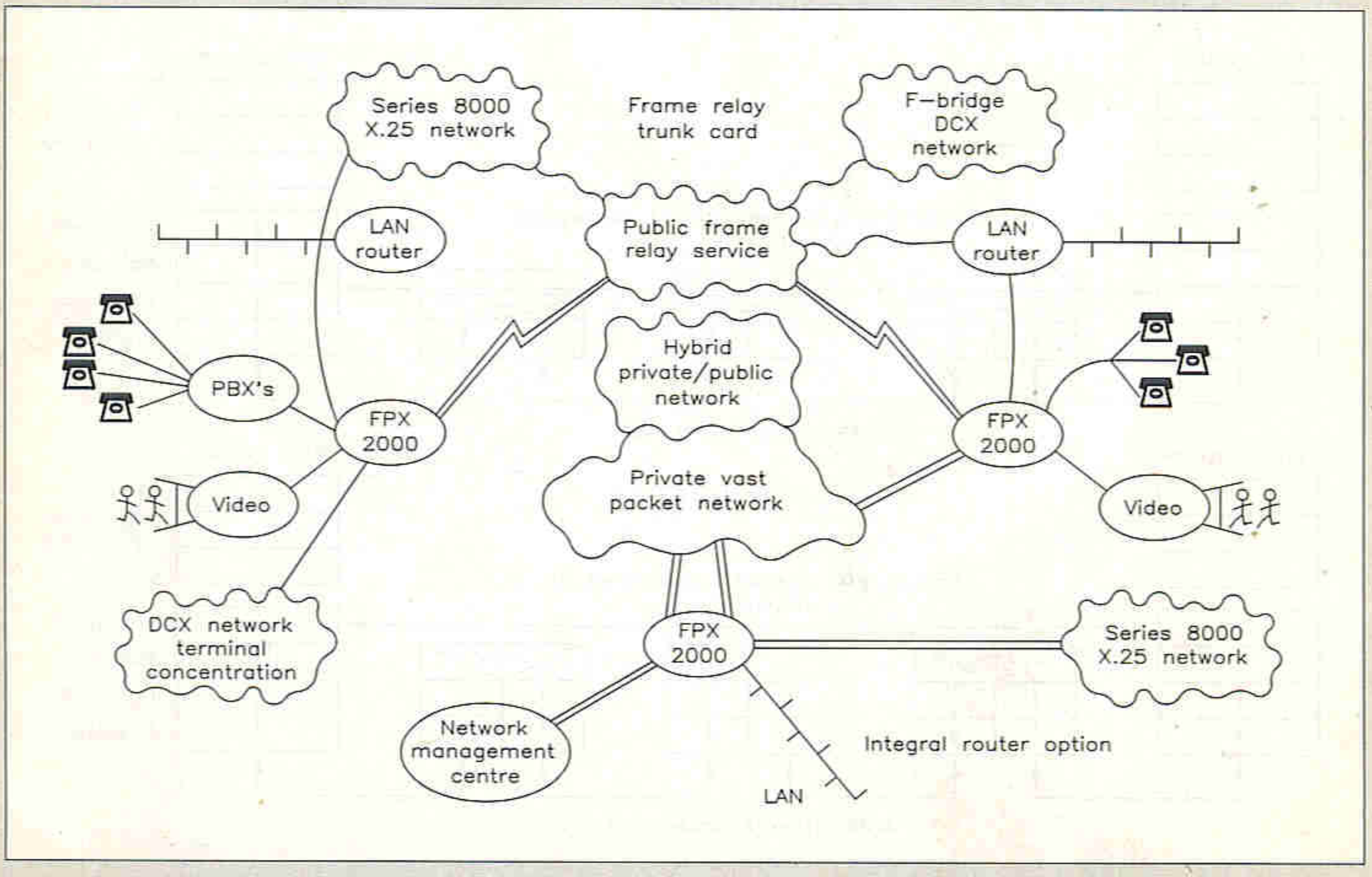


Figure 5. FPX 2000 strategy from dowty communications.

have had an effect in the UK and Europe, for our own BT delayed an announcement of a UK Frame Relay service in the Autumn of 1991. Was the pricing structure not right? Was there low customer take up? One may never know. The first European public Frame Relay service was launched in Finland by Telecom Finland. Here, the initial access speed is 64k-bit/s with transmission speeds of 1M-bit/s, but Telecom Finland has already said transmission is going to 2M-bit/s this year.

The Frame Relay capability was added to the existing DataNet LAN interconnection service, previously based on routers. The initial Frame Relay backbone consisted of five nodes, each of which can support 120 ports, although Telecom Finland is adding more switches.

SPREADING THE WORD

While the speed at which Frame Relay networks are rolled out is very fast, there are not many customers, which is usually attributed to a lack of understanding. So another reason for the demonstrations of compatibility and usage is to increase awareness of what the technology is and what it can do for users.

As a subject of international standardisation, Frame Relay can be seen as the successor to X.25 packet switching for the implementation of high performance WANs. Designed to support bursts of high-speed data over high quality (digital) links, Frame Relay can, in appropriate implementations, be used for relaying sensitive traffic such as voice or video, traditionally associated with circuit switched or Time Divisional Multiplexing (TDM) networks.

Frame relay will become widely used in private as well as public data networks, and is particularly suited to the interconnection of widely dispersed data systems such as X.25 networking components, networked statistical multiplexers and LANs. The use of variable length frames of information, rather than fixed length cells, is inherently more efficient at the sort of circuit speeds likely to be available before the general advent of Broadband ISDN.

Across the Board continued from page 21.

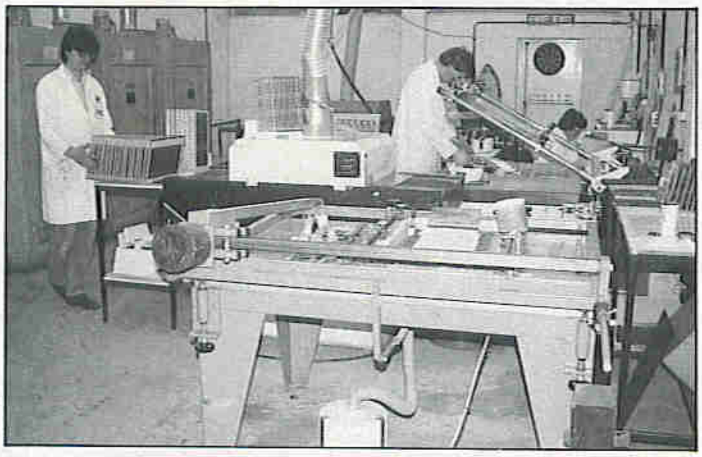


Photo 9. Screen printing is used to apply the solder resist and component identification layers. The blue machine in the foreground is one of several that PMS uses for this purpose.

Photo 11. If things can go wrong, they undoubtedly WILL go wrong. The machine pictured is used for modification work carried out at the request of the manufacturer.

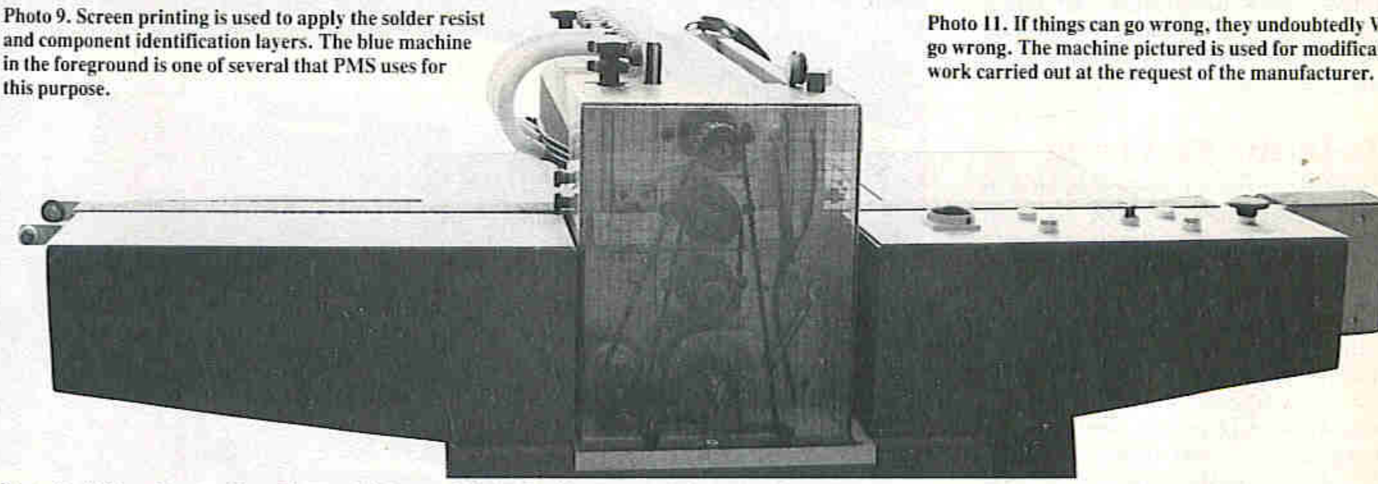


Photo 10. PCB scoring machine. The precision rotary blades that it uses cost £120 *each*!

up without breaking) and is barely perceptible.

In accordance with BS5750, PMS operates a Quality Control (QC) system which ensures that the quality of the PCBs is consistent at each stage of manufacture, from the moment it arrives at Goods Inwards, right up to the point at which it is sent to the customer. This includes monitoring such areas as plating thickness and electrical resistance. QC also monitors working procedures and the tolerances of processes themselves, ensuring that they adhere rigidly to the specifications of the British Standard.

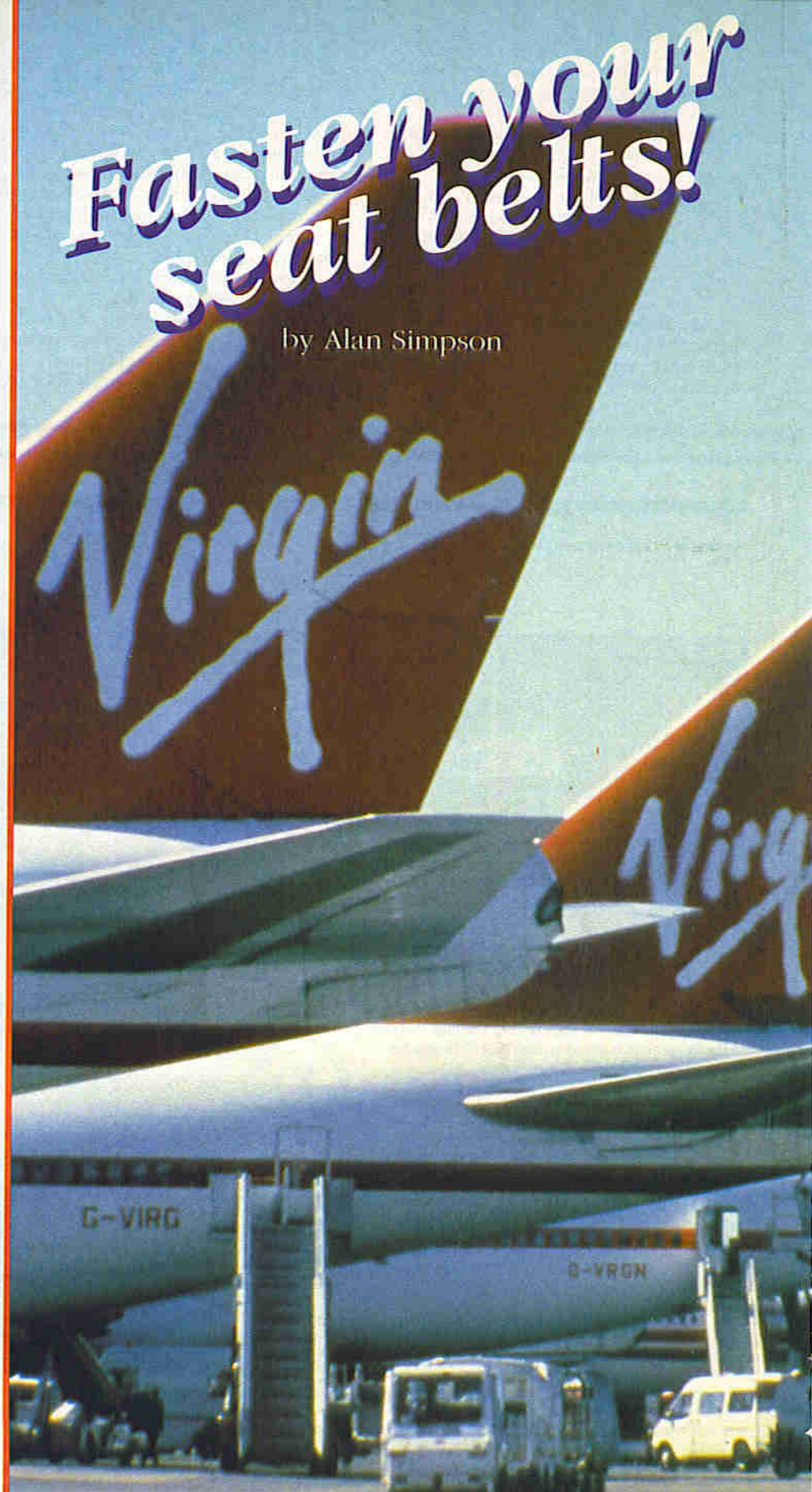
So there you have it. Industrial PCB manufacture is a very capital-intensive process and there is a lot more to it than meets the eye. As with most things, a large production run helps to keep the cost per board down, and this is why the PCBs supplied in Maplin's kits are available at such low prices. To put things into perspective, though, the Maplin NICAM decoder PCB retails for £6.95. If it were not for the large (thousands at a time) quantities ordered by Maplin, a board of this type could cost several hundred pounds if, say, only ten were required! Until the Versatronics V3000 was installed in the Maplin Development Lab, PMS was employed to make one-off prototype boards for the company, and these cost incredible amounts of money!

Acknowledgments

Acknowledgments are due to Brian Stivey, Richard Johnson, Ian Paterson and the rest of the staff at Photomechanical Services (Essex) Ltd for providing their valuable time, answering questions and allowing photographs to be taken.

Fasten your seat belts!

by Alan Simpson



There is, it seems, no escaping from Blackadder or Jonathan Ross. Even on a flight to some far-away place you can fasten your seat belt, relax and switch on your individual TV set with a choice of channels to suit all tastes. This is not some far away fantasy, but practical reality.

Already all Virgin Atlantic planes have been fitted with seat-back TV, giving access to Hollywood blockbusters, music, sport, comedy, and of course Blackadder repeats.

In fact, Virgin Atlantic have won an award – not for making better use of that unsightly seat-back, but for the 'Best In-flight Entertainment'.

Virgin is the first airline in the world to equip its wide-bodied air-craft with individual TV screens for every passenger, offering a choice of six channels of entertainment. The airline also won the 'Airline of the Year' award for the second year running (or should that be flying?) as well as 'The Most Attentive Airline Staff', 'Best Audio' and the best 'Transatlantic carrier' awards.

Virgin Atlantic have been making a habit of winning awards and passenger plaudits ever since their service began back in 1984. Just three years later, the airline celebrated its 1 millionth transatlantic passenger. The month of May 1989 saw the airline expanding its network to Japan, and two years later it was flying out of both Gatwick and Heathrow. Plans are underway for new flight paths to South Africa, Singapore and Australia.

Virgin Atlantic is of course part of the fast expanding empire of Richard Branson. His empire-building achievements include the start of Virgin Mail-order in 1970, the first Virgin record store in 1971 and the launch of the Virgin Record Label in 1973. The rest, as they say, is history. More recently the Radio Authority have granted Virgin the license for INR2, Britain's first national commercial rock station, which will start broadcasting next year.

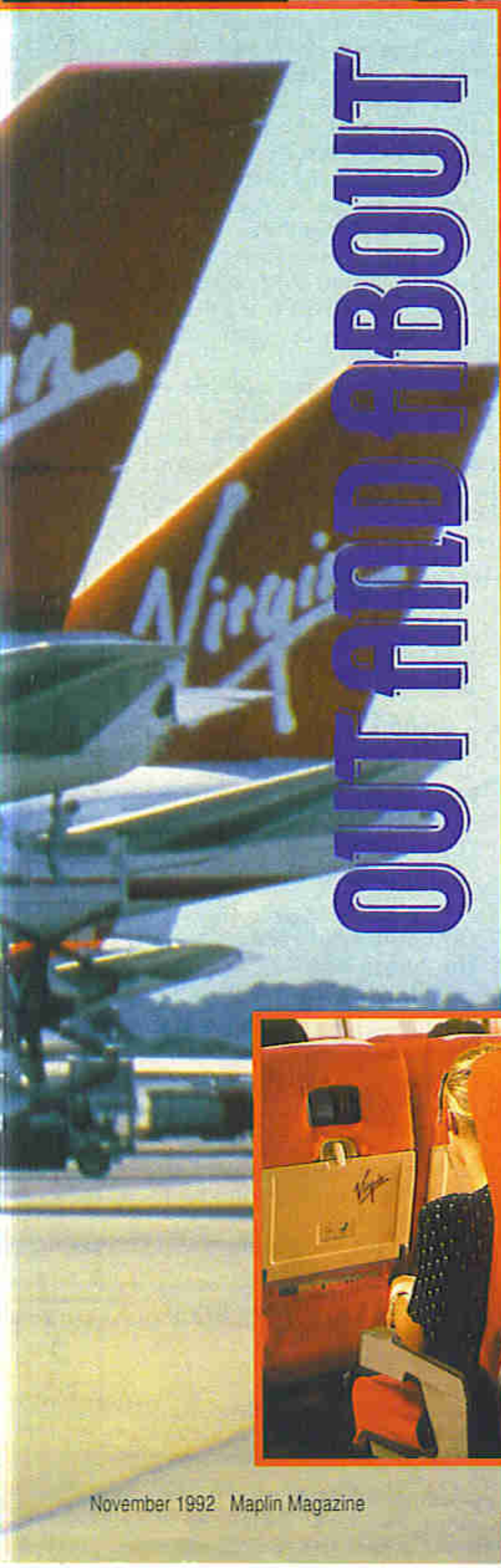
Life in the Fast Lane

Richard Branson himself is no slouch when it comes to creating records. In 1986 his boat, 'Virgin Atlantic Challenger II', crossed the Atlantic Ocean in the fastest ever recorded time. This was followed a year later by that epic hot air balloon crossing of the same ocean in 'Virgin Atlantic Flyer', which was not only the first hot-air balloon to cross the Atlantic, but the largest ever flown. A Branson balloon broke further records last year when he crossed the Pacific Ocean from Japan to the Arctic of Canada, a distance of 6,700 miles.

Not Just Hot-Air

For those who make note of such matters, Virgin Atlantic fly seven Boeing 747–200 airliners and one 747–100 from London (both Heathrow and Gatwick) to New

Top right: Upper class passengers enjoy a 6" LCD TV on an adjustable arm, whilst economy class have 3" or 4" screens (see bottom right).



York (Newark and JFK), Los Angeles, Miami, Boston, Orlando and Tokyo, mainly on daily schedules. However, if you want to enjoy the personal services of an 'in-flight beauty therapist' then you have to book 'Upper Class'. No wonder the airline suggests that booking is essential. This service gives a fresh meaning to that slogan 'Come Fly With Me'. The complimentary treatment includes a manicure or a head, neck and shoulder massage that includes the application of aromatherapy oils. A combination of Swedish, Pressure Point and Shiatsu massage effectively relieves tension and jet lag, and ensures that travellers arrive relaxed and refreshed at their destination.

It's a Hi-Tech, Hi-Flying World

It is not, however, just the First (sorry, Upper) Class passengers who benefit from individual TV screens. The airline has eliminated the old video projection main screen for all classes, replacing it with individual LCD TV screens for each passenger. It is not quite classless in-flight entertainment however. Upper Class passengers are equipped with a 6" LCD screen mounted on an adjustable arm, from the seat's arm rest. Economy Class have the benefit of a three or four inch screen, mounted on the back of the seat in front.

Although Richard Worrall, Virgin's Marketing Project Manager, sees a 12" video entertainment screen format as feasible, there are no plans at present to extend the choice above six channels. Since the system is centrally distributed, passengers choosing a full length movie will have to make a note of the starting times. Otherwise they can enter and leave the programmes at any stage.

In-seat video channels cover two film channels, with four movies on each channel; an arts and entertainment channel, comedy, sports and music channels, and a 'Kidzone' channel. Timing restraints do not affect the ten audio channels though, which serve to meet the needs of the most discerning passenger. Listening pleasures include rock, dance, chart, comedy, classical and, on certain routes, Captain Smilie's Radio Show for children.

Virgin is looking to digital quality sound and video, at which time a review will have to be made of the headsets. "The headset quality should match the system," says Richard Worrall.

Sit Back and Enjoy VTV (Virgin TV)

While the new personal TV monitors may not compare in terms of quality to wide-screen Nicam stereo, passenger response shows that 96% consider the system to be superior to other airlines' in-flight entertainment systems. 91% put the system into the excellent category, and for 80% of passengers the new personal TV screens would make them more likely to choose Virgin Atlantic above other transatlantic carriers.

Size apart, the quality of the picture is very good and the channel selection much appreciated. At least your immediate neighbours do not have to put up with six hours of Whitney Houston videos or repeated showings of Top Gun movies. Controlling the LCD equipment is easier than programming the proverbial VTR. Anyone who has handled a TV remote control will be familiar with the LCD system, which basically includes select, recall, volume, brightness and on/off.

Comfort Station

Passenger convenience does not stop at the LCD screen. Should you grow tired of the sight of Anneka Rice's Treasure Hunt bottom or 'Sleeping with Madonna', you can explore the contents of your complimentary Virgin Comfort Kit. This takes care of all those other little extras that are so essential to a pleasant flight. Inside each kit

Marketing Director Chris Moss receives the airline's 'Best Inflight Entertainment' award.

(stereo headphones apart) are eye shades, ear plugs and 'do not disturb' stickers for those who'd rather sleep; in-flight socks for tired feet and a toothbrush for tired teeth. And if you happen to be travelling Upper Class, your Comfort Kit includes lip balm, body spray, moisturisers and eye gel. All made from environmentally friendly ingredients of course. The airline also promises to supply a wide range of magazines on board ranging from computing to fashion. Don't forget to put in a request for your favourite 'Electronics' magazine to help digest your Upper Class gourmet meals!

Safety First and Fast

Not quite in the free take-away class, but an essential factor of international travel, are the on-board duty free products whose range includes– wait for it – Virgin Teddy Bears, Inflatable Dolphins and Biggles Bears! A more unfortunate event could be that of in-flight illness. Here again, Virgin Atlantic is setting the pace. The airline is now equipped with defibrillators to regulate the heartbeat of cardiac arrest victims. All senior crew on Virgin Atlantic flights now receive regular training in resuscitation and defibrillation techniques.

Virgin Atlantic are also pioneering the use of infant safety seats, similar in concept to infant car seats, but designed and tested for air travel. Until now it seems that the only method of restraining a young child onboard an airliner has been to seat the infant on a parent's lap and secure an extended seat belt around both adult and child. The new seat fits in the normal adult seat and is attached by the standard passenger lap strap. The child is then secured into their own seat in comfort and safety by a fully adjustable five point harness, with the type of buckle used on the Apollo Space Programme and on the Concorde flight deck. However, an ejector seat button is not included for the especially precocious child!

Closer to the ground, Virgin have installed ImageBase Technology's Photophone, an image transmission system, for use in trouble shooting maintenance problems between their Gatwick and Heathrow locations. The system transmits pictures and voice down a standard telephone line, using a camcorder and a colour video printer which prints A6 colour pictures. According to Paul Chappell, Virgin Atlantic's Chief Engineer "The Photophone gives us an essential communications link between our two engineering bases. It has reduced travel between Gatwick and Heathrow operations and has already paid for itself several times over, by ensuring that the length of time an aircraft is out of service for technical reasons is kept to a minimum. We are achieving our on-time performance objectives."

Keeping in Touch

Passenger in-flight communications are, it seems, just around the corner, or at least on the horizon. It will no longer be necessary to keep the busy businessman out of touch with his office and colleagues for a period of several hours. Delegates to a recent airline conference were told that this state of isolation will be short-lived as new levels of telephony reach for the skies. Until recently it has been a multi-channel problem which has held back the installation of in-flight telephones. Long haul carriers, says Richard Worrall, need multi-channel rather than single circuits. Now one US company, GTE, has developed a system which allows passengers to call any number by means of a low cost ground station link, or via a not so economical satellite link, using the now spare NATO radio wavebands. Before boarding, the businessman will be able to relay his personal number to his secretary or home. In addition, the GTE system will allow passengers to operate fax, PC communications and data transmissions from their seats.

As a next stage, Virgin Atlantic see the interfacing of cabin management facilities via a control computer to each seat. A plunge of your credit card into the equipment will allow you to purchase your drinks and duty free, order meals or summon the hostess. With satellite communications, the terminal will no doubt also enable passengers to phone or fax their mail orders from the Virgin catalogue. With the in-flight communications market worth an estimated £2 billion, it can't be long before our personal video screens are jostling for space with high-tech communications systems. So in the meantime, settle down and boogie your way to Orlando.

While we may not be able to offer you a ticket to Paradise, we can provide the next best thing. The opportunity to win three Virgin Atlantic T-shirts, which cost £9 each on board, they feature Virgin's elegant Scarlet Lady insignia. The design became one of the most famous pin-ups of World War II, by adorning the legendary Flying Fortress bombers. Now the Scarlet Lady decorates the nose of every plane in the Virgin fleet.

To enter the draw to win a Virgin T-Shirt, write the correct answers to the following questions on the back of a postcard or sealed envelope, with your name and address. The draw will be made from the threadbare editor's hat on 30th November 1992.

Please note that multiple entries will be excluded from the draw. Post your entries to: Virgin Atlantic Contest, The Editor, 'Electronics – The Maplin Magazine', P.O. Box 3, Rayleigh, Essex SS6 8LR. Happy landings!

Virgin atlantic COMPETITION

1. Who recorded the hit album 'like a Virgin?'
(a) Madonna
(b) Bing Crosby
(c) Bernard Cribbens

2. Is Heathrow close to:
(a) Hampstead Heath
(b) Rotton Row
(c) Slough, Middlesex

3. The earliest flight of an airship was in:
(a) 1700
(b) 1852
(c) 1912

4. The first transatlantic aeroplane flight was made via:
(a) Lisbon
(b) The Isle of Wight
(c) The City Airport

5. The first round the world flight took:
(a) Two weeks
(b) Two years
(c) Twenty five weeks.

WAVEFORM GENERATOR CIRCUITS

Part 3 by Ray Marston

Ray Marston takes a look at square-wave generators.

Parts and 1 and 2 took an in-depth look at modern sine wave generators. Part 3 continues the 'generator' theme by looking at a variety of practical square-wave circuits.

Square-Wave Basics

Square-waves are free-running 'pulse' waveforms and can be generated directly or derived (by conversion) from existing waveforms. Figure 1 illustrates the basic parameters of a square-wave. In each cycle the wave first switches from zero to some peak voltage value (V_{pk}) for a fixed period, and then switches low again for a second fixed period. The time taken for the waveform to rise from 10% to 90% of V_{pk} is known as its *rise time*, and that taken for it to drop from 90% to 10% of V_{pk} is known as its *fall time*.

Circuits that produce poor-quality square-waves, with fairly long rise and fall times, are colloquially known as 'squirt' generators. Such waveforms are useful in non-critical applications such as relay driving, LED flashing, sound generation, etc. High-quality square-waves have very short rise and fall times, and are produced by so-called 'clock' generators, and such waveforms are essential for correctly clocking fast acting digital counter and divider ICs, etc.

In each square-wave cycle the 'high' part is known as its MARK and the 'low' part as its SPACE. In a symmetrical square-wave (such as Figure 1) the MARK and SPACE periods are equal, and the waveform is said to have a 1:1 M/S-ratio, or a 50% duty-cycle (since the MARK duration forms 50% of the total cycle period). Square-waves do not have to be symmetrical, however, and their M/S-ratios, etc., can be varied over a very wide range, as illustrated in Figure 2.

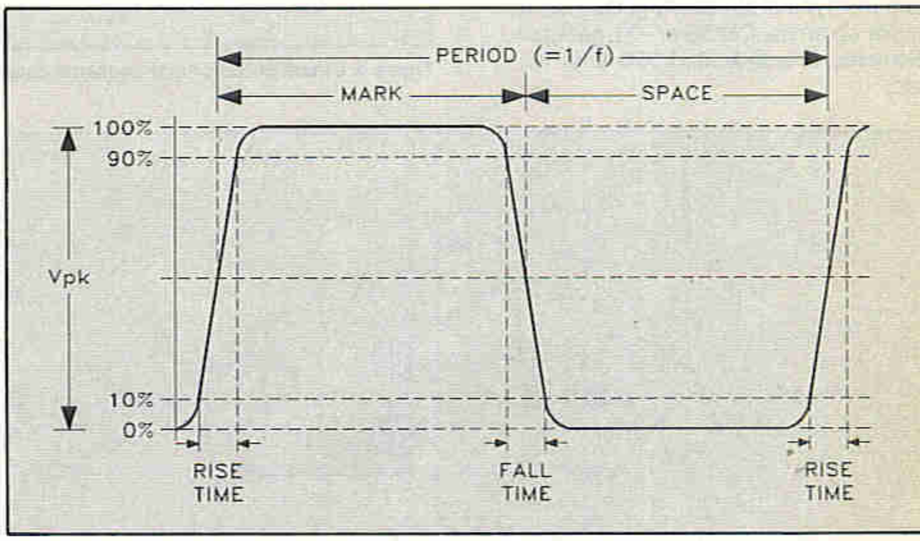


Figure 1. Basic parameters of a square-wave.

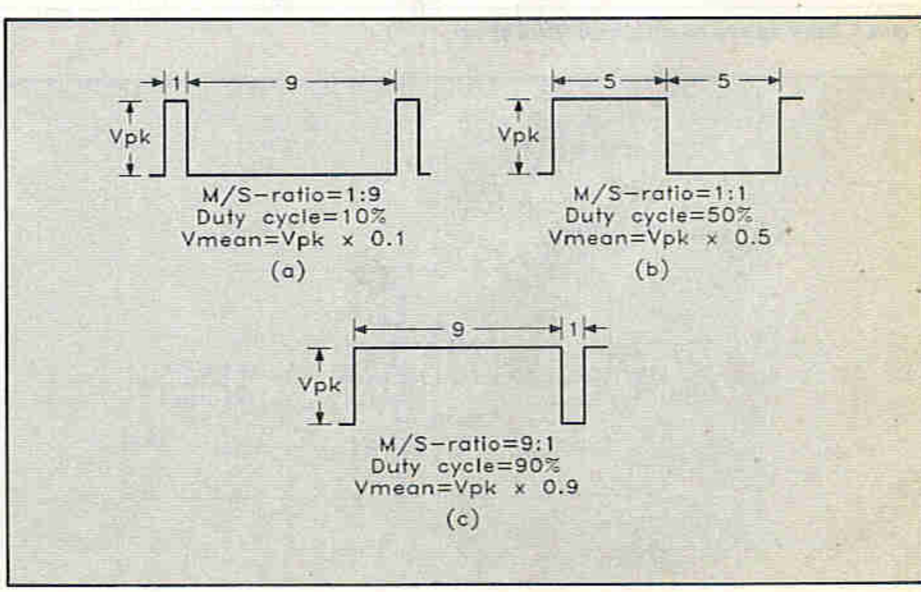


Figure 2. Square-waves with various mark/space values.

Note from Figure 2 that the mean output voltage (V_{mean}) of each waveform, integrated over a full cycle period, equals V_{pk} multiplied by the percentage duty cycle. Thus, if V_{pk} is 10V, the waveform of Figure 2a (which has a 10% duty-cycle) gives a V_{mean} of 1V. Figure 2b (which has a 50% duty-cycle) gives a V_{mean} of 5V. Thus, V_{mean} is fully variable via the M/S-ratio or duty-cycle value.

Sine-to-Square Conversion

Good-quality square-waves can be generated by feeding an existing sine wave through a simple sine-to-square converter, and the easiest way to do this is to use one of the four available gates of a CMOS 4093B quad 2-input NAND Schmitt IC, using the connections shown in Figure 3 (the three unused gates can be disabled by grounding their input terminals). This circuit produces an excellent square-wave output, with typical rise and fall times of less than 100nS when the output is loaded by 50pF. The Schmitt's trigger threshold can be set via RV1.

Transistor Astable Circuits

One way of directly generating square-waves is via a two-transistor astable multivibrator. Figure 4 shows a practical 1kHz version of this circuit, which can operate from supplies in the 1·5V to 9V range with good stability. It is a cross-coupled oscillator, with its MARK and SPACE periods controlled by the C1, R1 and C2, R2 time constants. If these time constants are equal (C1 = C2 and R1 = R2), then the circuit generates a symmetrical square-wave output and operates at a frequency of $1/(1{\cdot}4 \times C1 \times R1)$. Thus, frequency can be decreased by raising the C or R values, or vice versa, and can be made variable by using twin-gang variable resistors (in series with 10k limiting resistors) in place of R1-R2.

The square-wave outputs of this circuit can be taken from the collector of either transistor, and are in anti-phase. The leading edges of the output waveform are rounded and have rather long rise times, so this simple astable is really only useful as a crude square-wave 'squirt' generator. There are many variants of this basic circuit, designed to improve its voltage range and/or waveshape, but if a really good square-wave is needed it is best to use a different type of circuit altogether, using either op amps, CMOS or TTL gates or Schmitts, or a dedicated '555 timer' IC, etc.

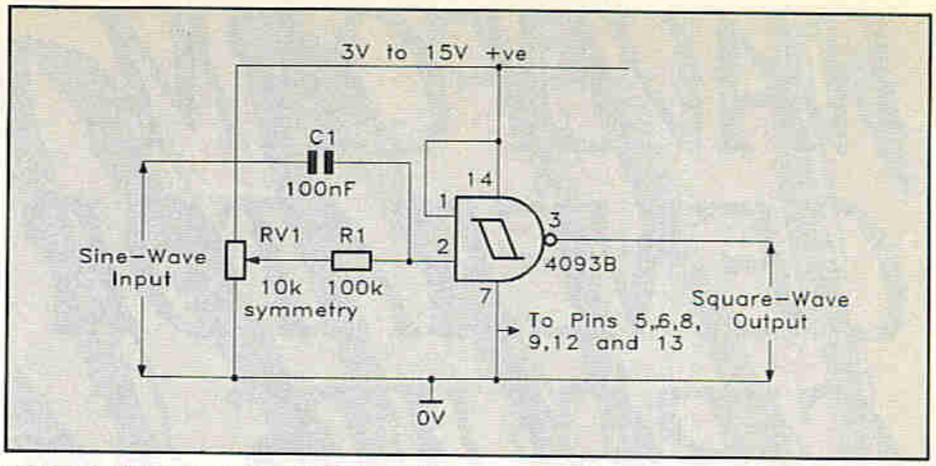


Figure 3. CMOS Schmitt sine/square converter.

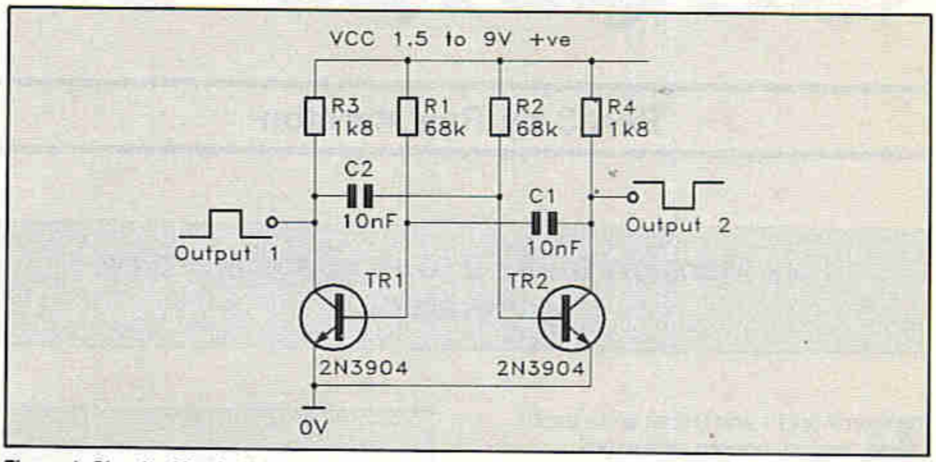


Figure 4. Circuit of basic 1kHz transistor astable multivibrator.

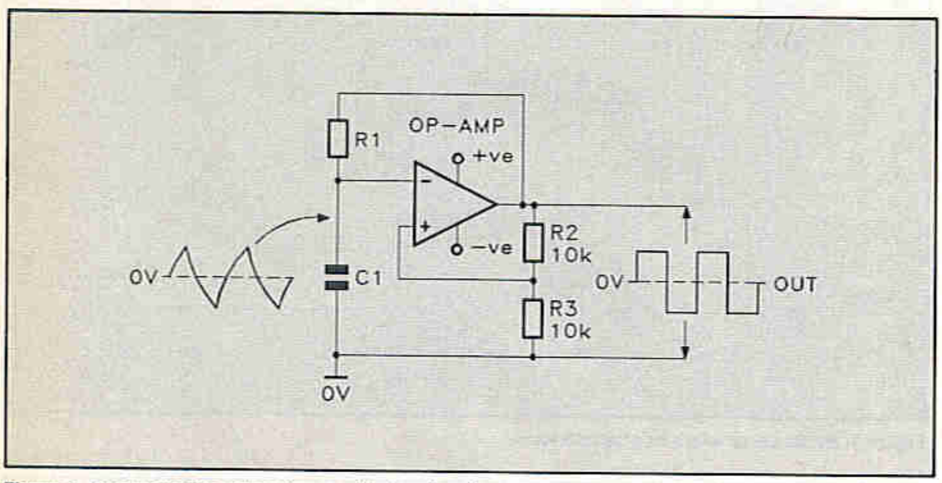


Figure 5. Basic op amp relaxation oscillator circuit.

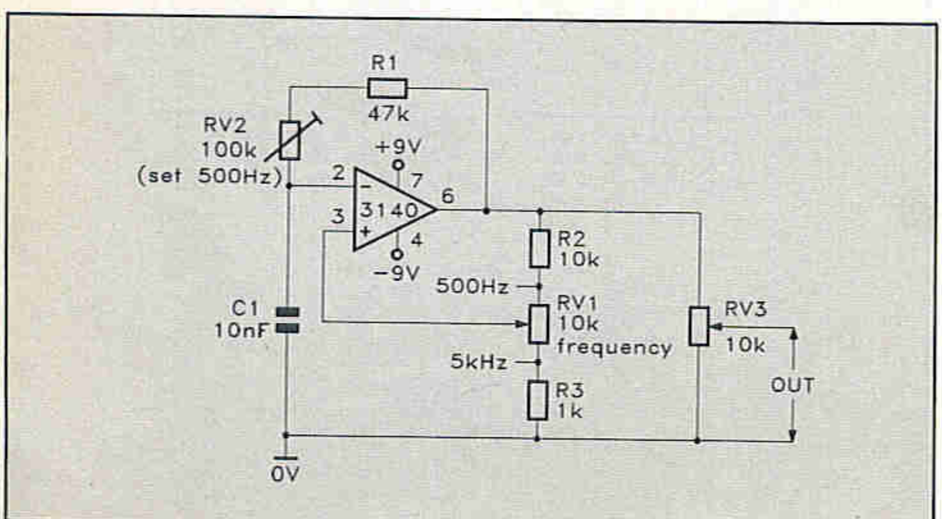


Figure 6. 500Hz to 5kHz square-wave generator.

Op Amp Square-Wave Generators

Useful square-waves can be generated by using an op amp in the basic relaxation oscillator configuration of Figure 5. This circuit's output switches alternately between the op amp's positive and negative saturation levels. Potential divider R2 and R3 feeds a fraction of this voltage back to the op amp's non-inverting input, forming a 'target' voltage or threshold for the input, and feedback components R1 and C1 act as a time-constant network. The circuit operation is such that, when the output is high, C1 is charged via R1 until its voltage reaches and passes the positive 'target' value or threshold set by R2 an R3. At this point a comparator action occurs and the op amp output regeneratively switches negative, meaning that the threshold level at the junction of R2 and R3 changes polarity as the op amp goes into 'negative saturation' because of the positive feedback loop set up by R2 and R3 to the non-inverting input. This causes C1 to begin discharging via R1 until its voltage falls to the negative threshold value set by R2 and R3. Here the op amp output switches positive again, and the whole sequence repeats *ad infinitum*, generating a symmetrical square-wave at the output of the op amp, and a non-linear triangle waveform across C1. A fast op amp, such as the CA3140, should be used if good rise and fall times are required from the square-wave.

This circuit's operating frequency can be varied by altering either the R1 or

C1 values, or by altering the ratio of R2 to R3. The circuit is thus quite versatile, and Figure 6 shows an adapted version to make a 500Hz to 5kHz square-wave generator, with frequency variation obtained by altering the R2-RV1-R3 attenuation ratio. RV2 can be used to pre-set the range of the RV1 frequency control, while RV3 gives output amplitude control.

Figure 7 shows the this circuit modified some more to make a general-purpose square-wave generator that spans 2Hz to 20kHz in four switched decade ranges. Pre-set pots RV1 to RV4 are used to precisely set the minimum frequency of the 2Hz to 20Hz, 20Hz to 200Hz, 200Hz to 2kHz, and 2kHz to 20kHz ranges respectively.

In the circuit of Figure 5, C1 alternately charges and discharges via R1, and the circuit generates a symmetrical square-wave output. It can be made to give a asymmetric or variable-symmetry output by providing C1 with alternate charge and discharge paths, as shown in Figure 8. Here, the waveform's M/S-ratio is fully variable from 650Hz to 6·5kHz via RV2. The action is such that C1 alternately charges up via R1 and D1 and the left-hand side of RV1, and discharges via R1, D2 and the right-hand side of RV1, giving a variable-symmetry output. Variation of RV1 has negligible effect on the circuit's operating frequency.

CMOS Astable Basics

Another way to make a square-wave generator is to use the gates of inexpensive CMOS logic ICs such as the 4001B, 4011B, etc. as simple inverters, which are then wired in the astable multivibrator mode, as in Figure 9a. This circuit generates a good square-wave output from IC1b (and a not-quite-so-good anti-phase square-wave output from IC1a), and operates at about 1kHz with the component values shown. The circuit is suitable for use in many (but not all) 'clock' generator applications, and operates as follows.

The two inverters are wired in series, and time-constant network C1-R1 is wired between the outputs of IC1b and IC1a, with their junction connected to the input of IC1a. Suppose that initially C1 is fully discharged and the output of IC1b has just switched high. Initially this makes the C1-R1 junction fully positive, thus driving IC1a output low, but the voltage starts to decay exponentially as C1 charges up via R1, until eventually it falls into the linear 'transfer voltage' range of IC1a, making its output start to swing high. This initiates a regenerative action in which IC1b output switches abruptly to the low state (and IC1a output switches high). This switching action makes the charge on C1 to try to apply a negative voltage to IC1a input, but IC1a's built-in input protection diodes prevent this and instead discharge C1.

Thus, at the start of the second cycle, C1 is again fully discharged, so the C1-R1 junction is initially at zero volts (driving IC1a output high), but then rises exponentially as C1 charges up via R1, until eventually it rises into the linear

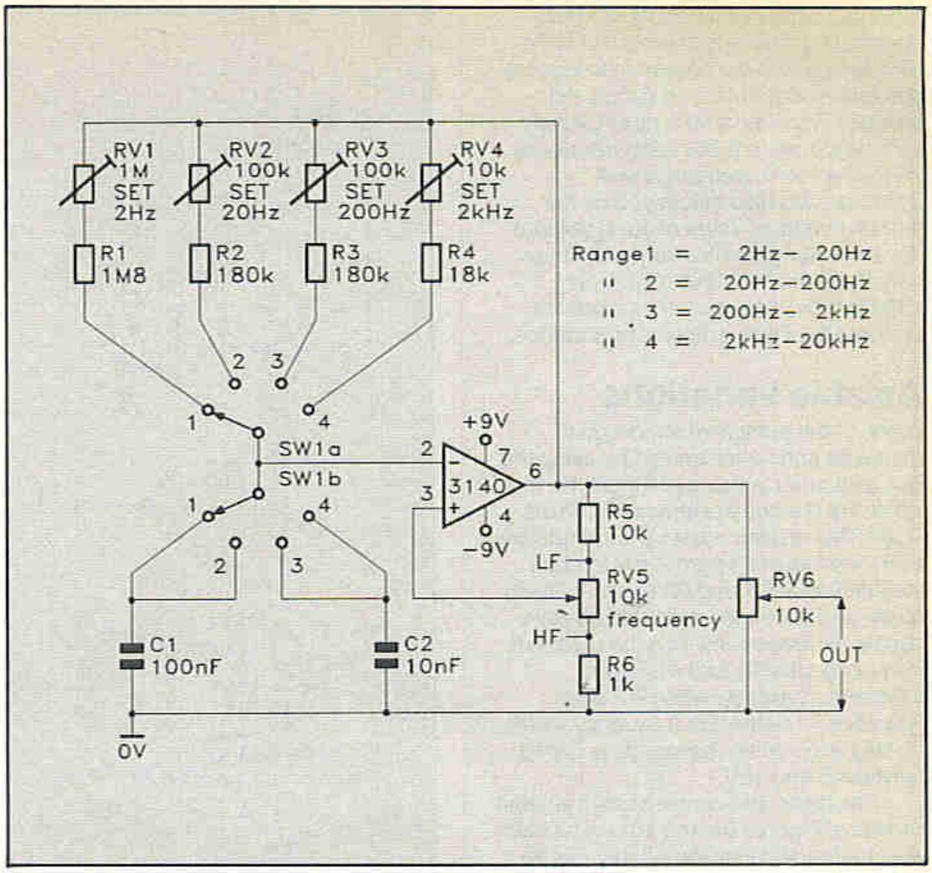


Figure 7. General-purpose 4-decade (2Hz to 20kHz) op amp square-wave generator.

'transfer voltage' range of IC1a, thus initiating another regenerative switching action in which IC1b output switches high again (and IC1a output protection diodes. The operating cycle then continues *ad infinitum*.

The circuit's operating frequency is inversely proportional to the C-R time constant (the period is roughly 1·4 × C × R), so can be raised by lowering the values of either C1 or R1. C1 must be non-polarised and can vary from a few tens of pF to several μF, and R1 can vary from 4k7 to 22M. The astable operating frequency can vary from a fraction of Hz to about 1MHz. For variable-frequency operation, wire a fixed and a variable resistor in series in the R1 position.

Each of the 'inverters' of the Figure 9a circuit can be made from a single gate of a 4001B quad 2-input NOR gate or a 4011B quad 2-input NAND gate, etc. by using the connections shown in Figure 9b. The inputs of all unused gates in these ICs must be tied to one or other of the supply-line terminals. The CMOS astable can be used with any supply level in the range 3V to 18V; the 'zero volts' terminal goes to pin-7 of the 4001B or 4011B, and the '$+V_e$' terminal goes to pin-14.

The output of the Figure 9a astable switches between the zero and positive supply rail values, but the voltage at the C1-R1 junction is prevented from swinging below zero or above the

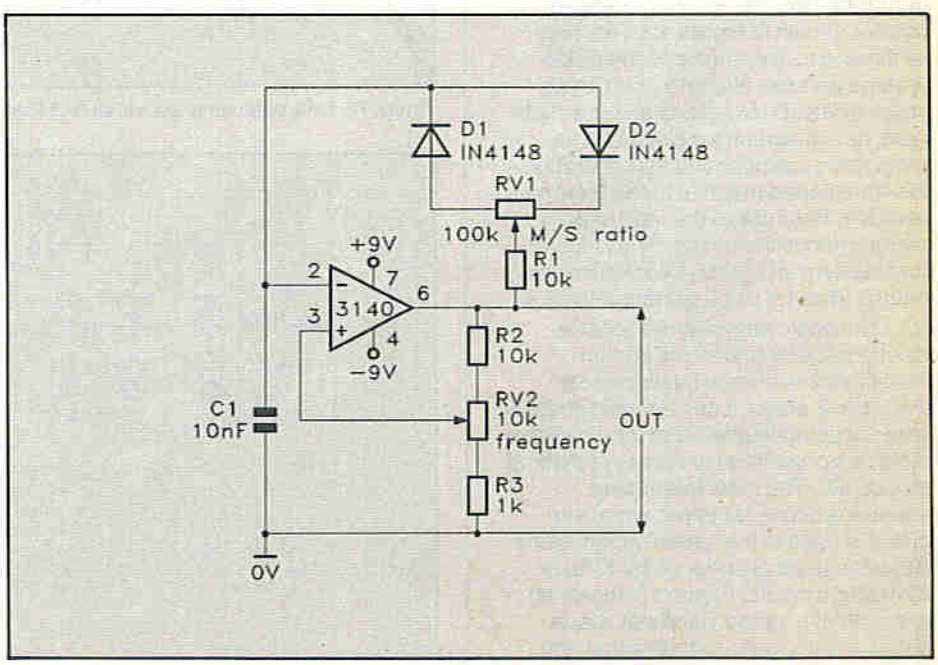


Figure 8. Square-wave generator with variable M/S-ratio and frequency.

positive supply-rail levels by the built-in clamping diodes at the input of IC1a. This fact makes the operating frequency somewhat dependent on supply rail voltage. Typically, a 10% rise in supply voltage causes a 0·8% fall in frequency. The waveform's frequency and symmetry are also influenced by the 'transfer voltage' value of the individual IC1a inverter/gate (the frequency may vary by as much as 10% between different ICs). However these defects are usually of little practical importance.

Astable Variations

Some of the defects of the circuit of Figure 9a can be minimised by using the 'compensated' astable of Figure 10, in which R2 is wired in series with IC1a's input. This resistor must be large relative to R1, and its main purpose is to allow the junction at C1 and R1 to swing freely below and above the zero and positive supply rail levels, and thus the astable's frequency stability and waveform symmetry. Typically, when R2 is ten times the R1 value, the frequency varies by only 0·5% when the supply is varied between 5 and 15V.

The basic and compensated astable circuits of Figures 9a and 10 can be built with several detailed variations. Figure 11 shows the basic circuit modified to give a variable-symmetry output. Here C1 charges via D1, RV1 and R1 to generate the MARK part of the waveform, but discharges via D2, RV2 and R1 to give the SPACE part of the waveform.

'Ring-Of-Three' Astable

The 2-stage astable circuit is a good, general-purpose square-wave generator, but is not always suitable for direct use as a 'clock' generator with fast-acting counting and dividing circuits, since it tends to pick up and amplify any existing supply-line noise during the 'transitioning' parts of its operating cycle, and thus produces an output square-wave with 'glitchy' leading and trailing edges. A far better type of 'clock' generator circuit is the 'ring-of-three' astable shown in Figure 12. The 'ring-of-three' circuit is similar to the basic 2-stage astable, except that its 'input' stage (IC1a-IC1b) acts as an ultra-high-gain, non- inverting amplifier and its main timing components (C1 and R1) are transposed (relative to the 2-stage astable). Because of the very high overall gain of the circuit, it produces an excellent and glitch-free square-wave output, ideal for clock-generator use.

The basic ring-of-three astable can be subjected to all the design modifications already described for the basic 2-stage, it can be used in either basic or compensated form and can give either a symmetrical or non-symmetrical output, etc. The most interesting variations occur, however, when the circuit is used in the 'gated' mode, since it can be gated at either of the IC1b or IC1c stage inputs. Figure 13 shows an example of a 'gated' oscillator that is gated on by a logic-1 input signal and has a normally-low output.

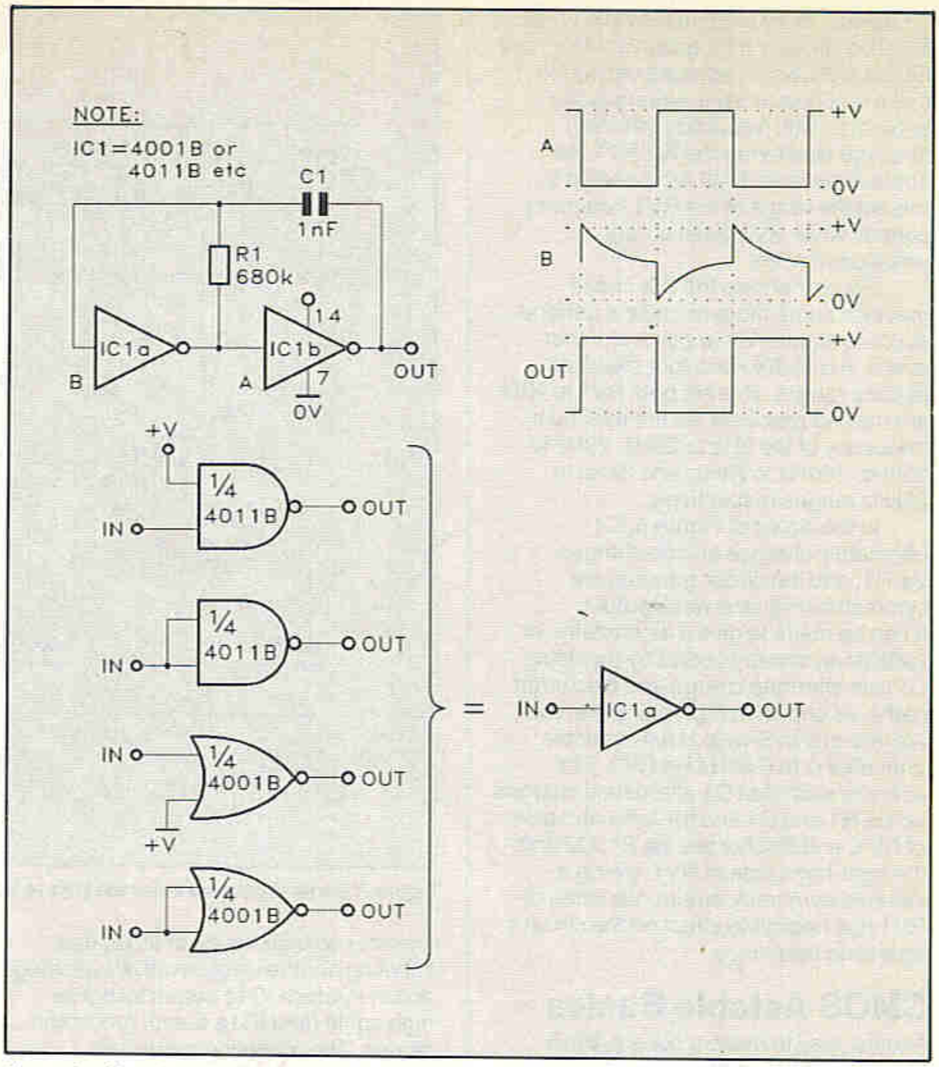


Figure 9a. Circuit and waveforms of basic 2-stage 1kHz CMOS astable.
Figure 9b. Ways of connecting a 2-input NAND 4011B or NOR 4001B gate for use as an inverter.

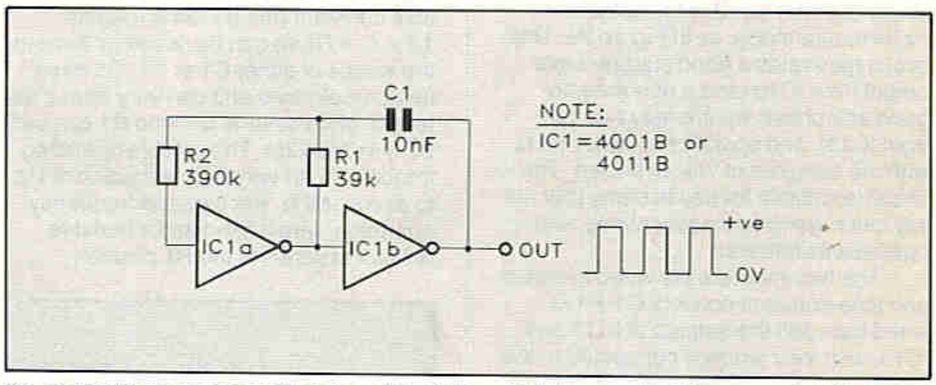


Figure 10. This 'compensated' version of the 1kHz astable has excellent frequency stability.

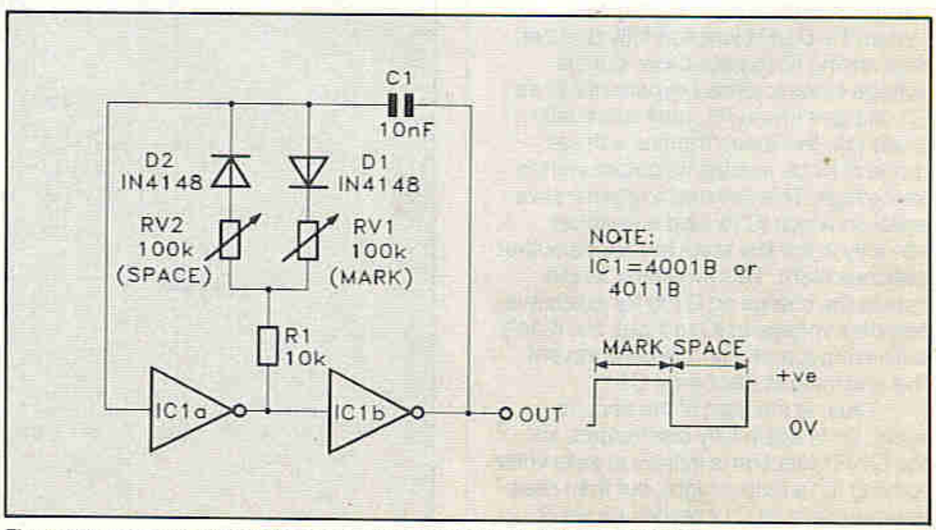


Figure 11. CMOS astable with independently variable MARK and SPACE times.

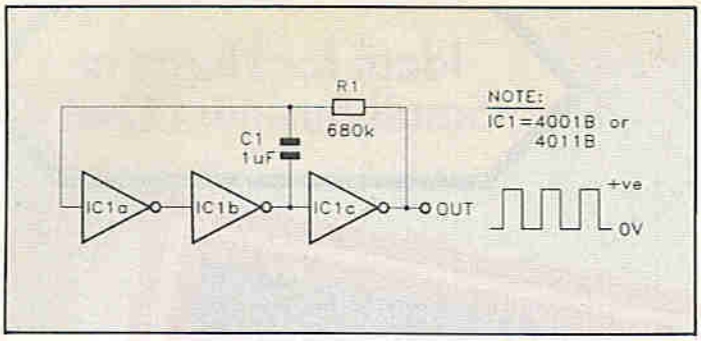


Figure 12. This 'ring-of-three' astable makes an excellent clock generator.

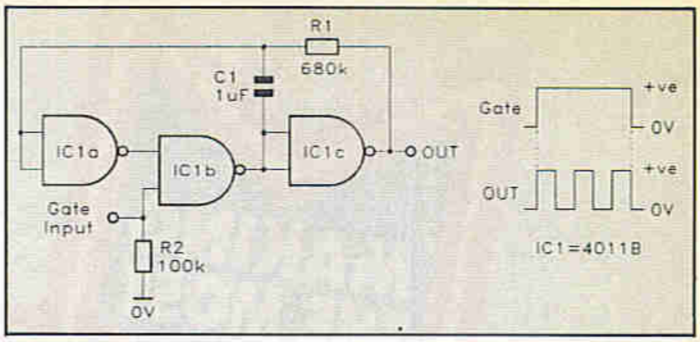


Figure 13. This gated 'ring-of-three' astable is gated by a logic-1 input and has a normally-low output.

The CMOS 'Schmitt' Astable

An excellent astable 'clock' generator can also be made from a single CMOS Schmitt inverter stage. Suitable ICs are the 40106B hex Schmitt inverter, and the 4093B quad 2-input NAND Schmitt trigger.

Each NAND gate of the 4093B can be used as an inverter by simply disabling one of its input terminals as shown in the basic Schmitt astable circuit of Figure 14. This circuit gives a square-wave output with edges that are unaffected by supply line ripple and other 'nasties'. Its operating frequency is decided by the values of C1 and R1, and can be varied from below 1Hz to above 1MHz. The circuit action is such that C1 is alternately charged and discharged via R1, without affecting the polarity of C1. C1 can thus be a polarised component.

The Figure 14 circuit can be gated via an external signal by disconnecting the 'spare' input terminal from the positive rail and using it as the gate input terminal. The astable is gated on by a high (logic-1) input to this terminal, but gives a steady 'high' output when gated off.

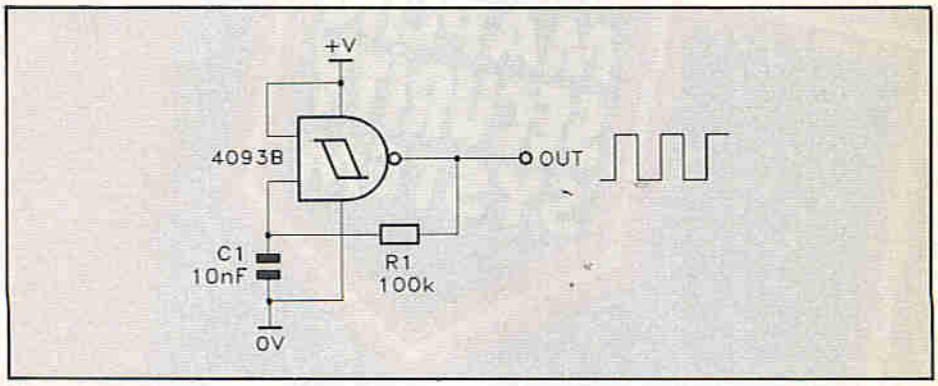


Figure 14. Basic CMOS Schmitt astable.

TTL Schmitt Astable Circuits

Astable square-wave generators can also be built using inexpensive TTL ICs, and one popular way of doing this is to use elements from the 74LS14 hex Schmitt inverter. Figure 15 shows an example of such a circuit, which generates a clean square-wave output with a 2:1 M/S-ratio and uses a second schmitt stage to give a buffered output. The circuit should be used with a fixed 5V supply, and its timing resistance (R1 + RV1) value must be within the 100Ω to 1k2 range. The circuit's frequency is variable (via RV1) from about 8·2kHz to 89kHz when C1 has a value of 100nF.

4046B VCO Circuits

One really useful CMOS square-wave 'clock' generator IC is the 4046B phase-locked loop (PLL) IC, which houses (amongst other things) a very useful VCO (voltage-controlled oscillator). This VCO is highly versatile, it gives an excellent and symmetrical square-wave output, has a top frequency limit in excess of 1MHz, has a voltage-to-frequency linearity of about 1% and can be 'scanned' through a 1,000,000:1 range by an external voltage fed to the pin-9 VCO input terminal. The VCO frequency depends on the values of a capacitor (minimum value 50pF) connected between pins 6 and 7, and a resistor (minimum value 10k) wired between pin-11 and ground, with the voltage applied to pin-9.

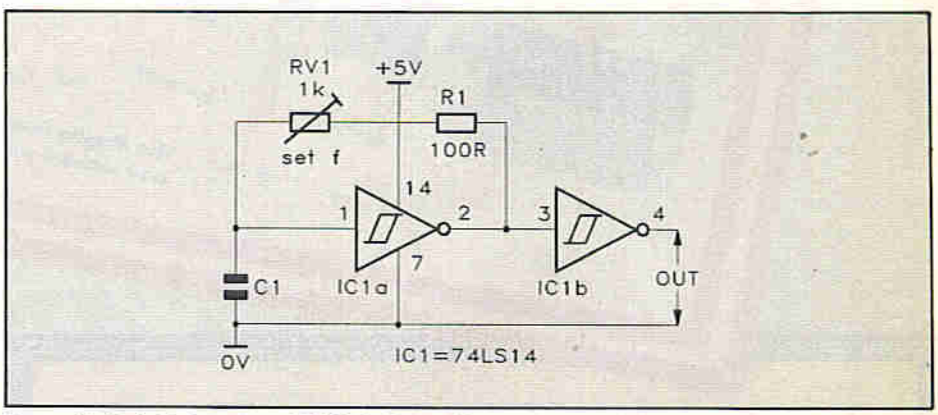


Figure 15. Variable-frequency TTL Schmitt astable.

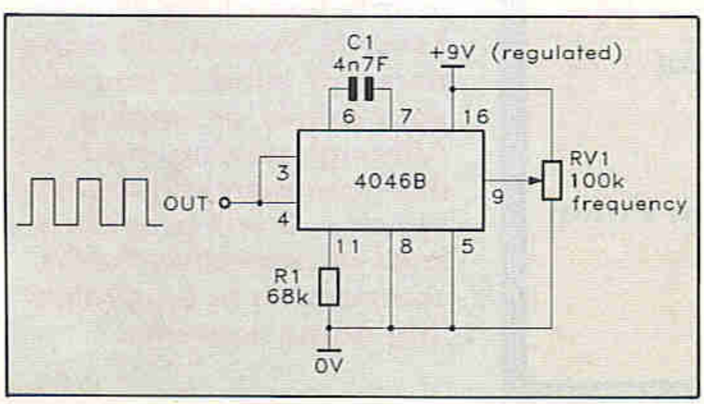


Figure 16. CMOS wide-range VCO, spanning near-zero to 5kHz via RV1.

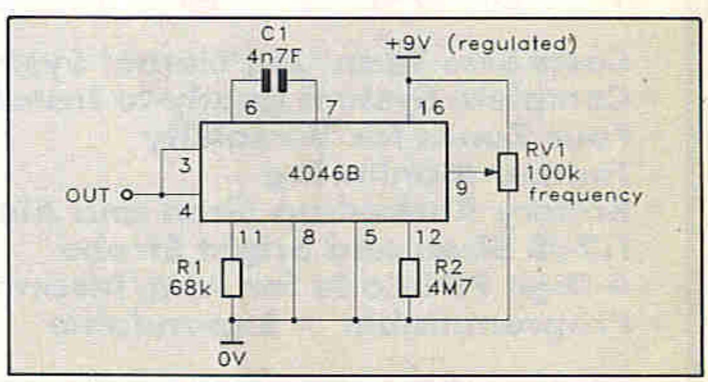


Figure 17. Restricted-range VCO, with frequency variable from roughly 72Hz to 5kHz via RV1.

Continued on page 71.

Ideal for Home or Small Business Use!

MAKING THE MOST OF THE MAPLIN SECURITY SYSTEM

The Maplin Security System as supplied (note: the bell box and sensors supplied may differ slighty from those shown).

FEATURES

* Costs Less Than 'Big Name' Systems
* Complete System Ready to Install
* Four Zones for Versatility
* Tamper Monitoring
* Battery Backed-up Siren and Alarm Panel
* 112dB Siren and Bright Strobe
* 4-Digit PIN Code for Arm/Disarm
* Programmable * Expandable

by Robert Ball and Martin Pipe

Installation of the Maplin Security System will bring peace of mind to you and your family or employees. Although costing much less than commercially installed systems, it will provide a level of protection that is comparable to equivalent 'big name' systems.

Installation of the Maplin Security System is both very easy and quick – providing that is, you plan the installation and read this article carefully!

The Maplin Security System is a collection of specially chosen security items available at a special 'all-in' price; offering a very substantial saving over the total price of the individual components. It contains all you need to provide a basic level of protection to you, your home or business, from intruders and assailants. The system comprises the following items: two passive infra-red (PIR) detectors; two surface reed switches; an external bell box (with 112dB siren, attention-grabbing strobe light and battery pack); 50m of six core cable; 60 plastic cable clips; a 12V lead-acid battery and the brains of the system, an MSS3000 Alarm Panel.

To extend further the protection afforded by this system, a complete range of accessory items are available from Maplin.

System Overview

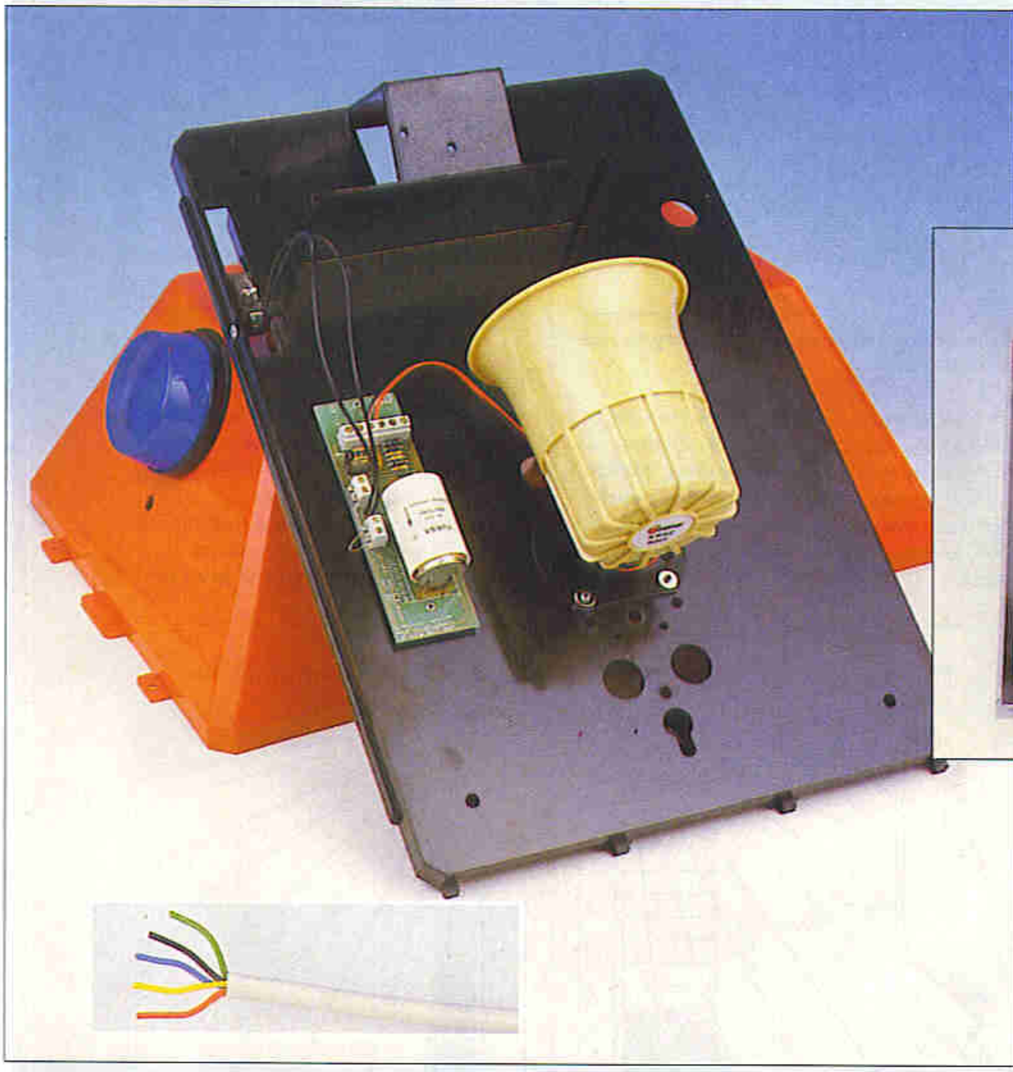
The MSS3000 alarm panel is a versatile, micro-controller based unit and is capable of monitoring up to four independent zones, plus 24-hour 'Personal Attack' buttons and a tamper loop. The functionally styled case incorporates status indication by means of coloured LEDs, and operation by means of a membrane keypad. During operation, various tones are emitted from an internal speaker; these indicate keypad operation, alarm triggered, etc. Access to the circuit connections is made by removing the front cover – any unauthorised attempt to open the unit will operate a tamper switch! The unit is powered by 240V AC mains, and when fitted with the lead-acid back-up battery (supplied), it provides continuous protection during a mains power failure.

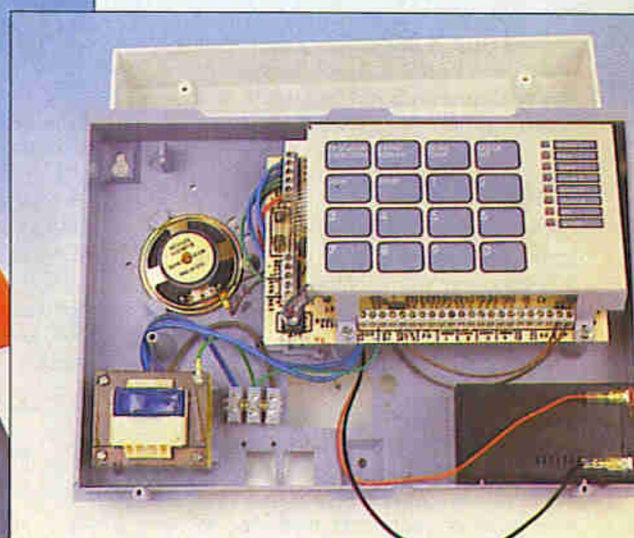
In use there are 4 main zones, each of which can be monitored as required; zones may be omitted as necessary. In addition a tamper loop is also provided. This loop is continuously monitored and detects interference to the system by unauthorised persons. The four zones can be provided wherever you need them – a zone is simply an area of the premises protected by one or more sensors; a number of zones will be used to cover the premises as a whole. As four sensors are supplied (two PIRs, two reed switches), one could be used for each zone – but more can be added by wiring them in series with the existing sensor(s) in the required zone. There is virtually no practical limit to the number of sensors that can be added this way.

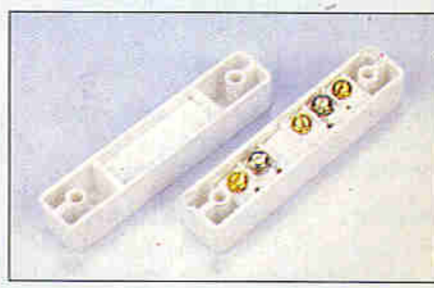
The external bell box – which is actually fitted with a siren! – is also fitted with a bright strobe light, tamper switch and a nickel-cadmium (Ni-Cd) battery pack. Any attempt to interfere with the box, or the wiring, will trigger the alarm. Even if the wires to the bell box are cut, the siren will still operate.

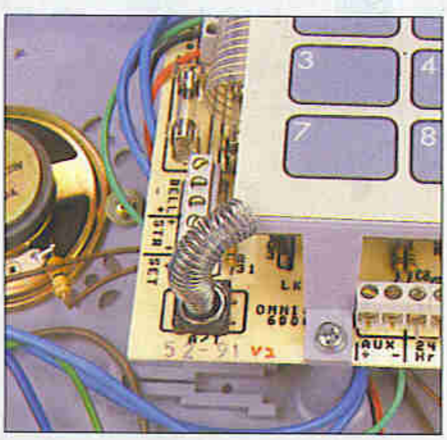
The system has two main modes of operation – 'Day' and 'Armed'.

In the 'Day' mode, the alarm panel monitors the personal attack buttons and tamper loop, but does not monitor the various zones. This is the normal mode of operation when premises are occupied. The way in which the alarm panel responds to a tamper loop violation or a panic button being pressed depends on how the user has programmed the alarm panel to respond.









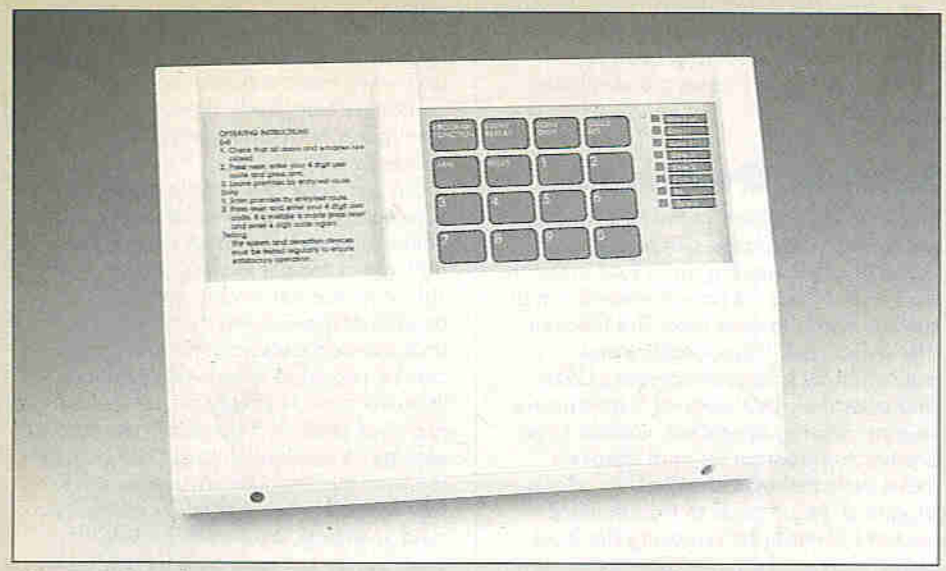
Above: Internal view of a typical bell box supplied with the system.

Inset: Colour coded wire supplied with the system.

Top right: Internal view of the MSS3000 alarm panel supplied with the system.

Bottom right: Underside view of the surface mounting reed switch.

Left: Tamper spring hooked under edge of keypad.



The MSS3000 alarm panel.

In the 'Armed' mode, the alarm panel monitors all zones, the personal attack buttons and the tamper loop.
This is the normal mode of operation when premises are unoccupied.
The system may also need to be armed whilst the premises are still occupied; for example, in a house at night, when the ground floor is unoccupied and residents are asleep upstairs. In this instance the upstairs zones are omitted whilst still providing full ground floor coverage.

Planning

It is important to properly plan the installation before proceeding any further; the following important points should be considered:

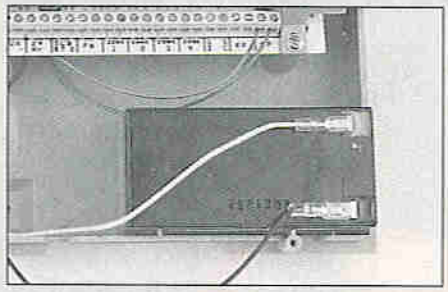
- Location of the alarm panel
- Provision of 240V AC mains supply to the panel
- Location of the external bell box
- Desired route(s) of entry/exit to the premises
- The number of zones required
- Location of each zone and area to be covered
- Type of sensors best suited to cover a zone
- Where wiring can be routed
- Safety Precautions
- Location of buried pipes and cables
- Local regulations regarding the installation of burglar alarms

Alarm Panel Location

The alarm panel should be located in a position where it is easily accessible to 'authorised' persons when entering the premises – however, it is advantageous to conceal the panel from direct view; for example, in a store cupboard. It is of course necessary to provide a source of 240V AC mains and run cables to the various sensors – choose a location where this can be easily done; take into account solid floors and concrete walls!

Mains Supply

The correct provision of a 240V AC mains supply, in accordance with IEE Wiring Regulations, is important for reliable operation. If in any doubt as to the correct way to proceed, consult a qualified electrician; otherwise the safety



Connecting the lead acid battery to the alarm panel.

of the electrical installation as a whole could be compromised. Before undertaking any work on mains wiring, switch off the supply at the main isolator switch. Similarly switch off the mains supply before removing the cover of the alarm panel.

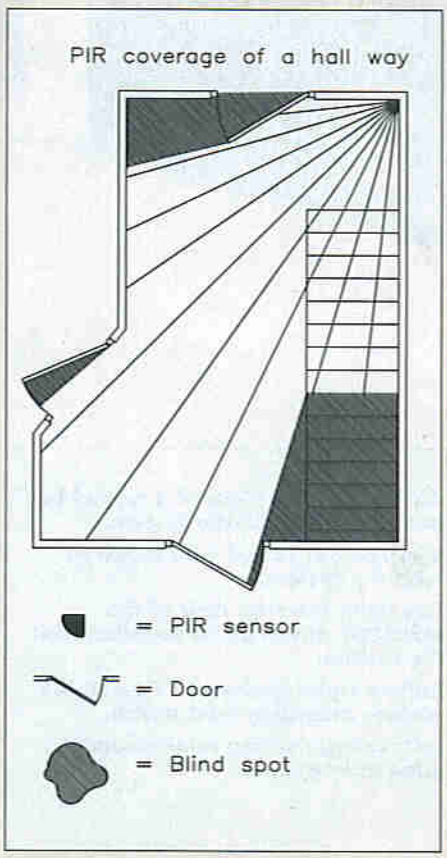


Figure 1. Typical PIR coverage of a hallway.

Ideally the alarm panel should be provided with its own circuit from the consumer unit (fuse box) – this will allow easy maintenance to the rest of the electrical installation without interrupting the mains supply to the alarm panel.
The dedicated circuit should terminate in a unswitched fused cable outlet. If you have a modern split load consumer unit fitted with a Residual Current Device (RCD), it may be better to add the alarm panel circuit to the group that is not protected by the RCD. This will prevent a loss of power, to the alarm panel, in the event of 'nuisance tripping'.
Murphy's Law dictates that such a power loss would happen when the premises are unoccupied for a long period of time; in such a case the back-up battery would not be capable of supplying the panel indefinitely!

However, in many cases it will be impractical or too costly to provide a dedicated circuit. In this instance a permanently wired unswitched fused spur can be added to an existing 30/32A ring main. The connection between the ring main and the unswitched fused cable outlet should be made using 2·5mm flat twin and earth cable.

The cable outlet should be fitted with a 2A fuse. The connection between the cable outlet and the alarm panel should be made using 3-core 6A mains cable.

It is inadvisable to connect the alarm panel to the mains by means of a 13A plug – it is likely that it will be inadvertently unplugged! The connection of permanently fitted apparatus to the mains in this way is in fact precluded by IEE wiring regulations.

It has also been found that mains-borne interference can, in some instances, cause misoperation of the

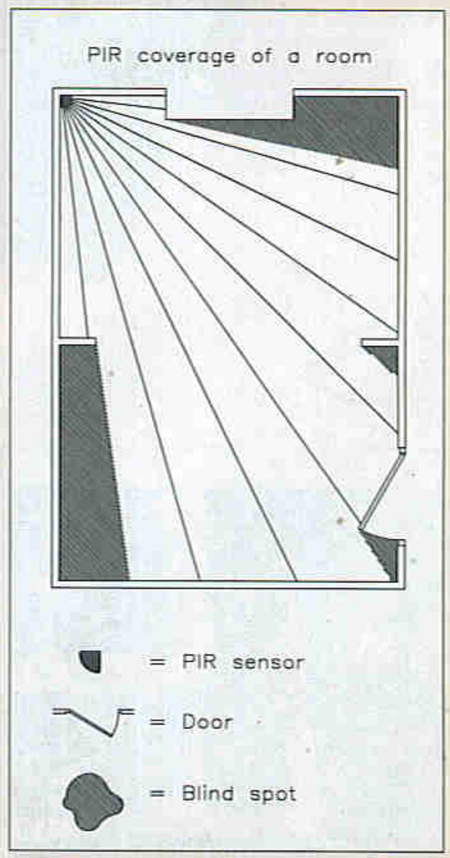


Figure 2. Typical PIR coverage of a room.

alarm panel. It is advisable, in such cases, to install a mains filter in the supply to the alarm panel and suppress the source of noise if it can be identified (e.g., large motors, etc.).

Bell Box Location

The bell box should be located prominently and as high as possible. The box should be orientated so that the strobe faces downwards. Avoid siting within easy reach of flat roofs. Although weatherproof, avoid locating the bell box where it will be subject to direct streams of water, e.g., underneath faulty guttering.

Zone Planning

The premises should be divided into zones; this will maximise versatility of the complete system. Zones can be designated as being: ZONE, ENTRY ZONE or WALK THROUGH ZONE. Understanding the difference between these is vitally important.

ZONE; these will be the zones not designated as entry zones. When the alarm is armed, violation of a ZONE will trigger the alarm panel and bell-box siren instantly.

ENTRY ZONE; this will cover the access route from the main door through to alarm panel. Adjacent areas where entry is not necessary to reach the alarm panel should be assigned as ZONES. When the alarm is armed, violation of the ENTRY ZONE will trigger the alarm panel, but the bell-box siren will not sound if the alarm panel is set to 'Day' (i.e., disarmed) within the pre-set entry time. If several entry/exit routes are required, more than one zone can be set as an ENTRY ZONE. Entry into another ZONE, unless designated an ENTRY or WALK THROUGH ZONE, will trigger the bell-box siren instantly.

WALK THROUGH ZONE; this is a zone that will ordinarily trigger the alarm panel and bell-box siren instantly, if it is violated, except if the ENTRY ZONE has previously been entered; if this is the case the zone will be treated as an ENTRY ZONE. A zone should be designated as a WALK THROUGH ZONE if it is necessary to walk through it to reach the alarm panel.

A typical example for a house, where the alarm panel is located in the reception room, would be:

ZONE	ZONE TYPE	AREA
ZONE 1	ENTRY ZONE	HALL
ZONE 2	WALK THROUGH ZONE	RECEPTION ROOM
ZONE 3	ZONE	REST OF GROUND FLOOR
ZONE 4	ZONE	UPSTAIRS

Sensors

The two types of sensors supplied are of the PIR and Reed Switch types.

PIRs afford protection to a complete area within the sensor's 'field of view'; the sensor works by detecting the infra-red heat radiation given off by people (and animals!). The sensors are usually best mounted in the corners of rooms, bearing in mind that walls and other solid objects will produce 'blind spots'.

Sensor Terminals

With reference to Figure 3, the sensor inputs are located along the bottom edge of the alarm panel circuit board. The connections to this row of terminals are, from left to right, as follows:

1 & 2 Auxiliary Power Output (AUX)
This output can supply +12V at 500mA max. (Pin 1 = +12V; Pin 2 = 0V). In the case of the system as supplied, this supply is used to power the PIR sensors. Other devices that require external power may be used in parallel provided that they run from a 12V supply, and that the total load does not exceed 500mA. Under no circumstances should a link be fitted across this pair of terminals; this will cause fuse F2 to blow!

3 & 4 24-Hour Tamper Loop (24-Hr) (Factory-fitted link)
This loop, which is operational whenever the system is powered up (i.e., in both 'day' and 'armed' modes), is used to detect any tampering with sensors. The tamper switches (normally closed contacts) are effectively connected in series; if the loop formed by the switches and wiring is broken at any time, the alarm panel will detect this. User programming will determine the panel's response to the tamper loop violation.

5 & 6 Bell Box Tamper Loop (SCB RT 0) (Factory-fitted link)
This loop is used to inform the alarm panel as to the integrity of the bell box. If the bell box is tampered with, or the cable to the bell box is cut, the loop will be broken, the alarm panel will be triggered and the bell-box siren will sound. User programming will determine the panel's response to the tamper loop violation.

The SCB 0 terminal also provides a return path for the bell-box battery charging current.

7 & 8 Personal Attack Loop (PA) (Factory-fitted link)
A personal attack button (optional), with normally closed contacts, is wired across these terminals; if required, several panic buttons may be connected in series.

9 & 10 Zone 1 Loop (ZONE1) (Factory-fitted link)
All of the sensors in this zone are connected in series to these terminals. If a zone is not to be used, its link should be left in place. Zone 1 is usually the entry zone, although others can be used.

11 & 12 Zone 2 Loop (ZONE 2)
13 & 14 Zone 3 Loop (ZONE 3)
15 & 16 Zone 4 Loop (ZONE 4)
(Factory-fitted links)
As Zone 1, except Zones 2, 3 & 4 are not normally entry zones. 17 & 18 Not used (SD SC).

19 & 20 Keyswitch (KK)
A keyswitch (optional) may be connected across these two terminals. This will enable the alarm panel to be armed or disarmed from a remote location outside the protected area, depending on how the system has been programmed. Even if a keyswitch is not to be used, DO NOT fit a link here! It is important that the keyswitch is mounted outside all the zones.

21 & 22 Internal Speaker (SP)
These terminals are factory connected to the internal loudspeaker.

Table 1. Sensor terminals.

Figure 1 shows an example of hall coverage and Figure 2 shows an example of room coverage. Additional PIRs can be purchased, of which there are several different types, each with its own particular characteristics.

Reed switches protect a single opening door or window; the type supplied are of the surface mounting type and are the easiest to install, being simply screwed to the surface of the door/window frame. Flush and recessed types are also available, although these require additional drilling to install.

Full details of a full range of PIRs, Reed Switches and other sensors may be found in the current Maplin Catalogue.

Wiring

Take time to work out the best way in which cables can be run. Wiring can be concealed in plastic mini trunking

Output Terminals

With reference to Figure 3, the alarm outputs are located along the left edge of the alarm panel circuit board. The connections to these terminals are, from top to bottom:

23 & 24 Low voltage AC Input (AC) (Factory connected)

25 Earth (E) (Factory connected)

26 & 27 +12V Input (batt - +) (Factory connected flying leads)
The wires from these two terminals are used for connecting the supplied 12V lead-acid back-up battery.

28 & 29 Siren Output (BELL - +)
These two terminals provide the power for the siren. The '+' terminal is permanently at +12V and the '–' terminal is taken 'low' when the alarm panel operates the siren. The '+' terminal also provides the charging current for the battery pack in the bell box.

30 & 31 Strobe Output (STR + -)
These two terminals provide power for the strobe when the alarm panel operates it.

32 +12V when Armed Output (+ SET)
This terminal is not normally used with the Maplin Security System; it provides +12V when the alarm panel is armed. It is possible to use this terminal to power a separate low current indicator (e.g., LED and series resistor, not supplied), to show that the alarm is armed.

Table 2. Output terminals.

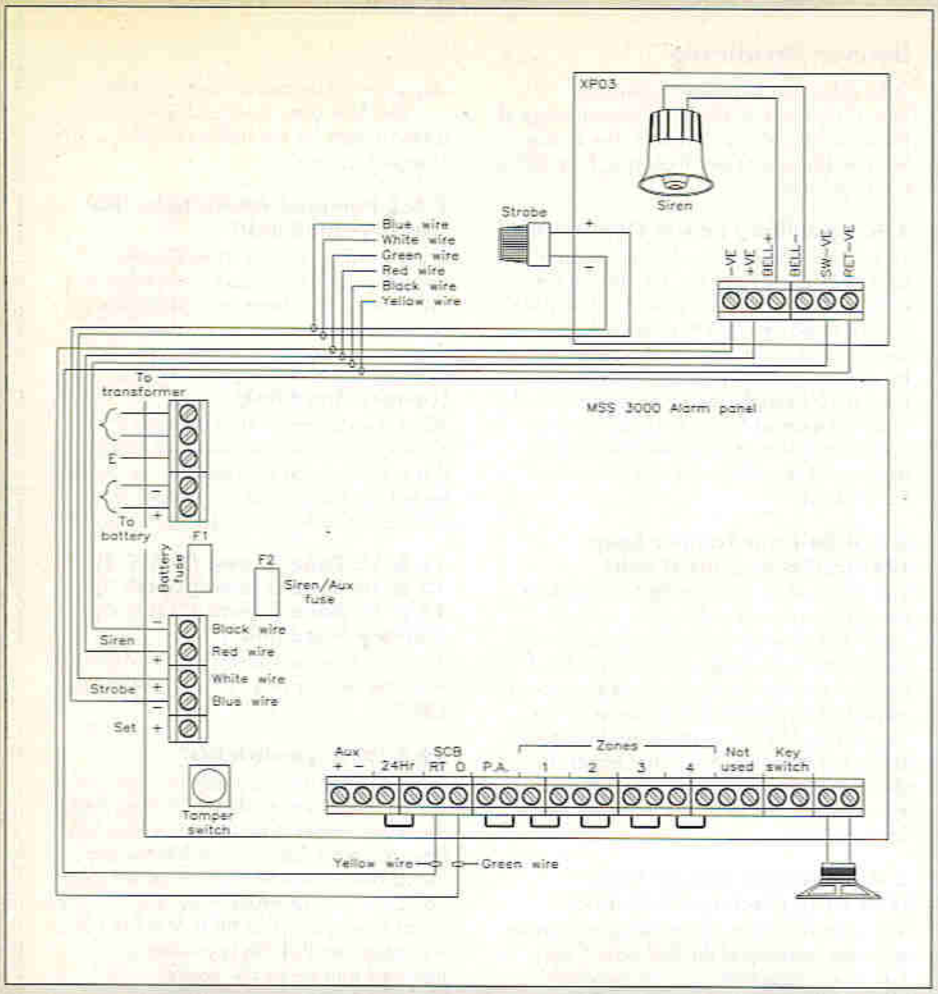


Figure 3. MSS3000 Alarm Panel and bell box connections.

(available from electrical retailers), buried in walls (use conduit to prevent cable damage and to allow for future expansion cabling), or simply fixed to the surface with the cable clips provided. Wiring can also be run through floor or wall voids, in existing conduit or trunking, etc., saving much time and effort–however, it is best to avoid running cables next to mains wiring as, in certain circumstances, this could cause false triggering.

It is best to hide wiring where possible, not only is this less visually obtrusive, but also hinders tampering.

Safety Precautions

In addition to the warning about working on mains wiring, when working on the alarm panel, bell box, sensors and wiring, ensure that both the mains supply and lead-acid standby battery are disconnected–otherwise damage may occur.

When using power tools, always wear appropriate safety equipment to protect you from flying debris–keep other people out of your work area! When using ladders, ensure they are properly erected according to the manufacturer's recommendations. Don't over-stretch–move the ladders if necessary.

When drilling holes or chasing out plasterwork, check first for buried pipes or cables–they may not always be where you expect them!–especially in older premises; if necessary, use a cable and pipe locator.

Local Authority Regulations

Most local authorities will require that, in accordance with the 'Code of Practice on Noise from Audible Intruder Alarms', the sounding time of the bell-box siren is limited to 20 minutes. However, it is possible that certain local authorities may impose other restrictions, such as bell box siting in conservation areas, informing Police of key-holders, etc. It is therefore advised that you contact the Environmental Protection and Planning Officers to check local bye-laws.

Generally, with bell box only type alarm systems, unless bye-laws dictate otherwise, there is no obligation to inform the Police that an alarm has been fitted. That said, it is a good idea to do so and provide the details of at least two telephone contactable keyholders.

Installation

To assist familiarisation with the operation of the alarm panel, it is advised that the alarm panel is initially fitted and tested without the bell box or any sensors attached. Tables 1 and 2 list the functions of the various terminals on the alarm panel.

Ensure that the mains supply is disconnected before proceeding with the alarm panel installation.

Secure the alarm panel to the chosen surface using appropriate fixings.

The terminal block for the 240V AC mains connection is situated to the right of the transformer and should be wired, using 3-core 6A mains cable to the unswitched fused cable outlet (see Mains Supply, above). Referring to Figure 4, connect the wires as follows; the terminal marked 'N' connect the Neutral (Blue) wire, the terminal marked 'E' connect the Earth (Green & Yellow) wire, and the terminal marked 'L' connect the Live (Brown) wire.

The factory fitted wire links connected across terminal pairs must be left in place for testing purposes; the links should, however, be removed when fitting sensors.

Alarm Panel Testing

Hook the tamper switch spring under the left hand edge of the keypad. Connect the 12V lead-acid battery to the trailing red (+) and black (-) wires. It is critical to observe the correct polarity as the spade terminals and lugs are the same size.

It is likely that the battery may already be partially charged, if this is the case, as soon as this has been done, the speaker will begin to 'beep'. If the battery is not charged, unhook the spring, fit the front cover of the alarm panel and proceed to 'Mains Test'.

To stop the beeping, type in the factory pre-set user code. The 'Day' and 'PA' LEDs will be illuminated. Pressing 'RESET' will extinguish the 'PA' LED.

Unhook the spring, the speaker will beep again, to stop this, type in the user code again, The 'Day' and '24-Hrs' LEDs will be illuminated. Fit front cover of the alarm panel. Pressing 'RESET' will extinguish the '24-Hrs' LED.

Mains Test

Switch on the mains supply; the 'MAINS' and 'Day' LEDs will be illuminated.

Arm Test

Type in the user code and the 'Day' LED will extinguish. Press 'ARM', the speaker will beep for 30 seconds; during the final 10 seconds the beep will increase in speed. After this time the speaker will silence. The alarm panel is now armed.

Maplin Colour	User Colour	Sensors	Bell Box
Red		+ supply (PIR only)	Siren +
Black		- supply (PIR only)	Siren -
Yellow		Tamper loop	SCB Return
Green		Tamper loop	SCB 0
White		Zone circuits	Strobe +
Blue		Zone circuits	Strobe -

Table 3. Wire colours.

Disarm Test

Type in the user code, the 'Day' LED will illuminate. The alarm panel is now disarmed.

This concludes basic testing. You may wish to repeat the arm/disarm procedure a few times to familiarise yourself with operation of the panel.

Disconnect the mains supply, remove the front panel (type in the user code to stop the beep), disconnect the battery.

Wiring

50 metres of six-core burglar alarm cable are supplied with the system. The various wiring diagrams give wire colours for clarity; when wiring the components into the alarm system it is a good idea to decide upon your own colour scheme for security reasons. The colours used in the diagrams are shown in Table 3. It may be helpful to write your own colours in the 'User Colour' space provided in the table.

Any joins in the cable should be made with screw-terminal connectors within a security junction box. Depending on the complexity of the installation, it may also be necessary to join cables inside the alarm panel and PIR enclosures. Joints should be made using either small terminal blocks or by soldering the wires together and using insulation tape or heat-shrink sleeving – just twisting wires together is unreliable and will cause false alarms.

Sensor Installation

To make the most of the sensors supplied with the system, they must be installed and set up correctly. Compatible sensors other than those supplied may also be used. Note that if more than one sensor is to be used in a single zone, then all the sensors in that zone should be wired in SERIES. If the sensors were wired in parallel, then only the simultaneous activation of *all* sensors (a break-in) would trigger the alarm!

The tamper loop is designed to prevent anyone interfering with the alarm system, and it works by making a circuit through the devices that need to be protected. If this circuit is broken by either cutting a wire or where tamper switches are fitted, opening one of the units, the alarm panel will be triggered.

Note that although there are separate zones, the tamper loop is common to all zones.

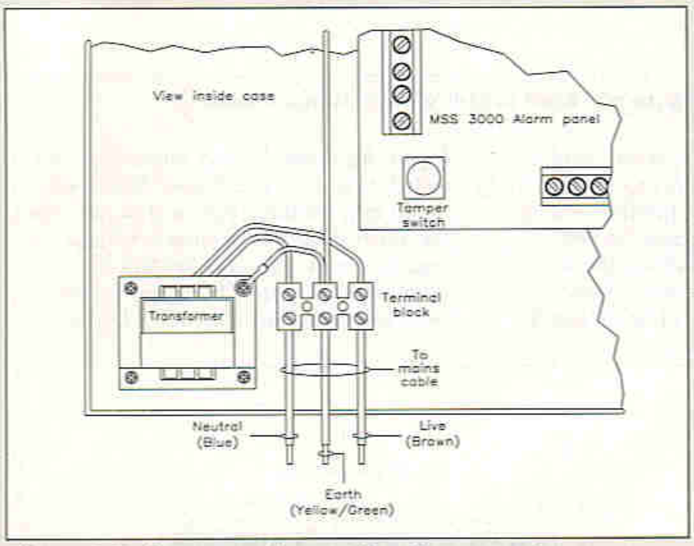
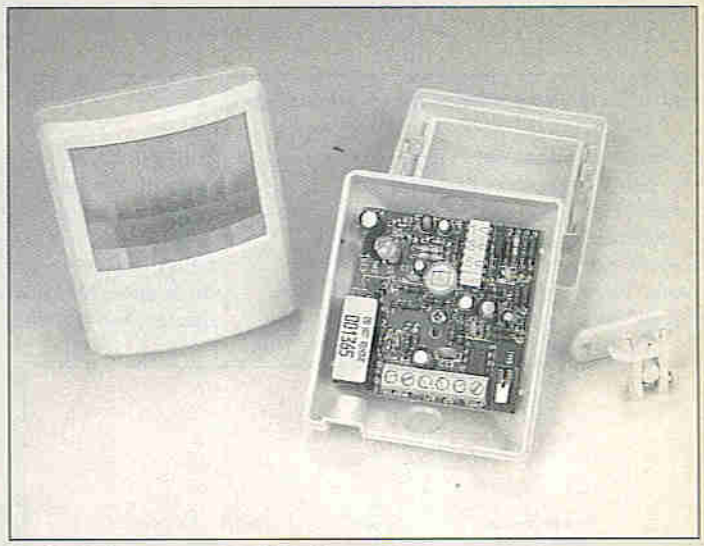


Figure 4. Mains connections to the alarm panel.



Typical PIR sensor used in the system.

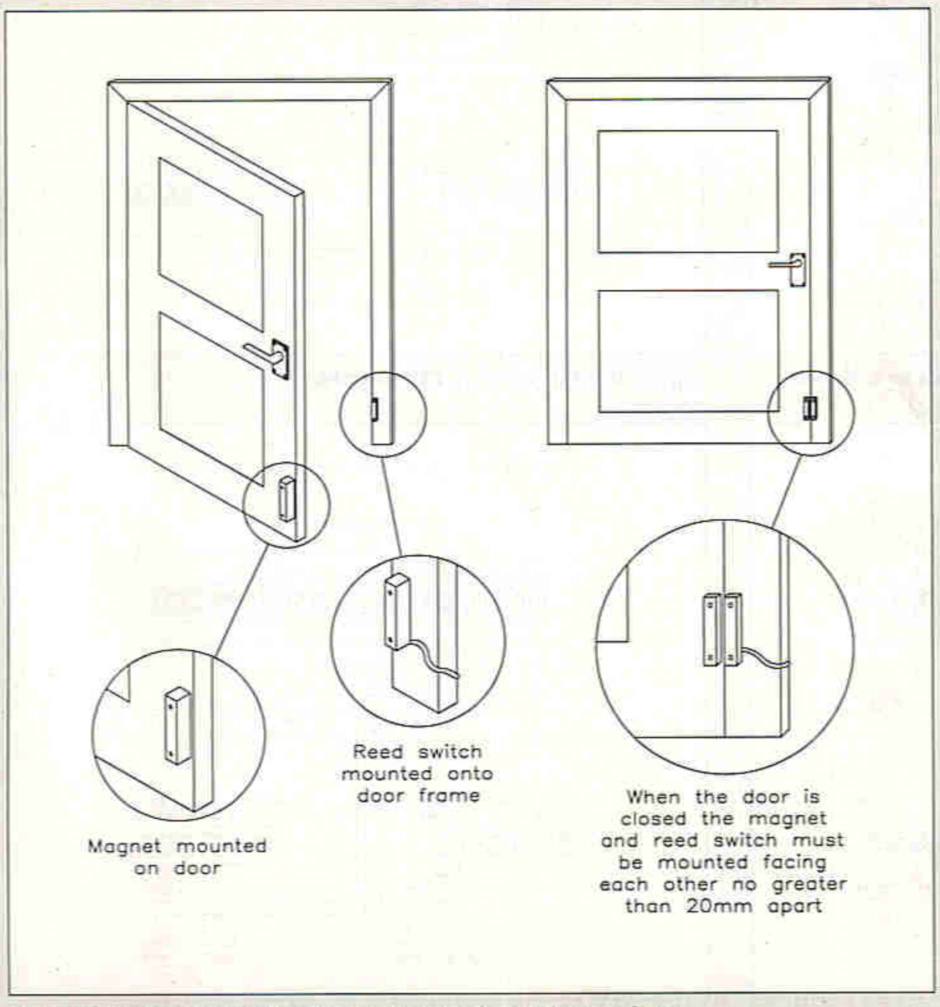


Figure 5a. Fitting a surface mounting reed switch to a door.

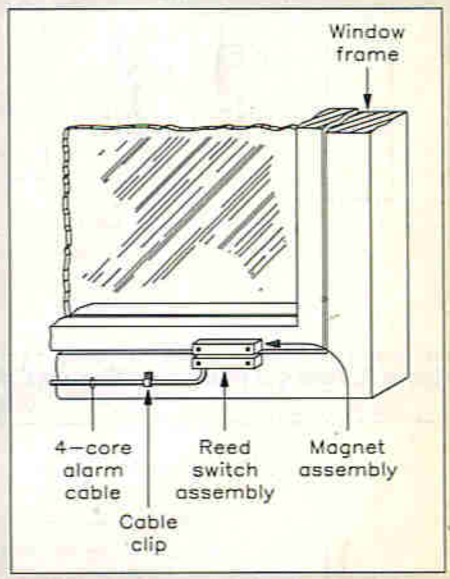


Figure 5b. Fitting a surface mounting reed switch to a window.

Reed Switches

The system is supplied with two surface-mounting reed switches; these can be

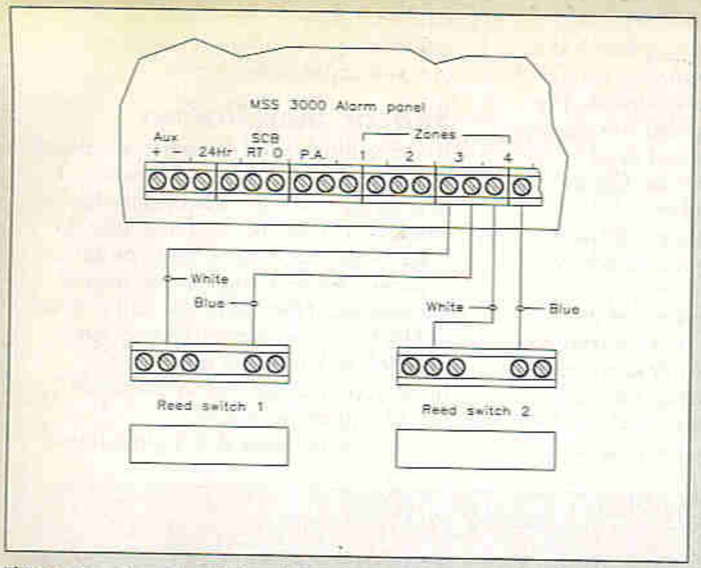


Figure 6a. Reed switch wiring: zone circuit.

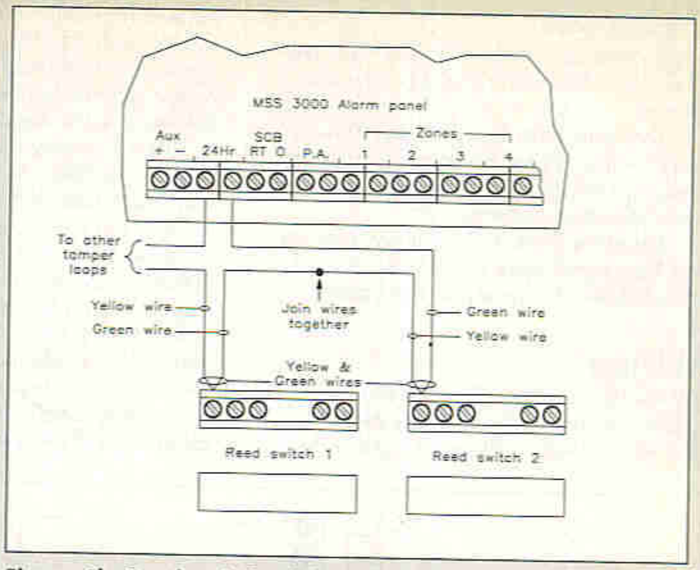


Figure 6b. Reed switch wiring: tamper loop.

mounted on either doors or windows. The switch comprises two parts, a magnet and the switch itself. The magnet is mounted on the 'opening' part of the door/window and the switch on the 'static' frame. When the door/window is closed, the magnet holds the switch contacts closed; when the door/window is open, the switch contacts spring apart. This simple action breaks the loop and triggers the alarm panel. When fitting, the two parts should be facing each other and not more than 8mm apart when the door/window is closed.

Figure 5a shows how to attach the reed switch to a door and Figure 5b shows fitting to a window. Figure 6 shows how the wires should be connected. Flush and recessed reed switches are also available; these may be preferred for practical or aesthetic reasons, Figure 7

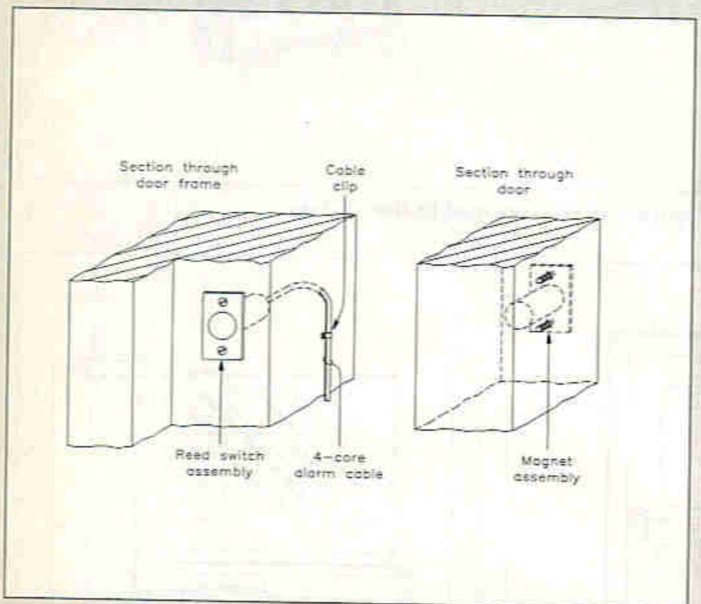


Figure 7. Fitting a flush mounting reed switch to a door.

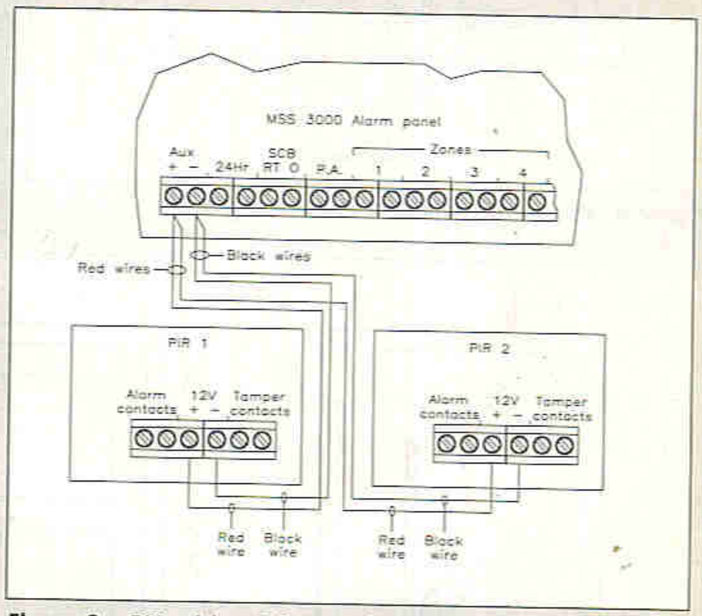


Figure 8a. PIR wiring: 12V supply.

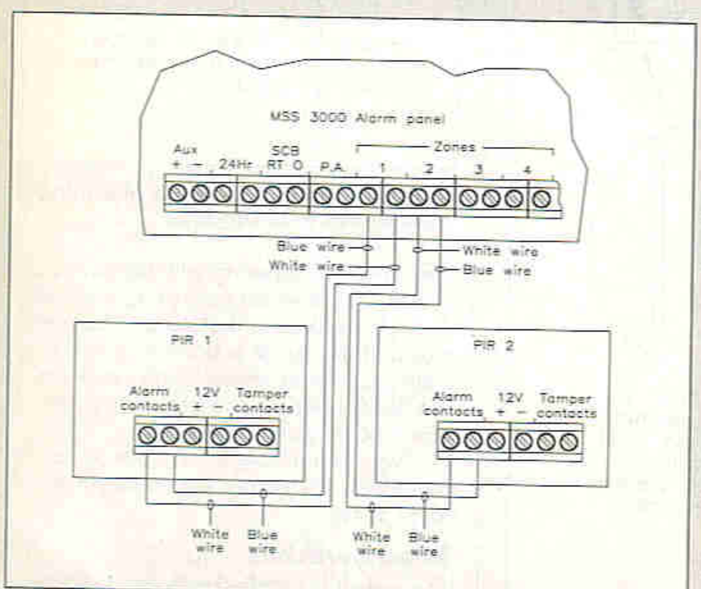


Figure 8b. PIR wiring: zone circuit.

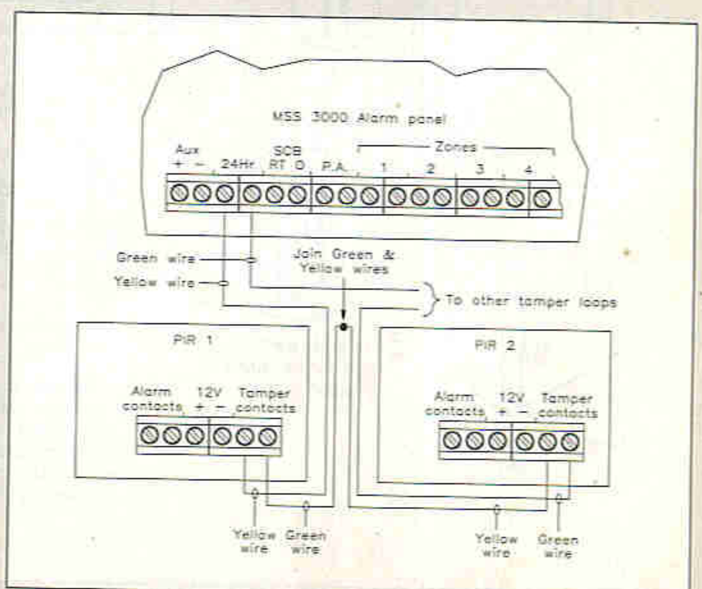


Figure 8c. PIR wiring: tamper loop.

shows how a flush reed switch can be fitted to a door.

Passive Infra-Red Detectors (PIRs)

The system is supplied with two PIR sensors. Since the exact type of PIR sensor supplied may vary, please refer to the instructions supplied with the sensor.

Generally, each PIR has a number of terminals for connecting to the alarm panel. These are the normally closed alarm contacts, +12V supply and normally closed tamper contacts. The 'alarm' terminals should be connected to the required zone (in series with other sensors). The +12V supply terminals, used for supplying power to the sensor, should be connected to the 'AUX' terminals of the alarm panel (in parallel with other PIRs). Ensure the correct polarity is observed when connecting the supply wires, otherwise damage could result. The tamper loop terminals should be connected to the '24 Hr' terminals on the alarm panel (in series with other sensors). Figure 8 illustrates typical wiring of a PIR.

Note: When the sensors are first 'powered up', they require a couple of minutes 'warming up time' before they will detect movement.

Bell Box

When the alarm is triggered the bell-box strobe will flash, and the siren will sound for 20 minutes. After this time the siren will then cease to sound, but the strobe will continue to flash until the alarm panel is reset. The siren sounding period can be changed, but ensure the time set complies with local authority regulations.

The siren is housed inside a tough brightly coloured plastic box, and has an integral tamper switch to detect any interference. This box is also used as a mounting platform for the strobe light. There are six connections from the alarm panel to the bell box. One pair operates the strobe and the other two pairs are used for activating the siren, charging the back-up batteries and to inform the alarm panel if the bell box has been tampered with, or the wires cut. Figure 3 shows how to connect the bell box to the alarm panel. Due to the manufacturer's policy of continued product improvement, it is possible that the exact layout of the connections will change; however, where necessary, full details of the changes will be supplied with the unit.

Before fitting the bell box, it is advisable to discharge the battery pack (it would have been charged sufficiently by the manufacturer to test it). This will prevent a 112dB siren sounding in close proximity to your ears, whilst up a ladder, when making the final connections! The easiest way to do this is to 'carefully stuff' a piece of cloth (e.g., a sock!) into the mouth of the siren and connect the battery link.

The cable to the bell box should, ideally, not be accessible from outside the premises, i.e., it should pass directly through the wall behind the bell box. The hole for the cable should be drilled diagonally upwards from the outside; this will prevent rain water running in!

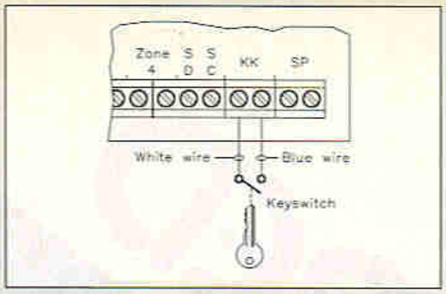


Figure 9. Connecting the optional keyswitch.

Accessories

Remote Keyswitch

An external keyswitch may be connected to the two terminals designated as 'KK' (Figure 9 shows the connections). This allows the alarm to be remotely armed or disarmed without having to enter the four-digit code. Note that this unit, for obvious reasons, incorporates a tamper switch; this should be incorporated in series with the other tamper switches in the system. It is important that the keyswitch is mounted *outside* all the zones.

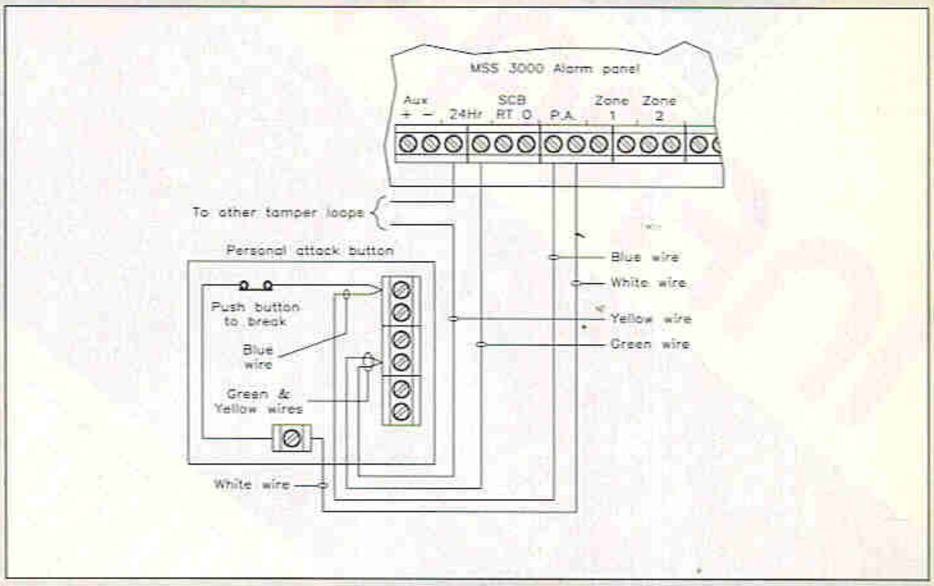


Figure 10. Connecting the optional personal attack buttons.

The bell box should be securely fitted to the desired surface with appropriate fixings.

Please note that once the alarm is fully operative any maintenance to the bell box will cause the siren to operate. Therefore, it is necessary to be ready for this – use earplugs when working up a ladder in close proximity to the bell box. It would also be a good idea to engage another person to disarm the alarm as soon as it sounds, minimising annoyance caused to others.

MSS3000 Fuses

The MSS3000 contains two internal fuses, which are both F1A 20mm types. F1 is used for protecting against any faults with the battery, while F2 protects the unit's power supply from short-circuits across the 'AUX' (PIR sensor 12V supply) or 'BELL' terminals – accidental or malicious. Even if the supply to the siren was to be cut, due to F2 failing in such a way, the back-up battery would power the siren for a significant period.

Normally Open Sensors

In the event that sensors with normally open type contacts need to be connected to the system, correct operation can be achieved by leaving the factory fitted link across the zone in question and wiring the sensor between the linked terminals and the 'AUX–' terminal. Examples of this type of sensor include pressure mats and some panic buttons.

Personal Attack Buttons

Although not supplied with the system, personal attack buttons can be easily added. If an intruder enters occupied premises or in the event of an emergency, the personal attack button can be pressed triggering the alarm panel and bell-box siren instantly, regardless of whether the alarm is armed or not. These buttons should be conveniently located, for example near main doors, under a counter, in bedrooms, etc. Depending on how the alarm panel is programmed, pressing the personal attack button will either trigger both the bell-box strobe and siren, or just the strobe. The button should have normally closed contacts. Connection is made to the 'PA' (personal attack) terminals on the alarm panel. It is also advisable to connect the tamper loop to the personal attack button; note the tamper loop wiring does not actually connect to the contacts of the button. Connection of the personal attack button is shown in Figure 10.

Other Accessories

A wide range of other accessories are available from Maplin, refer to the current Maplin Catalogue or visit one of the many regional Maplin stores.

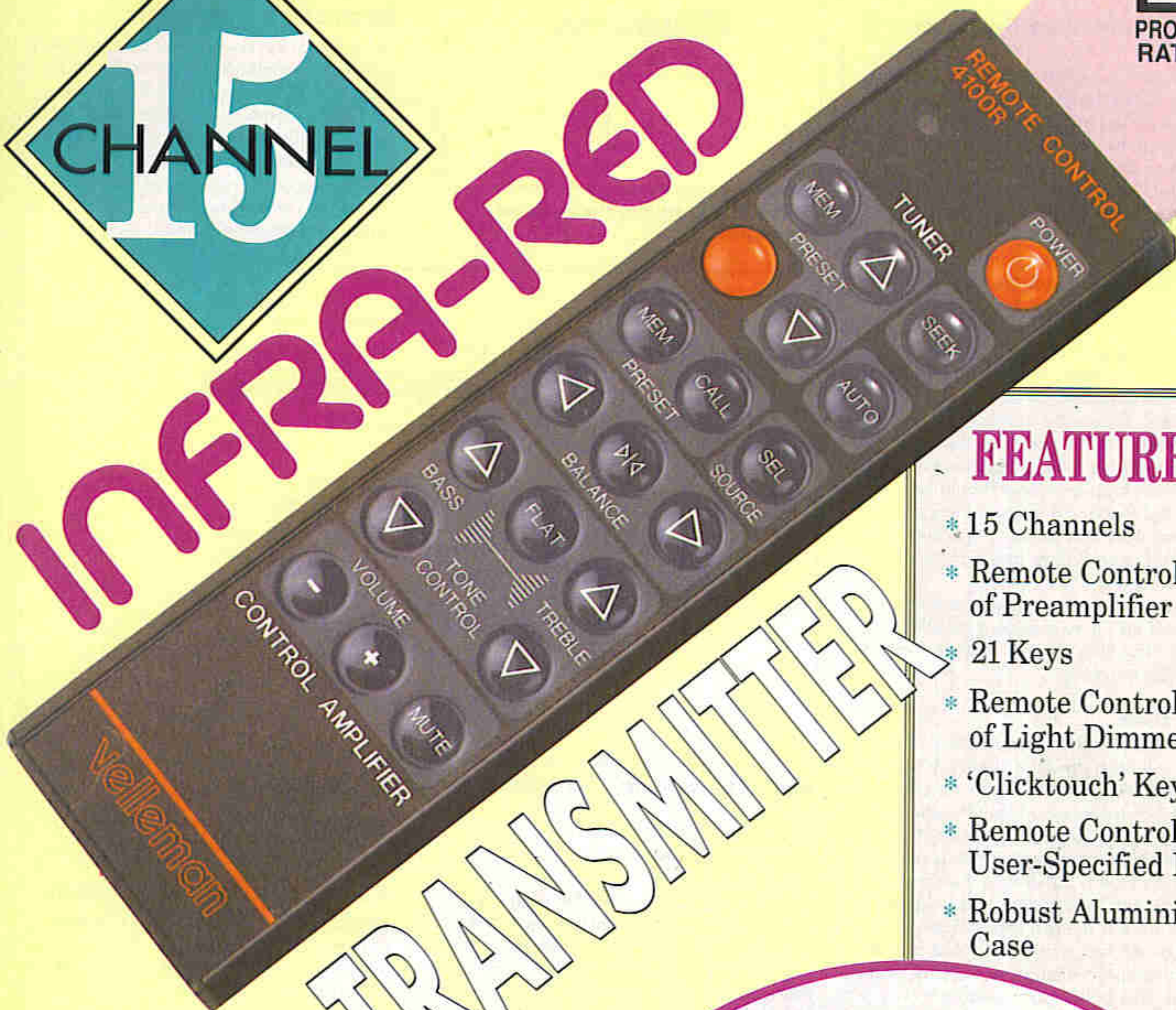
Testing

Advise your neighbours that you will be testing the alarm; otherwise you may get

Continued on page 64

15 CHANNEL INFRA-RED TRANSMITTER

2
PROJECT RATING

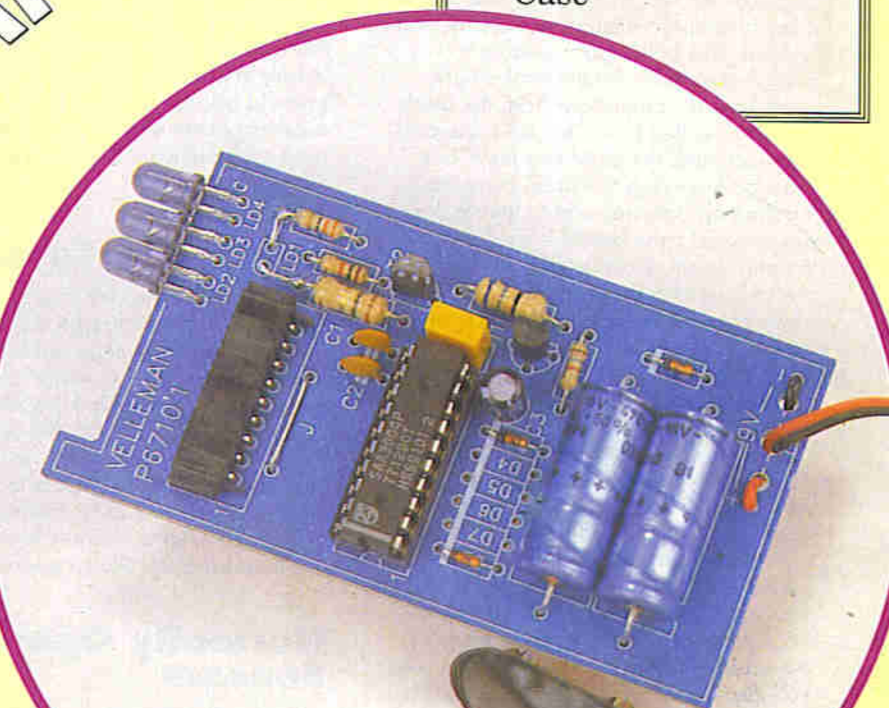


FEATURES

- 15 Channels
- Remote Control of Preamplifier
- 21 Keys
- Remote Control of Light Dimmer
- 'Clicktouch' Keypad
- Remote Control of User-Specified Items
- Robust Aluminium Case

Text by Martin Pipe and Nigel Skeels

This infra-red transmitter is designed to provide the Digitally Controlled Preamplifier Project (see Issue 52 of 'Electronics') with full remote control of all functions, including power, volume, tone and input selection. Another transmitter similar to this one is also available from Maplin; this is designed for use with the Dimmer Switch and the Single Channel and 15 Channel Infra-Red receivers – all featured in the Maplin Catalogue.



The Transmitter PCB.

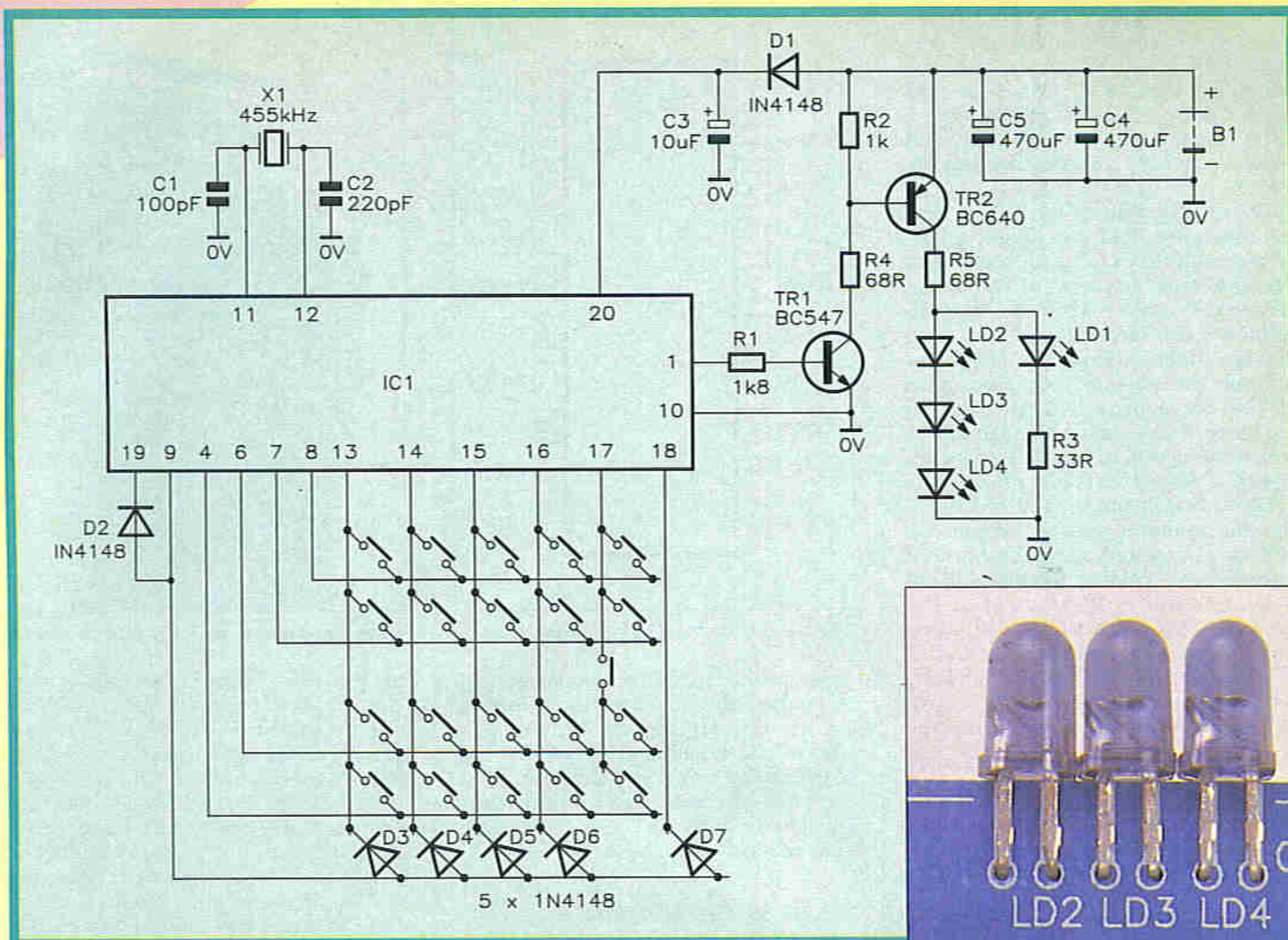
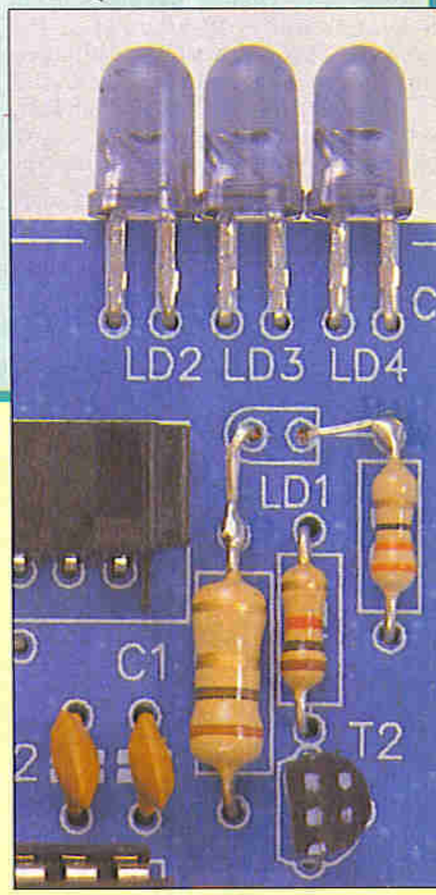


Figure 1. Circuit diagram of 15-Channel Infra-Red Transmitter.



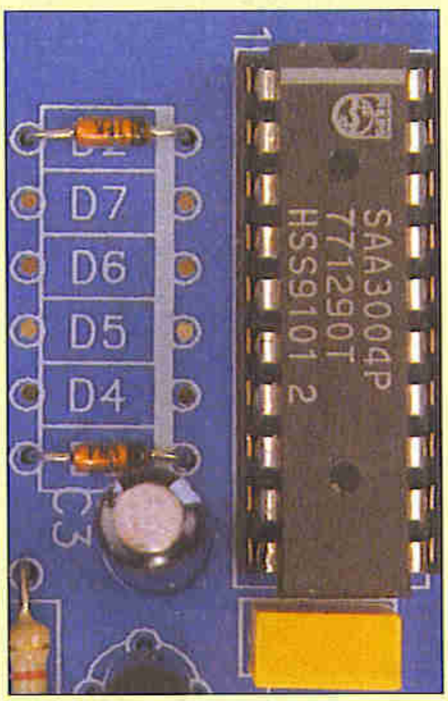
Close-up showing connections of the 'operate' LED to R3 and R5.

Apart from the two keypad leg ends, the two transmitters are exactly the same; in fact, one will do the job of the other – it is only the combination of diodes D3 to D7 that determine the unit with which the transmitter can be used. This is a distinct advantage if you have more than one remote controlled kit in the room; after all, you don't want to inadvertently dim the lights in your room whilst turning down the volume of your stereo system.

The case is extremely rugged – which is more than can be said for that of the average TV/VCR remote control unit! Its main body is an anodised aluminium extrusion with matching end-cheeks, while the keypad itself is one of the celebrated 'Clicktouch' designs. The latter has a characteristic responsive feel to it, unlike other membrane designs which offer no tactile feedback whatsoever. A positive advantage that 'Clicktouch' keypads share with their membrane counterparts is a high degree of protection against moisture ingress. A red LED, visible from the keypad, shows that the unit is functioning when a key is pressed and gives some idea as to the condition of the battery.

Circuit Description

As can be seen from Figure 1, most of the electronics are contained in IC1, a Mullard SAA3004. If it wasn't for this



Close-up of the 'configuration diodes'.

IC, the unit's slimline case (which fits comfortably in the palm of the hand) would simply not be large enough to contain a 15 channel system of this complexity.

The pinout of the SAA3004 is shown in Figure 2. Pins 2 to 8 (SENxN) and 13 to 19 (DRVxN) are the keypad matrix inputs (SENSE) and outputs (DRIVE) respectively.

The keypad of the remote control unit is arranged as a scanned matrix, formed by these two groups of seven lines. The SAA3004 can provide up to 64 commands; the 21 used in this design have been chosen for their compatibility with the remote control systems of the relevant projects. To avoid confusion, it is best to explain at this stage that the 21 keys of the transmitter provide the 15 functions – some of the functions require more than one key (volume up/down or balance left/centre/right, for example). Diodes D2 to D7 form a part of the 15-key matrix. The absence or presence of each of these determines which of the 64 overall functions will be used – different projects require different command codes. Pin 9 (ADRM) determines the output data format; when connected to DRV6N (pin 19), the pulses are modulated (otherwise they are output as 'flashes' of infra-red – suitable for use with wide-band receivers only, and not applicable here.)

Normally, the seven drive pins (columns) are held low. When a key, or a combination of keys, have been pressed, one (or more) of the seven sense pins (rows) – which are normally high – are forced to ground. This provides information as to which row contains the activated key. Next, each of the drive pins is held high in sequence to determine the column in which the operated key can be found. With the address of the key found, the 455kHz oscillator (based around a ceramic resonator present at pins 11 and 12) is powered up, and a burst of pulses corresponding to this address is sent to pin 1, the output of the SA3004. This pulse-width modulated information is supplied to the buffer (TR1) and the LED driver (TR2), which switches the LEDs on and off correspondingly. C3 and D1 are

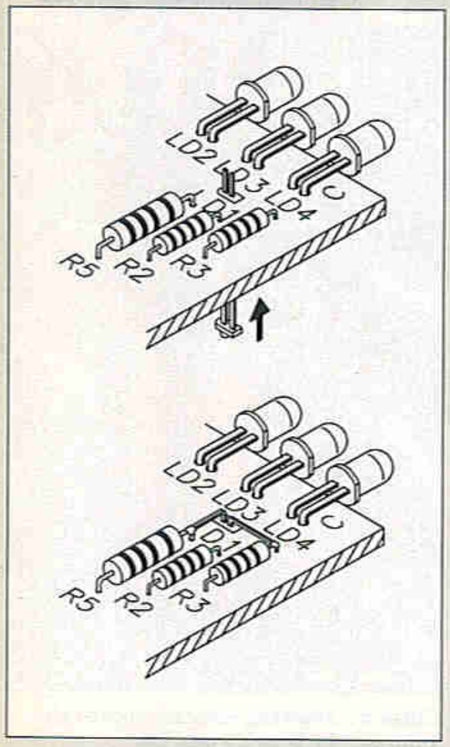


Figure 3. Installing 'operate' LED (LD1).

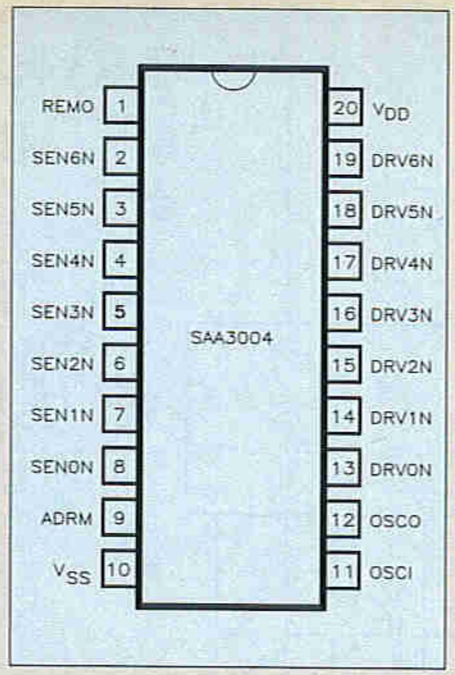


Figure 2. Pinout of IC1 (SAA3004).

present to ensure correct operation of IC1 when the batteries are running low. Relatively large value (470μF) electrolytic capacitors C4 and C5 are present for the same reason; TR2, for example, requires a significant current to drive the four LEDs present between its collector and ground.

PCB Construction

Construction of the PCB is straightforward. However, it is important to ensure that all polarised components (electrolytic capacitors and semiconductors – particularly the LEDs) are orientated correctly prior to soldering. Diodes D3 to D7 should be inserted

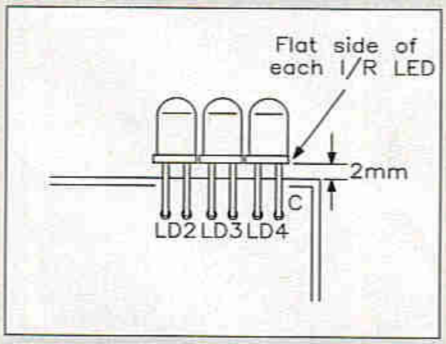


Figure 4. Fitting I/R LEDs (LD2 to 4).

Take care inserting PCB into the case!

or left out – see 'Configuring the Transmitter'. Note that IC1 is socketed; it should be fitted so that the groove in one end, lines up with that shown on the legend. Do not insert the IC at this stage. The connector for the keypad's ribbon cable should be installed so that it points to the top of the PCB. Helpful constructional information, if you need it, can be found in the Constructors' Guide (Order Code XH79L, if you don't have one already!) As you can see from Figure 3, LD1 (the red 'operate' LED) is inserted from the track side of the PCB so that it can be seen from the keypad side of the unit; in addition, its body is fitted flush against the

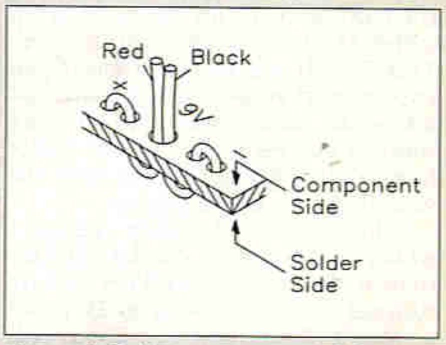


Figure 5. Battery connector wiring.

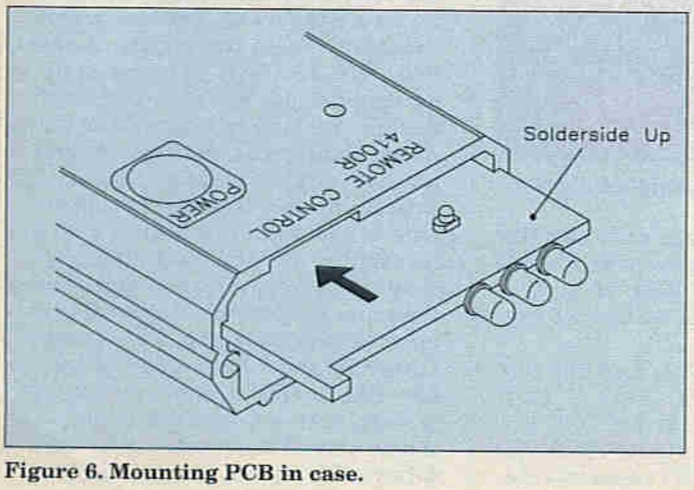


Figure 6. Mounting PCB in case.

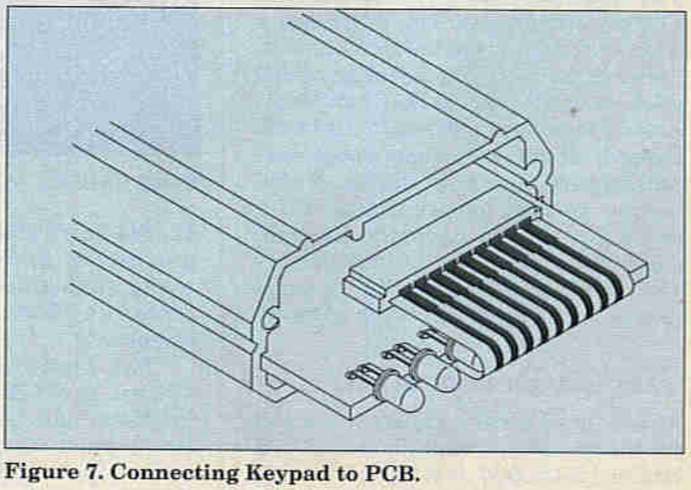


Figure 7. Connecting Keypad to PCB.

Project (Maplin order codes in brackets)	Diodes (Yes = Fitted)				
	D3	D4	D5	D6	D7
Preamplifier (VE46A)	Yes	No	No	No	No
15 Channel Receiver (VE73Q)	No	Yes	No	No	No
1 Channel Receiver (VE75S)	No	Yes	Yes	Yes	Yes
Light Dimmer (VE74R)	No	Yes	Yes	Yes	Yes

Table 1. Configuration of transmitter

Transmitter carrier frequency:	38kHz
Number of identification codes:	6 (set by diodes)
Number of independent channels:	15
Power supply voltage:	9V (PP3 battery)
Current consumption (standby):	0·1µA
Current consumption (transmit):	10mA (average)
Keypad:	Velleman 'Clicktouch' with tactile feedback
Dimensions:	50mm (W) x 23mm (H) x 175mm (L)

Table 2. Specifications

PCB. Note from the diagram that the anode of the LED is soldered to R5, while its cathode is soldered to R3. The three infra-red LEDs are mounted as shown in Figure 4; note that their leads are folded by 90°, and that the base of each LED is at a distance of 2mm away from the PCB. Polarity is important – each device should be mounted so that its flat side (cathode) should appear on its right-hand side, when viewing the top of the PCB from the component side. Figure 5 shows how the battery clip leads are fitted; each wire is passed through three holes before being soldered. This arrangement has the effect of acting as a cord grip, keeping the strain off the solder connections. It is critical that the wires are fitted the right way round, or the components could be damaged when the battery is fitted.

Configuring the Transmitter

Each of the projects intended for use with this remote control transmitter identifies a specific group of codes. As mentioned in the circuit description, these codes will depend on what has been sensed by the SAA3004's keypad matrix. The presence or absence of D3 to D7 determines the arrangement of this matrix, the commands sent, and thus the equipment with which it can be used, refer to Table 1.

Mechanical Assembly

Once the PCB has been assembled, mechanical assembly can commence– but only after a thorough check has been made for misplaced components, solder bridges, etc. Spotting problems at this stage helps to prevent trouble later on!

When fitting the membrane to the case of the unit, extreme care must be exercised when positioning it, as it sticks very well! Note that the viewing hole in the case for the 'operate' LED must line up with the corresponding clear 'window' of the membrane. With the membrane in place, the case is ready to accept the PCB – as shown in Figure 6. From this diagram, it can be seen that the PCB (bottom end first) is fed into the top of the case – with the track side of the PCB facing the same way as the keypad. As it is passed through the case, the battery connector should appear out of the other end. When the top of the board is about 30mm from the top of the case, the ribbon cable should be looped over the PCB and mated with its connector – see Figure 7. The board can then be pressed home so that the lug protruding from the top of the PCB is level with the case (the 'operate' LED should be visible through the window). The excess ribbon cable can then be folded and pushed into the case. Next, the supplied piece of foam should be inserted from the bottom, making sure that the battery connector is not fouled in any way. Finally, the unit can be tested with a PP3 battery, and if all is well the top and bottom plates can be screwed in place. Your remote control transmitter is now complete!

INFRA-RED TRANSMITTER PARTS LIST

RESISTORS: All 0·25W Carbon Film (Unless specified)

R1	1k8	1
R2	1k	1
R3	33Ω	1
R4	68Ω (1/2W)	1
R5	1Ω (1/2W)	1

CAPACITORS

C1	100pF ceramic	1
C2	220pF ceramic	1
C3	10µF electrolytic	1
C4, C5	470µF electrolytic	2

SEMICONDUCTORS

IC1	SAA3004	1
T1	BC547 (or equivalent)	1
T2	BC640 (or equivalent)	1
D1–7	1N4148 (or equivalent)	6 (used as required)
LD1	Subminiature Red LED1	
LD2–4	Infra-Red LED3	

MISCELLANEOUS

X1	455kHz Ceramic Resonator	1
	Battery Connector	1
	Keypad	1
	Case	1
	PCB	1
	Top plate	1
	Bottom plate	1
	5mm M3 countersunk screw	4
	Construction/user guide	1

OPTIONAL (Not in Kit)

Alkaline PP3 Battery	1 (FK67X)
Constructors' Guide	1 (XH79L)

The Maplin 'Get-You-Working' Service is available for this project. See Constructors' Guide or current Maplin catalogue for details.

The above items (excluding Optional) are available in kit form only.

Order As VE47B (Pre-Amp Remote Control) Price £37.95

Order As VE72P (15 Channel Remote Control) Price £39.95.

Please Note: some parts, which are specific to this project (e.g., PCB), are not available separately.

The Inside Story – How a Superhet Radio Works

by Ian Poole (G3YWX)

From the very simplest transistor portable radios to the most sophisticated scanners, all radios use some fairly complicated circuitry. They reject unwanted signals (some of which could be just off the frequency of the required channel) whilst amplifying the wanted ones. They are able to tune over wide ranges. Even straightforward broadcast receivers will often cover bands from the relatively low frequencies of the long wave, to the VHF FM band located between 87·5 and 108MHz. Scanners will cover much more than this! To be able to do all of this successfully a lot of development has been needed, from the very earliest days of radio right up to the present day. Many people have spent large parts of their lives investigating better methods for use in radios. Some have been remembered for their work, whilst other names have faded into the mists of time.

One of the most successful developments has been that of superhet radio, which is used as the basis for virtually all of the radio and television sets available today.

Although it gained its popularity in the 1920s, its use is still widespread. The first designs used valves, and in the 1950s the first transistor sets were introduced. Now ICs are widely used, but despite the technology the same basic principles have been used since 1918, when the superhet system was first developed.

The Need

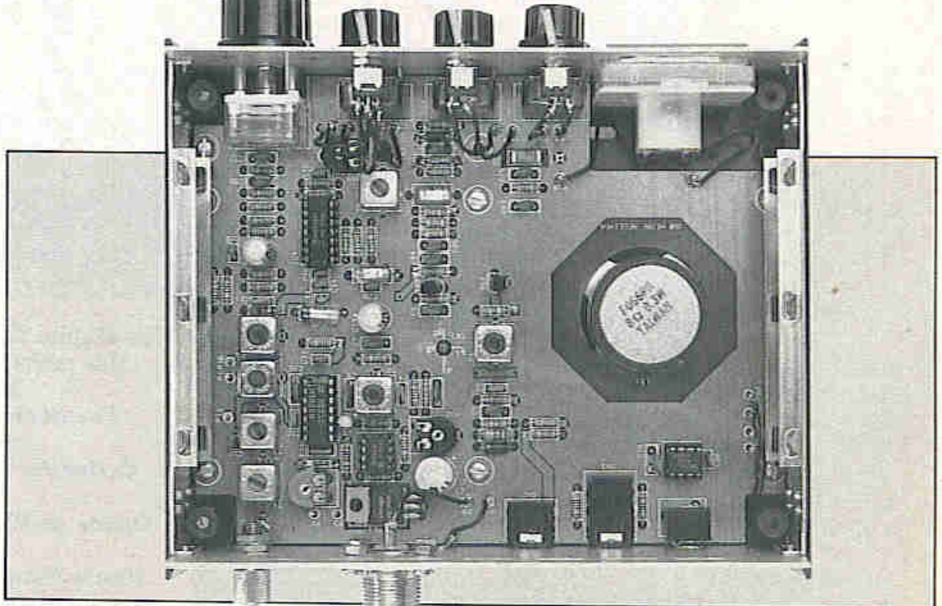
With the vast number of stations which are using the radio spectrum these days, good selectivity in a radio is of paramount importance. For example, a radio on the medium wave broadcast band must be able to select a signal on one frequency and reject one on an adjacent channel only 9kHz away. Scanners operating up to frequencies of 1000MHz or more must be able to distinguish between stations spaced by 25kHz or possibly less. This calls for quite sophisticated circuitry.

Most early radio receivers used the tuned radio frequency (TRF) principle. As is implied by the name, tuning took place at the frequency of the signal itself. Accordingly all the selectivity was contained within the radio frequency stages of the radio. This approach was not at all easy to implement for two reasons. The first was that it was not at all easy to obtain sufficient selectivity at the frequencies being used. The second problem occurred when several stages of filtering were used. Each stage needed tuning from one frequency to the next and they all had to move, or 'track', at the same rate. Anybody who has, at some time, built a crystal set will have experienced one of the limitations of a system in which all tuning takes place in the RF stages; with these simple sets you can often hear two stations at once – an indication of poor selectivity. Even though other techniques were used to improve on the basic selectivity, they still left a lot to be desired and so a quantum leap in thinking was required.

Mixing

To overcome the selectivity problem, a receiver known as the supersonic heterodyne was developed. Nowadays, the name has been shortened to 'super-

The Maplin 'Ranger' 160m receiver, featured in Issue 43 (April/May 1991) of 'Electronics'.



Inside the 'Ranger' receiver, which is based around the LM3820 AM IF sub-system IC. This IC (bottom left) contains RF/IF amplifiers with automatic gain control (AGC), a local oscillator and a mixer. As a result, the component count is considerably reduced.

het', but its name gives a clue to the principle involved. Two signals are 'heterodyned', or mixed, to give a signal on another frequency.

An everyday example of this process happens when two musical notes, which are almost at the same pitch, are heard together. The two notes appear to cancel one another, and then reinforce one another. The beat note which is produced is used by musicians to tune their instruments to the same frequency, because when the frequency of the note seems to fall to zero, it means that the notes of both instruments are the same. From this it can be deduced that the frequency of the beat note is equal to the difference between the two original signals.

To produce this type of effect electronically is quite simple. Two signals are fed into a circuit which enables them to interact with one another. This is done by electronically multiplying them together. It means that for any instant, the output is proportional to the instantaneous levels of two input signals multiplied together. By doing this, a beat note is produced at a frequency equal to the difference of the two input signals. In addition to this, there is another signal at the sum of the two frequencies. In other words, if the two input frequencies are f_1 and f_2 then the output frequencies are at $f_1 + f_2$ and $f_1 - f_2$.

In practice, it is found that any circuit without perfect linearity will have a mixing effect on signals entering it. This is why power amplifiers for AM and SSB transmitters must be linear. If they are not, extra frequencies are then generated and the signal sounds very distorted.

It is quite easy to demonstrate the effect of mixing two signals together in a multiplying circuit or mixer. It can be done as shown graphically in Figure 1. In the diagram the two signals have been multiplied together. To show the effect clearly, two signals which are fairly close together have been chosen. In this way, the result of the mixing process gives two signals that are well removed from one another and quite easy to see. The low frequency 'difference' component (consisting of $f_1 - f_2$) has the high frequency 'sum' component $f_1 + f_2$ superimposed upon it.

In the Radio

The idea of the superhet radio is to use the principle of mixing to convert the signals from a higher frequency (such as the medium wave broadcast band) down to a fixed intermediate frequency (IF). By mixing the incoming signal with the output of a variable frequency oscillator, different frequencies can then be received. This means that the IF can use fixed filters which can be finely tuned to give good selectivity. The output of the variable frequency oscillator (also known as the 'local' oscillator, or LO) is normally kept close to that of the incoming signal, so that the sum and difference signals will be markedly different. This makes the design of IF filters much more straightforward – but there *are* problems, as you will find out.

Figure 2 shows the basic operation of the superhet system. It involves the LO, a mixer, an IF filter and an amplifier. Unfortunately, it can be seen from the diagram that there are *two* input frequencies that will, for a particular oscillator frequency, give the IF frequency.

To see how this happens, take the example shown in Figure 2. The IF is 500kHz and the LO frequency is 1500kHz. In order to have frequencies converted down to a lower IF, the difference frequency is generated by the mixing process. However, there are two routes by which this can happen. The first is the incoming radio frequency minus the LO frequency, while the second is the LO frequency minus the (different) frequency of another incoming radio signal. From Figure 2, for example, it can be seen that an input of 2000kHz gives an output at 500kHz (2000kHz – 1500kHz), but so does 1000kHz (1500kHz – 1000kHz)!

This is obviously not acceptable. To overcome the problem, some tuning or filtering is placed in the RF section (the

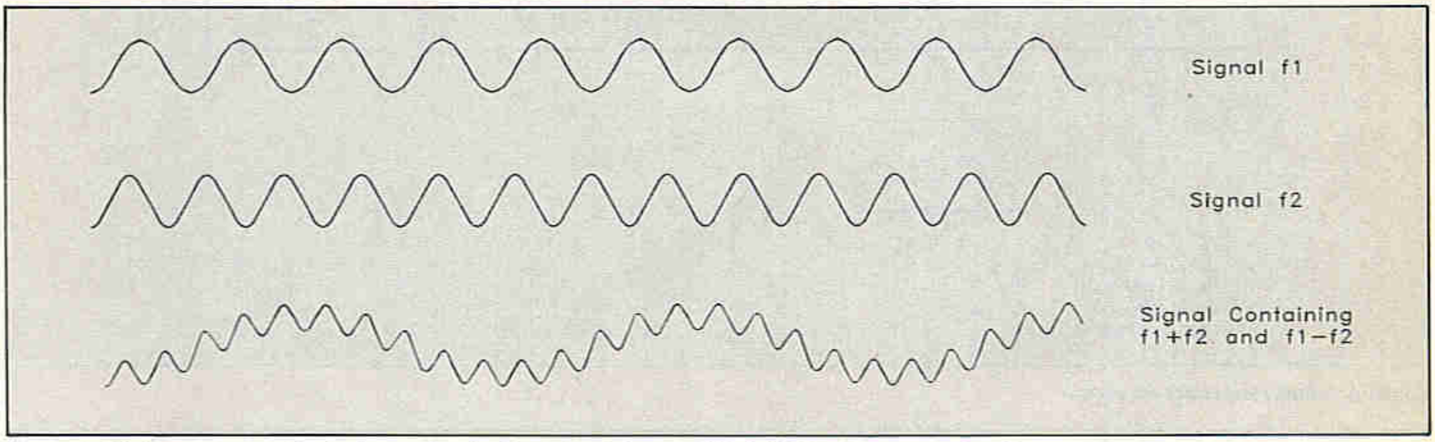


Figure 1. Mixing, or 'heterodyning', two signals. Note that f_2 is at a slightly higher frequency than f_1.

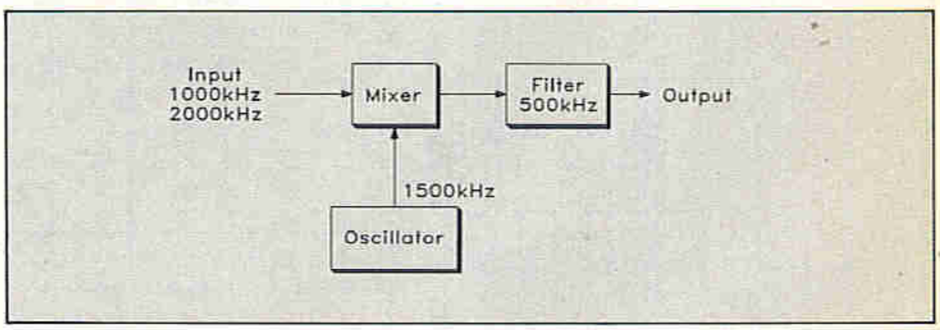


Figure 2. Block diagram of the down-conversion part of a superhet radio.

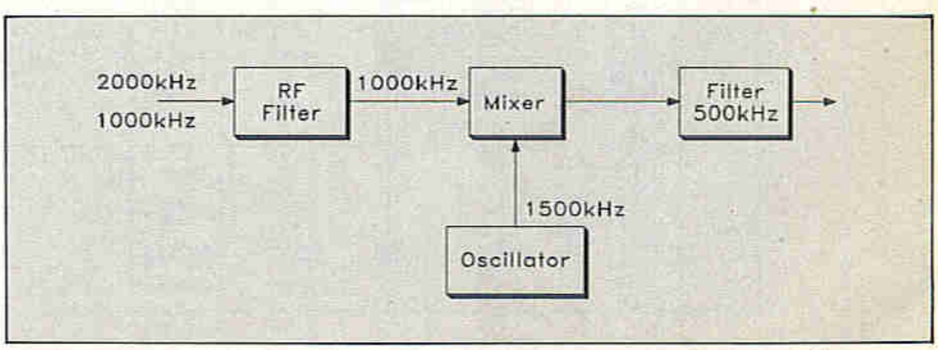


Figure 3. A tuned circuit in the RF stage considerably attenuates the unwanted image frequency.

The Maplin Mk.2 FM Radio, based around the TDA7000 IC. Details on this set can be found in Issue 27 (June/August 1988) of 'Electronics'.

'front end') of the receiver – see Figure 3. Because the superhet design, unlike the TRF receiver, does not need to reject stations on the next channel (which may only be a few kilohertz away), the response of this filter does not need to be particularly sharp. Instead, it needs to be able to accept stations on the wanted frequency – and reject others on the unwanted one (known as the 'image' frequency), which might be a megahertz or more away.

Tuning

The circuit of Figure 3, in its current state, will only accept signals on one frequency. For the sake of argument, let us assume it to be 1000kHz. To tune the radio, it is necessary to change the oscillator frequency. If it is moved up by 10kHz to 1510kHz, it will be found

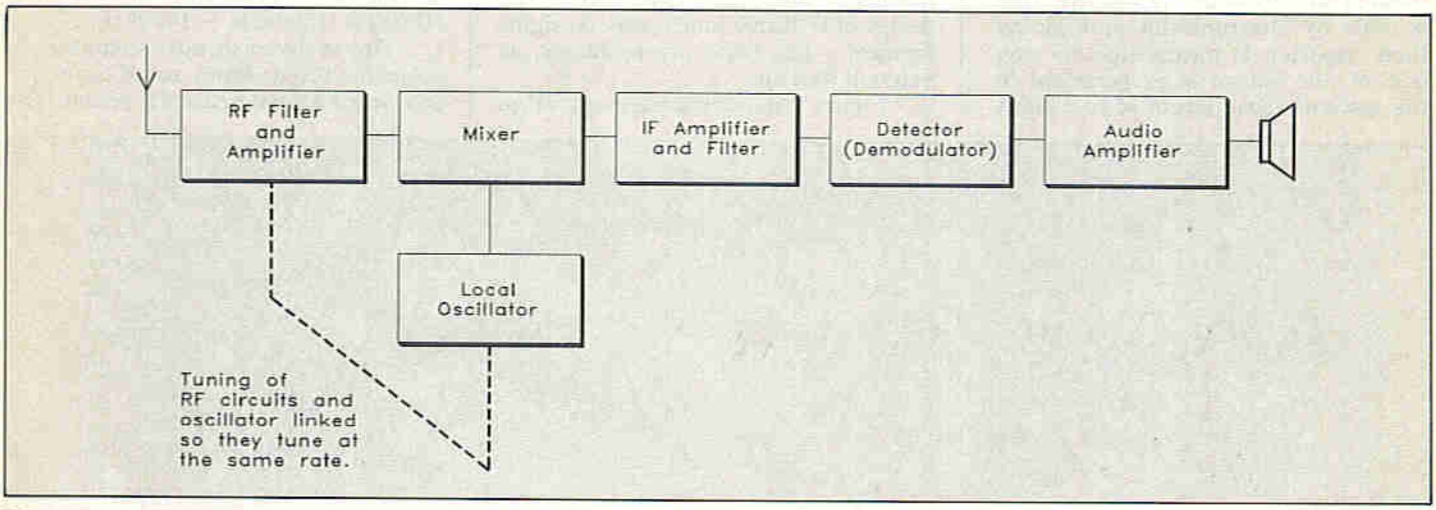


Figure 4. A basic superhet receiver.

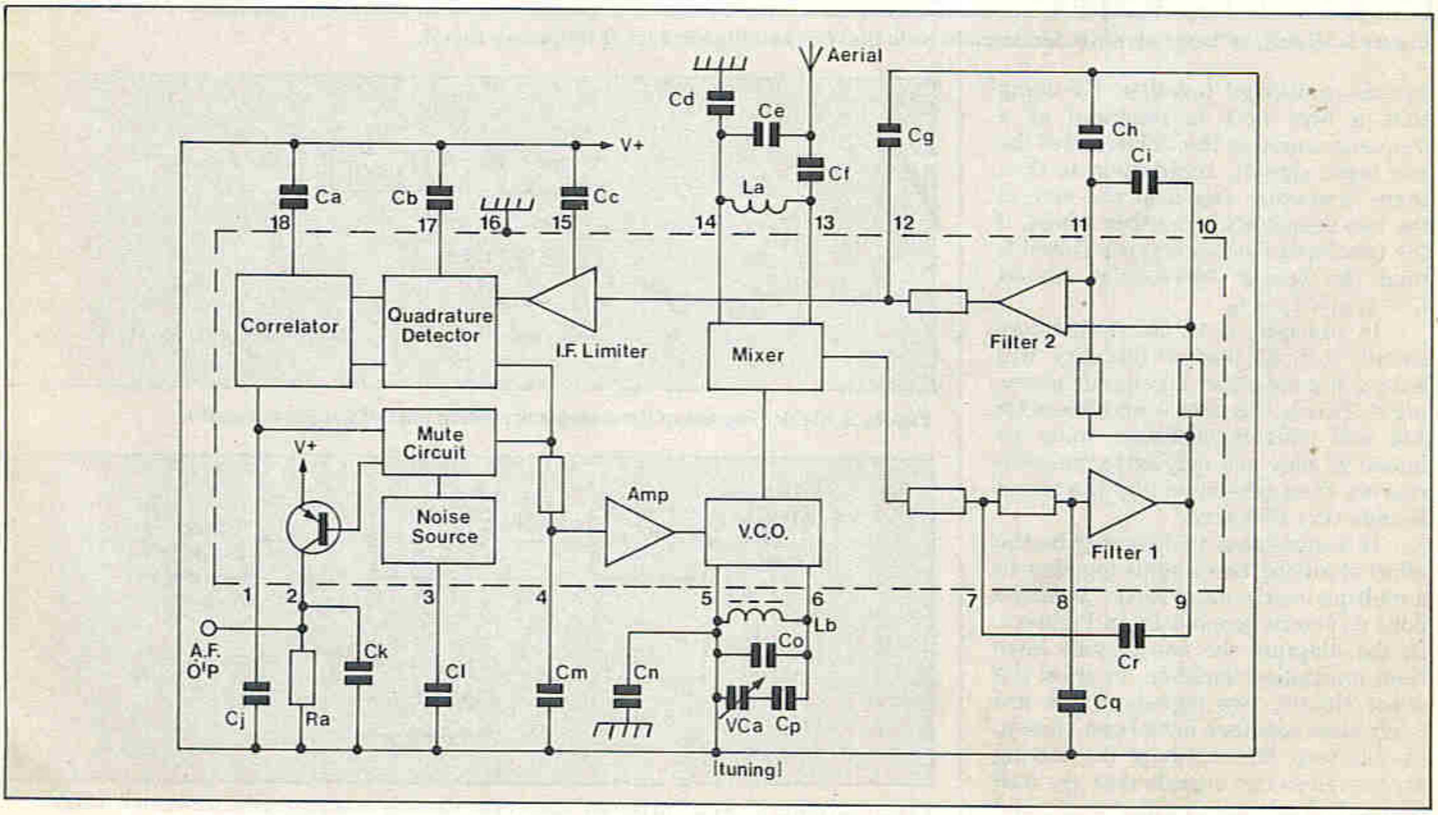


Figure 5. Block diagram of the TDA 7000 'single chip' FM radio.

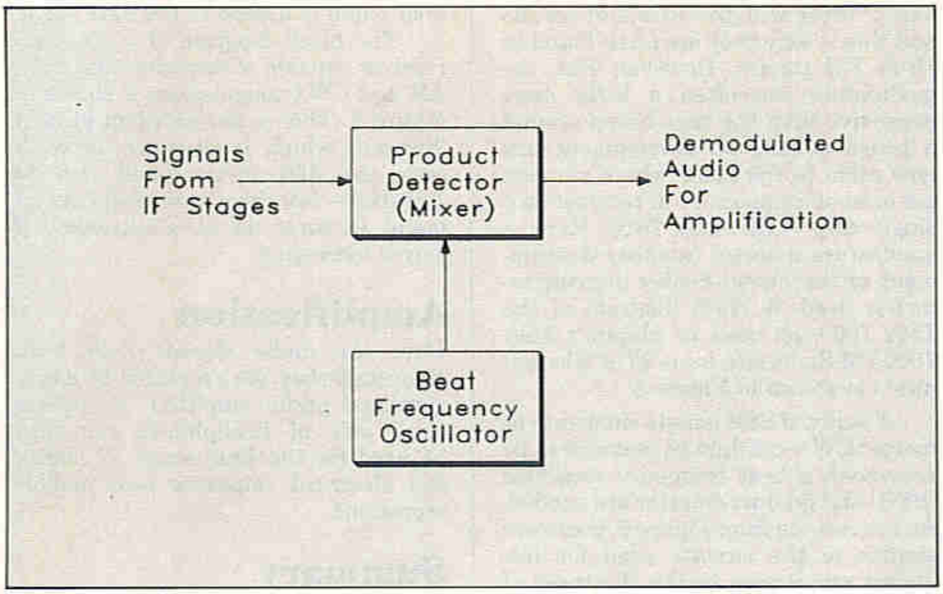
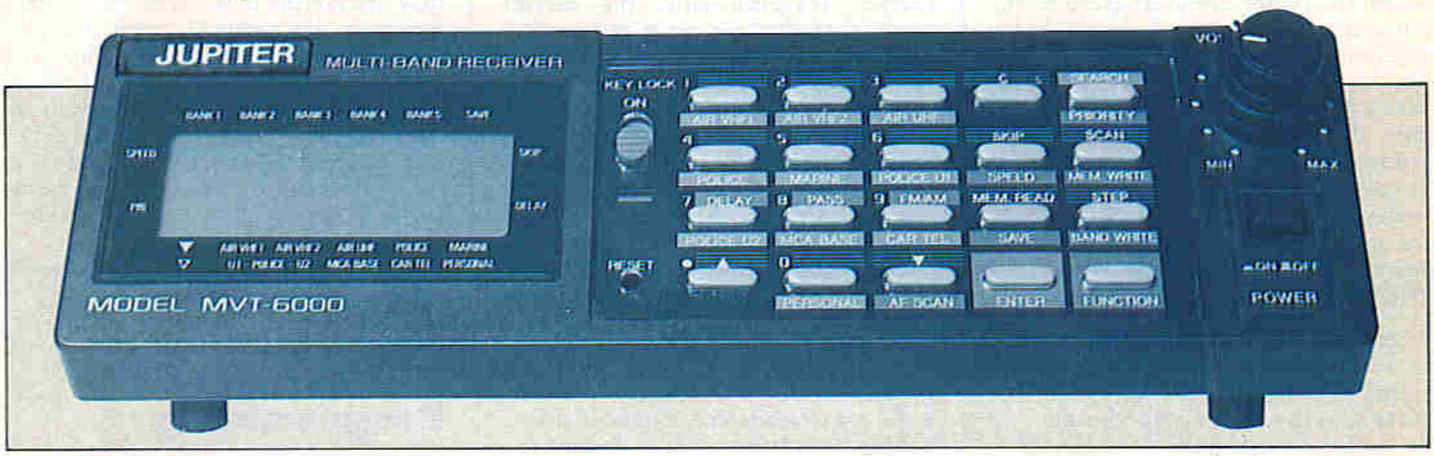


Figure 6. Demodulating SSB (or Morse).

that radio signals at 1010kHz will appear from the mixer, having been downconverted to 500kHz. Similarly, if the LO frequency is reduced by 10kHz then signals at 990kHz will appear at 500kHz.

As well as the LO, the RF stages must be tuned – and both must be tuned simultaneously, as shown in Figure 4. Fortunately, this is not a major problem because one tuning capacitor with two sections can be made to tune both circuits at the same time. This ensures that both circuits are always in line with each other.

The advantages of the superhet system are enormous. It forms a tuning system that is effectively a highly selective variable filter. By adopting this approach it is possible to achieve results which could not be even approached with a TRF radio receiver.



The Yupiteru MVT 6000 scanner. This comprehensive microprocessor-controlled scanner can receive AM and FM transmissions ranging from 25 to 1300MHz. However, its superb performance relies upon superhet radio principles that date back to the First World War!

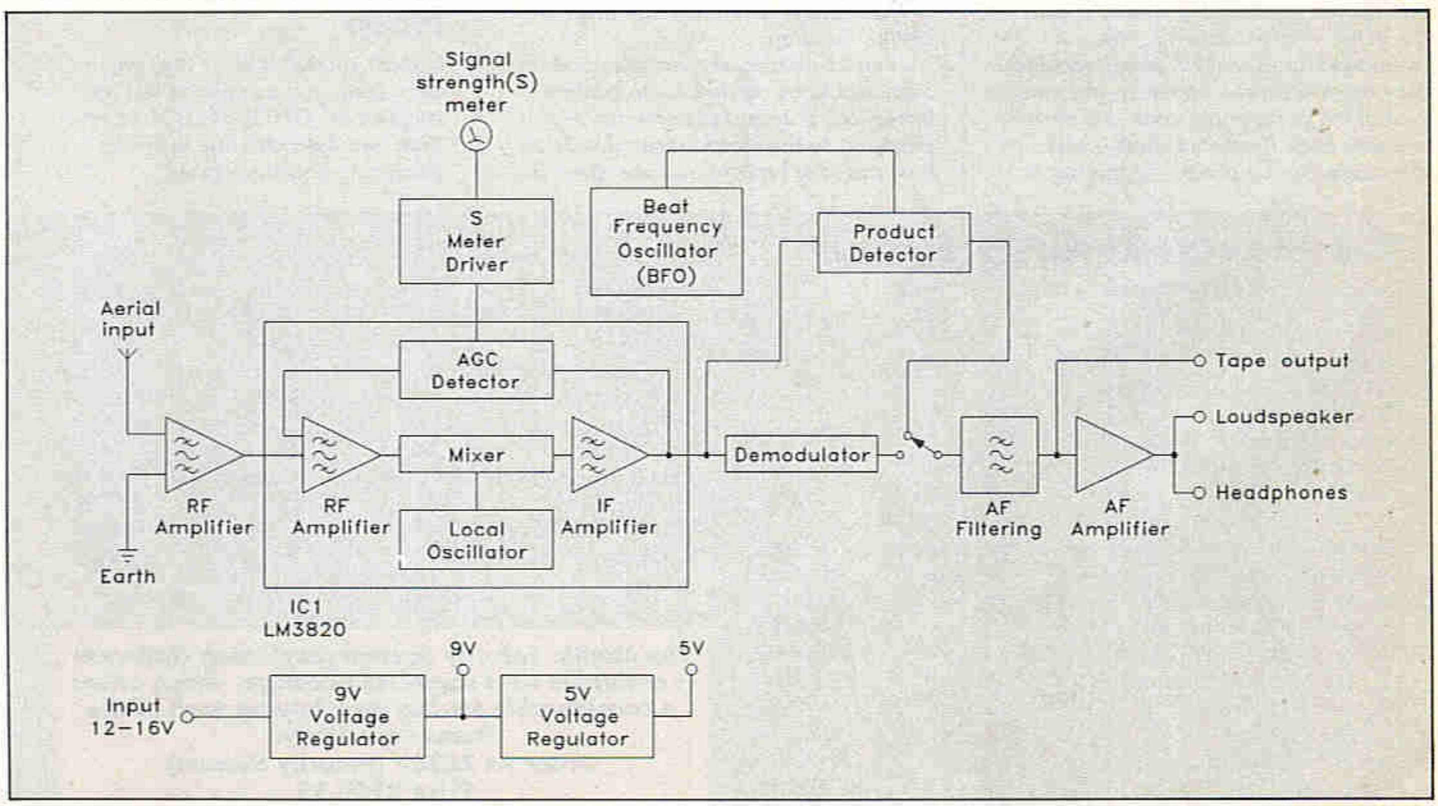


Figure 7. Block diagram of the Maplin Ranger – a superhet receiver for use on the 160m band. Note the presence of a BFO and product detector for recovering SSB and CW transmissions.

Demodulation

In order to make the superhet into a useable receiver, a few extra circuits are required. The first stage is to recover the audio (or whatever!) information from the IF output, before amplifying it in the normal way. This process is known as 'demodulation' and it can be achieved in a number of ways, depending upon whether the transmission being received is AM, FM, SSB or whatever.

AM (amplitude modulation) is the easiest mode to demodulate. It simply needs the signal from the IF to be rectified. To do this only a diode, capacitor and resistor are needed. In fact to make the most use of components the resistor can be the volume control for the set.

To demodulate FM is a little more complicated, but by no means difficult. It needs a circuit which converts the variations in frequency into audio amplitude variations. One type of demodulator, the Foster-Seeley discriminator, relies upon the 90° ('quadrature') phase difference between a couple of tuned circuits for its operation. When coupled with a few diodes, resistors and capacitors, these will generate an output voltage proportional to the frequency deviation. A variation of the Foster-Seeley circuit is the ratio discriminator, which offers better rejection of AM signals. Another method of demodulating FM is to use a phase-locked loop. One of these will give excellent results and this is why they are often found in Hi-Fi FM tuners. However, PLL demodulators are often a little more expensive than the ones based around a tuned circuit. IC development has now come to the point where you can get most of a superhet FM receiver on a single chip – the TDA 7000. Here, a quadrature detector (another development of the Foster-Seeley discriminator) is used. A block diagram of the TDA 7000, as used in Maplin's TDA 7000 FM Radio (see issue 27 of 'Electronics') is shown in Figure 5.

Finally, if SSB (single sideband) or morse (CW – continuous wave) is to be recovered, a beat frequency oscillator (BFO) and product detector are needed. As you can see from Figure 6, these are similar to the circuits used for frequency conversion in the IF stages of the receiver. With these 'suppressed carrier' transmissions, the carrier wave is missing and must be inserted. The BFO effectively generates the missing carrier; it is mixed with the incoming IF in the product detector to produce the audio signal (in the case of SSB), or the beat frequency (in the case of CW). A variable frequency oscillator is used as the BFO, because the locally-generated carrier must be at the correct frequency. After filtering out the unwanted mixing products, the recovered audio is passed to the next stage.

The block diagram of a superhet receiver capable of demodulating SSB, AM and CW transmissions is shown in Figure 7. This is the excellent Maplin 'Ranger', which is designed to work over the 160 metre band (1·8 to 2·2MHz) – full details of which can be found in issue 43 of 'Electronics', if you're interested.

Amplification

Once the audio signals have been generated they are amplified by a conventional audio amplifier. A speaker or a pair of headphones can then be used for the final stage to change the electrical impulses into audible vibrations.

Summary

The receivers that have been described here are not the most complicated sets. Scanners are naturally more complicated; they cover a much wider frequency band and may use two, or even three, frequency conversions as well as frequency synthesisers for their oscillators. Despite this, they use exactly the same principles which have been outlined here – at the end of the day, they are still superhet radios!

Maplin Security System continued from page 55.

a visit from the boys in blue!

Once all of the sensors have been wired into the system and the connections have been thoroughly checked, a simple functional test may be carried out by performing the Alarm Panel Test mentioned at the beginning of the Installation section. The sensors should be in the inactive state (i.e., doors/ windows closed and PIR zones vacated). Any faults will show up by the illumination of the appropriate zone LED once the user code is entered. If all is well, the alarm can be armed. Triggering a sensor within the entry zone will trigger the alarm panel (indicated by beeping) – the alarm should then be disarmed, within the pre-set entry time, to prevent the bell-box siren from sounding. Triggering a sensor in any of the other zones will trigger the alarm panel and sound the bell-box siren – disarm the alarm to silence the siren.

Periodic testing of the strobe and siren should be carried out to confirm operation; a strobe/siren test function is provided on the alarm panel, details on how this may be achieved are given in the programming instructions supplied with the system.

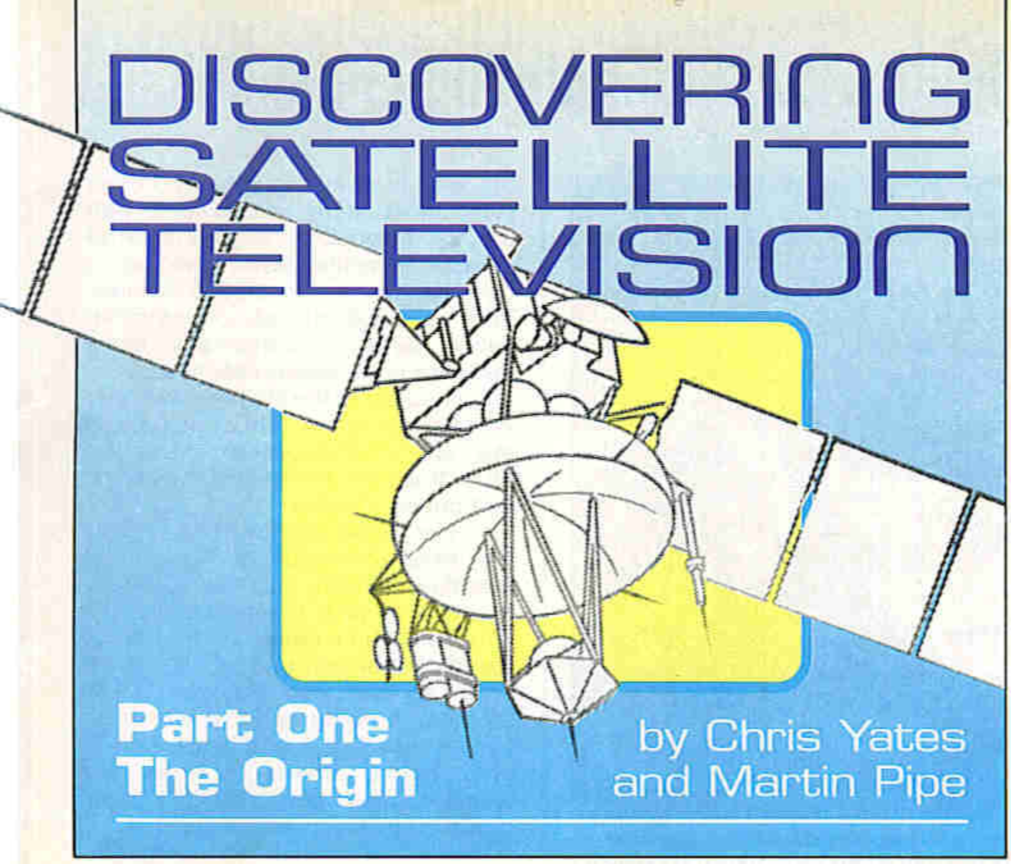
Programming

Full details on programming the alarm panel are supplied with the system.

Help

If, during installation or use, you run into difficulties, you can phone the Technical Helpline on (0702) 556001 between 2pm and 4pm Monday to Friday (excluding public holidays).

DISCOVERING SATELLITE TELEVISION



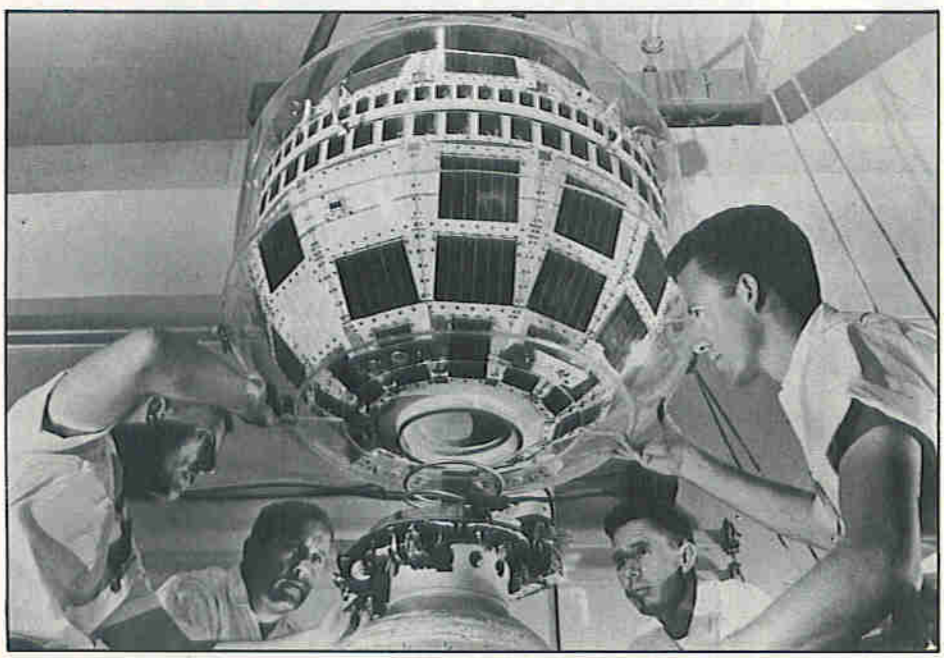
Part One The Origin

by Chris Yates and Martin Pipe

When science fiction writer Arthur C. Clarke discussed communication via satellite in his now-legendary *Wireless World* article back in 1945, he could hardly have imagined that it would lead to the explosion in satellite technology apparent today.

His idea, first outlined in a short science-fiction story in 1940, was based upon an important (if simple) scientific fact. In order to obtain the greatest reception area (known now as a 'footprint' in satellite terminology) at low power, a transmitting antenna should be sited as high as possible.

Clarke theorised that by positioning such a system in space, much greater distances could be covered than would be from its equivalent on the ground. However, there was an element of lunacy to the scheme. Realising that, due to the Earth's rotational movement, any stationary antenna array would not maintain a constant footprint, he proposed anchoring the satellite firmly to ground! Naturally the suggestion was looked upon with some amusement – but, as history has shown, the basic concept was not dismissed out of hand, particularly when the concept of a geostationary orbit was introduced in his 1945 *Wireless World* paper.



Telstar, shown here being mated to the third stage of the Delta rocket, which was responsible for lofting it into orbit. Apart from heralding a new age in telecommunications, it also inspired a No. 1 hit record by the Tornados! Source: Hulton Picture Library.

Pioneering Days

With aviation still relying on the piston engine, jet propulsion was only a glimmer in Air Commodore Sir Frank Whittle's eye and, with the world at war, space exploration was the last thing exercising the scientific community's collective mind. However, rocket technology was a wholly different story.

For years Nazi Germany had conducted secret research into rocketry, and when the V1 flying bomb (and to a lesser extent, the V2 rocket) began to fall on London, they demonstrated their leadership in this new technology. Eager to get their hands on the secret behind the flying bombs, as the war drew to its inevitable close the superpowers enticed many of the Nazi's leading scientists to continue working in their respective countries.

The United States obtained hardware – as evidenced by the launch, from Cape Canaveral, of a much modified V2 rocket which attained an altitude of ten miles on July 24, 1950. It was not until the late fifties that the military turned their attention from missile testing to launching artificial satellites. This change in priority was prompted by the October 1957 launch of the Soviet Union's Sputnik satellite – the first man-made object in space – which heralded the beginning of the space race. The 'free' world's first satellite – Explorer 1 – lifted off from Cape Canaveral on January 31st 1958, and later that year NASA was formed with a brief for the *peaceful* exploration of space.

Earlier Birds than Early Bird

From the outset, NASA had to rely on the military for launch vehicles and facilities, but it was not long before work began on the Kennedy Space Centre and the Cape resounded to the near-continuous lofting of vehicles into space. Many of those early satellites helped scientists study not only space, but also the weather and Earth's resources. In the communication field, Telstar provided UK television viewers with the first glimpse of live pictures from overseas, in 1962. This low-orbit satellite needed to be 'tracked' as it circled the Earth, and complex computer-controlled systems were required to achieve this. When, on July 11th 1962, the first (barely recognisable) glimmers of a transatlantic television picture were introduced to BBC viewers by Johnathan Dimbleby, the exceptionally weak signals responsible for it were picked up using the massive dish at Goonhilly Downs, where a team of experts had to be present to ensure any reception at all. Compare that to

The first live (and watchable) transatlantic TV pictures, as seen on French TV on July 11th 1962. These surprisingly good quality images were received via the earth station at Lannion, near Brittany. (On the morning of that day, the BBC obtained pictures at the Goonhilly Earth Station, but these were barely recognisable!). The person on the left is Mr. Kappel, then the chairman of the board of the American Telephone and Telegraph Company; on the right is a French interviewer. Source: Hulton Picture Library.

the cheap, fixed 60cm dish required today, to give high-quality colour pictures from Astra! Incidentally, contrary to popular belief it was the French, to the obvious annoyance of the BBC, that were the first to bounce a complete television programme off Telstar! They, in typical French style, ignored the target date which was set at 24th July of that year! The official transatlantic broadcast, seen in 18 European countries on that date, lasted for 18 minutes and was reported as being 'remarkably clear'. Later, European television pictures were broadcast back to the United States.

Shortly after Telstar captured the imagination of the public, it was discovered that the higher a satellite flew, the longer it appeared to hold its footprint. This gave birth to Clarke's theory of a geostationary orbit.

It was known that the Earth revolved in an East/West direction at some 960mph, but in order to achieve this orbit, a satellite had to climb to 22,300 miles above the equator. Nevertheless the theory was proven, and on the 26th of July 1963, Syncom 2 became the first communication satellite to be lofted into this area of space, which is now known as the Clarke Belt. However, it was Early Bird – also known as Intelsat 1 – that has the distinction of being the first international communications satellite in geostationary orbit. It was launched on June 4, 1965.

Launch Vehicles

As the technology behind satellite communication developed, so did the means of lofting them into orbit. After those early experiments with the V2, a whole new generation of launch vehicles have evolved – culminating in the Space Shuttle. That said, the majority of communication birds – particularly those destined for television services – are launched using the Delta rocket. This vehicle has been the workhorse of the space programme, launching more than 180 craft since it was first introduced in 1960.

The latest version, Delta 11, is the most powerful of the family. Standing at 128ft tall, the first stage thrust at lift-off is a massive 873,400 pounds, which alone is enough to launch satellites into a low earth orbit. An attached Payload Assist Module, burning solid propellants, boosts the craft into a high elliptical orbit, before motors on board the satellite take over for the final positioning along the Clarke Belt.

Although NASA once had the monopoly over satellite launches, there is now competition, mainly in the form of the European Space Agency. From their launch site in

The first 'official' transatlantic TV broadcast, seen in 18 European countries.

Kourou, French Guyana, the Ariane rocket has lofted many European television satellites (including Intelsat, Eutelsat and Astra craft) into orbit, having overcome many early problems (in 1982, for example, two satellites ended up in the Atlantic Ocean – not quite the undiscovered vastness that Clarke had in mind!) China has also moved in on the act, with their Long March rocket launching birds – particularly those owned by Panamsat – over the Pacific Ocean.

Cost

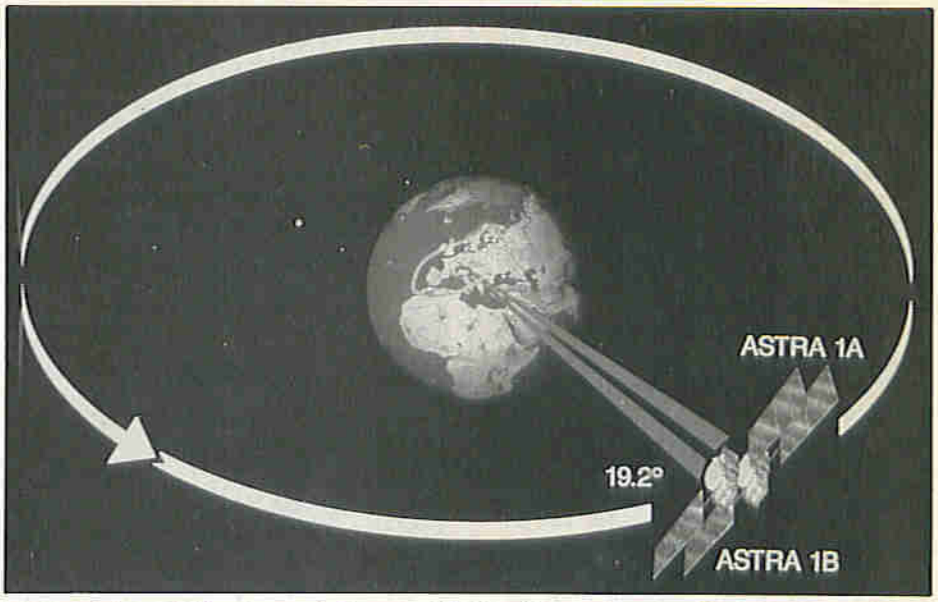
Today, satellites and their launch facilities are, by any standard, expensive. Eutelsat recently spent around 170 million dollars to launch its controversial 2F3 bird by Atlas/Centaur rocket from Cape Canaveral. Should anything go wrong, this huge amount of money is effectively poured down the drain. However, if the satellite fails while in orbit, the shuttle programme has been developed to such a degree that orbiters can be used to bring them back to Earth (see 'Electronics in Aviation' – Part 6, 'Electronics' issue 55). That was dramatically demonstrated when the Westar 6 satellite was successfully recovered by Discovery in 1984. This bird had remained in low Earth orbit after its Payload Assist Module had failed during deployment by an earlier mission.

Pictures from Above

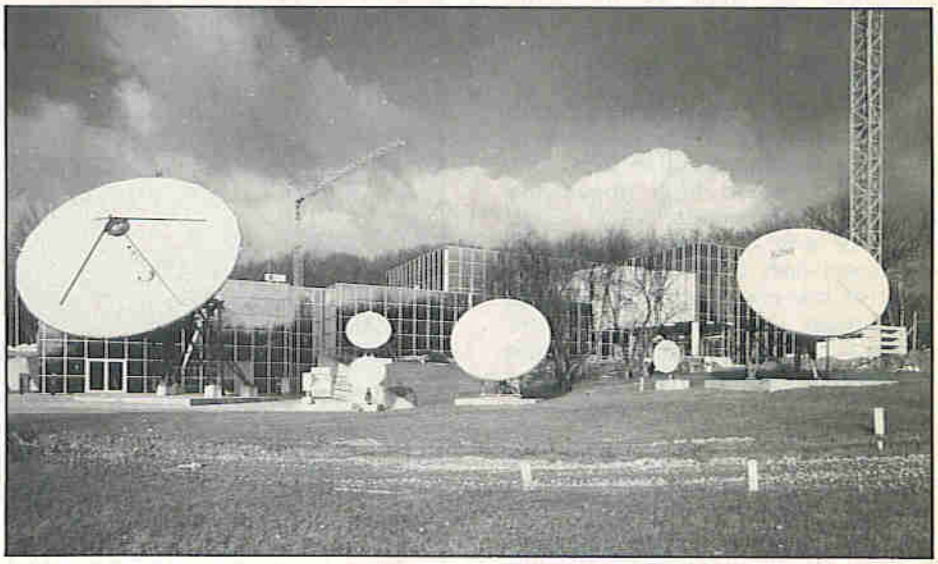
To receive Telstar, it was necessary to use a dish antenna many metres in diameter, and the most sensitive of monitoring and tracking apparatus. Whilst the basic concept of satellite communication remains the same today, technology has paced onwards. The discovery of a geostationary orbit has removed the need to track the birds, whilst advances in microelectronics and solar energy mean that designers can use much higher frequencies at even greater power – bringing the world of satellite communication directly into the home. The birds are nothing more than orbiting repeater stations, receiving their signals from an uplink facility like BT's London Teleport, returning them on another frequency to ground via on-board transponders.

When satellite television first came within the grasp of enthusiasts in the early eighties, most birds operated in the 'C' Band (3·6 to 4·2GHz) and were very low-powered, which meant that a dish of around 3 to 4 metres in diameter was required in order to monitor them.

Such a large dish was clearly impractical for most home installa-



The two Astra satellites in geostationary orbit. The distance between Earth and the two satellites is 22,300 miles. Proof that some good *does* come from the European Community!



Astra's Satellite Control Facility in Betzdorf, Luxembourg. This is responsible for keeping Astra 1A, and the newer 1B, co-located in their allocated position of 19·2° East. It is also used for programme uplink. At the time of writing, an interesting promotional film on the Astra set-up is being shown on Astra channel 30. This is shown on a continuous basis, and the soundtrack is broadcast cyclically in one of several different European languages. Presumably, this will continue until such time as the transponder is leased to a broadcaster!

Inside the control room at Astra's Betzdorf Satellite Operations Centre.

tions, and so in 1977 the World Administrative Radio Council (WARC) allocated the band 11·7 to 12·5GHz for direct broadcasting by satellite (DBS). The WARC move meant that a dish antenna with a diameter of one metre or less could be used to receive the satellites expected to occupy this band. However, there was a catch – the new channels wouldn't be available until the late eighties.

Eager to steal a march on their competitors, many satellite operators used a loophole in the regulations to start direct-to-home broadcasting early, broadcasting in the slightly lower 10·95 to 11·70GHz band. The French – as always, a law unto themselves – did much the same, but using the higher 12·50 to 12·75GHz slot. Many of today's high-powered television satellites can be received on dish, flat-plate (remember the 'Squarial'?) or even horn antennae, as small as 45 centimetres!

Astra

The Société Européenne des Satellites own perhaps the best known of the birds broadcasting to Europe – Astra. Co-located high above the Equator at longitude 19·2° East, Astra 1A and 1B transmit some 32 channels, with a footprint covering most of the continent. Built by GE Astrospace and launched by the Ariane rocket, each transponder has a 26MHz bandwidth, and an output power of 45W – a figure inconceivable in Telstar's day!

The Astra channel count will increase to 48 with the launch of 1C early in 1993. Unlike its predecessors, this Hughes-built satellite will offer an output power of 63W per transponder. It will also provide full back-up for Astra 1A which will have, by then, been in orbit for over four years.

How a Receiver Works

In basic terms, satellite television receivers operate in much the same way as a simple FM radio – it has a RF stage/aerial (the dish and LNB), 2 (sometimes 3) IF stages, and a FM demodulator (two or three, if you include the one(s) used for recovering the sound). The overall scheme of things is shown in Figure 1a. The dish, the most recognisable feature of domestic satellite TV and the bane of council planning departments, does nothing more than collect satellite signals, focusing them onto perhaps the most important part of the entire system (certainly the most intricate) – a device called a low-noise block downconverter, or LNB for short. In the case of Astra receiving equipment, the LNB lowers

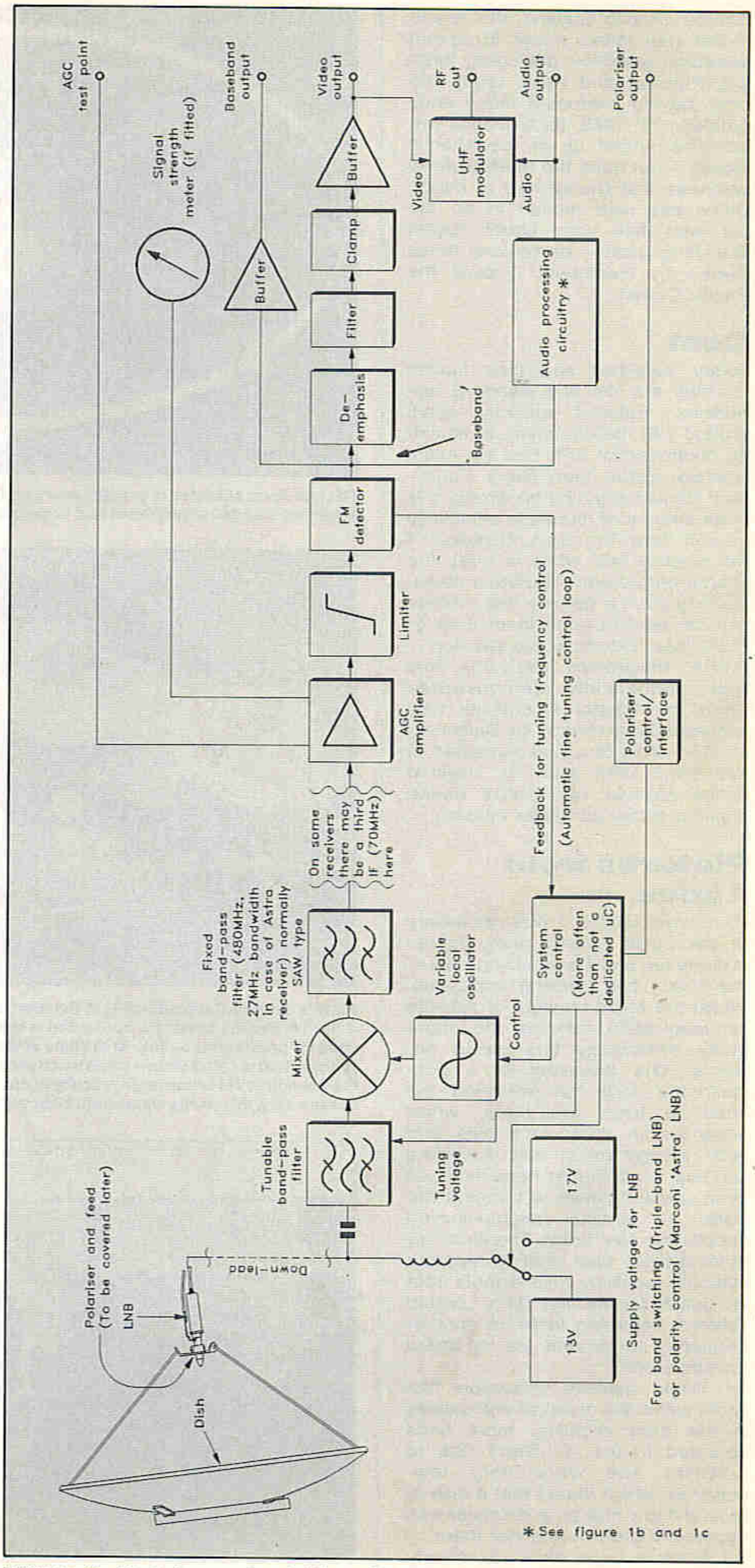


Figure 1a. The block diagram of a satellite receiver.

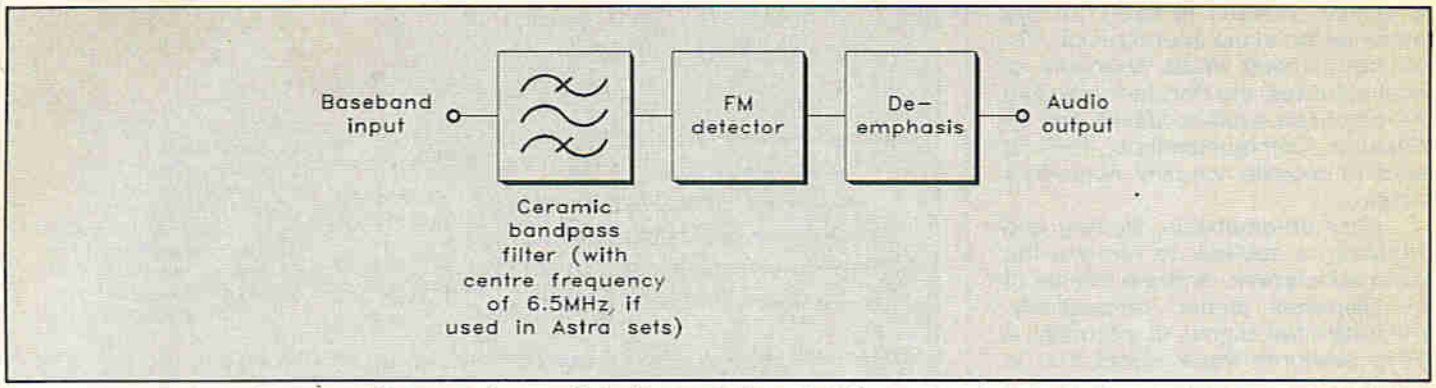


Figure 1b. Fixed-subcarrier mono audio system (as supplied with very basic early Astra receivers).

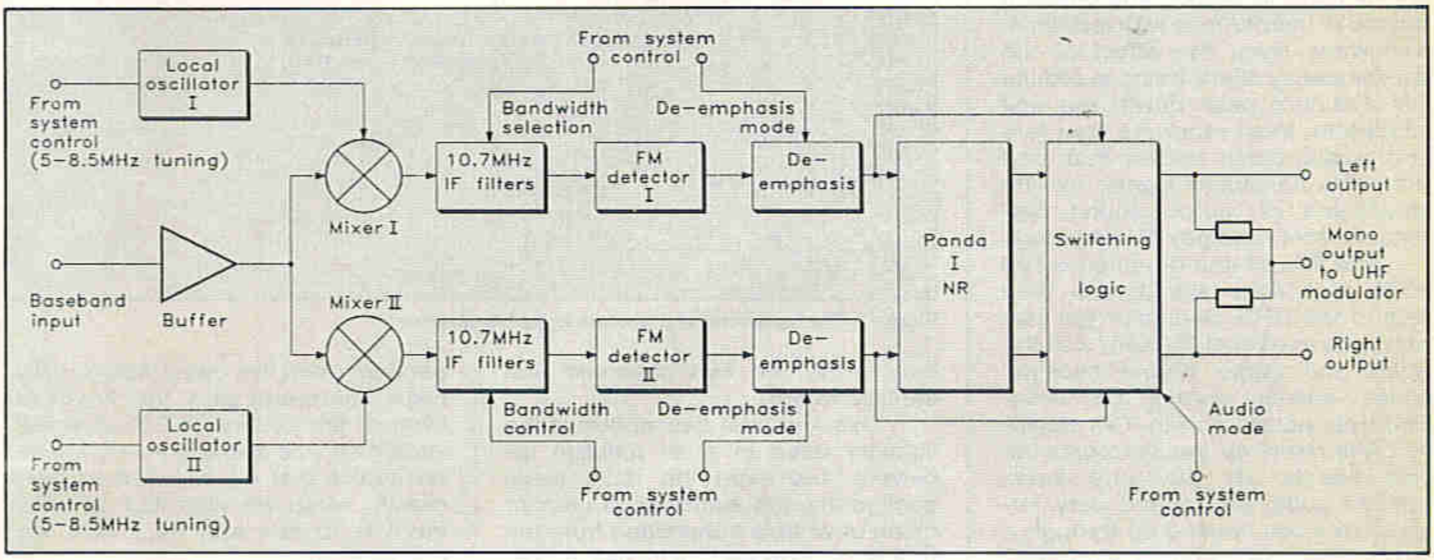


Figure 1c. Full-mode tuneable stereo audio system (additional 'superhet' configurations are used).

the incoming 10·95 to 11·70GHz signals to a band of frequencies that are more easily handled by co-axial cable and the receiver – in most cases 950 to 1750MHz – which are known as the first intermediate frequency band (IF for short). If this system was not used, ugly and lossy copper piping (used as a waveguide) would have be used to direct the weak microwave signals to the receiver, where down-conversion would have to take place, anyway.

After passing the first IF through a tunable band-pass filter, the first IF frequencies are 'mixed' with a variable local oscillator signal, in a process known as 'heterodyning'. Such a process is used in all superhet receivers – which includes nearly all radio sets. The much lower second IF frequency produced as a result is usually centred around 480MHz. Tuning the receiver to your favourite satellite channel simply adjusts the local oscillator frequency, and correspondingly adjusts the input bandpass filter, so that its response 'peaks' at the frequency of the desired channel.

After mixing, it is filtered again to pass a 27MHz-wide (in the case of Astra receivers) slot of signals, representing a single transponder channel. This is frequency-demodulated to give a 9MHz wide baseband signal, using a FM quadrature demodulator that works using the same principles as the FM radio discussed earlier. Some other receivers, intended for use by enthusiasts and the professional market, utilise a third IF (which, for such receivers, is standardised at 70MHz). The connection between this third IF and the demodulator is often brought to the back of the receiver (as a 'loop through' – of similar type to that found between the preamp and power amplifier sections of many integrated stereo amplifiers). 'Breaking the loop' enables various peripheral goodies to be attached – for example, variable bandwidth controllers, which enable the best picture to be extracted from a weak 'DX' signal.

The baseband signal contains video (5·5MHz bandwidth in the case of Astra's PAL transmissions), wideband (180kHz) mono sound modulated on a 6·5MHz centre frequency (in the case of Astra channels), and up to twelve narrowband sound subcarriers. The Astra baseband signal is shown in Figure 2. Another FM quadrature detector is used here, or two in the case of a stereo receiver. The narrow bandwidth (130kHz) audio subcarriers are used to convey stereo sound, or independent radio broadcasts (such as Sky Radio, which transmits in stereo on the 7·38 and 7·56MHz subcarriers of Sky One's Astra transponder). If you have a satellite system, these excellent radio stations are well worth listening out for (turn the TV set off and pipe the sound through your Hi-Fi, which you should do anyway!); many owners of satellite systems, in the UK at least, seem to ignore them which is a pity. Mono and stereo audio system block diagrams are shown in Figures 1b and 1c respectively.

The video signal is processed further, before being sent to the UHF modulator and video output socket; de-emphasis takes place, followed by filtering and clamping. Pre-emphasis is a process applied at the transmission end (i.e. the satellite up-link), whereby the higher frequencies are increased in amplitude. At the receiving end, de-emphasis is carried out, which correspondingly attenuates the pre-emphasised high frequencies. The result of this is a better signal-to-noise ratio; noise generally raises greater problems at higher frequencies than it does at lower ones. The practical upshot of all this is that the picture is less grainy – and the sound is less hissy (a similar process is used for the transmission of the soundtracks). On the narrowband audio channels of most satellites, the Panda-1 adaptive pre-emphasis system (developed by Wegener Communications, Inc.) is used to provide virtually noise-free audio.

After de-emphasis, filtering and clamping is applied, to remove the audio subcarriers, and the effects of the dispersal signal, respectively. The dispersal signal is normally a 25Hz sawtooth-wave signal that is added to the baseband signal before modulation at the broadcast end. This is done to reduce any possible chance of interference with terrestrial microwave links, the effect of the low-frequency signal being to reduce the channel's peak power per unit bandwidth. Most receivers also feature a rear-panel socket that provides the baseband signal, for the attachment of stereo sound processors, MAC and pay-TV decoders.

The filtered and de-emphasised audio and video signals are then sent to the UHF modulator (for use with a conventional TV set), and the video and audio output sockets. These should always be used, wherever possible, with TVs equipped with direct AV inputs to give the best results. At the very least, satellite audio can sound very impressive when hooked up through a reasonable Hi-Fi system – particularly MTV, the film channels and satellite radio.

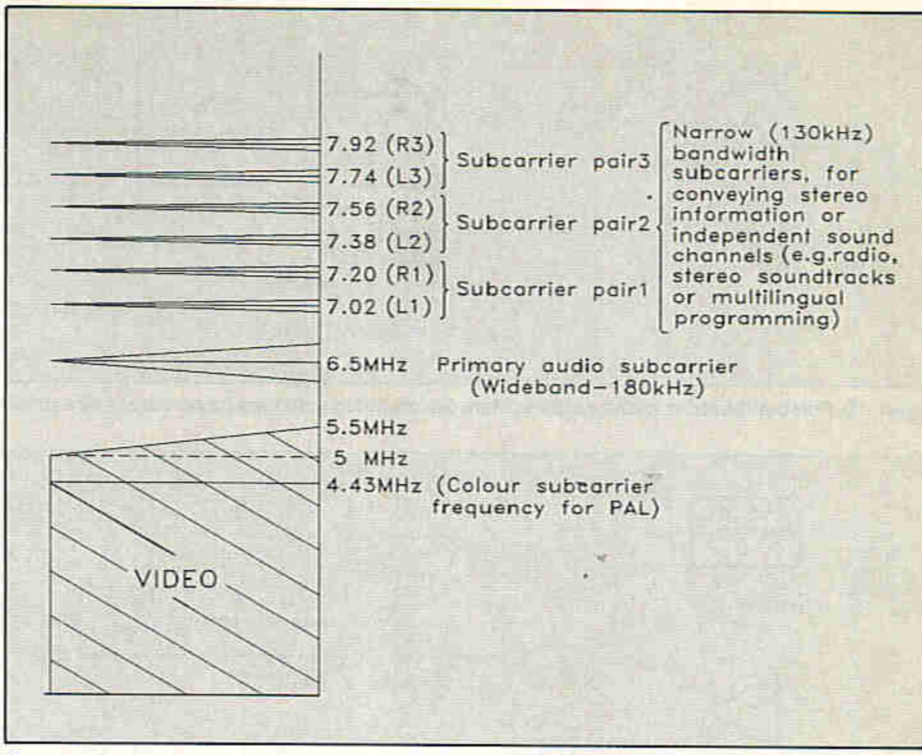


Figure 2. The baseband signal of an Astra transponder.

This is a brief description of the circuitry used in most satellite receivers, but even the most basic configuration is sufficient to monitor much of what is transmitted from the heavens. However, success is dependent upon five other factors: LNB noise figure and gain; the threshold level of the receiver's FM demodulator; dish size and alignment. These are topics that we will discuss next month, when we also look at what there is to see and hear from the Clarke Belt.

Chronology

Year	Event
1945	Arthur C. Clarke first suggests communication via satellites firmly anchored to ground.
1950	The United States conducts its first experiments with rockets. A modified German V2 attains an altitude of ten miles.
1957	The Soviet Union launches Sputnik – the space race begins!
1958	The United States launches its first artificial satellite – Explorer One – and the National Aeronautics and Space Administration (NASA) is formed.
1962	Telstar, the first commercial communication satellite, was launched for the American Telephone & Telegraph Company. First transatlantic satellite TV broadcasts take place.
1963	Syncom 2 becomes the first communication satellite in geostationary orbit.
1965	Intelsat (Early Bird) becomes the first international communication satellite in geostationary orbit.
1972	Anik 1 becomes the first geostationary orbit domestic communication satellite.
1988	Astra, the first of three television satellites designed to serve Europe, is launched.

Frequency Bands

Frequencies	Users
UHF Band TV (470 to 854MHz)	Terrestrial broadcasters. The output of satellite TV receivers is normally set to Channel 38 (607·25MHz).
C Band (3·6 to 4·2GHz)	Occupied by several of the broadcasters found in the higher bands, including companies who lease transponders for 'news-feeds', such as British Telecom and Brightstar. Popular in the Federation of Independent States, and the USA, for general broadcasting, disseminating TV programmes over a very wide geographical area, and down-links to cable networks. C band transponders often co-exist with Ku band transponders on satellites; for example the Intelsat and Telecom series.
Ku Band (10·95 to 12·75GHz)	This satellite band is split up into three parts, known as the FSS, DBS and Telecom bands.
FSS (10·95 to 11·70GHz)	Occupied by many birds – most notably Astra, Eutelsat and Intelsat. Transponders on the latter two often carry SNG (satellite news-gathering) feeds, outside broadcasts etc.
DBS Band (11·70 to 12·50GHz)	The official (WARC-designated) direct broadcasting by satellite band. Occupied by Marcopolo, Olympus, TDF and others.
Telecom Band (12·50 to 12·75GHz)	Occupied mainly by French broadcasters via the Telecom series of satellites. However, recent Eutelsats carry Telecom band transponders, which are often used for SNG feeds.

Waveform Generators continued from page 47.

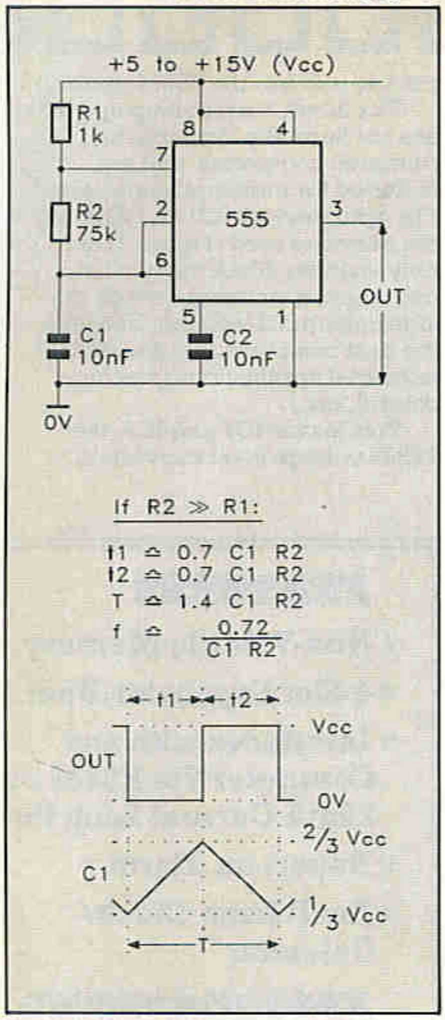


Figure 18. Basic 1kHz 555 astable multivibrator.

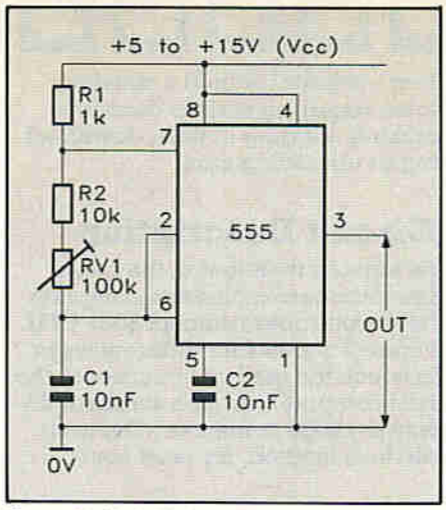


Figure 19. Variable-frequency (650Hz to 7·2kHz) square-wave generator.

by wiring a resistor between pin-12 and ground, to set the minimum operating frequency of a restricted-range VCO, where f_{min} is determined by C1 and R2, and f_{max} is determined by C1 and the parallel resistance of R1 and R2.

555 Astable Circuits

The 555 timer IC can be used as a free-running astable multivibrator or square-wave generator by using it in the basic configuration shown in Figure 18, in which pin-2, TRIGGER, is shorted to the pin-6 THRESHOLD terminal, and timing resistor R2 is wired between pin-6 and DISCHARGE pin-7. When power is first applied to this circuit, C1 begins

triangular waveform appears across C1. The R1 and R2 values can be varied from 1k to tens of MΩ. Note, however, that R1 affects the circuit's current consumption, since pin-7 is effectively grounded during half of each cycle.

Figure 19 shows how the operating frequency of the circuit of Figure 18 can be made variable by simply replacing R2 with a series-wired, fixed and a variable resistor. With the component values shown, the frequency can be varied from about 650Hz to 7·2kHz via RV1. The frequency span can be further increased by selecting alternative values of C1.

Mark-Space Control

In each operating cycle of the circuit of Figure 18, C1 is alternately charged via R1 and R2, and discharged via R2 only. It can thus be made to generate a non-symmetrical waveform with a desired mark-space (M-S) ratio by suitably selecting the R1 and R2 values. Figures 20 and 21 show ways of making the M-S ratios fully variable.

Figure 20 shows a way of gaining independent control of the MARK and SPACE periods. Here, C1 alternately charges via R1-D1-RV1 and discharges via RV2- D2-R2. R2 protects the IC against damage when RV2 is reduced to zero, and the MARK and SPACE periods can each be independently varied over a 100:1 to 1:100; the frequency varies as the M-S ratio is altered.

Figure 21 shows a way of altering the M-S ratio without significantly altering the operating frequency. Here, C1

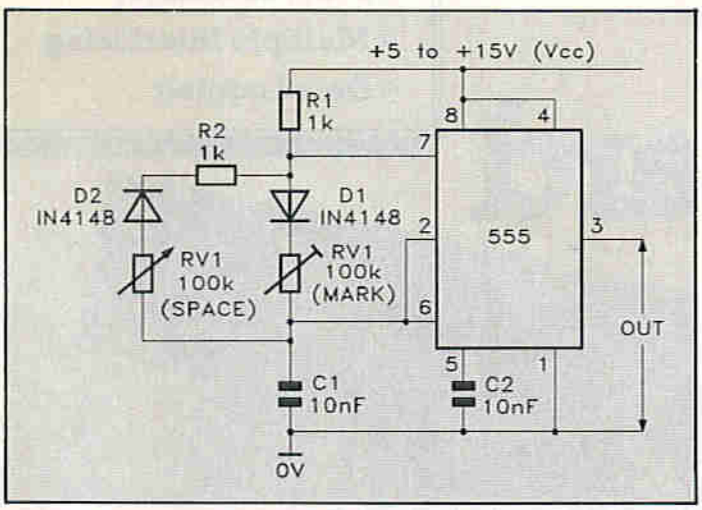


Figure 20. Astable with MARK and SPACE periods independently variable from 7μS to 750μS.

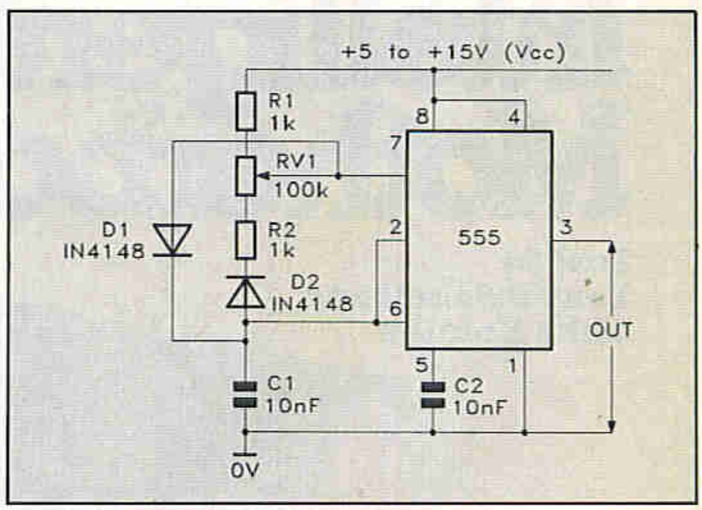


Figure 21. 1·2kHz astable multivibrator with duty cycle variable from 1% to 99%.

Figure 16 shows the simplest possible way of using the 4046B as a voltage-controlled square-wave generator. Here, C1 and R1 determine the maximum frequency which can be obtained (with the pin-9 voltage at maximum) and RV1 controls the actual frequency by applying a control voltage to pin-9. The frequency falls to a very low value (a fraction of a Hz) with pin-9 at zero volts. The effective voltage-control range of pin-9 varies from roughly 1V below the supply value to about 1V above zero, and gives a frequency span of about 1000,000:1. Ideally, the circuit's supply voltage should be regulated.

Figure 17 shows this circuit modified

to charge exponentially via the series R1-R2 combination, until eventually the voltage on C1 rises to ⅔ V_{cc}. At this point DISCHARGE pin-7 switches low (it is actually an open-collector transistor switch) and starts to discharge C1 exponentially via R2, until eventually the voltage on C1 falls to ⅓ V_{cc}. Here a new timing sequence is initiated, and C1 starts to recharge again towards ⅔ V_{cc} via R1-R2, and discharging towards ⅓ V_{cc} via R2 only.

When R2 is very large relative to R1, the operating frequency is determined mainly by R2 and C1, and an almost symmetrical square-wave output is developed on pin-3, and a nearly linear

alternately charges via R1, D1 and the upper half of RV1, and discharges via D2, R2 and the lower half of RV1. The action is such that the MARK period automatically increases as the SPACE period decreases and vice versa, so the total period of each cycle is constant. The circuit operates at a nominal 1·2kHz with the value shown for C1. The most important feature of this circuit is its 'duty cycle' of the waveform, or the relationship between the ON time and total period of each cycle, which is variable from 1% to 99% using RV1.

Next month Ray Marston takes this subject a stage further and looks at pulse generators.

The Serial Port Input/Output Extension System begins at the host computer's serial port with a basic microcontroller card having one expansion slot, to which can be added an extension card providing up to four expansion slots in total. Although microprocessor controlled, the system *does* require a host computer to control it using an RS232 port (or 20mA current loop link). Essentially, the motherboard will free the host computer from the job of scanning I/O ports, and only needs to alert the host computer should a situation arise requiring serious decision making, logging of data, downloading or uploading data.

Circuit Description

As already mentioned, the basic interface card includes a complete microcontroller using an 8031 CPU. Figure 1 shows four different ways in which the card can connect to the host computer, using a standard 25-way D-range connector. The most obvious method, for most computers, is to use the RS232 option.

The 20mA current loop options are not normally available on domestic computers, and are included for industrial computers. The opto devices IC9 and IC10 on the interface card (Figure 2) are only used for 20mA current loop operation, a technique which provides electrical isolation between the host computer and the card for industrial applications (machine control, etc.).

This leaves IC7 and IC8, the RS232 voltage level converters,

RS232
SERIAL PORT INPUT/OUTPUT
SYSTEM

FEATURES

- Non-Volatile Memory
- 4-Slot Expansion Board
- Interfaces with any Computer Via RS232 or 20mA Current Loop Port
- Report on Alarm
- Real-Time Clock/ Calendar

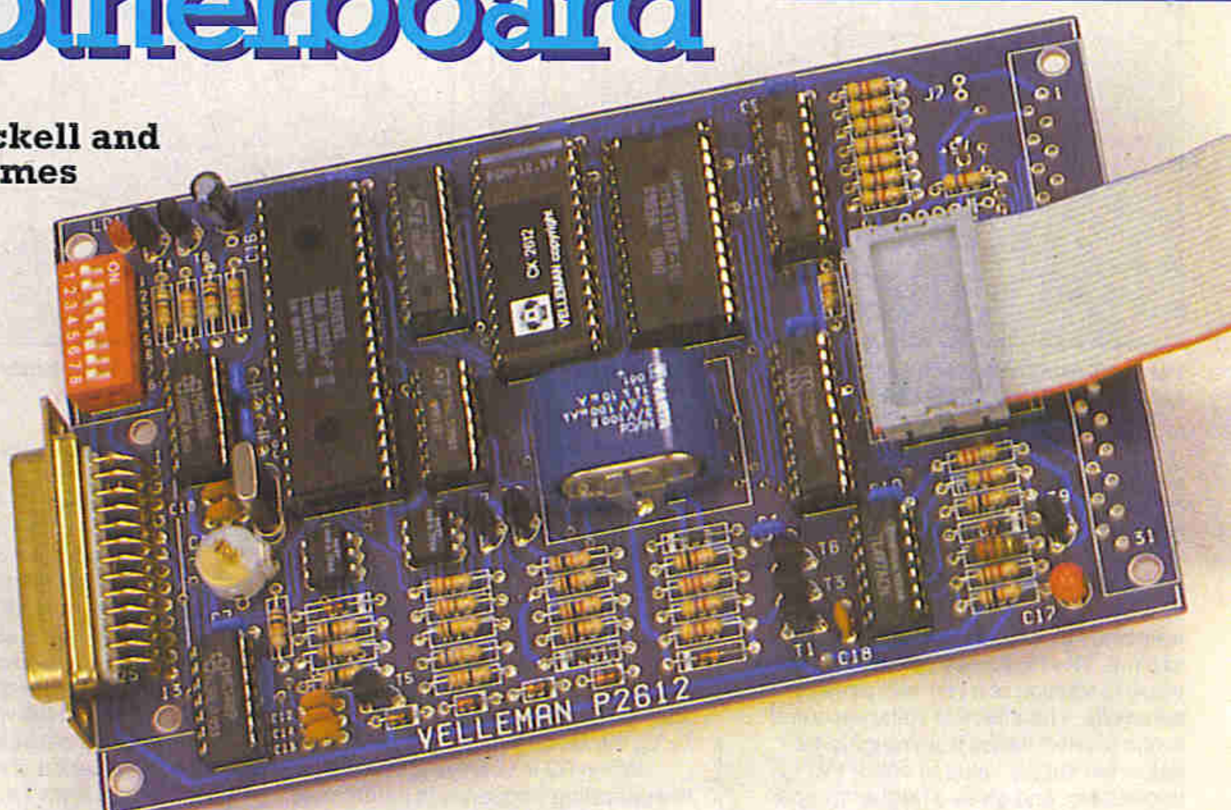
APPLICATIONS

- Process Control
- Multiple Interfacing
- Data Logging

PART ONE

Intelligent Motherboard

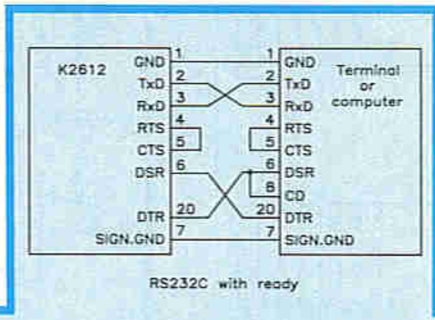
Text by Tony Brickell and Mike Holmes



interfacing the harsh 24V of the RS232 line (+12V and −12V) to the 5V world of the microprocessor, IC1. IC12 is a switching regulator, providing the negative supply rail required for the RS232 port output IC, IC7. If the host computer's RS232 connections are not at true RS232 levels (e.g., TTL level in early 8-bit micros), then it also needs to be provided with an add-on RS232 level converter to work with the card.

Also note that no socket for RS232 communications is supplied with the kit since the type used depends on compatibility with the host. The commonest type nowadays is a male 25-way D-range plug, and a right-angled PCB mounting type can be used (Order Code FG68Y, also see optional parts list).

In Figure 2, +V1 is the 'raw' supply line of nominally 9V DC, while +V2 is the 5V supply level. (−V1 is the negative supply generated by IC12 for RS232.) If only the intelligent interface card is used, then this 9V supply can originate from the host computer via pin 14 of the serial port J8, assuming that the host is able to supply it. However, the power drain of the interface card may be beyond that which some host computers can cope with, and



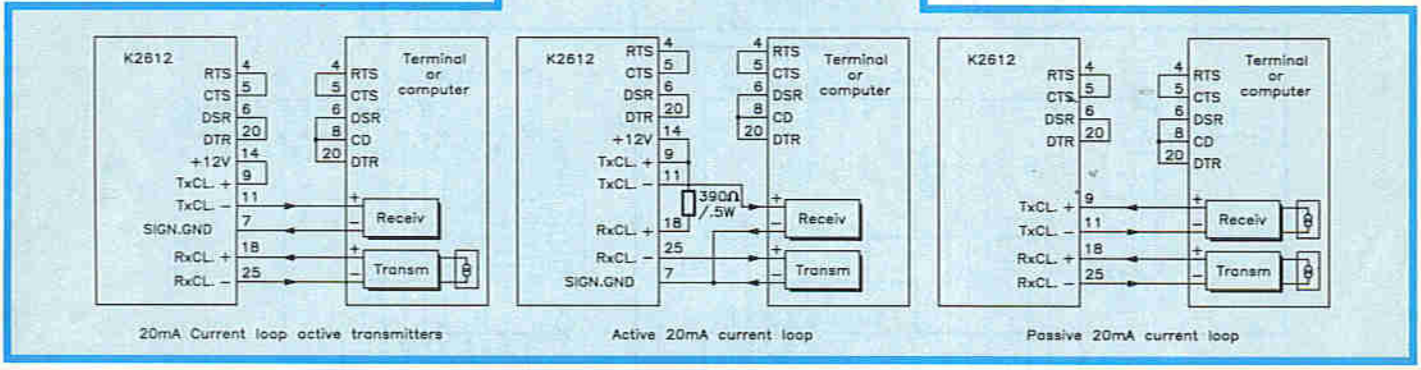
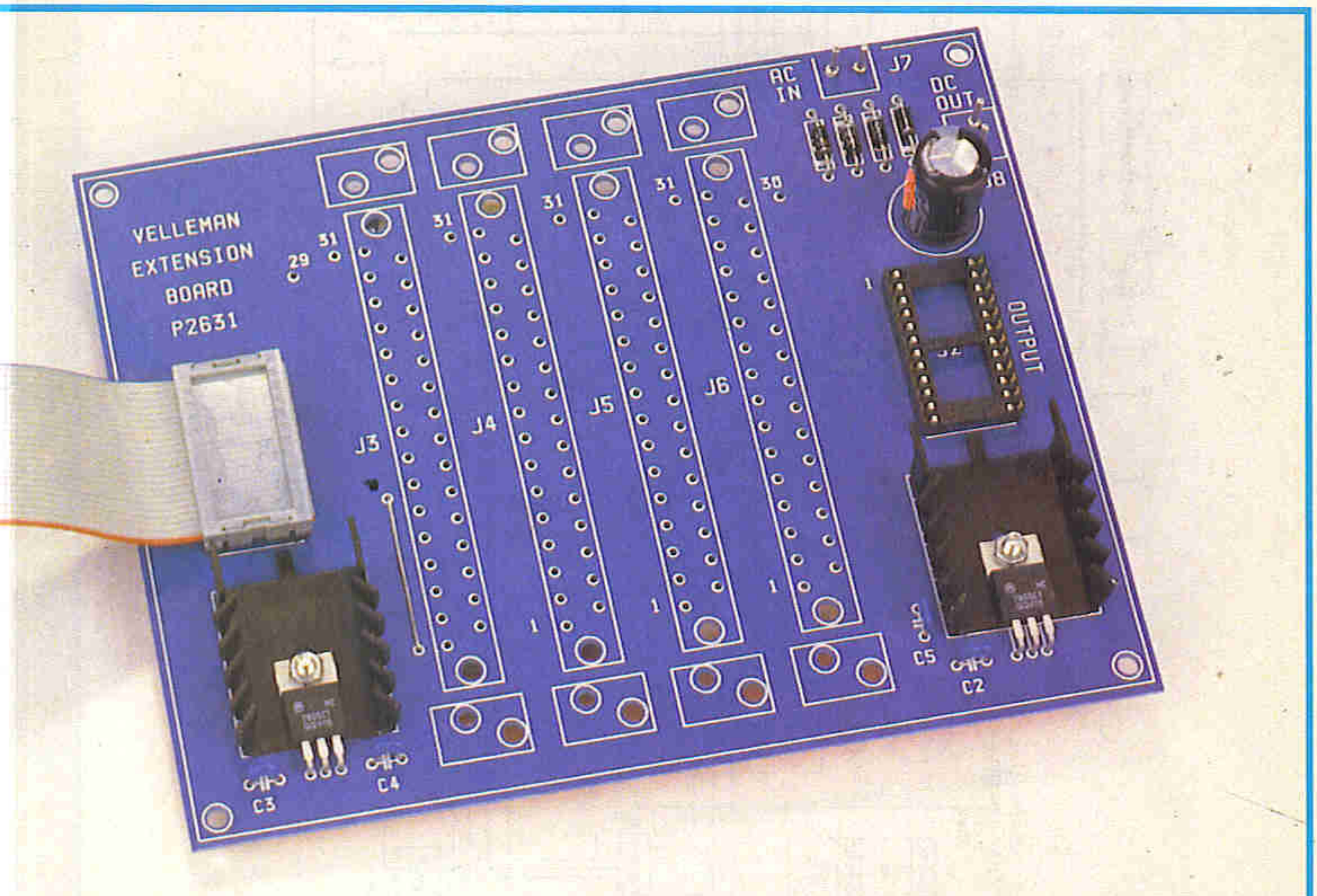


Figure 1. Some of the various communications methods supported by the interface card. The RS232 option with hand-shaking will be the most obvious choice for most computers.



Left: The Serial Port Input/Output Extension System Motherboard. Above: The Extension Card.

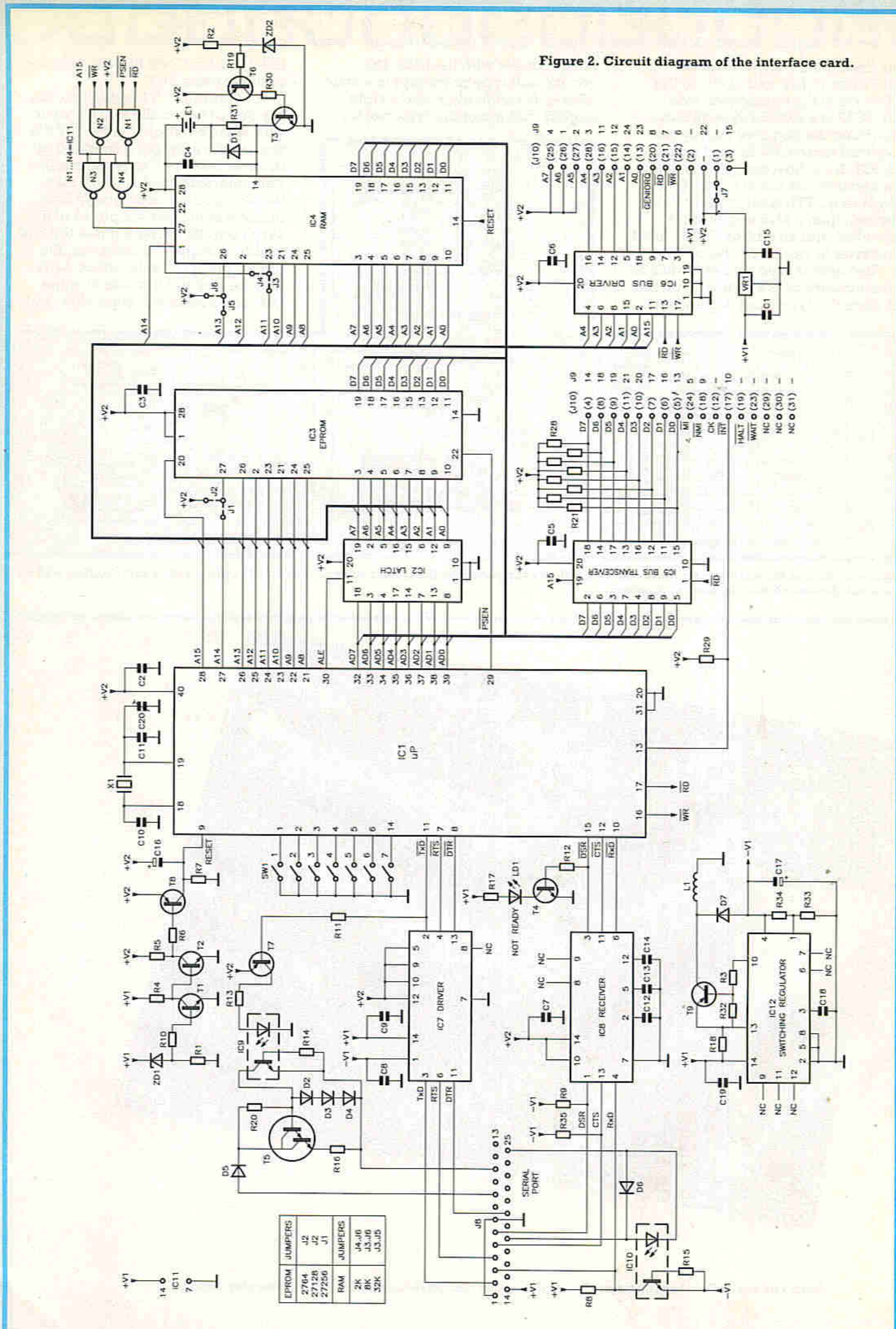
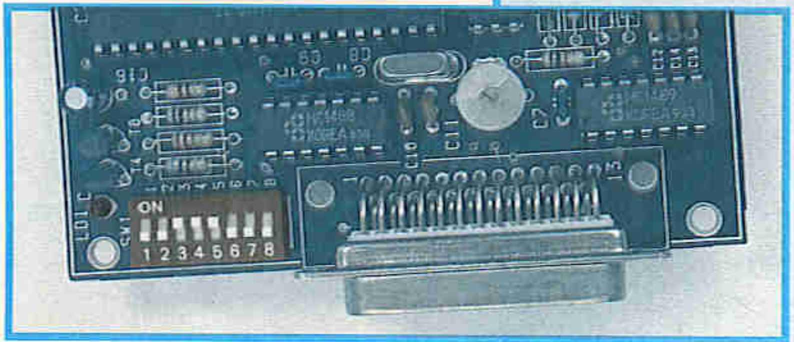


Figure 2. Circuit diagram of the interface card.



Close-up of the DIL Switches and RS232 Connector.

certainly will be if the extension card is also used. In this case +9V can be provided externally via a PCB pin. If the interface card is used by itself then the 5V regulator, heatsink and associated components are mounted on this card, but if the extension card is added then these are fitted to the extension card instead. This card will also have the components required to make a complete power supply in conjunction with the optional transformer, see Figures 3 and 4.

The micro-controller section is fairly straightforward, where the MPU, IC1, is as much as possible self-contained, thus simplifying board layout, construction and reducing component count. The CPU has one or two interesting features, including an internal clock which only requires the addition of a crystal X1, C2, C10, C11 and C20. Another feature is that the data bus is multiplexed with the lower 8 bits of the address bus because the number of available pins is limited. This requires that address lines A0 to A7 be loaded into an octal transparent latch, IC2, before a read or write can be made on the data bus. The latch holds the lower address for the memory chips IC3 and IC4.

The RESET input at pin 9 has a Schmitt trigger action and so only needs a simple time constant network, R7 and C16, to perform the reset at power-up.

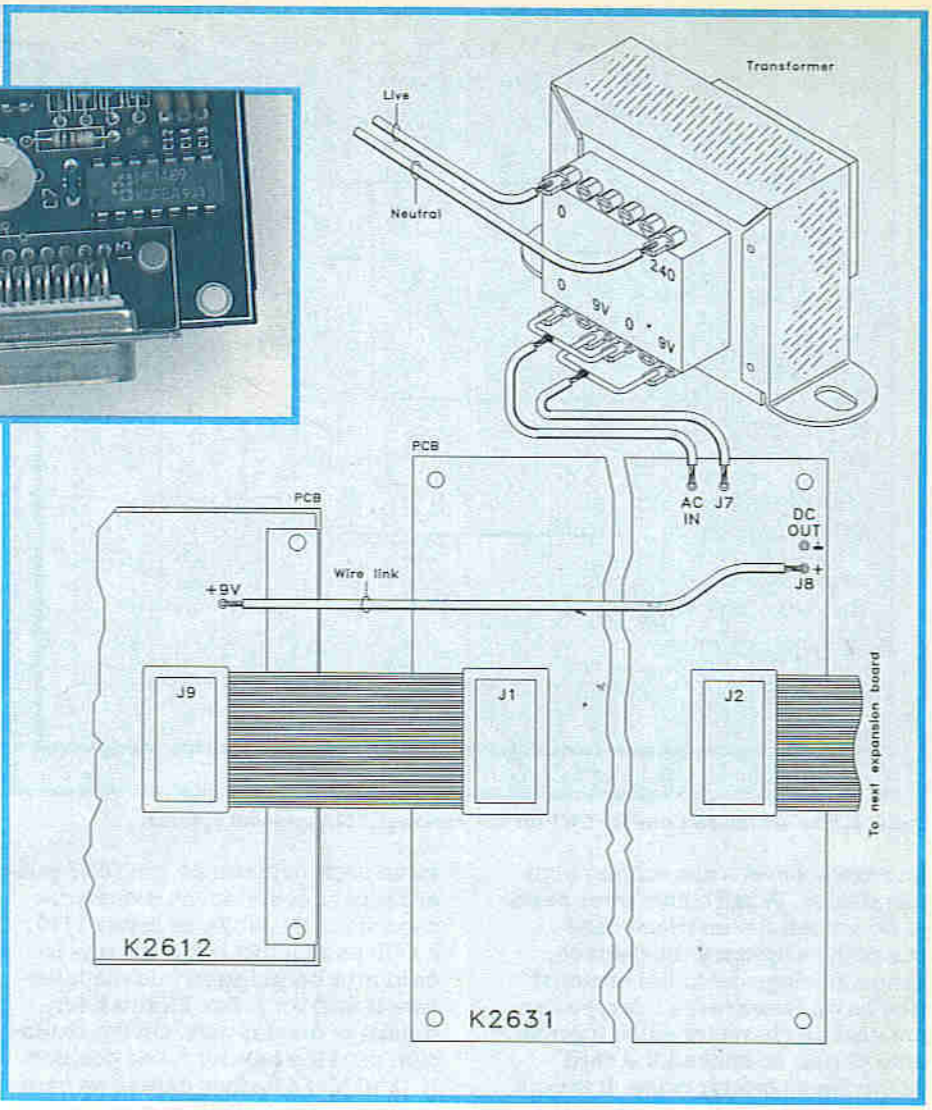


Figure 4. Interconnections between the interface and extension cards using the 24-way DIL headers. While all other connections are made through these, the +9V supply must be made separately by a wire link. The external supply transformer is connected to the extension card as shown.

The CPU is allowed to start once pin 9 goes low. For a bit of extra sophistication, an arrangement has also been provided to reset or halt CPU activities at power-down, and is based around T1, T2, T8 and associated components.

At power-up the time-constant capacitor C16 is not allowed to charge, by T8 being on, until the voltage at +V1 exceeds zener diode ZD1, switching on T1 which in turn switches off T2 and T8. ZD1 ensures that there is sufficient 'overhead' on the +V1 line to operate the regulator VR1 properly, at least 7·5V. Similarly, as soon as the +V1 level falls below this value at power-down (or due to a supply fault) the CPU is disabled via RESET, and the whole card is effectively shut-down 'cleanly' (no erratic reads and writes being attempted while the power supply is disappearing).

DIL switch SW1 is connected to a port of IC1, and is interrogated at start-up to define the serial communications protocol that will be used for conversing with the host. The switches are set up for the required protocol selected from Table 1. Apart from the usual baud rate, parity, and number of data bits, SW1/6 determines whether the interface card will 'echo' characters that have been sent. Echo mode is very useful when the system is being controlled 'manually'. However, where it is controlled by a program in the host computer the echoes can be annoying, so the facility is best switched off (SW1/6 = ON).

SW1/7 selects teletype or terminal mode, and the difference only affects the way in which the charac-

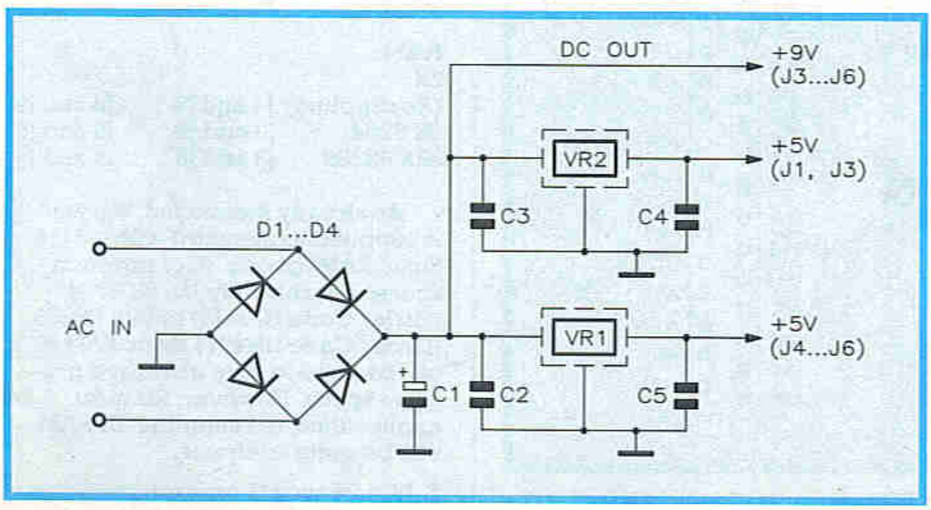


Figure 3. The external power supply as fitted to the extension card.

Switch SW1 Settings for Serial Protocol

Baud Rate (Switch 1)	(Switch 2)	
ON	ON	300
OFF	ON	600
ON	OFF	1200
OFF	OFF	2400

Parity (Switch 3)	(Switch 4)	
ON	ON	Even
ON	OFF	Odd
OFF	ON	Mark
OFF	OFF	Space

Function	Switch number	Setting
No. Data Bits	5	ON 7, OFF 8
Character Echo	6	ON NO, OFF YES
TTY/Terminal	7	ON Teletype, OFF Terminal

Table 1. The switch settings for SW1 for the various RS232 protocol options.

ters are echoed while editing command lines. When a character needs to be erased the interface card sends the sequence 'backspace, space, backspace' to the terminal (the host). However, a teletype cannot erase a character since it prints onto paper, so instead the card sends the character twice. It is very unlikely that you will be using the card with a teletype machine, so SW1/6 should be left in the 'terminal' option. SW1/8 is not used.

IC5 and IC6 buffer all signals to and from the extension board. IC5 is a 2-way, 8-bit bus transceiver and has pull-up resistors R21 to R28 included at socket J9/J10 so that no bus lines are left floating during the periods that IC5 is in the high impedance state. IC6 provides both address and control buses to the same socket. J9 is a 24-pin DIL header for connection to the extension card via a flat cable, or instead J10, a PCB connector, is fitted if one I/O card is to be plugged into the interface board only. See Figure 5 for details of the pin-outs. On the extension card the header takes position J1 (and J2 if a further extension card is added), while PCB connectors occupy J3 up to J6. See also Figure 4.

Although a full 8 address lines are provided in the interests of consistency, only 5 of them (A0 to A4) are controlled by IC6, the remainder being tied to +V2 (+5V). Up to 32 different addresses are therefore available. However, only 19 are implemented, 16 to access up to four I/O cards plugged into the extension PCB, and a further 3 for 'special purposes'. These locations are placed high up in the memory map as follows:

Upper 32K Block:

Base Address	&H7F00
+Offset, (A5-A7 at J9 = 1)	&H7FE0
I/O Cards	&H7FE0–&H7FEF
Real Time Clock	&H7FF0
A/D Card #1	&H7FF2
A/D Card #2	&H7FF3

The CPU itself can address up to 64K, however, its program address space is limited to the lower 32K occupied by IC3 and IC4. The size (in K-bytes) of IC3 is 16K and contains the essential interface software. A link must be made at position J2 on the board to ensure correct addressing of this device. (By linking J1 a 32K EPROM can be used instead, but then there will be no RAM space left; this option can usually be ignored.) Static RAM is accessed as a second 16K block as either 2K 6116, 5117 or 5517 (the minimum provided), 8K 6264, 5165 or 5565, or 32K 62256 or 55257, in which user written instructions can be stored. Battery back-up is provided where E1 is trickle charged via T3 and R31 – when supply is available, and isolated from 0V and left to power IC4 at standby level when power is off, under the control of T6 and ZD2.

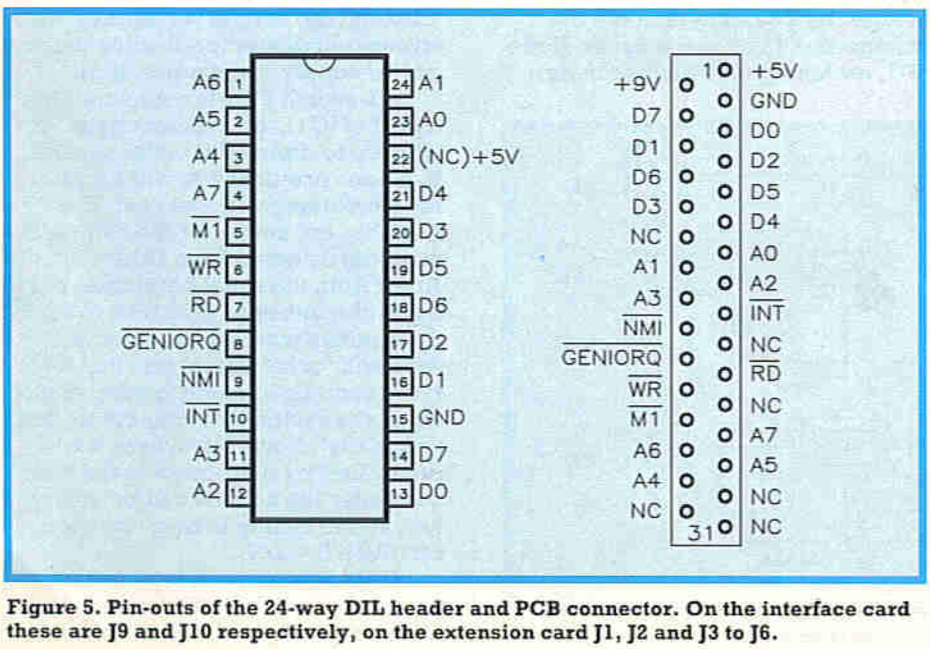


Figure 5. Pin-outs of the 24-way DIL header and PCB connector. On the interface card these are J9 and J10 respectively, on the extension card J1, J2 and J3 to J6.

Construction

Complete assembly instructions are provided in the assembly leaflet supplied with the kit. However, the following points should be stressed:

1. *Solder bridges* have to be made *under* both the static RAM IC and EPROM (ICs 3 and 4) for the links J1 to J6. This is an unusual technique and should be done carefully, and in accordance with the following table. See also Figure 6.

	Link with Solder Bridge	Cut
EPROM:		
CK2612	J2	J1
RAM:		
2K (As supplied)	J4 and J6	J3 and J5
8K 6264	J3 and J6	J4 and J5
32K 62256	J3 and J5	J4 and J6

As already mentioned, the unit is supplied as standard with a 6116 Static RAM, giving 2K of program space. Alternatively, an 8K 6264 (Order Code UF34M) or 32K 62256 (Order Code UH40T) Static RAM IC can be used to give increased program space. However, for most applications, the supplied 2K RAM will be quite adequate.

2. J8, a 25-way D-type connector, is not provided in the kit. A Male R/A

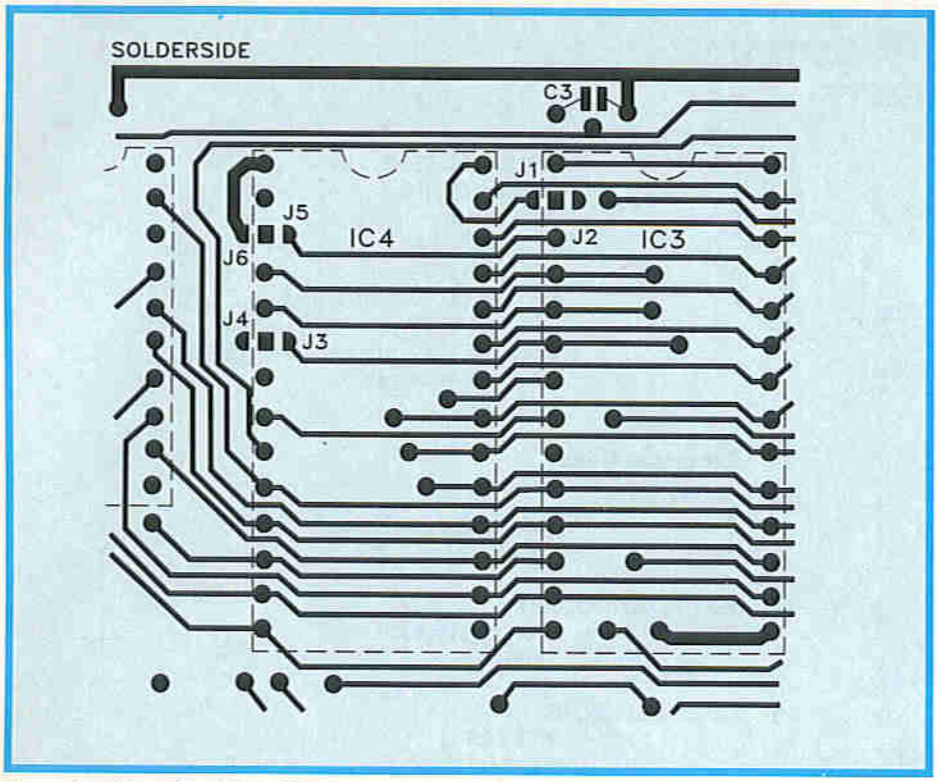


Figure 6. The underside of the interface card showing the locations where the special solder-bridge links must be made or left open.

PCB mounting connector should be used (Order Code FG68Y, R/A D-Range 25-way Plug, found under Optional in the Parts List).

3. Use of the expansion PCB is optional. J9, VR1, C15 and C1 should only be fitted to the Main PCB if you are NOT using the Extension PCB. Otherwise, these components fit on the Expansion PCB instead. If using the Expansion PCB, then while most connections are made between the boards via 24-pin DIL header plugs (as illustrated in Figure 4), a wire link is required from the DCOUT+ connection on the expansion board to the +9V pin on the main PCB. It's worth mentioning that the PCB connector sockets are only supplied as and when they are required with the chosen plug-in I/O card(s), they are not supplied with the interface or extension boards.

Optional item 0-9V, 0-9V, 9VA Transformer (Order Code WB11M) is recommended to power the unit through the Extension PCB. If you are not using the Extension PCB, then a +9V DC supply should be made available to the pin marked '+9V'. See also Figure 4.

It is advisable to house the unit in a screened metal box to prevent interference with other equipment.

Operation

The interface cable will have to be made up with the various connections in each D-range socket (normally a PC's rear panel RS232 connector is male) as shown in the connection diagram for RS232 hand-shaking. It is not recommended that you attempt an RS232 connection without hand-shaking. Note that the cable socket at the host computer end needs to be identified as such, as it has a special link between pins 6 and 8 which are not duplicated at the card end, to avoid confusion when plugging in.

Full details of the interface's instructions are impossible to repeat here fully, but a 24-page user's guide is provided with the kit. A sample GW-BASIC program for the IBM/PC range of computers is listed below as a guide; however, the motherboard works just as well with most commercially available terminal emulation programs.

```
 10 CLS:COLOR 7,0
 20 'The Intelligent Motherboard
    should be connected to the
    serial port (COM1)
 30 OPEN#"COM1:2400,E,7,1PE"
    AS #1
 40 LOCATE ,,1
 50 A$=INKEY$
 60 IF A$<>""THENPRINT#1,A$;
 70 IF LOF(1)<256 THEN GOSUB#90
 80 GOTO 50
 90 C$=INPUT$(1,#1)
100 IF C$=CHR$(10) THEN RETURN
110 IF C$=CHR$(8)THEN
    LOCATE ,POS(I)-1 ELSE
    PRINT C$;
120 RETURN
```

It is envisaged that the main applications for this product are in process control and monitoring slowly changing variables i.e. plotting discharge curves of batteries (in this instance, the motherboard can update the host computer every minute/ quarter hour/hour depending on the discharge rate). Using several A-to-D cards, the motherboard can even monitor the discharge of several batteries simultaneously!

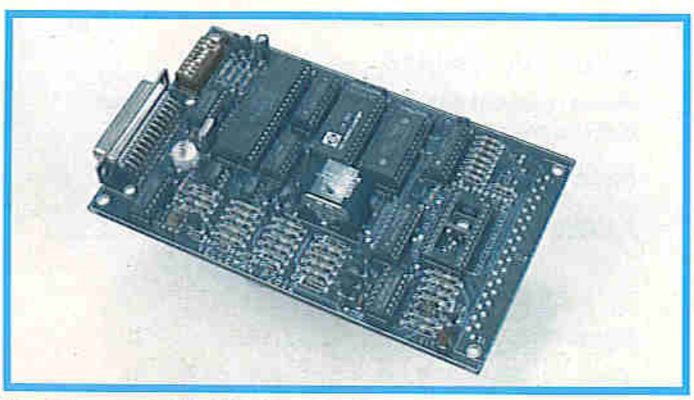
Several examples of control applications are shown throughout the user's guide. Some examples follow:

RDBI 15 XX XX 00 (Read bit 5 of card 1 on the minute, every minute).

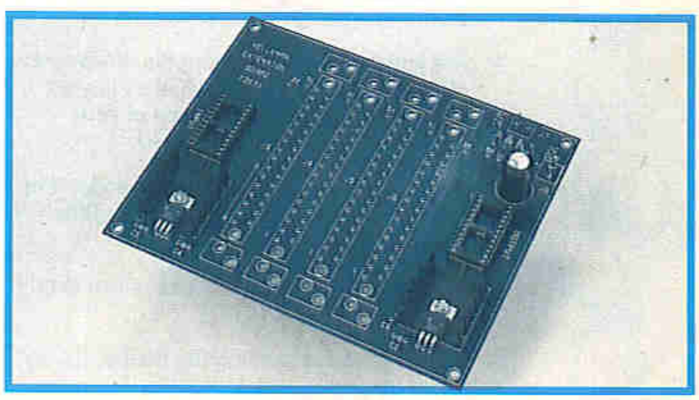
SABH 0 1 (Inform the host computer when bit 1 of card 0 becomes high).

SADE 3 154 (Inform the host computer when the data input from card 3 equals 154 decimal).

The motherboard relies on additional cards to provide input/output capability, for this reason examples of programs are not given here. These additional cards will be described in coming issues of 'Electronics'.



The fully assembled Motherboard.



The fully assembled Extension Board.

RS232 SERIAL PORT INPUT/OUTPUT MOTHERBOARD PARTS LISTS

Interface Card

RESISTORS		
R1-3	1k	3
R4-6,21-33, 8-10,35	10k	18
R7	4k7	1
R11,12	22k	2
R13	220Ω	1
R14,15	100k	2
R16	33Ω	1
R17	560Ω	1
R18	2Ω2	1
R19	2k2	1
R20	68k	1
R34	1k2	1
CAPACITORS		
C2-9,19	100nF	10
C10	47pF	1
C11	10pF	1
C12-14	100pF	3
C16	22μF Electrolytic	1
C17	22μF Tantalum	1
C18	270pF	1
CV1	39pF Trimmer	1
SEMICONDUCTORS		
D1-7	1N4148 (1N914)	7
ZD1	Zener 6V8	1
ZD2	Zener 3V3	1
LD1	Led RED	1
T1-4	BC547 (BC548, BC549)	4
T5	BC517	1
T6-8	BC557 (BC558, BC559)	4
T9	BC327	1
IC1	8031	1
IC2	74LS373	1
IC3	CK2612	1
IC4	6116 (5117, 5517, 6264, 5165, 5565, 62256, 55257)	1
IC5	74LS245	1
IC6	74LS244	1
IC7	1488 (75188)	1
IC8	1489 (75189)	1
IC9,10	4N27 Opto-Coupler	2
IC11	74LS00	1
IC12	TL497A	1
MISCELLANEOUS		
SW1	DIP Switch 8PST	1
X1	Crystal 12MHz	1
E1	PCB Battery	1
	PCB P2612	1
	DIL Socket 14-pin	4
	DIL Socket 20-pin	3
	DIL Socket 28-pin	2
	DIL Socket 40-pin	1
	DIL Socket 24-pin	1
	PCB Pin	1

Extension Card

CAPACITORS		
C1	1000μF Electrolytic	1
C2-5	100nF	4
SEMICONDUCTORS		
D1-4	1N4001 (1N4002 etc.)	4
VR1,2	7805	2
MISCELLANEOUS		
	PCB P2631	1
	DIL Socket 24-pin	2
	PCB Pins	4
	PCB Vaned Heatsink	2
	M3 x 10mm Bolts	2
	M3 Nuts	2
	IDC Flat-Cable Assembly	1
	Assembly Instructions	1
	User's Guide	1

OPTIONAL (Not in Kit) For Both Cards.

6264 100ns	1	(UF34M)
62256/43256 150ns	1	(UH40T)
R/A D-Range 25-Way Plug	1	(FG68Y)
Min Tr 9V	1	(WB11M)

The Maplin 'Get-You-Working' Service is available for this project.

The above items (excluding Optional) are available in kit form only.

Order As VE91Y (Serial Expansion Kit) Price £109.95.

Please Note: Some parts, which are specific to this project (e.g., PCB), are not available separately.

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