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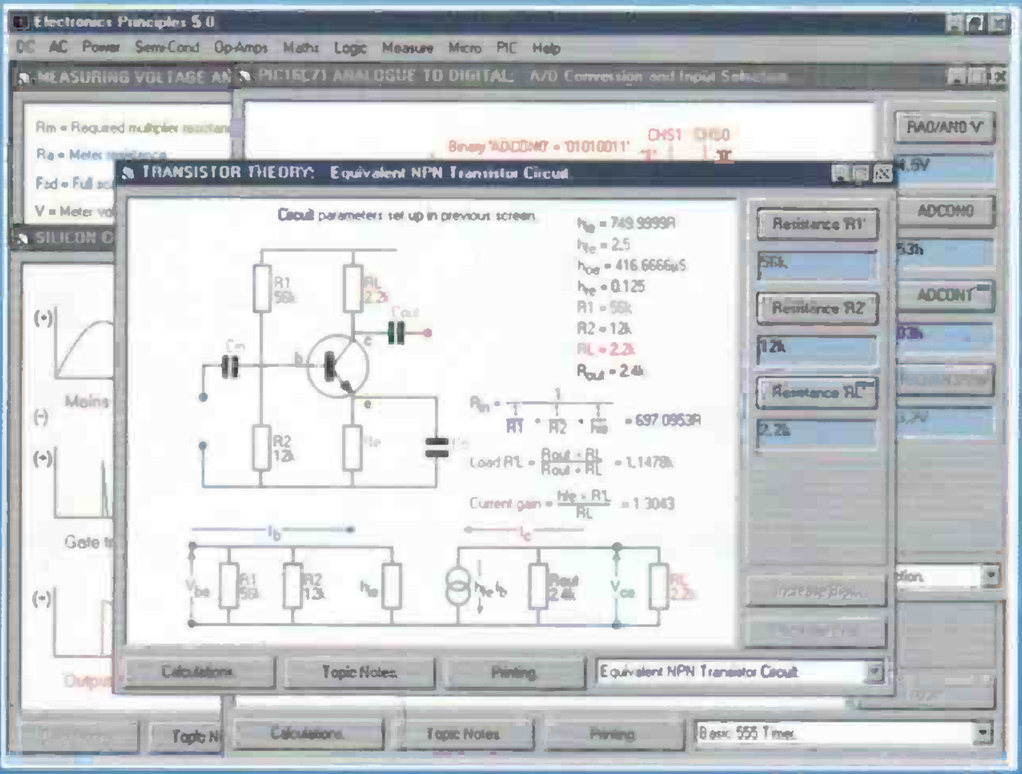

Electronics Principles 5.0 is a significant upgrade of our popular electronics educational software. Now containing even more analogue, digital and microcomputer theory. PLUS over a hundred new mathematics topics to further your understanding of formulae and calculations. Telephone for a comprehensive list or upgrade details.

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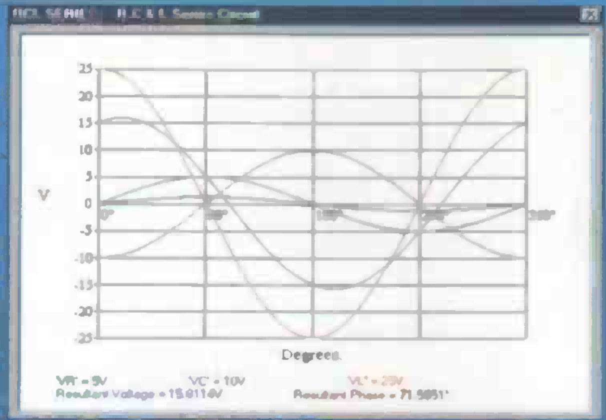
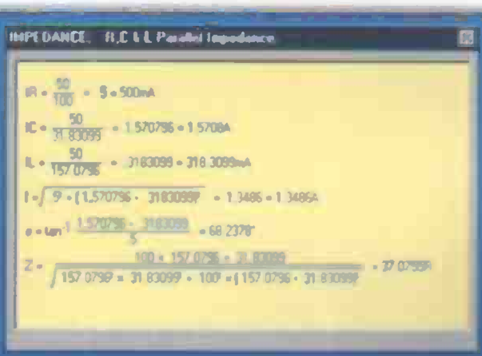
The PIC16C84 microcontroller hardware and instruction set has been introduced and brought to life through colourful interactive graphics where you can study the architecture of this device by changing the data values to simulate all of the registers, direct/indirect addressing, program/data memory and input/output port configuration. Along with those analogue to digital functions of the PIC16C71. If you would like to learn more about the principles of these popular microcontrollers then it could not be made easier.

Electronics Principles software is currently used in hundreds of UK and overseas schools and colleges to support City & Guilds, GCSE, A-Level, BTEC and university foundation courses. Also NVQ's and GNVQ's where students are required to have an understanding of electronics principles.





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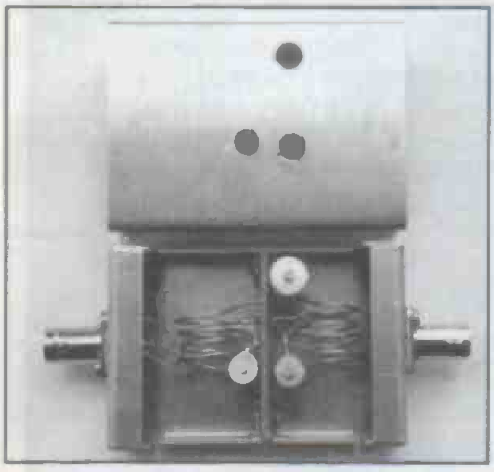

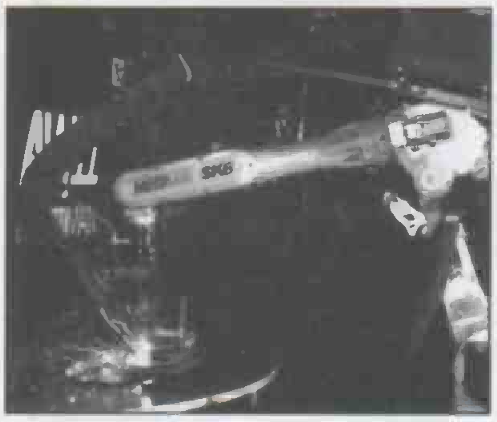

Understanding Robots 8
Harprit Sandhu introduces the expanding family of "programmable general purpose manipulators" and the mechanisms and control loops that make them function.

Three-Range Inductance Meter 19
To partner last month's Capacitance Meter, Robert Penfold's Inductance Meter has three ranges of full-scale value 1mH, 10mH, and 100mH.

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Strong legal transmissions, particularly the ever-expanding range of radio-paging signals, can swamp VHF reception. E Chicken MBE's filter is designed to reduce swamping and clear reception.

LED Voltmeter for 12V battery check 29
Twelve-volt lead-acid "leisure" batteries are designed to run down significantly before re-charging. Terry Balbirnie's four-LED battery checker indicates the charge state.

BB Ranger 35
The Ranger is an eprom-driven electronic score-board for a BB pellet-gun shooting range. A specially-built set of fall-down targets enable an instant readout of the accumulated score.

GCSE Grounding: Sound Effects Module 46
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The Orphan Decibel 51
The Decibel is an unusual unit of measurement - it describes a thing not by what it is, but by what it does. E.Chicken MBE FIEE describes how to calculate power with decibels.

Spiced Circuits: Logic Simulation and Maths 56
In the last of Owen Bishop's series on Spice-based circuit simulation, he looks at logic simulation, including B2Logic V3.0

Digital Tic Tac Toe 60
An electronic game of Noughts and Crosses which allows you to play against a PIC 16C64 microcontroller. By Rose and Andy Morell.

Line-Up Oscillator With Glitch 63
When you are sending an audio signal to a remote destination, it is necessary to know which stereo channel you are monitoring. Tony Sercombe's glitch will tell you.

Review: Peak DCA50 Component Analyser 73
An advanced new meter for the identification of component types, pin-outs and functions.

Regulars

Advanced IBM Disk Technology Loads More Than Before

"Giant Magnetoresistive (GMR)" disk drive heads, pioneered by IBM Research scientists, are the essential component behind the world's highest capacity desktop PC disk drives. The IBM Deskstar 16GP is a 16.8-gigabyte drive capable of holding eight times more information than today's average desktop hard drive. The 16GP can hold eight hours of full-motion video (MPEG-2 quality video), or, according to IBM, sufficient information to fill more than 16 pick-up trucks if printed out as hardcopy (presumably on USA standard 11 x 8.5-in paper stock).

A pickup truck is a traditional North American lightweight open-backed flatbed van with low sidings. Goods and passengers are either stacked loose or lashed in place, usually accompanied by a dog. Not generally robust enough for full commercial loading, pickups are widely used for local deliveries, general agricultural transport and riding around. Loading capacity (depending on age and condition, and taking into account the low compressibility of paper) may be approximately compared to one "transit" van, half a Luton box van, or a reasonable fraction of a corporation dustcart.

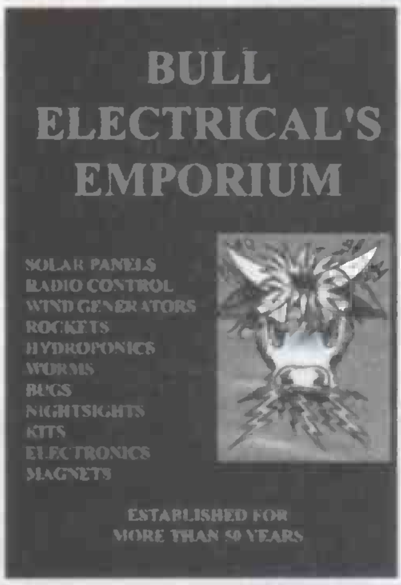
For large companies like IBM, mass storage of this kind once promised the "paperless office", but the comparatively slow spread of electronic documentation, and paper hardcopy's flexibility and freedom from compatibility problems, has tended to increase the amount of paper in circulation, rather than decrease it. In the future, mass storage by removable hard disk may help to reduce the physical need for filing space.

The GMR disk head is no bigger than the head of a pin and is the world's most sensitive sensor for reading data on hard disks. According to IBM, the massive storage capabilities of the Deskstar 16GP allow television-like sound and picture-quality multimedia programs on a suitable computer.

GMR technology expects to be able to provide storage of more than 10 million bits per square inch on the disk platter by 2001.

The Deskstar range has 10 disk capacities to choose from. For high performance as opposed to maximum capacity, The Deskstar 14GXP family has a choice of three different capacities from 10. gigabytes to 14.4 gigabytes running at 7200 revs per minute. The 5400 RPM 16GP drive family has seven capacities from 3.2 go 16.8 gB.

For more information see IBM Storage Systems Division's web page: www.ibm.com/storage, Dept. Star 30, or contact IBM UK Ltd., South Bank 76 Upper Ground, London SE1 9PZ, UK. Tel 0171 202 3744, fax 1071 202 3792.



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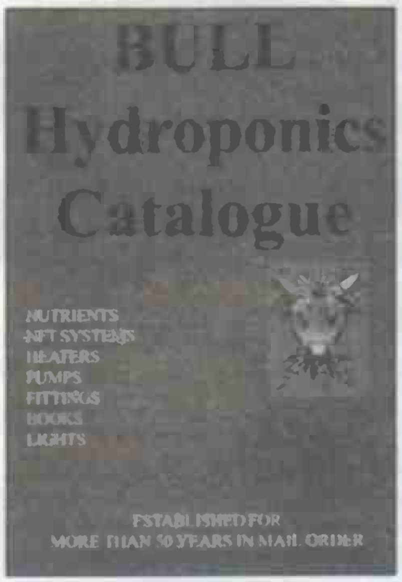
New Bulls On The Loose!

Bull Electrical's latest catalogue is now out. It features remote control systems, telescopes and microscopes, batteries and battery chargers, surveillance bugs and camera accessories, video cameras, solar panels and a complete wormery with 1000 worms to convert kitchen waste into organic compost.

Bull have also started a new catalogue concentrating on the scientific hobby of hydroponic gardening. The catalogue includes nutrients, heaters, pumps, lighting, accessories and how-to books. An ideal way to utilise the rich organic nutrients from your wormery!

For more information and copies of their catalogue, contact Bull Electrical, 250 Portland Road, Hove, Sussex BN3 5QT, UK. Tel. 01273 203500, fax 01273 323077.



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ETI ELECTRONICS TODAY INTERNATIONAL News...

All Micro Show at Bingley Hall in April

The SAMS'98 Spring All Micro Show will take place on Saturday 18th April at Bingley Hall, Staffordshire Showground, Weston Road, Stafford. The show will be open from 10am to 4pm, with plenty of free parking. Entrance is £3.00 for adults, 50p for children under 14, £2.00 for concessions: OAPs, RSGB members, student cards, UB40. Advance tickets are also £2.00 plus a stamped, self-addressed envelope.

The Showground is on the A518 Stafford-Uttoxeter Road, signposted from junction 14 on the M6. There is a bus shuttle from Stafford railway station.

This is the 10th consecutive year of the All Micro Show at Bingley Hall. Last year saw 3,000 people and 100 trade stands covering all formats computing, including PC, Sinclair, Einstein, Amiga, Atari St and Atari 8-bit computing supported by various user groups, along with stands selling accessories, software, books, components, shareware, media, hardware, radio, satellite and a big Electronics Bring and Buy Stall. There are refreshments, a cafeteria and a licensed bar from 11 am.

There will be another All Micro Show in Bingley Hall on November 14th.

For further details, advance tickets etc. contact Sharon Alward at Sharward Promotions, Knightsdale Business Centre, 30 Knightsdale Road, Ipswich, Suffolk IP1 4JJ. Tel 01473 741533, fax 01473 741361. Email: services@sharward.co.uk

Electronic Recycling Guidelines from Industry Council

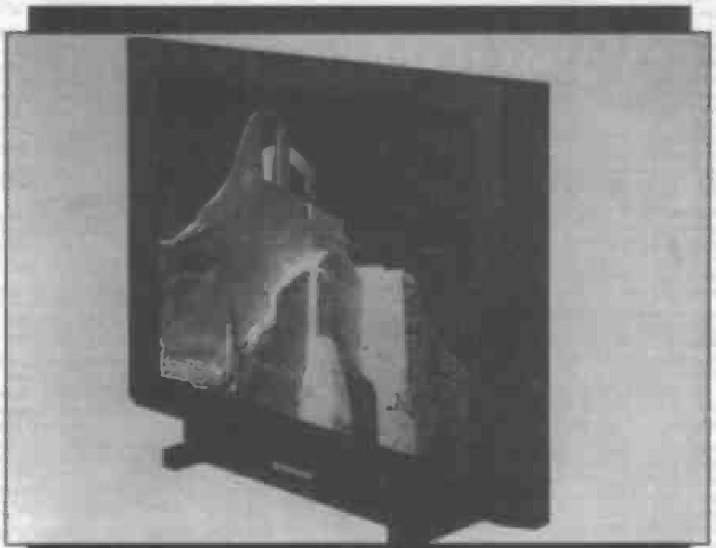
ICER – the Industry Council for Electronic Equipment Recycling - has set up a Recycling Directory for use in industries looking for serious suggestions about what to do with unwanted electronic equipment.

The directory lists some 30 UK companies which specialise in recycling different kinds of electronic and electrical equipment, ordered by category of equipment and the recyclers who handle is, as well as an alphabetic list of recyclers giving more information about the companies. A website giving access to the directory is also planned.

Anticipating that an EU directive will eventually require that recycling is carried out by "approved recyclers", ICER has produced a summary of "best practice", "for defining the criteria for approved recyclers", according to Gary Griffiths of R Frazier, who chairs the ICER recycling group. This includes points such as:

"A recycler will need to: show the company has appropriate licences or exemption certificates for all sites in accordance with waste regulations, and uses waste transfer notes and authorised transport operations", and "... classify any waste from processes (eg Controlled Waste, Special Waste) and dispose of it properly."

An ICER publication, ICER Guidelines: Design for Recycling Electronics and Electrical Equipment is available, price £20 plus postage and packing (depending on destination) from Pam Gibson, ICER, 6 Bath Place, Rivington Street, London, EC2A 3JE. Tel 0171 457 5038.



New Plasma Screen Technology Ready to Hang on the Wall

Pioneer's new television monitors are using new plasma technology that allows them to be slimmed down to just 9 cm (88mm, in fact) deep.

The immediate result of this ultra-slim profile is likely to be more "Public Information Screens" in public places. The plasma screens are thin enough to be hung on the wall like a picture, making them useful in areas normally too small or inaccessible for normal screens. For example, all the lifts at major airports could be fitted with plasma screens giving the latest departure, arrival and check-in information.

Pioneer's innovative 40-in colour plasma display screens can be linked to video, PC CD-rom, a normal television tuner, even DVD, making them a versatile choice for conference organisers and marketing organisations.

In due course the plasma screens are expected to cross over into homes for use with a TV tuner, to hang on the wall or sit on slimline stands, far less bulky than current TV tubes. The plasma screens' high brightness (400 candela per square meter - the highest level in the world) and a 160-degree vertical and horizontal viewing angle ensure that the screen is a screen that's seen - a flat, non-glare surface makes the screens suitable for bright environments (no more need to turn all the room lights down to cut off the glare and screen washout), while their long lifespan (20,000 hours) and optional rain-proof housing making them durable enough for indoor or outdoor use.

The base-model screens are available from April 1998 and have built-in compatibility with TV tuners, amplifiers, SPs, external CPUs and DVD players, and are compatible with PAL, NTSC and VGA video standards.

For more information, contact Kate Moir or Julia Savage, Storm Communications (Pioneer Multimedia Press Office) tel. 01494 670444. Email stormcomm@compuserve.com

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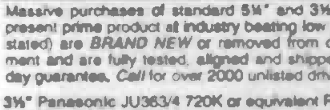

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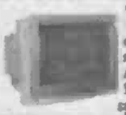

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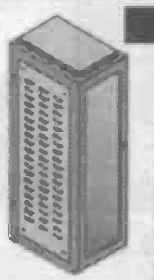
19" RACK CABINETS



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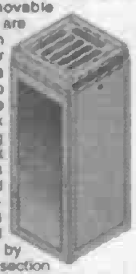

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News...

Construction Toolkits Get A Free Upgrade

The new versions of the Minicraft 12-volt kits now come with extra power and accessories. The Hobby Kit (MB 1000), designed for the beginner, now has a more powerful 30-watt motor and heavy duty single-speed MB714 transformer. The list price is £44.99. The Precision Drill Kit (MB5001) is designed for the person with system-expansion in mind, and also has a more powerful 30-watt motor. The list price is £68.99. The High Precision Drill Kit (MB8571) is designed for the serious enthusiast and is upgraded with 40 accessories instead of 15. The list price is £84.99. Particularly recommended for Minicraft's lathe attachment (MB850).

The new features have been added to the kits at no extra cost. All kits come in a useful plastic carrying case.

For more information, catalogue or list of stockists, call Minicraft on 07000 646427238.

MODMODMODMOD

In ETI 2, 30th January 1998, Smartcam: In figure 1, the circuit diagram, an erroneous wire link is shown between IC5 (7806) and Video Out. This was intended to represent pointers to two wire links: one between IC4 pin 1 and a 75-ohm resistor (R6, also omitted) just before Video Out, and one between IC5 (7806) Vi and +12V/IC6 (7805) Vi. The component layout, figure 3, shows the links correctly.

On the component layout, figure 3, R13 has been omitted. JP2 should move one pad to the left, and R13 inserted between IC1 pin 14, and IC1 pin 16/C13. The pads appear correctly on the PCB foil.

JP1-4, omitted from the Parts List, are option pin/pin jumpers, available from Maplin.

The author advises us that 0.25-watt resistors will work as well as 0.5-watt.

A query raised about the connections from IC7 and the opto-module board is still outstanding and any correction will be added to the MODs sheet as soon as possible

Adaptable 8-Output Metrabyte KPCMCIA-8AO Cards from Keithley

Keithley Instruments has released a Metrabyte KPCMCIA-8AO 12-bit analogue output PCMCIA card for use with notebook and PCMCIA-equipped PCs. The KPCMCIA-8AO is "uniquely capable" of updating eight independent bipolar or unipolar outputs simultaneously at 100kHz. Because the card has an onboard event timer that permits it to interrupt a PC's CPU at software-programmable intervals, it can generate waveform-quality outputs. In addition, the card offers eight channels of TTL-compatible digital I/O.

The Metrabyte card is available in two versions: the KPCMCIA-8AOU with eight unipolar outputs with a range of 0 to +5V, and the KPCMCIA-8AOB, with eight bipolar outputs with a range of +/- 5V. The KPCMCIA-8AO is PCMCIA standard 2.1 compliant, supports hot swapping, and accommodates external interrupt inputs. The card can update multiple outputs simultaneously under software control or with an external event. Each of its eight I/O channels are software configurable as an input or output, providing for control or monitoring of digital information. The KPCMCIA-8AO is fully programmable and Windows '95 compatible, and is shipped with cabling.

The KPCMCIA-8AO's small size and low power consumption make it suitable for an array of portable and field applications in laboratory and industrial settings. It is especially suitable for product testing and control applications where an input stimulus is required to generate a variable-output control signal, such as in the control of a proportional solenoid. It is also useful for waveform generation and voltage sourcing, which are important elements of many laboratory applications.

The KPCMCIA-8AO supports Windows '95 and comes with the Daqware (tm) standard software package, which includes Testpoint driver software. Labview drivers are also available.

Daqware includes everything the user needs to install, configure, test, calibrate and program a The KPCMCIA-series card, including example programs for all supported languages. Testpoint, available as an option, allows the user to create applications without programming. It provides a drag-and-drop interface for data acquisition. Testpoint incorporates most commonly used mathematical, analysus, report generation and graphics functions, and includes features for controlling external devices, responding to events, processing data, creating report files and exchanging information with other Windows programs. Testpoint is Keithley's preferred "packaged software".

Optional Labview driver software provides an interface to National Instruments' Labview application software, allowing the Labview programmer to take advantage of software previously developed using Labview for National Instruments boards without expensive reprogramming.

For more information contact Keithley Instruments Ltd., The Minster, 58 Portman Road, Reading, Berks RG30 1EA. Tel 0118 9575666, fax 0118 9596469

Understanding Robots

This introduction to robotics by Harprit Sandhu explains what robots are and the basic conditions needed to make them functional.

A robot can be described as a programmable manipulator doing work that otherwise a human would have to do, in a manner at least somewhat similar to the way a human would do it. A washing-up machine, for instance, is not normally considered a robot. It washes dishes, but it does not place the dishes in a sink, use a mop, or stack them in the drying rack afterwards. The robot of popular fiction is a mechanical person; more often today, a robot resembles a part of a mechanical person. Most shop-floor robots are the emulation of one arm of a human being.

Robot arms are used to weld, package, paint, position and assemble a host of everyday products. Parts from integrated circuits to printed circuit boards and VCR tapes to automobiles are now wholly or partly made and assembled by robots.

There are three distinct component groups within any sophisticated robot(ic) system. They parallel human functions:

1. Hardware: the body
   Robot arm and gripper: the arm and hand
   Vision system: eyes

2. The computer electronics: the brain

3.The software programming: the education

The mechanical part of the robot that does the physical work is designed to perform a specific family of tasks within a specified envelope determined by the physical size of the robot. The majority of the mobile robot population are Automatically Guided Vehicles (AGVs). Their main use is the delivery of raw material components. They provide an intelligent, mobile, programmable conveyor function.

A robot arm is a series of linkages connected up to work as a manipulator or arm. A motor controls each joint or movement. The operation of each joint does not have to be independent, but there are advantages to independent operation. If operation is not independent, the computer can be programmed so that for our purposes operation is virtually independent. However, this makes the task more computer-intensive, because calculations may have to be made before every move, and this computing time is no longer available for other computations. Even so, the mechanism is nowhere near as complex or flexible as the human arm.

The modern robot arm is a six-axis device fixed to the shop floor or to the machine it serves. It is controlled from a powerful computer, usually nearby. The computer cabinet contains all the logic components and amplifiers needed to run the robot. Shop floor robots can pick up pieces that weigh over 100 kilograms (220 pounds) and place them within about 1 mm (0.040 inches) of a desired location with ease. They can move loads at about 1 meter (3 feet) per second and put them down as softly as you please. Grippers or robot hands of many kinds can manipulate and control all manner of things.

Types of robots

Robots can be divided into families according to the type of work they do. The major divide is between mobile and stationary robots. (See Table 1.)

Defining a robot

In some ways, a "robot" is whatever we agree to call a robot. We tend to use "robotic" to describe machines designed to act automatically or autonomously. We might call an automated vehicle a robotic jeep. Industrial robots are called robotic arms, and machine vision is referred to as robotic vision.

Robots in general:
Are normally computer-controlled.
Have components that move in some way
Have servo-motors incorporated
Have have a user interface to allow us to interact with them.
The interface may consist only of a start button or a keyswitch
Can be programmed to do tasks
Interact with their environment with input and output signals
Handle or examine something external to themselves in some way

An AGV (Automatically Guided Vehicle) transporting paper rolls automatically in a factory environment. Note the hand-held pendant on the right, used for controlling the AGV manually. (Picture courtesy of Rocla (Finland)/Mentor (USA).)

It is worth noting that though playing chess is very "human", we do not call chess-playing computers robots. If, however, we were to add a rudimentary robot arm to manipulate the chess pieces, a mundane task compared to the ability to play chess, we would all agree that this was indeed a chess-playing robot. This shows that manipulation is an important element in our perception of a robot. Yet we often call vision systems "robotic vision" even though no manipulations are involved.

Conclusions

We conclude that a robot is a programmable, computer-controlled machine that manipulates products and/or tools to do work. It can make decisions and interact intelligently with its environment. It can receive and send information to its environment. It may or may not be mobile.

This is not the official definition of a robot stipulated by the RIA, but it sums up what the the official definition conveys:

"A re-programmable, multi-functional manipulator designed to move materials, parts, tools, or specialised devices through various programmed motions for the performance of a variety of tasks." Robot Institute of America, 1979

A broader definition is: "An automatic device that performs functions normally ascribed to humans or a machine in the form of a human." Webster.

Robots as workers

We humans have an overwhelming interest in doing as little as we can to get the job done. We design robots to improve on the positive attributes and eliminate the negative attributes of humans. Almost the total effort is in this direction. The essential difference between the automatic machines of today and yesterday is that today's machines are programmable. Today, what they do depends on the information that we put into them. Tomorrow, they will add intelligence, eventually massive intelligence. They will be able to optimise their work and react intelligently to all predictable and most unpredictable disturbances. Gross unpredictable disturbances can be handled by shutting down, sounding an alarm, summoning a human supervisor, or rejecting the part. Minute changes from cycle to cycle and part to part are harder to handle.They are subtle and hard to define, detect and react to appropriately.

Intelligence

In machines, intelligence is the implementation of sophisticated "If... Then...." strategies in which action depends on what has already happened. This looks intelligent, but it is really rigid logic, perhaps with some randomness, range and flexibility added to the decision-making process. "If... Then..." strategies can be made extremely complex - this is what makes them useful. Today, most robot language programming is done in the programming language C. C has around 28 instructions in it. I say "around 28", because 28 instructions are defined although not all are used. There is little limit to what can be built up with these 28 kernels, and there are many sophisticated versions of the language. (Separate instruction sets address different tasks). A language with only 28 instructions is relatively easy to write (or port over) for a new computer design. All that has to be done is to implement these 28 instructions.

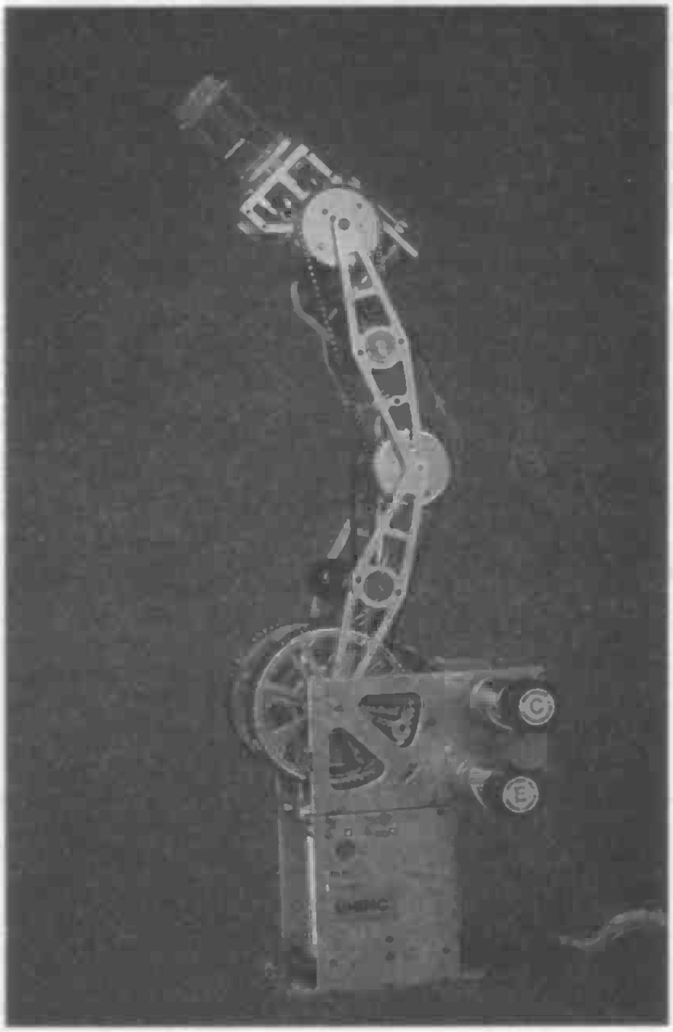
Robot geometry

Two basic factors govern the motion and abilities of the robot: the geometry of the design and the sophistication of the software. Robots come in many shapes and sizes, and the software is optimised to the needs of the specific robot. In "three-space", our everyday three-dimensional environment, there are various ways to design a robot that will reach all points in its work environment. As a rule you need one motor for each degree of freedom that you want to specify. So, at least three motors are needed to reach a location in three-space (X, Y and Z coordinates). Another three motors are needed to orient the hand in the three possible orientations (roll, pitch and yaw). This is the basic universal six-axis robot.

There are some mechanical design aspects of the human arm that we should observe:

The distance from shoulder to elbow is greater than the distance from elbow to wrist; which is greater than the distance from wrist to knuckles; which is greater than the distance from the first finger joint to the second finger joint. The distance from the second finger joint to the fingertip is the smallest distance on the mechanism.

The resolution of the system gets finer as we get closer to the gripper and the work. There are also increasing numbers of nerves in the human arm as we move from the shoulder to the fingertip. After the wrist, flexibility is provided by splitting the palm, by opposing the thumb to the fingers, by removing one digit from the thumb and by duplicating the fingers. Providing fingers of different lengths is a further refinement.



A 5-axis, 6-motor robot arm that can lift about 1kg and run at about 1 foot per second. This 32-inch high Rhino XR-4 robot was designed to mimic larger industrial robots in a teaching environment

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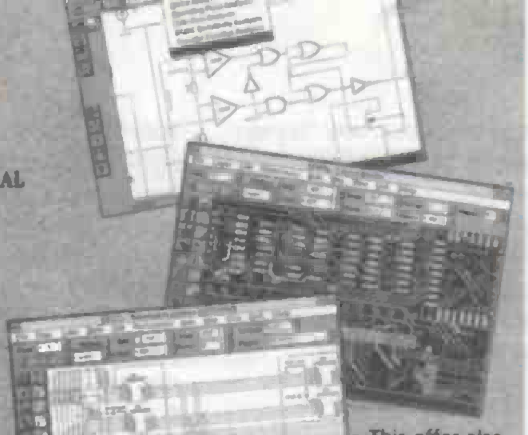

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A Motorman SK6 robot arc-welding. The welding rod is fed in automatically, and co-ordinated by the robot controller. All aspects of welding (arc detection, puddle size, depth of weld, wedling current, etc.) can be detected and controlled by the robot controller. (Picture courtesy of Motoman USA.)

This should give us a framework in which to think of the human arm as a robotic mechanism. This arm has done most of what we need for millions of years. What does it tell us about robot arms?

Industrial robots

The moves we want our robot to make are dictated by the work we want it to do. The design will be an expression of the minimum capabilities needed to get that work done. The reach of each axis, the number of axes, the capabilities of the computer, the memory needed and the number of sensors (to mention just some of the major design parameters), will all be minimised to produce the most economical robot possible **(figure 1)**.

Robot geometries are defined by the shapes that the robot's design mimics. The most common robot configurations are:

Articulated: Articulated robot arms act like the human arm. This is a flexible design that allows the most humanoid arm movements.

Cylindrical: A cylindrical configuration dictates a robot whose axes are designed to be specified as cylindrical co-ordinates. This usually means an axis that moves up and down like a cylinder, and another axis that moves in and out like a radius vector.

Spherical: In a spherical co-ordinate robot the two angles and a radial specification specify the point in space.

XYZ or Orthogonal: An orthogonal robot is an XYZ machine. It has three sides that are arranged at right angles to one another.

Gantry robots: Gantry robots have a robot gripper suspended from a gantry that covers a large space.

Grippers

The design of robotic grippers is a discipline in itself. Sophisticated grippers have microprocessors dedicated to their control. Almost all grippers fall into the following three categories:

Vacuum Operated Grippers: these allow the robot to pick up parts that have a flat surface. Small, delicate parts or large flat sheets often need vacuum grippers.

Pneumatic Operated Grippers: these allow simple open-close control. The fingers can have many shapes and configurations, including two-, three- and four-finger units.

Electrically Operated Grippers: these are the most sophisticated type. They allow the greatest flexibility of use and need the most sophisticated software. They also need the most maintenance.

Software

The most important part of the robot is the software. Software determines what can be done with existing hardware and how it is done. Of course, if the appropriate hardware for a task does not exist, the task cannot be carried out, and if the software does not address the hardware in an appropriate way, even appropriate hardware is useless.

Sensors and transmitters

Sensors that the robot employs can be located either on the robot itself, on the gripper, or in the robot's immediate environment. Sensors tell the robot controller about the robot itself, or its immediate environment, or about what is currently in the gripper. The robot can only take in information for which

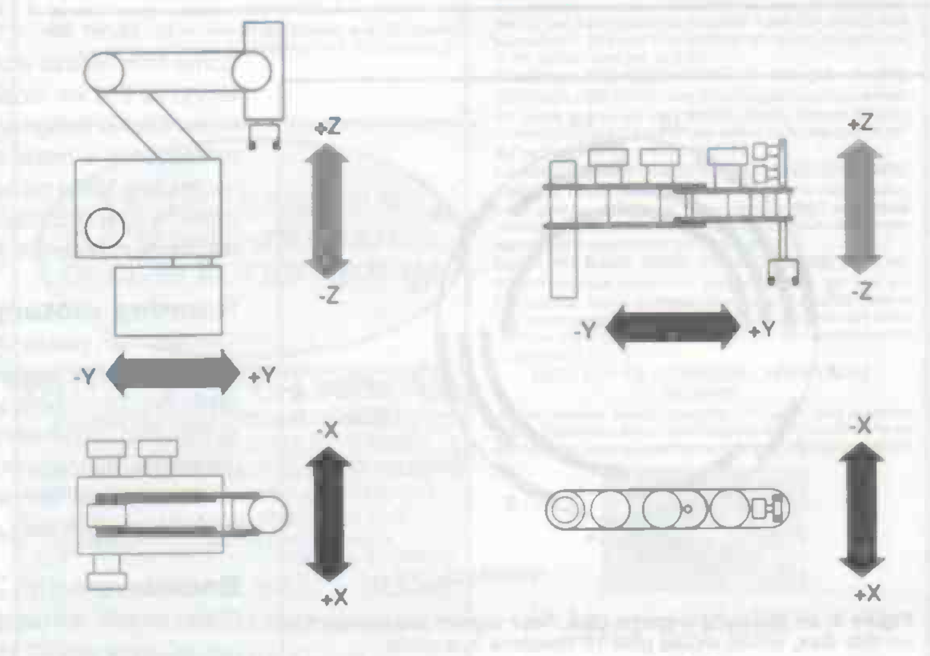

Figure 1: axis designations in articulated and side-arm robots

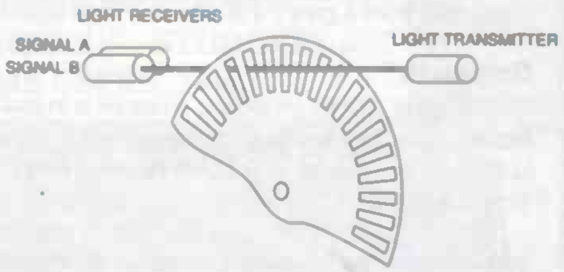

Figure 2: an optical encoder construction. Signals A and B will be 90 degrees out of phase. Here, signal B is On and signal A is Off.

it has the appropriate sensors, and only transmit information for which it has appropriate transmitters. Only those things that affect the robot and its operations are of interest to the robot operating system. All other phenomena are ignored.

Sensors used with robots fall into the following categories. These are listed in "distance to robot" categories. A robot can only receive signals from its environment through its sensor systems. The robot emits signals to send information to its environment. These can be electrical signals by wire, the physical closing and opening of relays, specific light, sound and radio signals or some other form of signal.

Robotics and sound

Sound is easy to generate, detect and record. Using sound to detect distance involves emitting a specific frequency in short bursts and waiting for the sound to bounce back from surrounding objects. Emission and detection are relatively time-consuming, so this can be done only 20 to 50 times a second.

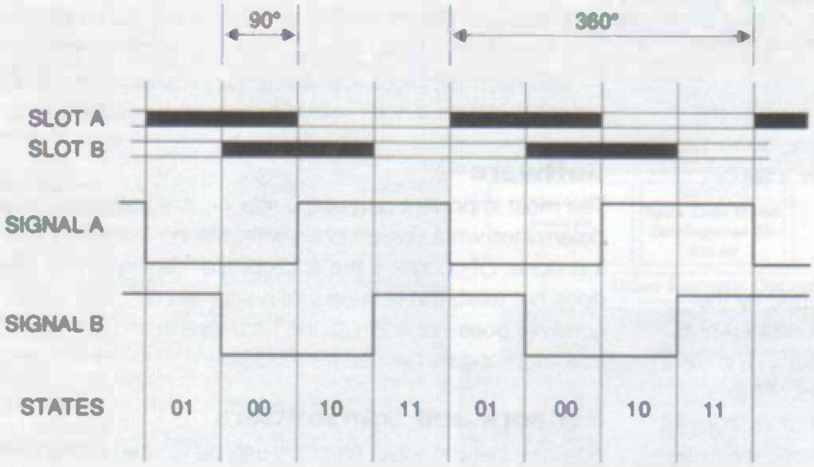

Figure 3: incremental optical encoder signals shown 90 degrees out of phase

Sound moves across a space as a series of pressure waves. If we sample a sound 40,000 times a second (twice the highest frequency we can hear), we can re-transmit that sound, and the human ear will find the reproduction completely faithful. However, less than 20,000 Hz is sufficient for robotics.

Signal noise (such as a bad connection, or distortion) can be a problem, but the biggest problem is normal acoustic background noise - the kind of noise that makes conversation in a noisy factory impossible. Noise problems can be minimised by using high frequencies and modulating them so that the signal can be more easily distinguished.

Having our 20,000 bytes per second, we must analyse it. The analysis is complex and time-consuming. It is pretty certain that the sound will not be deciphered neatly one byte at a time. Some form of front end filtering is used to sort out the correct sound so that we receive the information efficiently. Once we know what is being said, we must decipher what it means. In robotics, this is made easier by limiting the machine's vocabulary. Voice recognition is already available for quite small systems (one of ETI's contributors uses it on a PC), and telephone companies are using it to some extent.

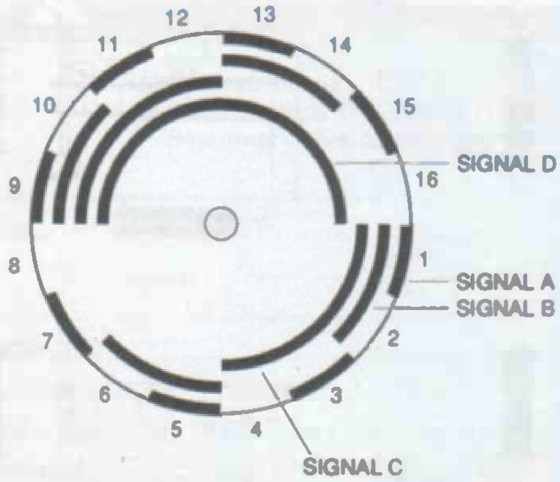

Figure 4: an absolute encoder disk. Four signals are shown on this disk, which would give 16 divisions in a circle.

Running motors

The two main pieces of equipment needed to control a motor with a computer are optical encoders and power amplifiers. Encoders tell us what a motor is doing in terms of its rate of motion and overall revolutions, and amplifiers allow us to control the motor by controlling the energy supplied. By combining these with the speed of a computer, we can control a motor very precisely.

Encoders

Robot motors are usually linked to optical encoders using an optical signal system to provide motion information. The signals sent to the computer are usually of the type that switch

WIND GENERATORS 380 WATT 1,14 metre dia blades, carbon matrix blades, 3 year warranty, 12vdc output, 24v version available, control electronics included, brushless neodymium cubic curve alternator, only two moving parts, maintenance free, simple roof top installation, start up speed 7mph, max output (30mph) 380w, £499 ref AIR1

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TELEKINETIC ENHANCER PLANS Mystify and amaze your friends by creating motion with no known apparent means or cause. Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect. Excellent for science projects, magic shows, party demonstrations or serious research & development of this strange and amazing phychic phenomenon

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COPPER VAPOUR LASER PLANS Produces 100mw of visible green light. High coherency and spectral quality similar to Argon laser but easier and less costly to build yet far more efficient. This particular design was developed at the Atomic Energy Commision of NEGEV in Israel. £10/set Ref F/CVL1.

VOICE SCRAMBLER PLANS Miniature solid state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit. Use on telephone to prevent third party listening and bugging. £6/set Ref F/VS9.

PULSED TV JOKER PLANS Little hand held device utilises pulse techniques that will completely disrupt TV picture and sound! works on FM too! DISCRETION ADVISED. £8/set Ref F/TJ5

BODYHEAT TELESCOPE PLANS Highly directional long range device uses recent technology to detect the presence of living bodies, warm and hot spots, heat leaks etc. Intended for security, law enforcement, research and development, etc. Excellent security device or very interesting science project. £8/set Ref F/BHT1.

BURNING, CUTTING CO2 LASER PLANS Projects an invisible beam of heat capable of burning and melting materials over a considerable distance. This laser is one of the most efficient, converting 10% input power into useful output. Not only is this device a workhorse in welding, cutting and heat processing materials but it is also a likely candidate as an effective directed energy beam weapon against missiles, aircraft, ground-to-ground, etc. Particle beams may very well utilize a laser of this type to blast a channel in the atmosphere for a high energy stream of neutrons or other particles. The device is easily applicable to burning and etching wood, cutting, plastics, textiles etc £12/set Ref F/LC7.

DYNAMO FLASHLIGHT interesting concept, no batteries needed just squeeze the trigger for instant light apparently even works under water in an emergency although we haven't tried it yet! £6.99 ref SC152

ULTRASONIC BLASTER PLANS Laboratory source of sonic shock waves. Blow holes in metal, produce 'cold' steam, atomize liquides. Many cleaning uses for PC boards, jewllery, coins, small parts etc. £6/set Ref F/ULB1.

ANTI DOG FORCE FIELD PLANS Highly effective circuit produces time variable pulses of accoustical energy that dogs cannot tolerate £6/set Ref F/DOG2

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PHASOR BLAST WAVE PISTOL SERIES PLANS Handheld, has large transducer and battery capacity with external controls. £6/set Ref F/PSP4

INFINITY TRANSMITTER PLANS Telephone line grabber/room monitor. The ultimate in home/office security and safety! simple to use! Call your home or office phone, push a secret tone on your telephone to access either: A) On premises sound and voices or B) Existing conversation with break-in capability for emergency messages. £7 Ref F/TELEGRAB

BUG DETECTOR PLANS is that someone getting the goods on you? Easy to construct device locates any hidden source of radio energy! Sniffs out and finds bugs and other sources of bothersome interference. Detects low, high and UHF frequencies. £5/set Ref F/BD1.

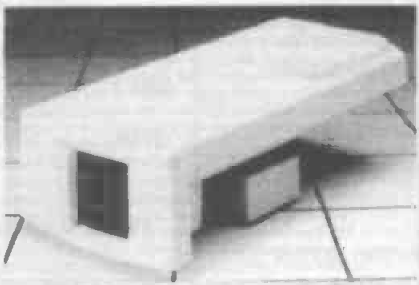
ELECTROMAGNETIC GUN PLANS Projects a metal object a considerable distance-requires adult supervision £5 ref F/EML2

ELECTRIC MAN PLANS, SHOCK PEOPLE WITH THE TOUCH OF YOUR HAND! £5/set Ref F/EMA1.

SOLAR POWERED WIND UP RADIOS BACK IN! These FM/AM radio's have a solar panel and a hand operated charger! £17.95 ref SOLRAD

PARABOLIC DISH MICROPHONE PLANS Listen to distant sounds and voices, open windows, sound sources in 'hard to get' or hostile premises. Uses satellite technology to gather distant sounds and focus them to our ultra sensitive electronics. Plans also show an optional wireless link system. £8/set ref F/PM5

2 FOR 1 MULTIFUNCTIONAL HIGH FREQUENCY AND HIGH DC VOLTAGE, SOLID STATE TESLA COIL AND VARIABLE 100,000 VDC OUTPUT GENERATOR PLANS Operates on 9-12vdc, many possible experiments. £10 Ref F/HVM7/ TCL4



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CIRCUIT PACKS Packs of 35 circuit diagrams covering lasers, SW radios, geigers, bugs, char etc. Pack1, Pack2, Pack3 £4.99 each.

SMOKE ALARMS Mains powered, made by the famous Gent company, easy fit next to light fittings, power point. £4.99 ref SMKX

CONVERT YOUR TV INTO A VGA MONITOR FOR £25! Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware. Ideal for laptops or a cheap upgrade. Supplied in kit form for home assembly. SALE PRICE £25 REF SA34

***15 WATT FM TRANSMITTER** Already assembled but some RF knowledge will be useful for setting up. Preamp req'd, 4 stage 80-108mhz, 12-18vdc, can use ground plane, yagi or dipole £69 ref 1021

***4 WATT FM TRANSMITTER KIT** Small but powerful FM transmitter kit, 3 RF stages, mic & audio preamp included £24 ref 1028

YUASHA SEALED LEAD ACID BATTERIES 12v 15AH at £18 ref LOT8 and below spec 6v 10AH at £5 a pair

ELECTRIC CAR WINDOW DE-ICERS Complete with cable, plug etc SALE PRICE JUST £4.99 REF SA28

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt. £12.99 REF AUG10P3

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SOLAR NICAD CHARGERS 4 x AA size £9.99 ref 6P476, 2 x C size £9.99 ref 6P477

GIANT HOT AIR BALLOON KIT Build a 4.5m circumference, fully functioning balloon, can be launched with home made burner etc. Reusable (until you loose it!) £12.50 ref HA1

AIR RIFLES .22 As used by the Chinese army for training puposes, so there is a lot about! £39.95 Ref EF78. 500 pellets £4.50 ref EF80

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12V OPERATED SMOKE BOMBS Type 3 is a 12v trigger and 3 smoke cannisters, each cannister will fill a room in a very short space of time! £14.99 ref SB3. Type 2 is 20 smaller cannisters (suitable for simulated equipment fires etc) and 1 trigger module for £29 ref SB2. Type 1 is a 12v trigger and 20 large cannisters £49 ref SB1

HI POWER ZENON VARIABLE STROBES Useful 12v PCB fitted with hi power strobe tube and control electronics and speed control potentiometer. Perfect for interesting projects etc 70x55mm 12vdc operation. £6 ea ref FLS1, pack of 10 £49 ref FLS2

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NEW LASER POINTERS 4.5mw, 75 metre range, hand held unit runs on two AA batteries (supplied) 670nm. £29 ref DEC49

HOW TO PRODUCE 35 BOTTLES OF WHISKY FROM A SACK OF POTATOES Comprehensive 270 page book covers all aspects of spirit production from everyday materials. Includes construction details of simple stills etc. £12 ref MS3

NEW HIGH POWER MINI BUG With a range of up to 800 metres and a 3 days use from a PP3 this is our top selling bug! less than 1" square and a 10m voice pickup range. £28 Ref LOT102

BUILD YOU OWN WINDFARM FROM SCRAP New publication gives step by step guide to building wind generators and propellors. Armed with this publication and a good local scrap yard could make you self sufficient in electricity! £12 ref LOT81

NEW LOW COST VEHICLE TRACKING TRANSMITTER KIT £29 range 1.5-5 miles, 5,000 hours on AA batteries, transmits info on car direction, left and right turns, start and stop information. Works with any good FM radio. £29 ref LOT101a

CCTV CAMERA MODULES 46X70X29mm, 30 grams, 12v 100mA, auto electronic shutter, 3.6mm F2 lens, CCIR, 512x492 pixels, video output is 1v p-p (75 ohm). Works directly into a scart or video input on a tv or video. IR sensitive. £79.95 ref EF137.

IR LAMP KIT Suitable for the above camera, enables the camera to be used in total darkness! £6 ref EF138

UK SCANNING DIRECTORY As supplied to Police, MOD, M15 and GCHQ! coverers everything from secret government frequencies, eye in the sky, prisons, military aviation etc £18.50 ref SCANB

INFRA RED POWERBEAM Handheld battery powered lamp, 4 inch reflector, gives out powerful pure infrared light! perfect for CCTV use, nightsights etc. £29 ref PB1.

SUPER WIDEBAND RADAR DETECTOR Detects both radar and laser, X K and KA bands, speed cameras, and all known speed detection systems. 360 degree coverage, front &rearwaveguides. 1.1"x2.7"x4.5" fits on sun visor or dash £149 ref

CHIEFTAN TANK DOUBLE LASERS 9 WATT+3 WATT+LASER OPTICS

Could be adapted for laser listener, long range communications etc. Double beam units designed to fit in the gun barrel of a tank, each unit has two semi conductor lasers and motor drive units for alignment. 7 mile range, no circuit diagrams due to MOD, new price £50,000? us? £199. Each unit has two gallium Arsenide injection lasers, 1 x 9 watt, 1 x 3 watt, 900nm wavelength, 28vdc, 600hz pulse frequency. The units also contain an electronic receiver to detect reflected signals from targets. £199 for one. Ref LOT4.

NEW LOW PRICED COMPUTER/WORKSHOP/HI-FI RCB UNITS Complete protection from faulty equipment for everybody! Inline unit fits in standard IEC lead (extends it by 750mm), fitted in less than 10 seconds, reset/test button, 10A rating. £6.99 each ref LOT5. Or a pack of 10 at £49.90 ref LOT6. If you want a box of 100 you can have one for £250!

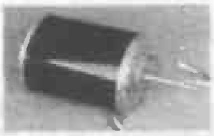
DIGITAL PROPORTIONAL B GRADE RADIO CONTROLLED CARS From World famous manufacturer these are returns so they will need attention (usually physical damage) cheap way of buying TX and RX plus servos etc for new projects etc. £20 each sold as seen ref LOT2DP.

MAGNETIC CREDIT CARD READERS AND ENCODING MANUAL £9.95 Cased with flyleads, designed to read standard credit cards! complete with control electronics PCB and manual covering everything you could want to know about whats hidden in that magnetic strip on your card! just £9.95 ref BAR31

WANT TO MAKE SOME MONEY? STUCK FOR AN IDEA? We have collated 140 business manuals that give you information on setting up different businesses, you peruse these at your leisure using the text editor on your PC. Also included is the certificate enabling you to reproduce (and sell) the manuals as much as you like! £14 ref EP74

HIGH POWER DC MOTORS, PERMANENT MAGNET

12 - 24v operation, probably about 1/4 horse power, body measures 100m x 75mm with a 60mm x 5mm output shaft with a machined flat on it. Fixing is simple using the two threaded bolts protruding from the front



£22ea REF mot4

on and off with respect to time. The information is in the timing, and there are often millions of zeros and ones to read and sort out.

The position of a motor shaft must be measured precisely to be controlled accurately. These measurements can be taken with measuring devices that divide the position of the motor into thousands of counts per revolution. Optical encoders can divide a circle into over 1000 divisions. Combining this with appropriate gearing to the robot arm achieves the necessary accuracy.

Optical encoders come as incremental and absolute encoders.

Incremental encoders

Incremental encoders **(figures 2 and 3)** provide two signals 90 degrees out of phase. Each signal is assumed to switch on and off for equal periods of time during each cycle, as shown below. The convention states that one complete on/off signal cycle represents a 360-degree rotation.

When a motor moves in one direction, one signal leads; when it moves in the other direction, the other signal leads. This tells the computer which way the motor is turning, and allows it to determine the progress and position of the motor even after many revolutions. Speed is determined by taking two encoder counts a known time apart, and dividing the positional difference by the elapsed time.

Absolute encoders

Absolute encoders give the position of the axis they are connected to within a single revolution; therefore, they are usually fixed not to the motor but to a robot arm joint. Whereas incremental encoders must have a known starting point to count from, absolute encoders can provide the arm position at all times without reference to a known start-point **(see figures 4 and 5)**. Each ring on the encoder is divided into alternate dark and light segments to give a binary signal. Each ring has twice as many segments as the previous ring, providing finer and finer positional information moving away from the centre. The rings must be read simultaneously. Eight rings provide a resolution of 1.41 degrees, or 1 part in 256 in a circle. Sixteen rings provide a resolution of one part in 65,536 (256 x 256), or 0.0055 degrees.

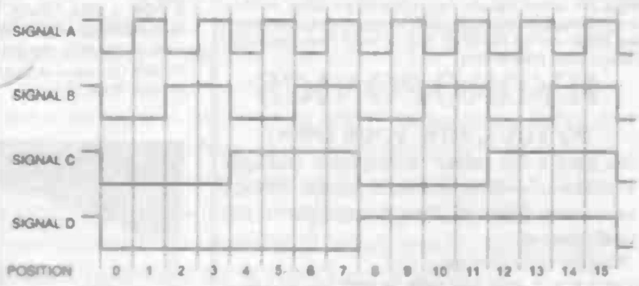


Figure 5: signals from an absolute encoder.

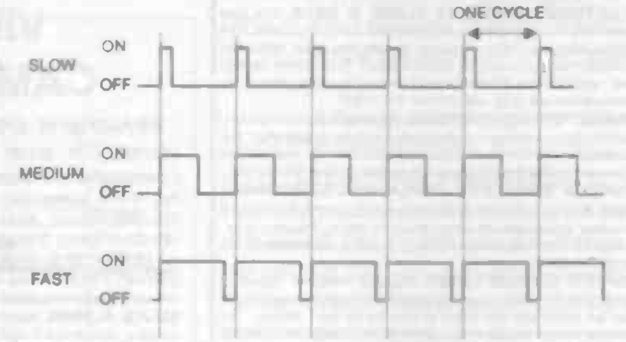


Figure 6: PWM signals. Energy fed to a DC moto

Motors

Now that we have an understanding of how positional information can be obtained with the desired accuracy, we need to understand how a motor is positioned to exactly the position we are interested in.

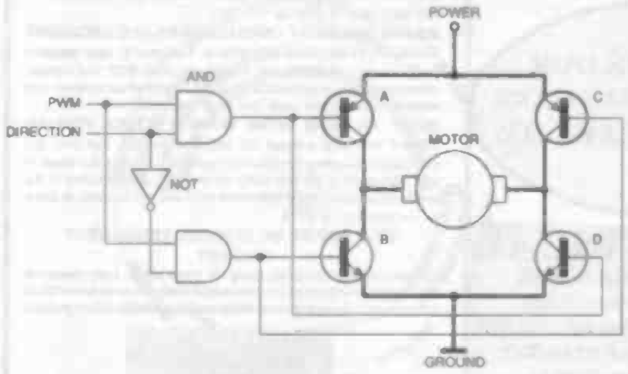


Figure 7: a basic "H" Bridge amplifier. In this A, B, C and D are large transistors that act as switches. Either A and D or B and C can be turned on at one time. Power wiring is shown as heavy lines.

With regard to the motor, there are two things you need to know over a period of time: how fast is it running and how long has it been running. With this information we can determine what the motor has done and what it is currently doing. Add to this the very accurate clock in the computer, and we can do the following:

Start a motor when we want; accelerate it at a desired rate; reach any velocity reasonable for the application; maintain the velocity under varying loads; slow the motor down as we want; slow down the motor at a desired rate; stop the motor at the exact point that we want; base the stopping point on time or on revolutions turned; base the control on internal or external events; change the control algorithm at will and as often as we want.

The speed of a DC motor can be controlled by changing the amount of energy supplied to it. Changing the load on a DC motor also changes its speed. The motor is stabilised by monitoring it and modifying the energy supplied to maintain the desired speed. In a robot with an ever-changing load on the motor, these energy corrections must be made hundreds of times a second.

There are two basic ways of controlling motor speed electrically: to control the voltage to the motor by an analogue method, or to turn a fixed voltage rapidly on and off. In a digital system it is easier to turn the signal on and off to vary the amount of energy sent. This technique is called Pulse Width

PINHOLE CAMERA MODULE WITH AUDIO! Superb board camera with on board sound! extra small just 28mm square (including microphone) ideal for covert surveillance. Can be hidden inside anything, even a matchbox! Complete with 15 metre cable, psu and tv/vcr connnectors. £73.95 ref CC6

BBC SELECTORS WITH SMART CARD SLOT AND VIDEO CRYPT interesting new item in this week is this Selector, Originally made for the BBC to send encrypted video films to your VCR at night time. The project seems to have failed. Very complex units consisting of a smart card slot in the front plus several switches and an IR receiver. Fully cased and measuring 230 x 430 x 90mm, new and boxed. On the back of the unit is a scart socket plus a UHF input and output. A channel tuning control numbered 28 to 40 and an IR socket. Inside is a comprehensive tuner section, smart card reader mechanism and control electronics plus a power supply section. These units are sold as strippers but we imagine you could use one to convert a monitor into a TV or maybe use the videocrypt side of things for something else. Supplied complete with manual and mains lead. Clearance price just £9.95 ref BBC1X

INLINE RCB UNITS This in line miniature earth leakage unit instantly shut off the mains supply in the event of any current flowing between live and earth thus preventing a potentially lethal shock. IEC plug one end, socket the other, fitted in seconds, reset button. The ultimate safety aid when working on electronic equipment, computers etc. As these units are fitted with an in-line IEC plug on one end and socket on the other than could even be used to extend standard IEC computer leads Pack of 3 £9.95 ref LOT5A

THE ULTIMATE ENCLOSURE for your projects must be one of these!Well made ABS screw together beige case measuring 120 x 150 x 50mm. Already fitted with rubber feet and front mounted LED. Inside is a pcb fitted with other bits and pieces you may find useful. Sold either as a pack of five for £10 ref MO1,pack of 20 for £19.95 ref MO2

17 WATT 12V SOLAR PANEL A solar panel designed to give a nominal 12v. The solar cells are laminated within a high quality resin materiall which offers excellent protection against UV and moisture. Mounted on tempered glass in an aluminium frame. The panel is ideal for charging sealed lead acid batteries and a protection diode in the circuit prevents reversed current flow. Mounting is by four adjustable hooks and connection is by screw terminals. Max power 17 watts, 35 cells, 17vdc peak, 433x402x15mm, 1000mA max, 1.9kg. Solar panel £115 ref SOL4

SOLAR POWERED AM/FM RADIO A compact, AM/FM mono radio complete with earphone and a solar panel that recharges the built-in battery when placed in direct sunlight or under a strong lamp It features a rotary Volume/On/Off control (which must be set to 'Off' for recharging), AM/FM selector switch, rotary tuning control, metal belt clip and socket for external 3V DC supply. Solar Radio £7.95 ref SR23

MOTOR CYCLISTS RADAR DETECTOR Now in is the Whistler 1580 Laser/Radar detector complete with a speaker for motorcycle helmets. Super wid band covering X,K and Ka plus lasers at 950nm+/-10nm. 360 deg total perimeter protection, detects laser, radar and VG-2 wherever they come from. £150.95 ref RD4

MAGIC EAR Unlike previous 'sound-magnifiers' we have offered, Magic Ear fits unobtrusively behind the ear itself. Magic Ear's micro technology is very advanced, its built-in microphone is extremely sensitive and there's also a volume control to help you adjust to all conditions in use. Magic Ear is startlingly effective. It'll help you to follow every word of conversation even at a distance, and enjoy theatre, cinema or live music with stunning new sound. Comes fitted with 3 long life batteries, a free travel pouch, plus a choice of 3 different ear pieces designed to fit all shapes of ear. Magic ear £16.99 ref MAGE3

RADIO METER Perhaps the best of the scientific knick-knacks of the past and well overdue for revival! Fascinating, soothing and educational. In the vacuum inside the inverted bulb like container the vanes revolve, driven round by light particles alone! (each vane is black on one side white on the other) Radiometer £9.99 ref SC120B

SATELLITE NAVIGATION £119 The GARMIN~ GPS 38~ is the one navigational tool for the great outdoors that offers big features in a small, lightweight package - all at a truly affordable price. Mark your favorite fishing spot, tree stand or camp site. Or retrace your steps back to the safety of your starting point using our all - new TracBack feature. The GPS 38 shows you exactly where you are, where you've been and where you're going. The GPS 38 features easy, one-thumb operation and weighs only 255g. There's a resettable trip odometer, graphic compass' and highway steering guidance. And it provides up to 20 hours of use on a set of 4 AA batteries. The GARMIN GPS 38. The affordable way to bring you back. £119 ref GPS1

DIFFERENTIAL THERMOSTAT KIT An electronic self assembly kit designed for use in solar heating systems, heat recovery systems etc. The principle of the kit is that it has two thermistors that are placed on the items to be measured (typically a solar panel and a water storage tank) the controller then operates a relay all the time one temperature is higher than the other. The temperature difference is adjustable. A typical use would be to operate a pump all the time a solar panel was at a higher temperature than the water storage tank. Differential thermostat kit £29 ref LOT93

10 WATT SOLAR PANEL Amorphous silicon panel fitted in a anodized aluminium frame. Panel measures 3' by 1' with screw terminals for easy connection. One of these panels will run our solar water pump in full sunlight although we would recommend that for optimum performance two panels would be preferable. 3' x 1' solar panel £55 ref MAG45

12V SOLAR POWERED WATER PUMP Perfect for many 12v DC uses, ranging from solar fountains to hydroponics! Small and compact yet powerful. Will work direct from our 10 watt solar panel in bright sunlight. Max head 17 ft Max flow rate : 8 1pm Current :1 .5A (Ref AC8) £18.99

BOOST CELL PHONE RECEPTION ON THE MOVE! Compared to high-powered carphones, hand-portable mobile phones don't always work too well in moving vehicles. Sometimes the signal 'drops out' during a call, other times there's too much interference to get through at all. However, the affordable Cell Patch provides a major improvement, dramatically boosting signal reception without wires or batteries. The 9.5 x 9.5cm (3.3" X 3.3") microthin antenna adheres to your car window sunvisor, ideally within 61-122cm (2-4') of the handset, or can be carried in a pocket. Works with all types of portable cellular phone. Cell Patch £11.99 ref CEL1

CAT SCARER produces a blanket of high sonic and low ultrasonic sound, which is inaudible to humans, birds and fish - so it is ideal where you want to protect your bird table or fish pond against feline predators. It will deter cats from your garden and other protected areas. It will also deter foxes. mains operated, 10 m of cable. Running cost will be approximately 1 p per day. Garden watcher £42.45 ref GW2

VIDEO PROCESSOR UNITS ?/6v 10AH BATTS/24V 8A TX Not too sure what the function of these units is but they certainly make good strippers! Measures 390X320X120mm, on the front are controls for scan speed, scan delay, scan mode, loads of connections on the rear, inside 2 x 6v 10AH sealed lead acid batts, pcb's and a 8A? 24v torroidal transformer (mains in). sold as seen, may have one or two broken knobs etc due to poor storage. £9.95 ref VP2X

SOLAR MOTORS Another new line for us are these tiny motors which run quite happily on voltages from3-12vdc. We have tried one on our 6v amorphous 6" panels and you can run them from the sun! 32mm dia 20mm thick. £1.50 each

TELEPHONES Just in this week is a huge delivery of telephones, all brand new and boxed. Two piece construction with the following features- illuminated keypad, nice clear easy to use keypad, tone or pulse (switchable), recall, redial and pause, high/low and off ringer switch and quality construction. Each telephone is finished in a smart off white colour and is supplied with a standard international lead (same as US or modem card sockets) if you wish to have a BT lead supplied to convert the phones these are also available at £1.55 each ref BTLX. Phones £4.99 each ref PH2

INFRARED CAR PHONE KIT £7.99 interesting box of goodies! this kit was designed to convert car phones to enable hands free dialling, the kit contains the following items 1) A keypad designed to mount in the centre of the steering wheel, it requires a 9v PP3 battery and transmits the numbers using three on board high power infra red LEDs. 140 x 120mm. 2) An infra red receiver module containing a IR photo diode, IR filter and control electronics 60 x 30 x 15mm (cased). 3) Control box (nice case) 100 x 170 x 35mm which we understand is the interface between the infra red and the car phone, it is also supposed to adjust the volume of your car stereo at the same time! made for Phillips car phones (but we don't know the model)Complete kit is £7.99 ref CP1

Hi power 12v xenon strobe variable rate flasher modules and tubes £6Useful 12v PCB fitted with control electronics and a powerful Xenon tube! just apply 12v DC to the input and the tube will flash. On the board is a small potentiometer which can be used to vary the flash rate! PCB measures just 70x 55mm and could be incorporated into many interesting projects! £6 ref FLS1 Pack of 10 is £49 ref FLS2

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TALKING WATCH Yes, it actually tells you the time at the push of a button. Also features a voice alarm that wakes you up and tells you what the time is! Lithium cell included. £8.99 ref EP26A

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GIANT INSULATORS Just in this week are some giant ceramic insulators, each one measures 130mm high and about 170mm diameter. Finished in a high gloss brown and black glaze. In the base of each insulator is a threaded hole approx 1" diameter, rather like a mop/broom head thread. If you are into shortwave radio, crystal sets or high voltage experiments then these are for you. (We've got one as a door stop) Not too sure what their original purpose was, all we know is they were made for export about 25 years ago, never exported and been in store since then. Price is £8 each ref INSX

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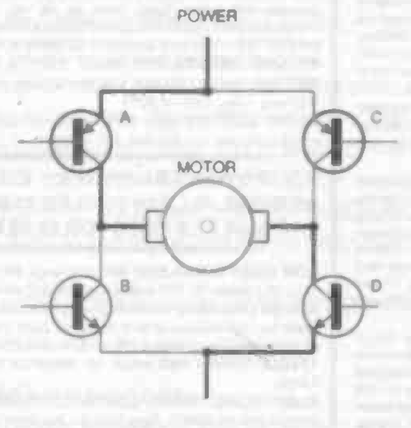


Figure 8: motor turning in one direction

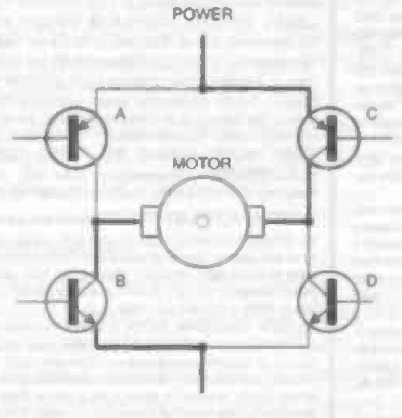


Figure 9: motor turning in the opposite direction

Modulation (PWM). The length of the energy pulse is modified in each cycle (see figure 6). If the signal is on all the time, the pulse width is long, and the motor runs at a high speed. If it is on half the time, the pulse width is 50 percent and the motor runs at about half speed. If it is on none of the time, the pulse width is zero and the motor remains off.

The motor must be switched very rapidly for smooth operation. About 200 times a second (Hz) is enough for most motors, because the mass of the motor and its attached components averages out the speed. However, these are frequencies that human beings find very annoying when something loose in the motor windings starts to vibrate. An on-off frequency above 20,000 Hz is usually chosen. 40,000 Hz takes it above the hearing range of most domestic animals as well.

The PWM amplifier

The basic PWM motor amplifier is an H bridge **(see figure 7)**. In this bridge, if transistors A and D are turned on, current flows in one direction in the motor windings, and the motor runs in one direction. If A and D are turned off and transistors B and C are turned on, the current flows in the other direction and the motor runs the other way **(figures 8 and 9)**. If transistors A and C or B and D come on together, there is a direct short circuit from power to ground, destroying the amplifier. It is crucial that one set of transistors is shut completely before the other set comes on. Because the switching of the transistors is very rapid but not instantaneous, overlap is a risk. Logic circuits in the amplifier should ensure that this does not happen.

A servo-motor must respond to commands within certain parameters to be useful in a robotic application. A motor would not be performing its job if any of the following happened:

It does not turn on immediately when power is applied; it does not stop immediately when power is removed; it does not move as fast as it needs to; it moves faster than told to; its operation is not repeatable.

Motor control schemes should ensure that none of this occurs. Otherwise, the system should detect it and warn the operator. Usually, when the error between what the motor is supposed to do and what it does exceeds a certain number of encoder counts, the condition is flagged as a performance error. Nevertheless, there are always delays between an event, the taking of readings, their interpretation, and initiating corrective action.

Speed control

The control of motor speed by the percentage of time the motor is switched on **(figure 10)** is done with software. As the motor turns, the encoder counts go to a counter that the computer reads whenever it needs to. The computer uses that information, and the time from its internal clock, to change the pulse width to the amplifier to maintain the speed and position of the motor.

What follows here is an English-language-like program to maintain a motor speed with the integrative function only:

```
Label 1
Read the position counter
Compare it with the last reading
Calculate the motor speed
 If it is faster then desired, lower the current
 If it is slower than desired, increase the current
Take care of other functions
 Go to Label 1
```

The computer code will look less like English, but will fulfil the same function.

The control loop consists of a series of expressions representing the proportional, integrative and derivative components of the energy needed by the motor. This is a PID

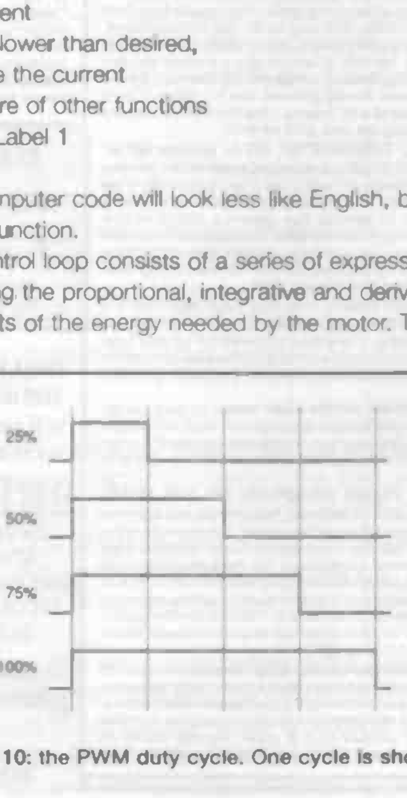


Figure 10: the PWM duty cycle. One cycle is shown.

equation, and we often refer to this form of control as PID control. It is important to know that having three components allows better control of a motor.

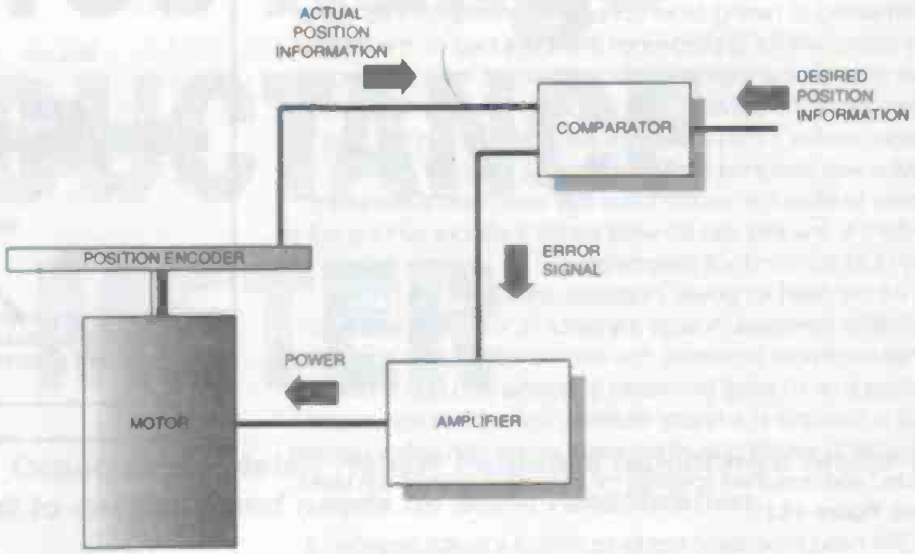


Figure 11: motor feedback scheme schematic

The motors used to control robots are called servo-motors **(see figures 11 and 12)**. "Servo" (derived from Latin *servus*, a slave) expresses the idea that the motor takes orders from a changing signal, here called an error signal. In effect, the motor responds to an error signal by trying to make the signal disappear. Whatever the motor is connected to affects the magnitude of the error signal, and the motor is made to work or move in the direction that will reduce the error signal. An external (to the motor-load) device is also able to manipulate the error signal. Since the motor is designed to follow the signal, we can make the motor do useful work by programming the error signal.

We can now tell the motor exactly when to start, how fast to speed up, how fast to run, how long to run, how to slow down and exactly when and where to stop. We can tell the motor to repeat the cycle as often as we like, we can cycle it just once, and we can modify the cycle at will while the cycle is in progress. This allows us to make the operation of the motor dependent on any condition within the controlling computer or on any signal that can be read by the computer.

In current technology, electric motors are put into motion by creating opposing and attracting magnetic fields. The magnetic fields are manipulated sequentially to rotate a shaft attached to the rotating armature. Since at least one of the magnetic fields is created by passing an electric current through a winding, and we can control electricity, we can control the motor by controlling the electricity through its windings.

The following motor designs are suitable for robots:

Rotating Servo-motors: these are usually DC motors with a position encoder attached to the motor shaft, usually an incremental optical encoder, to provide a feedback signal giving the position and speed of the motor.

Linear servo-motors: these use the same technology as rotating motors, except that their armatures and fields are arranged in a straight line rather than a circle. Imagine cutting a regular motor along a radial plane, opening it up and laying it flat on the table. (Don't try this at home!) The field, the armature and the commutator are in straight lines, and the motor armature moves across the field in a straight line. (Appropriate physical constraints and guides are added.)

Stepper motors: these move through a small segment of a circle each time the current to the motor is changed. There are several independent windings in the motor, and usually a sequence of four electrical changes. The motor moves a step during each change. There are also half steps and micro steps, created electronically. Stepper motors usually move between 0.9 and 15 degrees per step, and they do not normally need feedback encoders, as we can count the motor's steps as we send them. However, if the motor is overloaded, it can slip, and the count will be compromised. Stepper motors usually have low speed and low torque characteristics. Their main use is in office machinery and other low power applications.

For the motor movement to be predictable, it is made to follow a trapezoidal profile (figure 13): the motor accelerates at a fixed rate until it reaches its operational velocity. It then decelerates at a fixed rated until it stops. The computer calculates the energy needed by the motor to do its work in the time required. Motors operating in synchronisation with another motor must accelerate and decelerate for the same length of time as the lead motor to keep their encoder counts in synch.

For very short moves, there is no constant speed operation. The motor accelerates, decelerates and stops, never getting up to the running speed. This move profile is called a triangular (three-point) move.

It is very hard to run a motor at a very slow speed. Imagine trying to run a motor at one revolution per day (gears not allowed). If we wanted to adjust the speed every second we would need 24 x 60 x 60 = 86,400 encoder counts per revolution to get one count per second, and we probably need 1000 thousand times that for smooth motion. Let's assume an encoder that gives the minimal 86,400,000 counts: if we also wanted to run this motor at 3000 revolutions per minute at its top speed, we will need encoder counts for 3000/60 x 86,400,000, or 4,320,000,000 counts per second. Though not impossible, this causes problems. Minimum speed, maximum speed and encoder counts are interrelated.

For a motor in a servo application, we want to define a top speed that will use less than the maximum energy the motor can accept. For example, if we want to run a device at 100 rpm and we have geared the motor to the device with a 20:1 ratio, the full speed of the motor will need to be 2000 rpm to achieve the speed we want. It is desirable that this full speed be attained when the motor is being given as little as 25 percent of the energy that it can readily accept (without overheating or having other operational problems). The rest of the energy will be applied when there is a load on the device. This gives us the reserve power we need to meet the load demands of the application. A 25 percent duty cycle is not a magic number - the percentage would depend on the load the device was designed for. There must be plenty of reserve power to allow the system to be fully compliant: a compliant system is one that can do what we tell it without running out of any of its performance parameters.

As the need for power increases, the size of the driving transistor increases. A large transistor is, very roughly, a lot of small transistors in parallel. You can control a larger current by putting 8 or 10 small transistors in parallel with one another. This is tolerable in a hobby situation, but not in a commercial application, where special transistor arrays with safety features added and designed specially for controlling motors are used. **(See figure 14.)**

We need three basic inputs to control a motor amplifier: a signal to enable the motor amplifier; a signal to select direction of motion (forward or backward); and a signal to determine the percentage of full power applied (the pulse width).

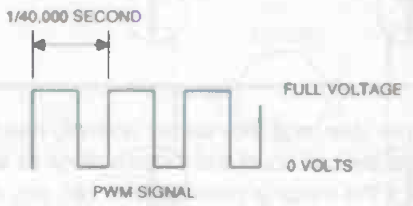


Figure 14: power applied to motor

A signal to enable the motor amplifier is important to ensure that the amplifier will remain turned off till the computer has come up to a stable condition and is ready to control the motor. This is specially important with a robot motor, because the motor must not move until we are absolutely ready for it, or damage may be done. This is achieved with fail-safe electronics and tying other signals to ground potential until they are ready to be released.

Model aircraft servo motors

Radio-controlled model aircraft use tiny servo motors, positioned by converting the length of pulse fed to them into the position of the servo's output shaft. These servo motors consist of motor, a gearbox, a potentiometer and a small integrated circuit. The ic converts the length of the incoming pulse to a desired output shaft position (represented by a shaft-mounted potentiometer). If the position of the pot does not match the desired shaft position, the motor is turned forwards or backwards till the pot reaches the desired position. The current to the motor is then turned off. The situation is monitored constantly, so that correction is taking place all the time. **(See figure 15.)**

The positioning accuracy depends on the accuracy of both the pot and the pulse length. A resolution of about half a degree can be achieved with most model aircraft servos.

These servo motors run on three wires: the power line, the pulse signal line and a common ground. As model aircraft servos operate by converting a known pulse width to a motor output shaft position, they are relatively easy to use if a source of short pulses can be created. This is quite easy with the small single chip microcomputers now on the market. These inexpensive units are suitable for robotic experimentation.

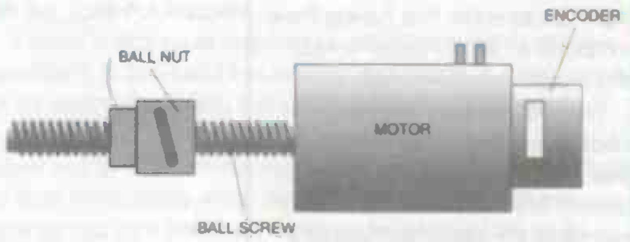


Figure 12: components of a typical servo motor installation. Gearboxes are usually avoided to eliminate backlash problems.

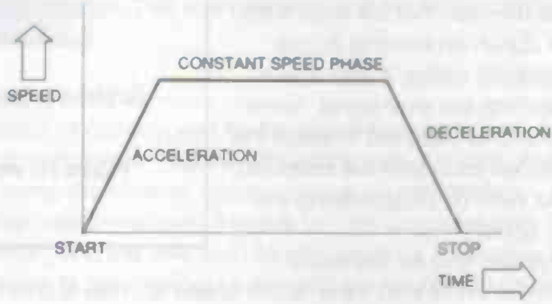


Figure 13: a trapezoidal motor move

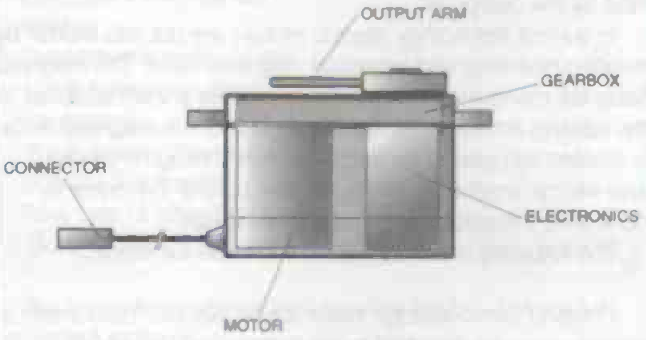


Figure 15: model R/C servo-motor

(My book "Introduction to Robotics" from Nexus gives detailed plans and instructions on how to build and program a walking robot with such motors.)

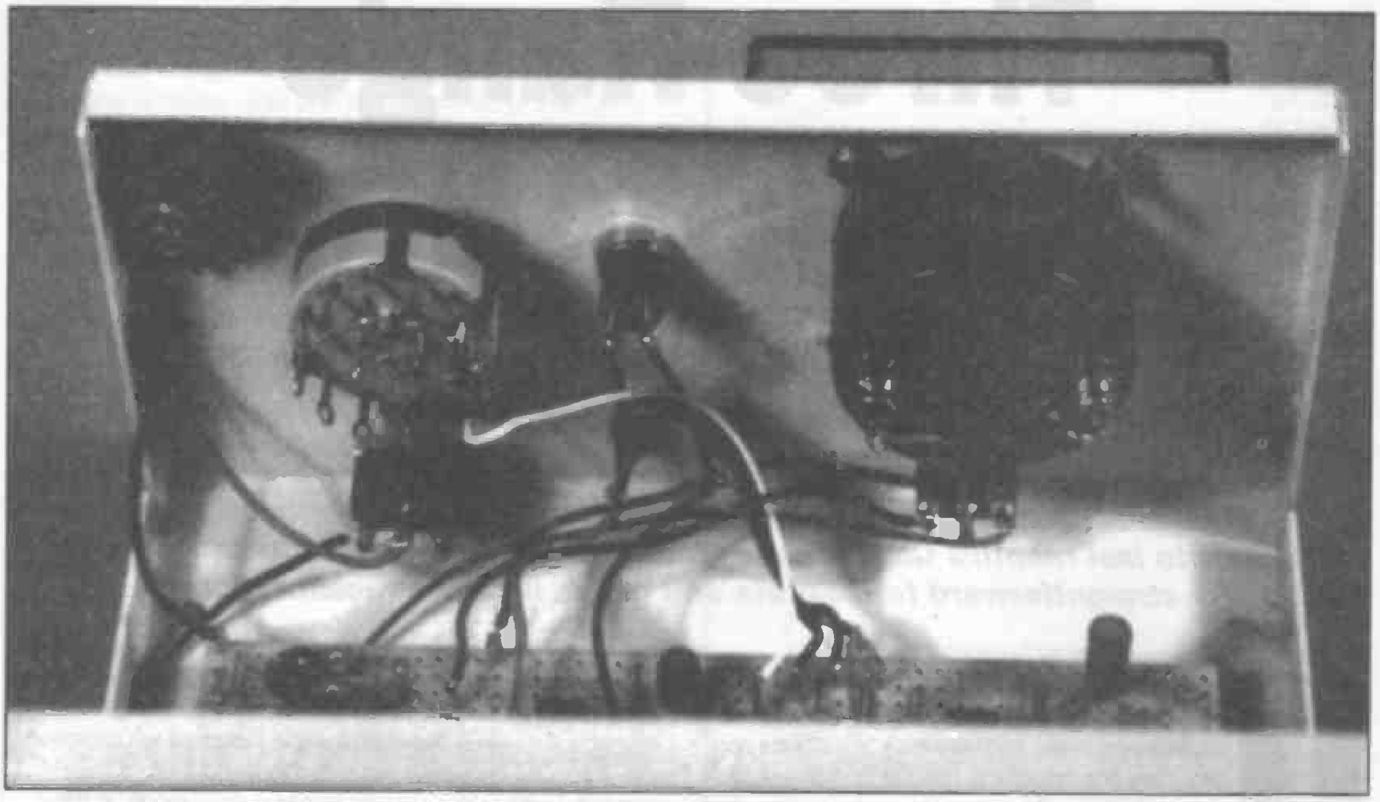
Cover: The Mitsubishi RV-E2M Movemaster, a small sophisticated table-top robot with a positioning "teach" pendant and controller. (Courtesy: Rixan, US Mitsubishi distributor.)

Three-Range INDUCTANCE METER

A partner to last month's Capacitance Meter, Robert Penfold's Inductance Meter is straightforward to calibrate and needs no scale recalibration.

This inductance meter is a companion project to the capacitance meter published last month. Like the capacitance meter, it is very easy to calibrate and use. Only one inductor is needed to calibrate the unit, and no recalibration of the meter's scale plate is needed, because the unit has linear scaling. The three ranges have full-scale values of 1mH, 10mH, and 100mH, which enables a wide range of inductors to be checked. This includes high value components for use in audio filters, medium value inductors as used in switch mode power supplies, and many of the small chokes used in radio frequency circuits. The unit cannot be used to measure accurately very low value chokes of less than about 22uH in value, but these are little used in practice. They are difficult to measure accurately because the inductance in the leadout wires and test leads is quite significant in relation to the value of the components under test. In fact, the inductance of a very small choke can be considerably less than the inductance of its leadout wires!

It is only fair to point out that there is a slight problem when trying to test inductors, which is that their inductance is invariably frequency dependent. Most inductors are designed with a specific frequency range in mind, and tend to have generally lower values outside that frequency range. In this case, the inductance is measured at a frequency of just over 10kHz, which gives good results with medium to high value inductors as they are usually designed for optimum results at low to medium frequencies. Results with radio frequency chokes may seem to lack accuracy because the unit is measuring the inductance at a frequency that is below their designed operating range. The meter is giving accurate results, but at an inappropriate frequency. Readings obtained when measuring high frequency chokes must therefore be treated with a degree of caution. This is a problem that is common to most inductance meters and bridges incidentally, and it is not a shortcoming specific to this particular unit.



System Operation

As can be seen from the block diagram in **figure 1**, the general make-up of the unit is quite similar to that of the companion capacitance meter project. It operates in essentially the same manner, but things have to be swapped around slightly in the amplifier stage at the heart of the circuit. This compensates for the fact that the impedance of an inductor rises with increased value, whereas the impedance of a capacitor reduces with increased value.

The oscillator stage of this circuit is simpler than the equivalent stage of the capacitance meter. As before, the accuracy of the unit depends on the oscillator providing a reasonably pure sinewave signal. In the capacitance meter, the oscillator operated at about 100Hz, and the sinewave signal was generated using a triangular waveform generator plus some lowpass filtering. In this case a much higher frequency of about 10kHz or so has to be used, because the impedance of the test components are impracticably low at lower frequencies. There is potentially some advantage in using a higher test frequency, but the operational amplifiers in the circuit do not perform well at much more than about 10kHz, and this was found to be a good compromise figure. The signal is generated by a Wien oscillator, which has the usual thermistor stabilisation to ensure good results. Although simpler than the filtering method, using a Wien oscillator is more expensive. However, at the higher test frequency of 10kHz a Wien oscillator seems to give more consistent results.

An inverting amplifier receives the sinewave signal, and a negative feedback network governs the closed loop gain of this circuit. This is a two-section network that has one of three switched resistors forming the input arm. These resistors provide the unit with its three measuring ranges. The inductor under test provides the other arm of the negative feedback network. The voltage gain of the circuit is equal to the impedance of the test inductor divided by the resistance of the input resistor. At a fixed test frequency, the impedance of an inductor is proportional to its value. For example, if a 10mH inductor has an impedance of 10k, a 5mH inductor would have an impedance of 5k, and a 1mH inductor would have an impedance of 1k. Suppose the input resistance has a value of 10k, this would equate to voltage gains of 1, 0.5, and 0.1 with test values of 10mH, 5mH, and 1mH. Of more importance, if the output voltage were 1 volt with a 10mH choke, it would respectively be 0.5 volts and 0.1 volts with 5mH and 1mH chokes. In other words, the AC output potential is proportional to the value of the test component.

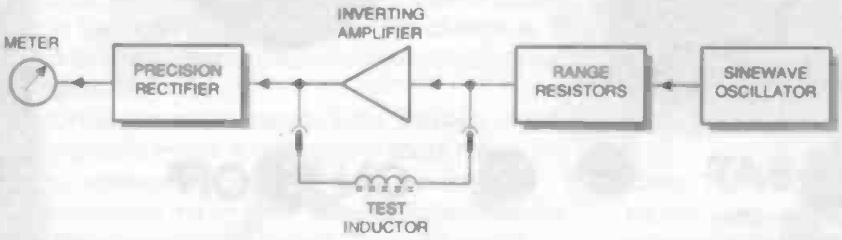


Figure 1: the block diagram of the inductance meter.

The output signal from the amplifier is fed to a precision half-wave rectifier and a moving coil meter. These form a simple but accurate AC voltmeter circuit that has good linearity. The meter responds to the output voltage from the amplifier, but as already explained this voltage is proportional to the value of the test component. With the right voltmeter sensitivity, test frequency, and so on, the meter will read directly in terms of inductance, and the scaling will be linear. This avoids the need for any

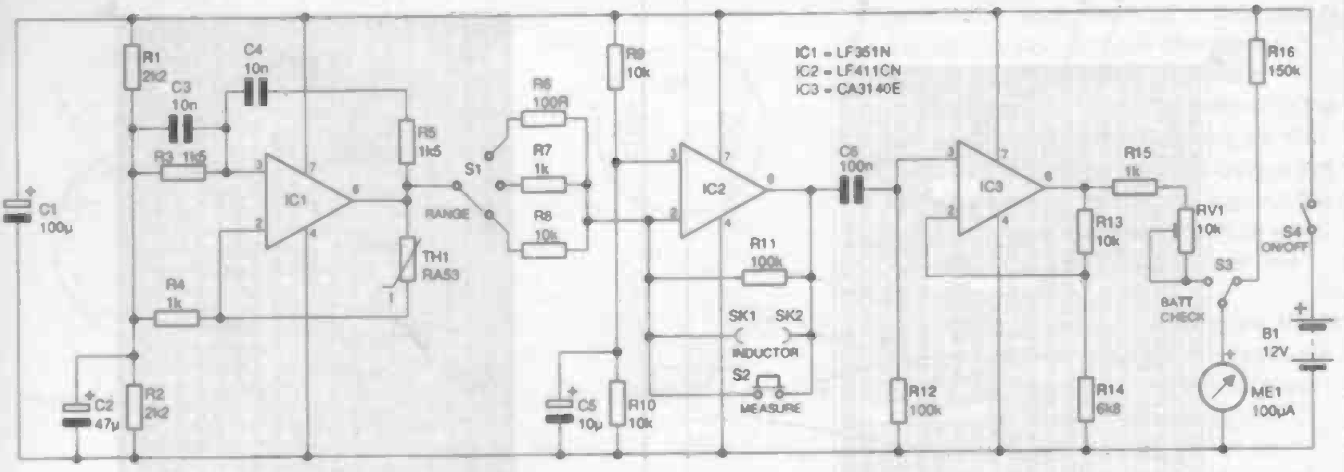


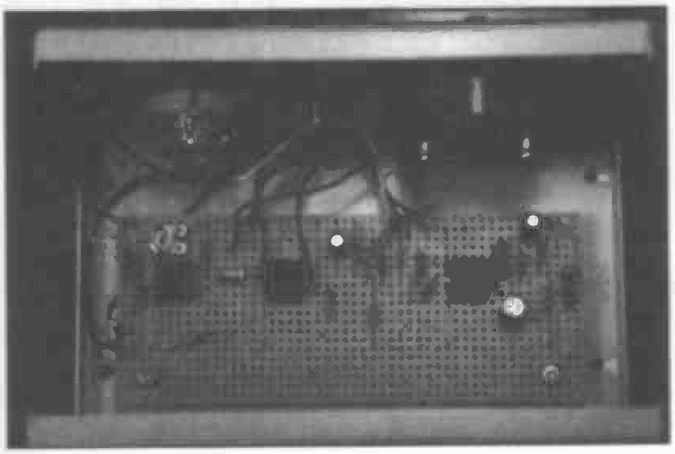
Figure 2: the full circuit diagram of the Inductance meter.

recalibration of the meter's scale plate, and renders the calibration process very easy indeed.

Circuit operation

The full circuit diagram for the inductance meter is in **figure 2**. The Wien oscillator uses IC1 in the conventional arrangement with the positive feedback provided by R3, R5, C3, and C4. These set the operating frequency of the sinewave oscillator at about 10.7kHz. Negative feedback is provided by R4 and TH1, with TH1 stabilising the output level of the oscillator. Precise control of the negative feedback is essential if a low distortion output signal is to be obtained. Slightly too little feedback results in strong oscillation, and the output signal becoming heavily clipped. Fractionally too much feedback causes the oscillator to stall and the output signal to cease.

Thermistor TH1 is the usual negative temperature coefficient type, which means that its resistance falls as its temperature increases. Unusually, it is a self-heating thermistor that is contained in an evacuated glass envelope so that it is, as far as possible, isolated from the ambient temperature. At switch on TH1 has a low temperature and therefore exhibits a high resistance. This gives relatively little negative feedback, high closed loop voltage gain from IC1, and strong oscillation. A strong current flow through TH1 results, causing its temperature to rapidly increase. This produces a reduction in IC1's voltage gain, and the oscillation decays to a low level. Now there is reduced current flow through TH1, its temperature decreases, and the circuit oscillates more strongly. After a certain amount of seesawing, the output level tends to settle down and stabilise due to what is really a simple form of negative feedback action. The negative feedback stabilises the output level very efficiently, counteracting changes in output loading, the supply voltage, and so on. An output level of approximately one-volt RMS is produced at the output of IC1.



IC2 is the operational amplifier that forms the basis of the inverting amplifier stage. R6 to R7 are the three range resistors and S1 is the range switch. R6 to R8 respectively provide the 1mH, 10mH, and 100mH ranges. Using an inductor in the negative feedback of an operational amplifier tends to produce problems with instability, and can easily lead to strong high frequency oscillation. There are no major instability problems with this circuit, but it is necessary to include R11 to damp the test inductor slightly. Otherwise the circuit is apt to break into oscillation on the 100mH range. IC2 operates open loop with no test component in circuit, taking the meter beyond its full-scale reading. While this is unlikely to cause any damage to the meter, it is a possibility can not be completely ruled out. Therefore, S2 is used to place a short circuit across the test sockets until a test component has been connected across SK1 and SK2. S2 is then operated, removing the short circuit so that a reading can be taken.

The precision half wave rectifier is a very simple type that uses IC3 as a non-inverting amplifier. The circuit is basically just a standard DC non-inverting circuit, but IC3 does not have a negative supply rail. Consequently, positive input half cycles appear amplified at the output of IC3 in the normal way, but negative half cycles are not produced because the output of IC3 can not go negative of the 0 volt supply rail. The output signal from IC3 is therefore a slightly amplified and half-wave rectified version of the input signal. This signal is used to drive a simple voltmeter formed by R15, RV1, and ME1. RV1 enables the sensitivity of the voltmeter to be varied, and this enables the unit to be calibrated.

With S3 set to the right hand position ME1 operates as a simple voltmeter which measures the battery voltage. The full-scale sensitivity of this circuit is nominally 15 volts. This provides a simple battery check facility, and the unit will only produce accurate results if the supply potential is more than about 10 volts. The current consumption from the 12-volt

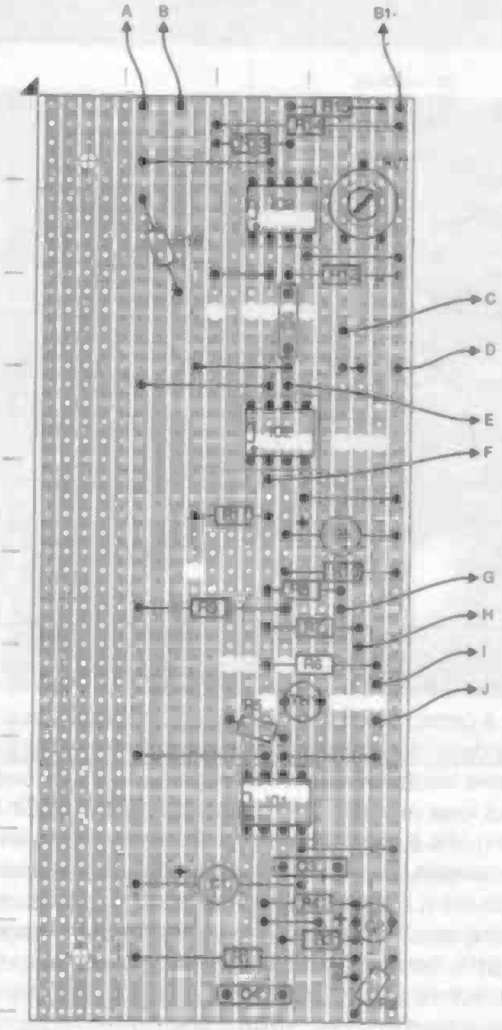


Figure 3: the component layout for the 50-hole x 20-strip stripboard panel.

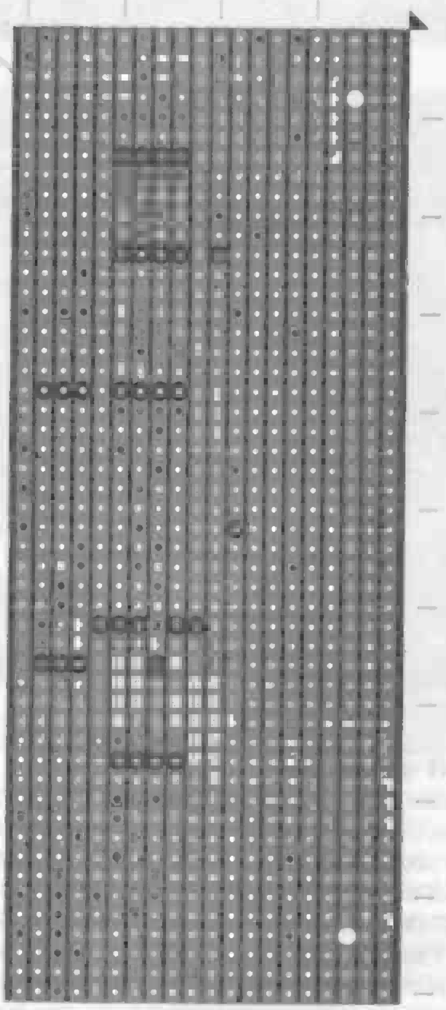


Figure 4: the underside of the component panel.

battery supply is about seven or eight milliamps, which gives an extremely long battery life. Note that a regulated supply is unnecessary because the thermistor stabilisation prevents the output level from IC1 changing significantly with variations in the supply voltage, and the closed loop voltage gains of IC2 and IC3 are also independent of the supply potential.

Constructors of this project should note that the operational amplifiers used in this device were chosen after careful consideration, and are not random choices. The device used for IC1 must be capable of providing a good quality sinewave signal at 10kHz into a fairly low load impedance. The amplifier used in the IC2 position must have high enough performance to give good results, but should not be so lively that instability becomes a major problem. It must also be capable of stable operation with less than unity voltage gain. The device used for IC3 must be a type that is suitable for use in a single supply rail DC amplifier circuits. Using alternative devices for any of the operational amplifiers in this circuit is likely to result in it failing to work properly.

Construction

This circuit is simple enough for stripboard construction, and a suitable layout is provided in **figures 3 and 4**. These respectively show the component and copper side views of the board, which measure 50 holes by 20 copper strips. Construction of the board follows along the normal lines, with a board of the correct size being cut out, the necessary breaks being made in the copper strips, and the two 3.2 millimetre diameter mounting holes being drilled. The components and link-wires are then fitted. The CA3140E used for IC3 is the only static-sensitive component, but I would recommend using holders for all three integrated circuits. Resistors R6, R7 and R8 should have a tolerance of 1 percent so that good accuracy is provided on all three ranges. Thermistor TH1 has a glass encapsulation that makes it relatively fragile, and it should therefore be handled with care. It is probably best to fit this component last of all. The RA53 thermistor is also available as the R53, and either will work properly in this circuit. It is quite an expensive component, and it seems to be worthwhile shopping around to find the best price.

The prototype is built into a small metal instrument case of the same size and type that was used for the capacitance meter project. The general layout of the unit is much the same as for the capacitance meter project, and the front panel layout is virtually identical. The only difference is that pushbutton switch S2 has been added between the range switch and the panel meter (see the accompanying photographs). Note that S2 is a push-to-break switch, and not the more common

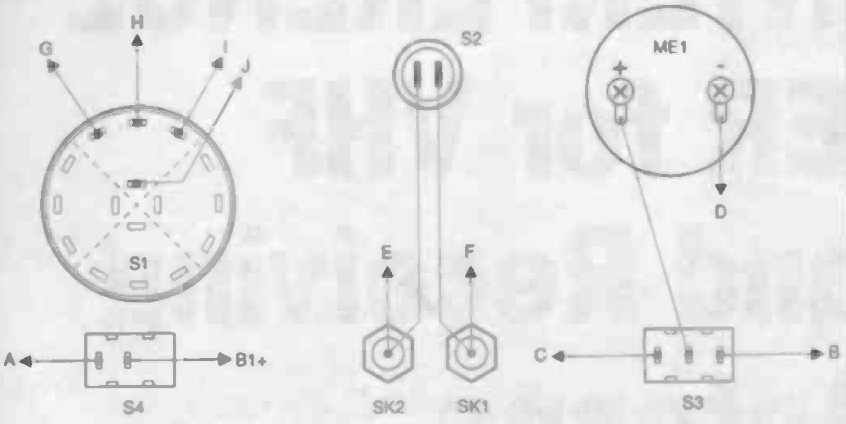


Figure 5: details of the hard-wiring (use with figure 3).

push-to-make variety. In general the exact layout used is not critical, but try to keep the leads from the circuit board to the test sockets (SK1 and SK2) as short as possible.

Details of the hard wiring are provided in **figure 5**, which should be used in conjunction with figure 3 (for example, point "A" in **figure 3** connects to point "A" in figure 5). This wiring is straightforward and should not present any problems. S1 is a standard three-way four-pole rotary switch, but in this circuit only one pole is used and 12 of its tags are left unconnected. The battery pack consists of eight HP7 (AA) size cells fitted in a plastic holder. There is just about enough space for the batteries inside the case, but the holder will probably have to be fixed to the rear panel or top of the case using double-sided adhesive pads. Do not simply leave the battery pack rattling around inside the case, as it would probably damage thermistor TH1. Connections to the battery holder are via an ordinary PP3 size battery clip.

Many inductors will connect direct to SK1 and SK2 without any difficulty, but some components have very short pins rather than leads. It can be quite difficult to make the connections to these, and the best solution is to make up a pair of test leads fitted with the smallest crocodile clips you can obtain. Alternatively small probe-clips can be used. The test leads should be as short as reasonably possible so that they add a minimal amount of inductance in series with the test components.

It is not difficult to remove the scale-plate of the meter and add figures to suit the 1mH and 10mH ranges (the existing 0 - 100 scale is correct for the 100mH range). Normally the front cover of a panel meter simply unclips, and removing two tiny screws then frees the scale-plate. Rub-on transfers can then be used to add the new numbers. As it is not difficult to mentally convert readings on the 1mH and 10mH ranges into measured values, and moving coil meters are easily damaged, it is probably not worth the risk and effort involved in altering the scale-plate. If you do decide to modify the scale-plate, proceed very carefully. In particular, avoid touching the meter's pointer and try not to get any dust into the meter movement.

Calibration and use

Ideally the unit should be calibrated against a precision inductor having a tolerance of one percent or better. In practice a lower tolerance component will probably have to be used because close tolerance inductors do not seem to be readily available. In fact most of the inductors currently on offer have a tolerance rating of some 10 percent. Probably the best choice for calibrating the unit is a 10mH type 8RB inductor (as sold by Cirkit Distribution Ltd.). This component has a five percent tolerance rating, but five percent is the guaranteed maximum error. Actual components tested were all well within the tolerance limits.

To calibrate the unit set S1 to the 10mH range (the middle setting) and connect the 10mH calibration component to SK1 and SK2. With S3 set to the "inductance" position, press S2 and adjust RV1 for precisely maximum reading on the panel meter. The unit is then ready for use. Bear in mind the warning given earlier about testing high frequency inductors. With these components the measured value at 10kHz is likely to be slightly different to the marked value.

PARTS LIST *for the Inductance meter*

Resistors

All 0.25W 5 percent metal film unless noted otherwise

R1,2	2k2
R3,5	1k5
R4,15	1k
R6	100R 1 percent
R7	1k 1 percent
R8	10k 1 percent
R9,10,13	10k
R11,12	100k
R14	6k8
R16	150k
RV1	10k min hor preset
TH1	RA53 or R53 thermistor

Capacitors

C1	100u 16V radial elect
C2	47u 16V radial elect
C3,4	10n polyester
C5	10u 25V radial elect
C6	100n polyester

Semiconductors

IC1	LF351N
IC2	LF411CN
IC3	CA3140E

Miscellaneous

S1	3-way 4-pole rotary (one pole used)
S2	Push-to-break switch
S3	SPDT min toggle switch
S4	SPST min toggle switch
B1	12 volts (8 x AA size cells in holder)
ME1	100uA moving coil panel meter
SK1,2	1mm or 2mm sockets

Metal instrument case about 152 x 105 x 75mm, 0.1 inch stripboard with 50 holes by 20 copper strips, battery connector (PP3 type), control knob, 8-pin DIL holder, wire, solder, etc.

RADIO INTERFERENCE FILTER for VHF High-Band Receiving Antenna

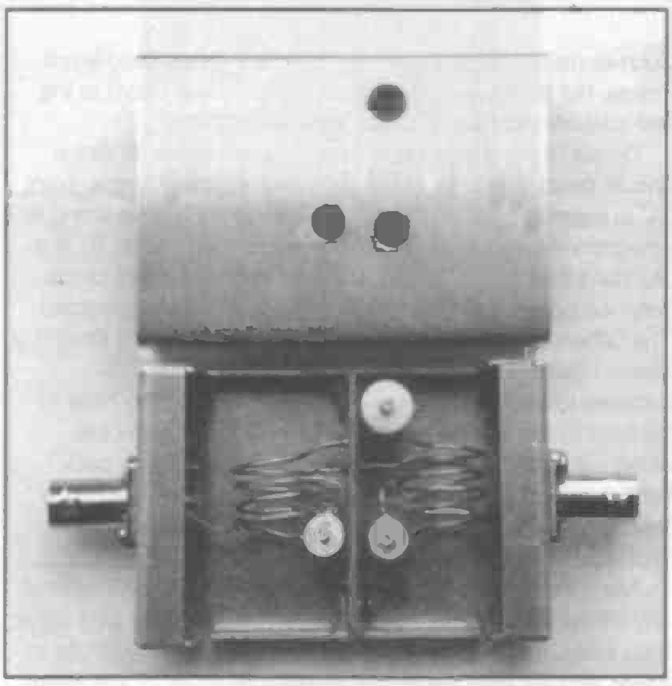
Reception can easily be swamped by legitimate strong transmissions nearby, particularly by radio-paging. This filter has reduced the problem dramatically for designer E Chicken MBE FIEE G3BIK.

This article describes a low-cost filter of straightforward construction, designed to remove or substantially reduce destructive interference from strong local transmissions in the 120-150MHz range, such as interference to amateur radio reception in the 2metre band, or to reception of weather-satellite or air-traffic signals.

"Swamped"

In some parts of the UK, legally authorised radio transmissions on frequencies close to the edge of the 144MHz amateur band can make reception of amateur transmissions difficult due to close-proximity swamping effects. For example, in my own locality, reception of 2-metre low-level signals front the Russian space-craft MIIR suffers badly from a nearby Home-Office radio tower. This does not imply that such transmissions are in any way at fault. It is simply a technological fact of life that the rf input stages of even the best receivers can be swamped by strong local transmissions, especially on adjacent frequency bands. Similar problems can also be encountered if you enjoy listening to air-traffic signals. And if you were to mention the word "radio-pager" in the presence of the 2000 or more UK weather-satellite receiving enthusiasts, you might be told in no uncertain terms to go wash your mouth out!

The reason for this powerful aversion to modern paging systems among 137-MHz weather buffs is that since that band was assigned to digital paging in the UK, weather picture signals from low-orbit satellites have been suffering severe interference throughout the UK. The very nature of the pager transmissions, coupled with the nationwide distribution of their radio-sites, has made this a very difficult problem to deal with, to the point where NASA may have to change a frequency on its proposed new weather satellite.

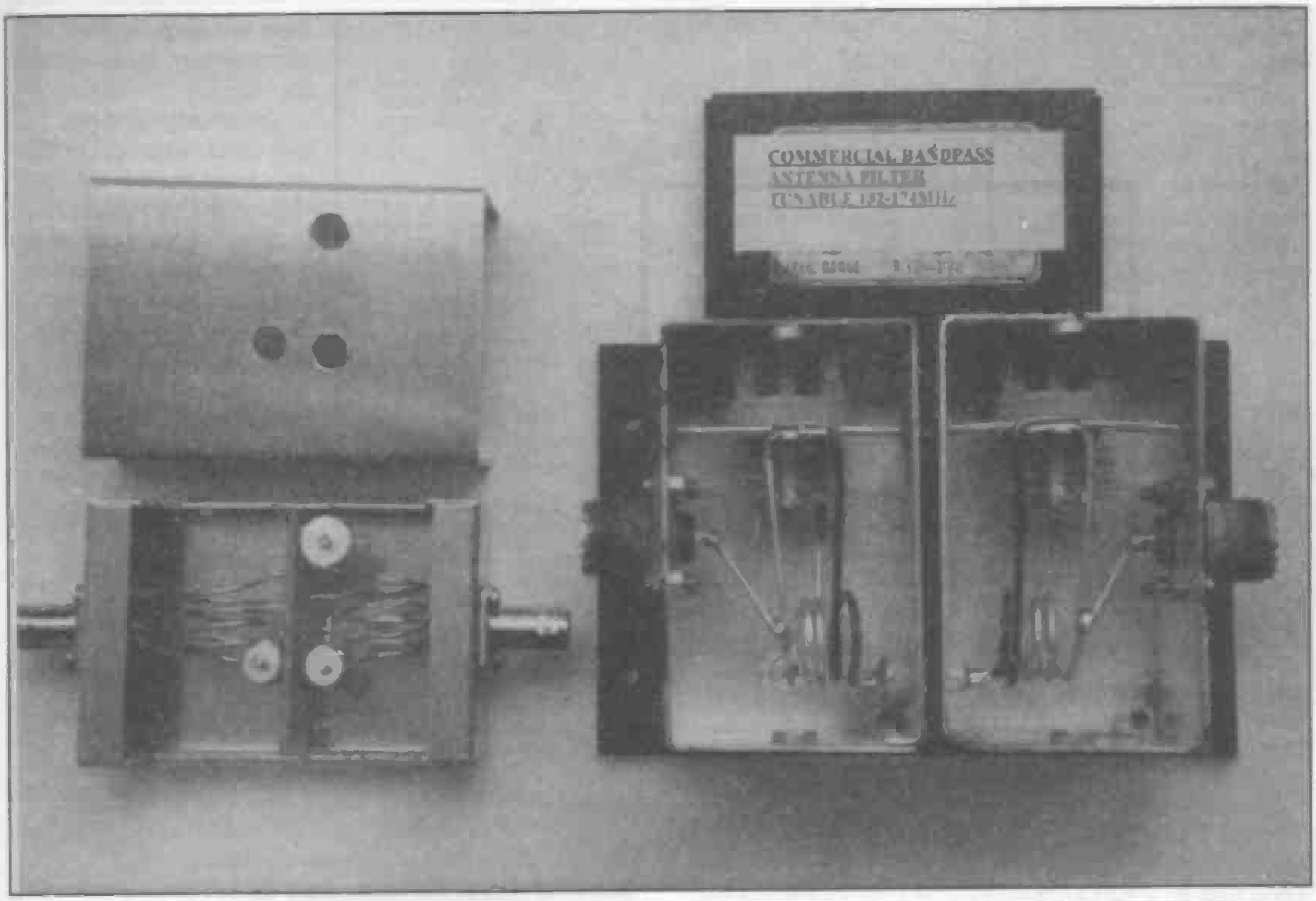


The Interior of the Interference Filter

Many long-established weather-satellite receivers have had to be redesigned to combat this new and destructive interference. In truth, my own receiving set-up does not suffer too badly, but only because it is a modified ex-pmr commercial receiver of very high technical specification with a highly selective multi-stage tuned rf input circuit and very narrow IF bandwidth. Although its narrow bandwidth causes some loss of detail on the received images, in practice the definition of cloud and land has up to now been adequate for my purposes.

Recently, however, following the announcement of extra frequencies for further planned satellites, and bearing in mind the cost of extra crystals for my ex-pmr set, I decided as an experiment to modify a domestic VHF FM radio-tuner bought as a bargain at the local car-boot sale. I re-tuned it to receive 137-MHz weather satellite transmissions.

It was a quality product with a tuned rf stage preceding the tuned mixer, and the usual upper limit of 108 MHz prior to modification. Results were encouraging, with sensitivity sufficient to give full background quietening by the satellite fm signals, but, alas badly disrupted by radio-paging



A good commercial filter beside the Interference Filter giving a size comparison. An unusual feature of our design is the third trimmer capacitor, which can resonate the link-loop itself for optimum signal transfer at the required frequency.

transmissions even though my nearest tower is some 1.5km away! Now I knew how my fellow Wefax enthusiasts really felt!

The problem of co-channel interference is not in itself new. It is and has always been of major proportions on commercial radio-communication sites, where receiving antennas have to share the same tower as transmitting antennas on adjacent frequencies. One effective and often-used cure to that problem is the installation of a sharply tuned band-pass filter such as that illustrated in **figure 1**, in line with the receiving antenna's coaxial feed-cable at the point where it connects to the receiver. Based on that knowledge from my professional experience, a similar filter was constructed using readily available low-cost components at a total outlay of about £6 at 1998 prices. This totally cleaned up reception on my 2metre amateur-band receiver.

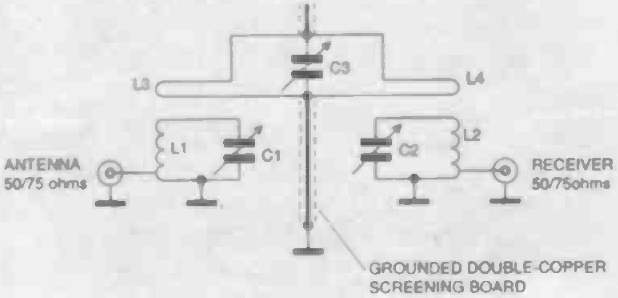


Figure 1: the circuit of the radio interference filter for vhf antennas

The filter also removed the last vestige of radio-pager interference to weather image reception on my modified ex-pmr receiver, and it even allows reception of acceptably clean weather images from my bargain-priced retuned domestic fm receiver. As with all filters, there is some slight insertion loss on the signals of interest, but not enough to cause concern, as the advantage far outweighs any disadvantage.

The circuit

Figure 1 gives the circuit diagram of the filter, which is fully reversible, with the antenna coax feed-line connecting to one end and the receiver to the other via a short coaxial jumper-lead with suitable plugs. It consists of two separate but identical parallel-resonant LC circuits each tuned to, for example, 145MHz for use on the 2-metre amateur band, or 137.5MHz, which is about mid-band for weather-satellites and is one of the most used frequencies. A metallic screen electrically separates the two timed circuits L1/C1 and L2/C2, and the required incoming signal is transferred from one to the other by means of a closed loop. This consists of two single-turn link-coils L3 and LA connected in series, each of which is inductively close-coupled to one of the resonant circuits.

An unusual feature of this design, which makes it different from a typical commercial version, is the addition of a third trimmer capacitor C3 whereby the link-loop itself can be resonated for optimum signal transfer at the required frequency. This also ensures maximum rejection of the radio-pager or other interfering signals.

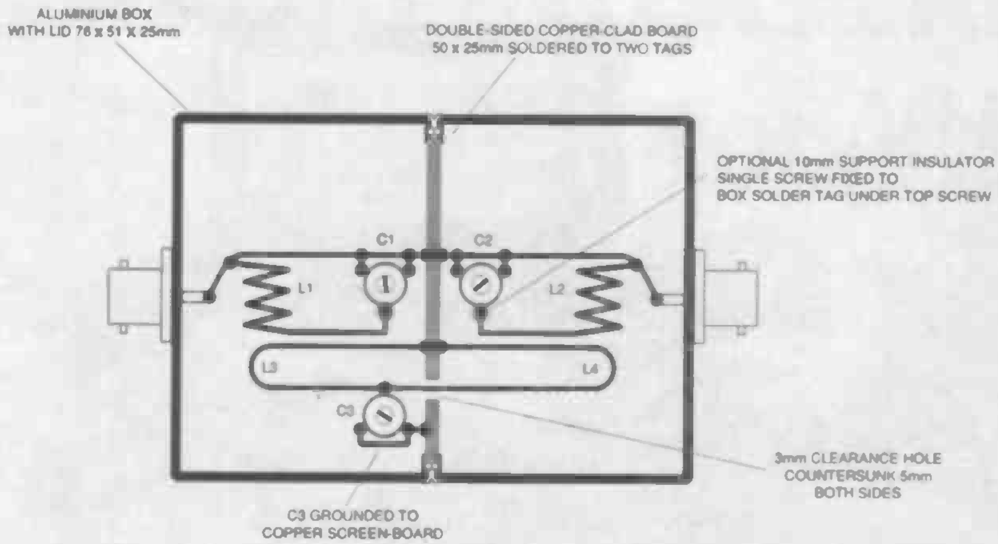


Figure 2: the component layout of the radio interference filter for vhf antennas

The design of the filter assumes that the receiving antenna for the vhf high-band receiver uses coaxial cable of characteristic impedance in the order of 50 to 75 ohms. This is impedance-matched into and out of the filter by tapping onto the tuned-coil at a low-impedance position close to its grounded end. The actual position of the tap is not unduly critical.

Construction

Drills of sizes 1,2,3, 5, and 7mm are needed. The prototype filter was contained in an aluminium box of size 76 x 51 x 25 mm (3 x 2 x 1 inches) with a removable lid. Mounted centrally on each end face of the box is a 50-ohm BNC or uhf coaxial socket chosen by you to suit your own receiver.

A 50 x 25-mm piece of double-sided copper-clad pcb laminate board serves both as the inter-screen for the tuned circuits, and the mounting-plate for the coils and capacitors. The board is secured and grounded at its two bottom corners by soldering each to a pair of solder-tags on the box sides. These tags are longer than their 6mm fixing-bolts, which allows the board to be gripped between them before soldering to both copper faces. Countersunk bolts are used to avoid mechanical conflict with the lid. Fixing of the lid is provided by drilling 2-mm holes through the lid and side-plates of the box to accommodate self-tapping screws. Two screws should be sufficient, one at each diagonal side.

Before soldering the screening board into the box, the component fixing-holes must be drilled as described in **figure 3** using a 1-mm drill which provides a neat fit for the 20swg wires, and then the four coils and three trimmer capacitors fitted onto the board and soldered into place. **Figure 2** gives guidance for mounting of the components, but positioning is not critical, as the wire tails of the coils can easily be bent in situ to suit your particular layout.

Four coils of 12-mm inside-diameter need to be wound with 20swg tinned copper wire, after first having straightened the wire by pulling it through a soft cloth. Coils L1 and L2 are each of three turns plus tails of about 25mm, with the turns spaced to give a span of 12mm. Link-coils L3 and L4 are each one single 12-mm diameter turn, again with 25-mm tails.

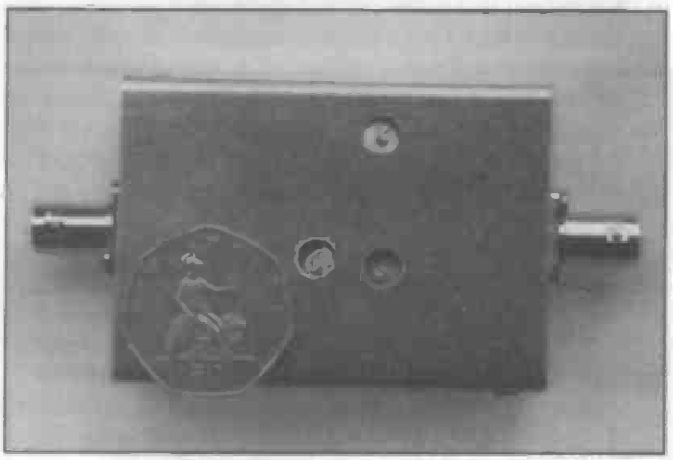
Temporarily bend one wire tail of coil L1 out of the way, insert its other tail through the appropriate hole with the coil horizontal, and solder the wire to the copper on both sides of the board. Cut off any surplus tail ~~wire~~. From the opposite side of the board, do the same with the other coil L2.

Solder the two common-tags of the green-coloured 22pF trimmer capacitor C1 to the grounded tail of coil L1, with the adjusting slot facing upwards and the centre-tag pointing inwards. With fine-nosed pliers, carefully bend the free tail of coil L1 and cut it to length such that it can then be soldered to the centre-tag of trimmer C1. Do the same with the trimmer C2 and coil L2 on the other side of the board.

This self-supporting coil capacitor method is mechanically adequate. Optionally but not really necessary, extra mechanical support for each centre-tag/coil junction can be provided by means of a 10-mm insulated-spacer, single-hole fixed to the bottom of the box by an M3 bolt. A solder-tag bolted to the spacer's free end would then serve as a firm anchor point for the solder joint.

One tail of each single-turn coil coupling-loop L3 and L4 is grounded by passing it through a hole in the board, and soldering it to both copper faces. Note that the 3-mm clearance-hole, through which the other tail of each loop passes, is countersunk with a 5-mm drill on both sides of the board to trim back the copper-plane so as to prevent the wires from touching it. These two tails are soldered together on each side of the hole, but not to the board itself. Each loop is then physically adjusted to be closely parallel to, but not touching, its associated coil L1 or L2.

Now solder the yellow-coloured 65pF trimmer capacitor C1 into position on one side of the screen. The choice of side



The filter boxed, showing the three trimmers and an old-style 50p coin for comparison!

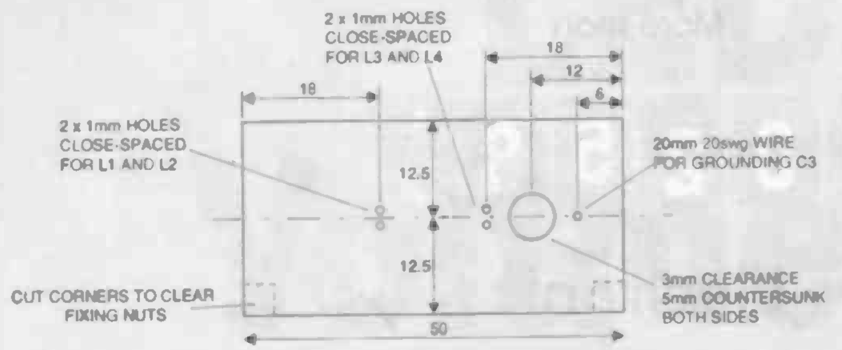


Figure 3: drilling details for the copper-clad laminate 50 x 25-mm screening board

is not important, but the trimmer should sit snugly against the copper with its adjusting slot upwards, and the centre-tag facing inward. The trimmer's two common-tags are soldered to the short piece of 20swg grounding wire which is soldered through the board at 6mm from the edge, as shown in **figure 3**. The centre-tag should be in contact with and soldered to the union of the two link-loops, close to where they pass through the clearance-hole in the board.

Fit the assembled screening-board into the box with each corner gripped between a pair of solder-tags, then solder the tags to both copper faces. It will be necessary to snip each corner to clear the solder-tag fixing nut. If necessary, shorten the two socket-pins to avoid unintended contact with the coils, then solder a wire link from each pin to the turn nearest the earth end of its own coil.

Finally, drill three 7-mm diameter holes in the top face of the lid located so as to give clearance-access to the adjusting slot of each trimmer. An easy way to determine the drilling points is to press a thin layer of Plasticine or wax on to the inner surface of the lid and to gently press it down on the trimmers. This leaves a clear impression of the trimmer adjusting-slots in the Plasticine, which can then be used as a drilling template. After drilling the trimmer adjustment-holes, set the moving plates of each trimmer capacitor to about mid-way, then fasten the lid into place.

Installing and tuning the filter

The filter must be connected between the antenna and the receiver, as close to the receiver's antenna input socket as possible. The antenna's coaxial lead plugs into either end of the filter. A short length of 50-ohm coaxial cable fitted with an appropriate 50-ohm plug at each end is required to make the connection between filter and receiver. The only adjustment necessary, is to tune each of the three trimmer capacitors for maximum received signal strength with the receiver set to say the local repeater channel for 2 metres, or to 137.5MHz for weather-satellite use. For convenience, a signal-generator should be used as the signal source. It should preferably be a tone-modulated vhf fm signal generator of 50-ohm output impedance, but a dip-oscillator would suffice. Alternatively, the 2-metre repeater or weather-satellite signal itself could be used.

It is very important that an insulated trimming tool is used on the trimmers, not a screwdriver. When tuning is completed, label one socket as Antenna and the other as Receiver.

It should be noted that, because of the filter's very high selectivity, it may not be possible at first to hear the off-air signal through the filter before it has been tuned, so using a signal generator may be the best option. However, if a signal generator is not available, adjustment of the filter on an incoming radio signal in the band 120.450MHz can be simplified as follows:

Remove the filter-lid. Set all three trimmer vanes to mid-mesh. Connect the antenna to the receiver and listen for, say, the 2-metre repeater signal, or air-traffic signals on or about 120MHz, or weather satellite signal on 137.5MHz. The latter would best be done during an overhead pass, when the satellite can be heard for 15-20 minutes. While the required signal is present, disconnect the antenna from the receiver, leaving the antenna cable unconnected. Connect the filter to the receiver, then touch the free antenna plug onto the adjusting slot of the yellow 65pF trimmer, allowing the signal to be heard. Adjust the green 22pF trimmer nearest the receiver socket for maximum signal. Now touch the antenna plug on to the adjusting slot of the other green 22pF trimmer, and adjust the yellow 65pF loop-trimmer for maximum signal. Connect the antenna plug to its own socket on the filter, and adjust its nearest green 22pF trimmer for maximum signal. Refit the lid and give a final adjustment for maximum signal to each of the three trimmers.

PARTS LIST Radio Interference Filter

C1	**5-65pF miniature film trimmer Maplin WL72P**
C2, C3	**2-22pF miniature film trimmers Maplin WL70M (Adjust each for maximum required signal.)**
L1, L2	**12-mm dia. 20swg tinned-copper wire single-turn links**
L3, L4	**12-mm dia. 20swg 3 turns each, spaced to 12-mm span**
SK1, SK2	**50-ohm square socket, bnc or uhf 50239 Maplin YW00A or BW850**

2 x 50-ohm twist-on plug, bnc or PL259 to suit receiver, Maplin JK21X or HL9SD; 2 x M3 6mm bolt and nut, countersunk, Maplin BF36P; 4 x M3 20-mm bolt and nut, pan-head, Maplin JY22Y; 6 x M3 solder tag, Maplin LR64U; 2 x 10-mm insulated spacer (optional), Maplin FS36P; 0.5-m 50-ohm 5-mm UR76 coax cable, fitted each end with appropriate 50-ohm plug; 50mm x 25mm double-sided copper-clad laminate pcb board, Maplin FA5SK; 0.5m 20swg tinned copper wire, Maplin BL13P; aluminium box with lid, 6 x 51 x 25mm (3 x 2 x 1 in), Maplin AB12; preset trim-tool, Maplin BR491.
Maplin catalogue numbers are given for guidance only, and any suitable alternatives can be used with confidence..

LED Voltmeter for 12V battery

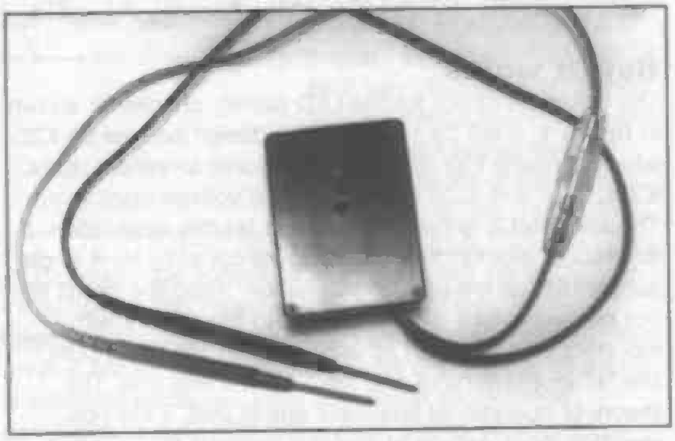
If 12-volt leisure batteries are run down very far, their life-span decreases dramatically. Terry Balbirnie's four-LED charge-state indicator helps to monitor battery health.

Twelve-volt "leisure" batteries are the standard power source for equipment in a caravan or boat. They are used to operate the low-voltage appliances such as lights, water pump, television, etc. This type of battery is also used by radio amateurs to operate transmitting equipment in remote locations and by those taking environmental measurements in the field. When used in conjunction with an inverter, they also serve to provide a 240V 50Hz supply for mains equipment, such as computers, where no actual mains supply is available.

How to kill a battery

Leisure batteries are a member of the lead-acid family. The most familiar one is the car battery. However, leisure batteries are specially designed for cyclic use, whereas a car battery is used chiefly in float mode. Cyclic means that the battery is run down significantly before re-charging. In float mode only a small fraction of the total charge is drawn at any time. The battery is then re-charged at a low rate and over a prolonged period - even continuously - as in the back-up supply for a burglar alarm. Batteries designed for float applications may be cycled occasionally, such as when the car fails to start in the winter and it runs flat. Car batteries, however, are not designed for cyclic use and will fail fairly quickly under such conditions - hence the need to buy the correct product and to avoid using a cheap car battery for any of the purposes mentioned earlier.

Even a leisure battery will fail much more quickly if it is regularly discharged to its rated low point. Typically, if a battery is only run down by one-third of its total charge, it may be expected to cycle some 1000 times. If the depth of discharge is 50%, this figure falls to some 500 times. If it is run down to its low point, the life may be expected to drop to some 100 to 200 cycles only. This is not always appreciated by users.



Deep discharge

Lead-acid batteries suffer from one major disadvantage: they must always be maintained in a satisfactory state of charge. If they are allowed to run down below the rated low point, permanent damage is likely to occur. The battery will then fail to accept a full charge. Under extreme conditions of "deep" discharge such a battery will be completely ruined, especially if it has been left that way for some time. It is interesting to note that a battery left with a terminal voltage of less than about 12.3V (50 percent charge) will slowly deteriorate anyway.

Although leisure batteries are described as having a 12V output, this is only an average figure. A fully-charged battery will develop an off-load voltage of some 13V irrespective of size or manufacturer. As the battery is run down, the terminal voltage falls. At 12.3V, some 50 percent of the charge remains. At about 11.7V it may be considered flat, even though some charge still exists. Below about 11.5V the battery is in a dangerously low state and must be re-charged as soon as possible. The state of a battery could therefore be found by using a digital voltmeter. However, some non-technically minded people would find difficulty interpreting the readings, and many would not wish to use their expensive instrument for this purpose anyway.

Thermometer display

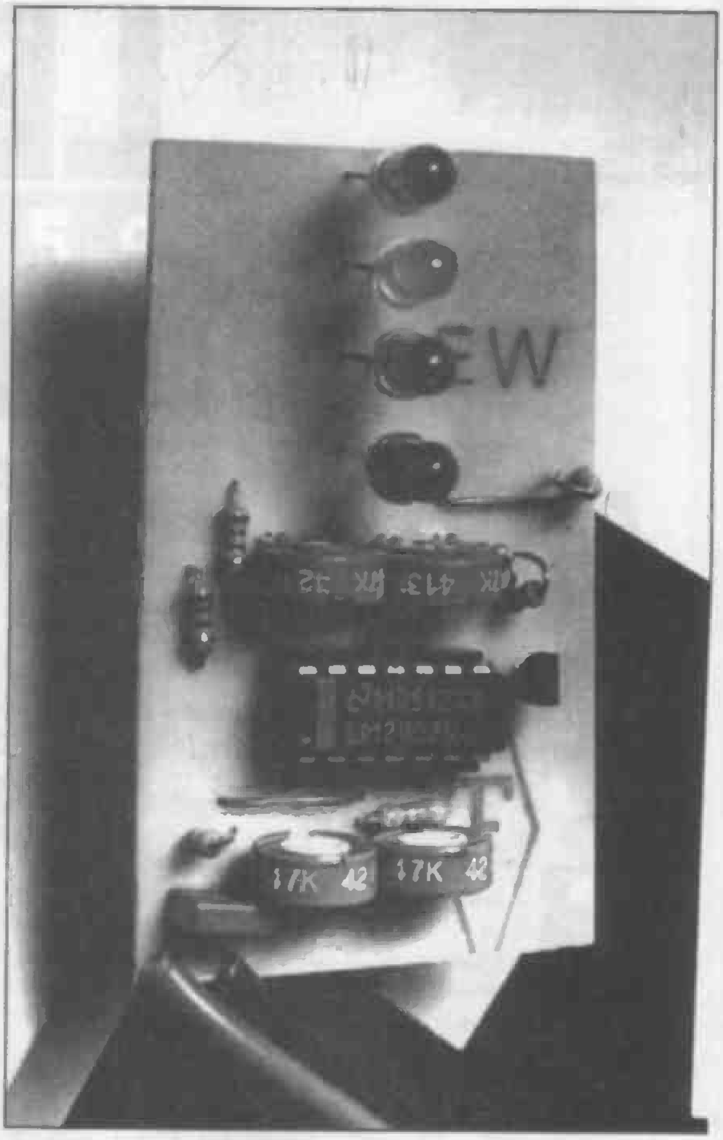
Most of the time, the user simply wishes to know the approximate state of the battery, and this battery check circuit fulfils that need. On the front panel of the unit are four LEDs (light-emitting diodes) arranged thermometer-fashion. The colours used are green, yellow, orange and red to indicate "good", "serviceable", "poor" and "flat" respectively. These will operate in turn when predetermined voltages are applied to the input. There is, of course, a further state where none of the LEDs are on. This indicates the point when the type of rapid damage referred to above is likely to occur.

The circuit is powered from the battery being monitored, drawing about 1.5mA plus a further 15mA for each illuminated LED. Thus, when all four LEDs are glowing (battery fully charged) the total requirement is a little over 60mA. The device should not be left connected permanently to the battery because even this small drain would eventually run it down. A large battery of 60Ah capacity would take several weeks to do so but a small one of, say, 1Ah capacity would take only a few hours. The intention is that the meter is used every now and again to monitor the condition of the battery.

How it works

The complete circuit for the LED battery checker is shown in **figure 1**. It will be seen that the design centres on IC2, which contains four identical operational amplifiers, IC2a, IC2b, IC2c and IC2d each used as a voltage comparator. The specified ic is particularly good for this application. It is a robust bipolar device and works correctly from single supply rails as are used in this circuit. Also, the circuit will not be damaged if it is connected to the battery with incorrect polarity. Each op-amp section has two inputs, the "+" (non-inverting) and the "-" (inverting) one. The theory of operational amplifiers states that, if the non-inverting input voltage at any unit exceeds the inverting one, the appropriate output will be on.

The circuit is connected to the nominal 12V battery through fuse, FS1. A supply is then provided to the 5V reference device, IC1. This operates in conjunction with load resistor, R3, to give a precise 5V between its ends. IC1 may be regarded as a superior type of zener diode and is represented by the same symbol. This reference voltage is connected to the inverting inputs of all four op-amps (pins 2, 6, 9 and 13). Meanwhile, each non-inverting input (pins 3, 5, 10 and 12) receives a voltage dependent on the adjustment of presets RV1, RV2, RV3 and RV4 respectively. These are connected as potential dividers and they operate in conjunction with fixed resistors, R1 and R2 which are common to all units. The purpose of these resistors is to narrow the range of adjustment of the presets so that they are more easily adjusted at the end. To make the operation clear, suppose RV1 is adjusted so that exactly 5V exists at IC2d non-inverting input, pin 3, when the battery supply is 11.8V (i.e. a poorly-charged battery). Suppose also that the other presets are adjusted so that each non-inverting input develops 5V with supply voltages of 12.2V (IC2c), 12.5V (IC2b) and 12.8V (IC2a) - that is, increasing states of charge.



Suppose the battery is in a very poor state of charge and only 11.5V exists between its terminals. It will be seen that all the non-inverting input voltages are less than 5V. None of the op-amp outputs will be on and therefore all LEDs will be off. Now suppose that the battery voltage just exceeds 11.8V. The voltage at pin 3 rises above the 5V reference at pin 2 so IC2d output, pin 1 is high. Thus, the red light-emitting diode, LED1, will operate via current-limiting resistor, R4. In a similar way, as the battery voltage rises above 12.2V, 12.5V and 12.8V, the non- inverting inputs of IC2c, IC2b and IC2a will exceed the 5V reference existing at the inverting ones. Thus, orange, yellow and green light-emitting diodes LED2, LED3 and LED4 will operate in turn via the appropriate current-limiting resistor. By adjusting the presets to the required working voltages at the end of construction, the colours will show at predetermined points and the device will behave as a narrow-scale voltmeter.

The op-amps are used without positive feedback. This means that the switching action will not be sharp. In other words, the LEDs will come on and go off gradually over a small range. For the present purpose, this does not matter.

Construction

Construction is based on a single-sided printed circuit board (PCB) and the component overlay is shown in

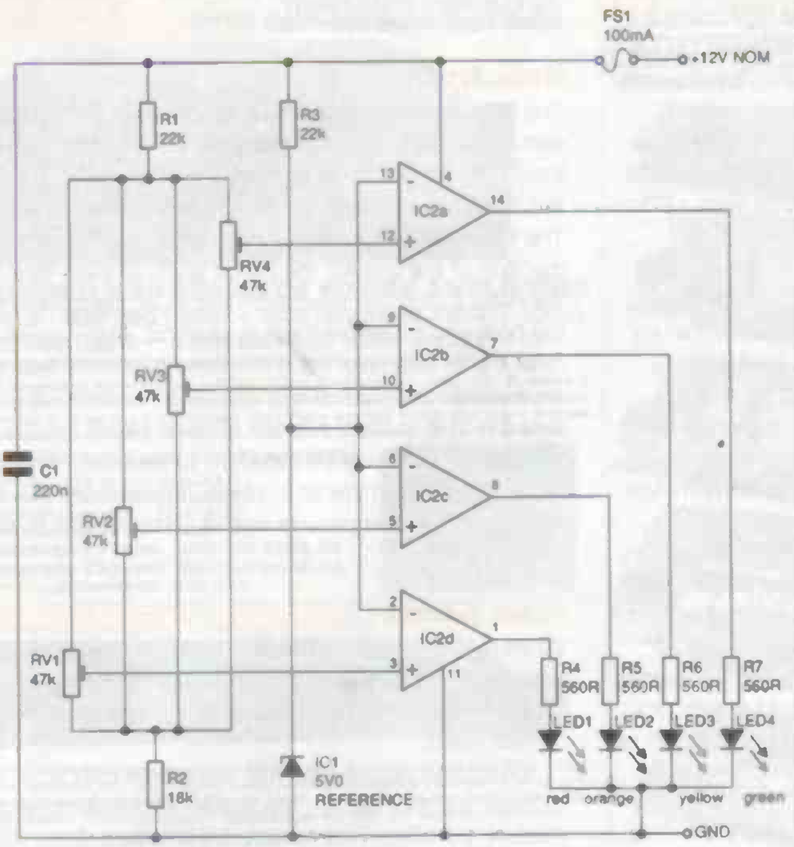


Figure 1: the circuit of the LED voltmeter battery checker

figure 2. Begin by soldering the ic socket and two link wires in position. Follow with all the resistors (including the four presets) and capacitor. Solder the LEDs in place taking care over their orientation (the cathode end is marked "k" in figures 1 and 2). Note that with LEDs 1 and 4, the cathode end is connected to the lower track on the PCB whereas with LEDs 2 and 3 it is the upper one - if the polarity is incorrect, the LED will not work. The tips of the LEDs should stand approximately 20mm above the circuit panel and should all have exactly the same height so that they appear neat in the finished device. Take IC1 and, holding it so that the flat face is towards you and with the leads pointing upwards, cut off the right-hand end one close to the body. This lead is connected to the substrate and has no effect if left unused. Solder the two remaining leads in position with the flat face of the ic towards the lower edge of the PCB.

Solder test probes to the points labelled "+12V nom" (nominal) and "gnd". The +12V one should be red and the "gnd" one, black. These could be easily made. However, in the prototype unit, a pair of inexpensive meter leads was used with the 4mm plugs cut off the other end. These give a more professional appearance. Connect the in-line fuseholder in the positive lead as shown in the photograph. Adjust the presets as follows: RV1 and RV2 fully clockwise; RV3 and RV4 fully anti-clockwise. These adjustments are as viewed from the edges of the circuit panel (that is, not from IC2 position)

Complete the construction of the circuit panel by inserting IC2 into its socket, taking care over the orientation. Insert the fuse into its holder. This should have a value not exceeding 100mA. Note that the use of a fuse is essential because, under accidental short-circuit conditions, a lead-acid battery can deliver an enormous current. This could cause wires to become red hot and result in burns or even fire. Also, in the event of connecting the probes to the battery with incorrect polarity, a larger current than normal will flow. If left for more than a second or so, the fuse will blow. The op-amp and voltage reference ic seem to survive, however.

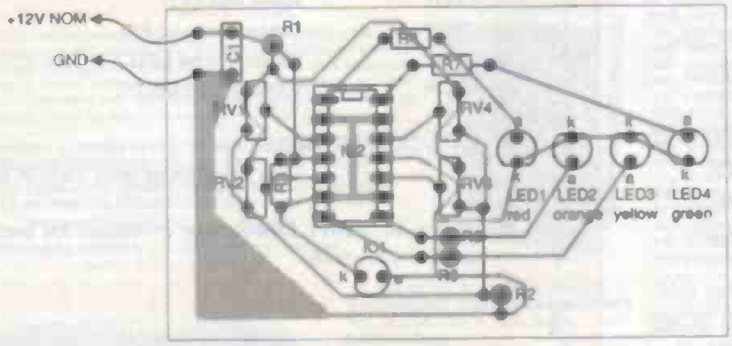


Figure 2: the component layout of the LED voltmeter battery checker

Adjustment and testing

If you have a continuously variable power supply unit and a digital voltmeter available, you could adjust the circuit with the aid of these. If you do not have this equipment, adjustments may be made by discharging the battery under controlled conditions. This takes longer but will probably produce better results because they are based on real experience.

If you are using the power supply method, connect its output (observing the polarity) to the input probes on the unit and also to the voltmeter. Set the output of the power supply unit to 12.8V and adjust RV4 using a trimming tool or small screwdriver so that the green LED is just completely off. Reduce the voltage to 12.5V and repeat with RV3 until the yellow LED is just off. Repeat at 12.2V adjusting RV2 so that the orange LED is just off. Finally, do the same at 11.8V adjusting RV1 so that the red is just off. Slowly increase the voltage again and note that each LED comes on in turn over a small range.

Absent voltmeter

In the absence of the above equipment, charge the battery fully and connect a suitable bulb to act as a load. Do not draw too large a current in an effort to speed up the process. Aim to run the battery down over a period of at least 20 hours. This may be done in more than one operation so it will not be necessary to get up in the middle of the night to adjust a preset!

Start by finding the Ah (amp-hour) capacity of the battery - this will be printed on it somewhere. A leisure battery will have a typical capacity of 60Ah. This means, in theory, that it could supply 1A for 60 hours, 2A for 30 hours, 3A for 20 hours and so on. With a small load connected, it will appear to have a larger capacity. For example, it would supply one amp for more than 60 hours. Conversely, the capacity will be less with a large load so it would not maintain a load of 60 amps for a full hour.

With the amp-hour capacity known, divide it by 20. This will give the approximate current that must be drawn to run the battery down in 20 hours. For example, the 60Ah leisure battery would need a load of 3A to do this but a small battery, of say 6Ahr capacity, will need only 0.3A or 300mA. Now choose a 12V bulb, or bulbs to roughly provide this load. To find the current needed by a bulb, divide the wattage figure by 12 (the nominal voltage of the supply). For an approximate result, you could divide by 10 instead. For example, a 10W car-sidelight bulb could be considered to draw 1A or a 21W flashing indicator lamp, 2A. If you applied the 21W bulb to the 60Ah battery, it would take some 30 hours to discharge and this would be a suitable time. For the smallest batteries, you would need a panel light bulb. These are available in a range of power ratings from car accessory shops. A typical one is rated at 2.2W which works out at about 0.2A. This would be a suitable load for the 6Ah battery mentioned above. One practical point - since filament bulbs become very hot in use, care must be taken that they do not cause burning. They must be placed on a suitable heat proof surface or (better) suspended in the air.

Connect the bulb to the battery and note how many hours it has been alight to the point where it begins to dim noticeably or until a voltmeter shows 11.8V. This time will probably not be the same as the theoretical value. Remember, this does not need to be done in one continuous session. Re-charge the battery. Now decide on suitable timings which will be used to decide "good", "serviceable", "poor" and "flat" states. Suppose it took 30 hours for the bulb to go slightly dim. It may be decided to regard times greater than 20 hours to be "good" (green just off after this time) down to 15 hours, "serviceable" (yellow just off), down to 10 hours, "poor" (orange just off) down to 5 hours "flat" (red just off). Less than 5 hours (all LEDs off) will indicate a dangerously discharged condition. In actual use, the unit will be used with the battery off-load. It is therefore best if the bulb is disconnected before making an adjustment. Wait for 10 minutes or more so that the voltage stabilises before adjusting the corresponding preset.

Hole truth

The circuit panel may be built in any small plastic box which can accommodate it. Measure the positions of the LEDs on the PCB and drill holes in the lid to correspond. Take care to drill them in a perfect straight line and make them a tight fit. The PCB will then require little extra support. Drill a hole in the side of the box for the probe leads to pass through. You will need to remove them from the PCB, pass them through the hole and re-solder them in position. Apply some strain relief by, for example, tying a knot in the wires. Leave some slack inside the case and check that the wires cannot be pulled free in service. A piece of foam plastic on the base of the box will probably be sufficient to support the circuit panel. Check with the lid in place. If necessary, make adjustments to the presets over a period of use to obtain the desired effect.

Final points

When using the LED voltmeter, make the test with the battery off-load and preferably after it has rested for a while. This will enable the terminal voltage to settle down to the correct value.

If a routine test reveals that the yellow LED is off (indicating about 12.5V), the battery should be charged as soon as possible. This will prevent the slow deterioration referred to earlier. In service, this will not always be possible but the battery should certainly be charged before the red LED has gone off.

PARTS LIST

for the LED Voltmeter for 12V batteries

Resistors

R1, R3	22k
R2	18k
R4-R7	560R
RV1-RV4	47k

Capacitor

C1	220n

Semiconductors

IC1	LM2902
IC2	REF50Z
LED1	5mm red LED
LED2	5mm orange LED
LED3	5mm yellow LED
LED4	5mm green LED

Miscellaneous

FS1	Line fuseholder with 100mA fuse to fit

14-pin dil socket; plastic box; materials for test probes (see text).

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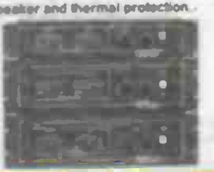

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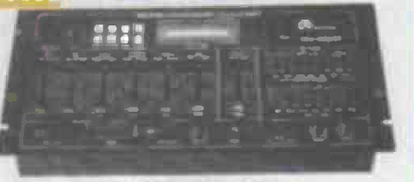

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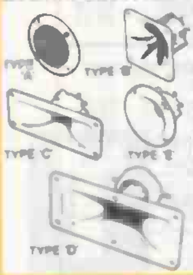

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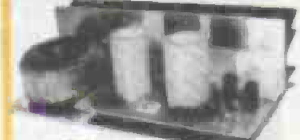

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4031	£0.70
4034	£1.24
4035	£0.31
4040	£0.38
4041	£0.31
4042	£0.22
4043	£0.28
4044	£0.35
4046	£0.52
4047	£0.34
4048	£0.28
4049	£0.22
4050	£0.26
4051	£0.38
4052	£0.32
4053	£0.40
4054	£0.56
4055	£0.34
4060	£0.44
4063	£0.29
4066	£0.19
4067	£2.20
4068	£0.16
4069	£0.20
4070	£0.25
4071	£0.23
4072	£0.17
4073	£0.17
4075	£0.17
4076	£0.30
4077	£0.78
4078	£0.20
4081	£0.22
4082	£0.21
4085	£0.28
4086	£0.26
4089	£0.55
4093	£0.23
4094	£0.31
4095	£0.56
4097	£1.20
4098	£0.48
4099	£0.38
4502	£0.38
4503	£0.40
4508	£1.40
4510	£0.36
4511	£0.38
4512	£0.32
4514	£0.77
4515	£0.99
4516	£0.44
4518	£0.44
4520	£0.41
4521	£0.62
4526	£0.40
4527	£0.40
4528	£0.40
4529	£0.44
4532	£0.32
4534	£3.24
4536	£1.00
4538	£0.37
4541	£0.33
4543	£0.49
4555	£0.32
4556	£0.40
4560	£1.18
4566	£1.96
4572	£0.25
4584	£0.24
4585	£0.47
4724	£0.94
40106	£0.25
40109	£0.58
40163	£0.46
40174	£0.46
40175	£0.36
40193	£0.60

74 Series

7407	£0.40

74HC Series

74HC00	£0.20
74HC02	£0.21
74HC03	£0.21
74HC04	£0.17
74HC08	£0.21
74HC10	£0.16
74HC11	£0.20
74HC14	£0.22
74HC20	£0.28
74HC27	£0.16
74HC30	£0.22
74HC32	£0.20
74HC42	£0.36
74HC73	£0.40
74HC74	£0.22
74HC75	£0.40
74HC76	£0.20
74HC85	£0.24
74HC86	£0.22
74HC107	£0.40
74HC123	£0.33
74HC125	£0.26
74HC126	£0.46
74HC132	£0.37
74HC133	£0.29
74HC138	£0.25
74HC139	£0.31
74HC151	£0.33
74HC153	£0.27
74HC154	£0.85
74HC157	£0.40
74HC158	£0.73
74HC160	£0.64
74HC161	£0.28
74HC162	£0.45
74HC163	£0.27
74HC164	£0.35
74HC165	£0.35
74HC173	£0.38
74HC174	£0.27
74HC175	£0.35
74HC192	£0.72
74HC195	£0.32
74HC240	£0.37
74HC241	£0.37
74HC243	£0.48
74HC244	£0.42
74HC245	£0.46
74HC251	£0.30
74HC253	£0.25
74HC257	£0.25
74HC259	£0.57
74HC273	£0.35
74HC299	£0.64
74HC356	£0.45
74HC365	£0.34
74HC367	£0.25
74HC368	£0.25
74HC373	£0.35
74HC374	£0.40
74HC390	£0.52
74HC393	£0.38
74HC423	£0.37
74HC553	£0.42
74HC563	£0.56
74HC564	£0.48
74HC573	£0.38
74HC574	£0.45
74HC595	£0.39
74HC640	£0.73
74HC688	£0.64
74HC4002	£0.31
74HC4017	£0.64
74HC4020	£0.36
74HC4040	£0.45
74HC4049	£0.31
74HC4050	£0.25
74HC4051	£0.40
74HC4060	£0.44
74HC4075	£0.27
74HC4078	£0.32
74HC4511	£0.64
74HC4514	£0.84
74HC4538	£0.41
74HC4543	£0.90

74LS Series

74LS00	£0.23
74LS01	£0.14
74LS02	£0.26
74LS03	£0.29
74LS04	£0.21
74LS05	£0.14
74LS08	£0.23
74LS09	£0.14
74LS10	£0.14
74LS11	£0.17
74LS12	£0.14
74LS13	£0.29
74LS14	£0.21
74LS15	£0.14
74LS20	£0.16
74LS21	£0.14
74LS22	£0.14
74LS26	£0.14
74LS27	£0.14
74LS30	£0.20
74LS32	£0.21
74LS37	£0.14
74LS38	£0.19
74LS40	£0.14
74LS42	[illegible]
74LS47	£0.58
74LS51	£0.24
74LS73	£0.40
74LS74	£0.32
74LS75	£0.30
74LS76	£0.40
74LS83	£0.38
74LS85	£0.48
74LS86	£0.20
74LS90	£0.48
74LS92	£0.45
74LS93	£0.42
74LS107	£0.30
74LS109	£0.21
74LS112	£0.24
74LS113	£0.21
74LS114	£0.36
74LS122	£0.31
74LS123	£0.31
74LS125	£0.27
74LS126	£0.25
74LS132	£0.21
74LS133	£0.34
74LS136	£0.22
74LS138	£0.40
74LS139	£0.24
74LS145	£0.56
74LS147	£1.17
74LS148	£0.64
74LS151	£0.25
74LS153	£0.40
74LS154	£0.70
74LS155	£0.25
74LS156	£0.36
74LS157	£0.22
74LS158	£0.21
74LS160	£0.48
74LS161	£0.32
74LS162	£0.44
74LS163	£0.32
74LS164	£0.24
74LS165	£0.48
74LS170	£0.30
74LS173	£0.24
74LS174	£0.24
74LS175	£0.24
74LS190	£0.60
74LS191	£0.24
74LS192	£0.60
74LS193	£0.24
74LS195	£0.24
74LS196	£0.24
74LS197	£0.24
74LS221	£0.40
74LS240	£0.32
74LS241	£0.32
74LS242	£0.32
74LS243	£0.30
74LS244	£0.32
74LS245	£0.60
74LS247	£0.32
74LS251	£0.24
74LS257	£0.24
74LS258	£0.24
74LS266	£0.14
74LS273	£0.32
74LS279	£0.25
74LS365	£0.21
74LS367	£0.21
74LS368	£0.21
74LS373	£0.33
74LS374	£0.34
74LS375	£0.34
74LS377	£0.32
74LS378	£0.62
74LS390	£0.25
74LS393	£0.24
74LS395	£0.26
74LS399	£0.62
74LS670	£0.69

Linear ICs

AD524AD	£23.04
AD548JN	£1.62
AD590JH	£5.28
AD592AN	£4.52
AD595AQ	£12.65
AD620AN	£9.88
AD625JN	£16.20
AD633JN	£8.09
AD648JN	£2.57
AD654JN	£7.25
AD708JN	£5.69
AD711JN	£1.51
AD712JN	£2.38
AD736JN	£8.75
AD797AN	£8.69
AD811N	£6.73
AD812AN	£6.32
AD817AN	£3.85
AD820AN	£3.20
AD822AN	£5.20
AD829JN	£6.41
AD830AN	£5.99
AD847JN	£5.71
AD9696KN	£7.73
ADEL2020A	£5.06
ADM222AH	£3.56
ADM232AA	£3.55
ADM485JN	£2.97
ADM690AN	£5.13
ADM691AN	£6.48
ADM695AN	£6.48
ADM699AN	£3.58
CA741CE	£0.26
CA747CE	£0.39
CA3046	£0.37
CA3059	£1.33
CA3080E	£0.73
CA3130E	£0.87
CA3140E	£0.49
CA3189E	£1.22
CA3240E	£1.12
DG211CJ	£1.55
DG212CJ	£1.55
DG411DJ	£3.11
ICL7106	£2.95
ICL7611DCP	£1.06
ICL7621	£1.70
ICL7660SCP	£1.68
ICL8038	£4.89
ICM7555	£0.32
ICM7556	£0.98
L165V	£2.72
L272M	£1.86
L293E	£4.35
L297	£5.71
L298	£6.26
L6219	£4.48
LF347N	£0.46
LF351N	£0.43
LF353N	£0.40
LF356	£0.84
LM301A	£0.25
LM308N	£0.58
LM311N-8	£0.29
LM318	£0.98
LM319N-14	£0.90
LM324	£0.24
LM335Z	£1.52
LM339N	£0.24
LM348N	£0.31
LM358N	£0.27
LM380N	£0.88
LM381N	£2.64
LM386	£0.79
LM392N	£0.79
LM393N	£0.21
LM709T	£0.79
LM748CN-8	£0.37
LM1458	£0.37
LM1881	£3.92
LM2917N8	£3.10
LM3900N	£0.72
LM3909N	£0.72
LM3914	£2.16
LM3915	£2.70
LM13600	£1.66
LMC660CN	£1.77
LMC6032IN	£1.55
LP311N	£0.74
LP324N	£0.67
LP339N	£0.73
LT1013CN8	£3.94
MAX202CPE	£2.97
MAX208CN	£6.99
MAX220CPE	£5.06
MAX222CPE	£5.06
MAX232CPE	£1.80
MAX483CP	£3.13
MAX485CP	£2.58
MAX631ACPE	£4.99
MAX635ACPE	£4.99
MAX1232CP	£2.96
MC1488	£0.39
MC1489	£0.39
MC3302	£0.56
MC3340P	£1.60
MC4558P	£0.33
MV601DP	£2.97
NE521N	£6.39
NE555N	£0.21
NE556N	£0.36
NE565	£1.84
NE566N	£0.90
NE567N	£0.39
NE571N	£2.47
NE592	£0.62
NE5532N	£0.45
NE5534N	£0.64
NE5539N	£4.35
NE5560N	£2.31
OP07CN	£1.42
OP27CN	£2.90
OP77GP	£1.99
OP90GP	£3.11
OP97FP	£2.43
OP113GP	£3.44
OP176GP	£2.09
OP177GP	£1.89
OP200GP	£5.60
OP213FP	£5.20
OP275GP	£2.57
OP282GP	£2.27
OP283GP	£5.20
OP290GP	£5.40
OP297GP	£5.74
OP400GP	£11.81
OP495GP	£8.69
RC4136	£1.00
SAA1027	£4.49
SG3524N	£0.96
SG3543	£6.88
SSM2017P	£3.38
SSM2131P	£4.19
SSM2141P	£4.21
SSM2142P	£6.16
SSM2143P	£3.78
TBA120S	£0.90
TBA800	£0.70
TBA810S	£0.64
TBA820M	£0.40
TDA1170S	£2.48
TDA2002	£1.04
TDA2004	£3.11
TDA2030	£1.18
TDA2050V	£3.12
TDA2611A	£1.88
TDA2822A	£0.86
TED3718DP	£5.03
TEA5115	£3.11
TL061CP	£0.35
TL081TCP	[illegible]
TL064CN	£0.72
TL071CP	[illegible]
TL072CP	£0.38
TL074CN	£0.48
TL081	£0.33
TL082CP	£0.54
TL084CN	£0.50
TL494CN	£1.46
TL7705ACP	£1.62
TLC271	£0.54
TLC272	£0.88
TMP01FP	£5.60
ULN2003	£0.52
ULN2004A	£0.48
ULN2803	£0.90
ULN2804A	£1.64
XR2206	£5.37

EPROM's

2716	£4.74
2732	£4.84
2764-20	£4.26
27C64-25	£3.44
27128-20	£4.08
27C128-15	£3.02
27256-20	£4.85
27C256-20	£3.68
27C512	£3.30
27C1001-20	£3.02
27C4001-120	£9.76

RAM

4164-15	£1.90
6116-10	£1.53
6264-10	£3.16
41256-10	£2.80
62256-10	£4.22
514256-8	£6.80

A/D Converters Data Acquisition

AD420AN	£25.38
AD557JN	£8.75
AD574AJN	£18.48
AD775JN	£18.48
AD7528JN	£11.42
AD7545AKN	£14.04
AD7828KN	£20.33
DAC0800	£2.72
ICL7109CPL	£7.75
TLC549IP	£3.04
ZN427E	£9.25
ZN448E	£7.34

PIC Micro's

16C54A04P	£3.07
16C54JW	£12.48
16C71-04P	£4.88
16C71JW	£17.34
16C84-04	£4.83

PHONE FOR OTHER DEVICES

Voltage Regulators

7805	£0.29
7806	£0.32
7808	£0.35
7812	£0.38
7815	£0.38
78L05	£0.23
78L06	£0.32
78L08	£0.33
78L12	£0.23
78L15	£0.24
78L24	£0.39
78S05	£0.70
78S12	£0.70
78S15	£0.98
7905	£0.40
7912	£0.30
7915	£0.38
7924	£0.38
79L05	£0.23
79L12	£0.23
79L15	£0.28
79L24	£0.30
ADM666AN	£3.44
L200CV	£1.30
L296	£6.87
L387A	£3.24
LM2940CT	£2.30
LM317LZ	£0.30
LM317T	£0.48
LM323K	£2.84
LM334Z	£1.35
LM337T	£0.68
LM338K	£5.52
LM723	£0.29
LP2950CZ	£2.70
REF01CP	£3.44
REF02CP	£4.66
REF12Z	[illegible]
REF195GP	£4.72
REF25Z	£1.24
REF50Z	£1.22
TL431CP	£0.45
ZN423	£1.00
ZN458B	£1.89

Diodes

1N914	£0.06
1N916	£0.06
1N4001	£0.04
1N4002	£0.04
1N4003	£0.04
1N4004	£0.04
1N4005	£0.04
1N4006	£0.04
1N4007	£0.05
1N4148	£0.05
1N4149	£0.06
1N5400	£0.09
1N5401	£0.08
1N5402	£0.08
1N5404	£0.09
1N5406	£0.10
1N5407	£0.10
1N5408	£0.11
6A05	£0.27
6A1	£0.27
6A2	£0.27
6A4	£0.28
6A6	£0.29
6A8	£0.30
6A10	£0.37
BA157	£0.10
BA158	£0.10
BA159	£0.10
BAT41	£0.24
BAT42	£0.10
BAT46	£0.28
BAT49	£0.36
BAT85	£0.17
BAV21	£0.07
BAW62	£0.07
BAX13	£0.05
BAX16	£0.05
BB405B	£0.26
BB909A	£0.36
BB909B	£0.36
BY126	£0.13
BY127	£0.18
BY133	£0.10
OA47	£0.24
OA90	£0.07
OA91	£0.26
OA200	£0.56
OA202	£0.29

Zeners 2.7 to 33V

500mW	£0.08
1.3W	£0.14

Bridge Rectifiers

1.5A 50V	£0.19
1.5A 200V	£0.20
1.5A 400V	£0.22
1.5A 600V	£0.22
1.5A 800V	£0.27
1.5A 1kV	£0.24
3A 200V	£0.36
3A 400V	£0.40
3A 600V	£0.33
6A 200V	£0.70
6A 800V	£0.59
10A 400V	£1.39
25A 200V	£1.68
25A 600V	£1.80

Thyristors

C106D	£0.30
PO102AA	£0.30
TIC116D	£0.66
TIC126D	£0.77

Triacs

ZO105DA	£0.42
TIC206D	£0.65
TIC226D	£0.94
BTA08-600B	£0.88
TIC236D	£1.12

Diac. Bi. Switch

DB3 32V	£0.20
BRY39	£1.30

Transistors

2N1613	£0.31
2N1711	£0.26
2N1893	£0.29
2N2218A	£0.28
2N2219A	£0.25
2N2222A	£0.18
2N2646	£1.12
2N2904A	£0.25
2N2905A	£0.25
2N2907A	£0.17
2N2926	£0.16
2N3053	£0.27
2N3054	£0.85
2N3055	£0.58
2N3439	£0.62
2N3440	£0.50
2N3702	£0.09
2N3703	£0.10
2N3704	£0.10
2N3705	£0.10
2N3706	£0.10
2N3771	£1.44
2N3772	£1.51
2N3773	£1.70
2N3819	£0.42
2N3820	£0.66
2N3904	£0.10
2N3905	£0.10
2N3906	£0.10
2N4036	£0.34
2N5245	£0.80
2N5296	£0.57
2N5322	£0.57
2N5401	£0.11
2N5460	£0.54
2N5551	£0.11
2N6107	£0.60
2N6491	£1.58
2SB548	£0.30
2SD1730	£1.44
AC126	£0.44
AC127	£0.50
AC128	£0.40
AC187	£0.68
AC188	£0.96
ACY17	£3.84
AD149	£1.67
AD161	£0.92
AD162	£0.92
BC107	£0.16
BC107B	£0.17
BC108	£0.14
BC108B	£0.16
BC108C	£0.15
BC109	£0.17
BC109C	£0.19
BC114	£0.19
BC115	£0.41
BC116	£0.41
BC118	£0.41
BC132	£0.36
BC134	£0.36
BC135	£0.36
BC140	£0.25
BC141	£0.27
BC142	£0.34
BC143	£0.38
BC149	£0.21
BC154	£0.36
BC157	£0.12
BC159	£0.17
BC160	£0.28
BC170	£0.16
BC170B	£0.16
BC171	£0.11
BC171B	£0.16
BC172	£0.13
BC172B	£0.13
BC177	£0.18
BC178	£0.18
BC179	£0.18
BC179A	£0.17
BC182	£0.11
BC182A	£0.11
BC182B	£0.12
BC182L	£0.08
BC182LB	£0.10
BC183	£0.08
BC183L	£0.08
BC183LB	£0.08
BC184	£0.08
BC184L	£0.08
BC186	£0.33
BC204C	£0.72
BC206B	£0.72
BC208	£0.72
BC209A	£0.72
BC212	£0.08
BC212L	£0.08
BC212LB	£0.08
BC213	£0.08
BC213B	£0.08
BC213LC	£0.08
BC214	£0.08
BC214L	£0.08
BC225	£0.15
BC237B	£0.09
BC238B	£0.09
BC238C	£0.09
BC239C	£0.10
BC250A	£0.15
BC252	£0.13
BC261B	£0.30
BC262B	£0.24
BC267B	£0.30
BC307	£0.10
BC308	£0.10
BC319C	£0.13
BC327	£0.10
BC327-25	£0.10
BC328	£0.10
BC328-16	£0.10
BC337	£0.10
BC337-25	£0.12
BC338	£0.10
BC338-25	£0.10
BC348B	£0.14
BC357	£0.25
BC393	£0.73
BC441	£0.40
BC461	£0.46
BC463	£0.29
BC478	£0.32
BC479	£0.32
BC516	£0.21
BC517	£0.17
BC527	£0.20
BC528	£0.20
BC537	£0.20
BC546B	£0.08
BC546C	£0.08
BC547B	£0.09
BC547C	£0.09
BC548C	£0.08
BC549C	£0.10
BC550C	£0.10
BC556A	£0.08
BC557B	£0.08
BC557C	£0.08
BC558B	£0.08
BC559C	£0.08
BC560A	£0.09
BC560B	£0.09
BC637	£0.21
BC638	£0.21
BC639	£0.21
BC640	£0.13
BCY70	£0.22
BCY71	£0.20
BCY72	£0.20
BD124P	£6.86
BD135	£0.21
BD136	£0.21
BD137	£0.23
BD138	£0.22
BD139	£0.25
BD140	£0.25
BD150C	£0.82
BD165	£0.42
BD166	£0.35
BD187	£0.39
BD201	£0.40
BD202	£0.70
BD203	£0.40
BD204	£0.40
BD225	£0.42
BD232	£0.50
BD237	£0.32
BD238	£0.44
BD240C	£0.37
BD243B	£0.50
BD244A	£0.53
BD244C	£0.53
BD245C	£1.18
BD246	£1.18
BD246C	£1.18
BD283	£0.61
BD284	£0.61
BD400	£0.79
BD441	£0.41
BD442	£0.37
BD534	£0.47
BD535	£0.50
BD536	£0.65
BD581	£0.62
BD597	£0.92
BD646	£0.52
BD648	£0.52
BD650	£0.58
BD707	£0.47
BD708	£1.04
BD807	£0.80
BDX32	£1.78
BDX33C	£0.56
BDX34C	£0.50
BDX53C	£0.47
BDX54C	£0.50
BF180	£0.31
BF182	£0.31
BF185	£0.58
BF194	£0.31
BF194B	£0.19
BF195	£0.19
BF244	£0.35
BF244B	£0.40
BF244C	[illegible]
BF257	[illegible]
BF259	£0.33
BF337	£0.40
BF355	£0.38
BF423	£0.13
BF451	£0.19
BF459	£0.33
BF469	£0.36
BFX29	£0.29
BFX84	£0.31
BFX85	£0.32
BFY50	£0.30
BFY51	£0.24
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BS107	£0.21
BS170	£0.23
BSW66	£1.35
BU126	£1.32
BU205	£1.41
BU208A	£1.24
BU326A	£1.40
BU500	£1.54
BU508A	£1.30
BU508D	£0.98
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BU806	£1.06
BUT11A	£0.57
BUT11AF	£1.14
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IRF530	£0.76
IRF540	£1.26
IRF740	£1.88
MJ2501	£1.60
MJ3001	£1.80
MJ11015	£2.45
MJ11016	£2.56
MJE340	£0.40
MJE350	£0.48
MPSA05	£0.14
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MPSA13	£0.12
MPSA42	£0.17
MRF475	£7.28
TIP29C	£0.31
TIP30C	£0.37
TIP31C	£0.41
TIP32C	£0.41
TIP33C	£0.72
TIP41A	£0.38
TIP42C	£0.39
TIP47	£0.48
TIP48	[illegible]
TIP50	[illegible]
TIP121	[illegible]
TIP122	[illegible]
TIP125	[illegible]
TIP127	[illegible]
TIP132	[illegible]
TIP137	[illegible]
TIP142	£1.30
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VN10KM	£0.48
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	Electrolytic Radial					**Electrolytic Axial**						
µF	16v	25v	40v	63v	100v	16v	25v	40v	63v	100v	250v	450v
0.47	—	—	—	£0.05	—	—	—	—	—	—	—	—
1.0	—	—	—	£0.05	£0.05	—	—	—	£0.13	—	—	£0.22
2.2	—	—	—	£0.05	—	—	—	—	£0.13	—	—	£0.30
4.7	—	—	£0.05	£0.05	£0.05	—	—	—	£0.13	—	—	£0.41
10	£0.05	£0.05	£0.05	£0.05	£0.09	£0.12	—	£0.12	£0.13	£0.17	£0.40	£0.51
22	£0.05	£0.05	£0.05	£0.07	£0.11	£0.12	£0.13	£0.14	£0.15	£0.21	£0.52	£1.06
33	£0.05	—	£0.05	—	—	—	—	—	—	—	—	—
47	£0.05	£0.05	£0.07	£0.10	£0.19	£0.13	£0.13	£0.15	£0.19	£0.32	£0.57	—
100	£0.06	£0.06	£0.10	£0.13	£0.26	£0.14	£0.16	£0.19	£0.26	£0.44	—	—
220	£0.08	£0.09	£0.13	£0.25	—	£0.19	£0.20	£0.27	£0.39	£0.48	—	—
330	£0.09	—	£0.19	—	—	—	—	—	—	—	—	—
470	£0.12	£0.17	£0.24	£0.33	—	£0.24	£0.28	£0.43	£0.53	—	—	—
1000	£0.15	£0.33	£0.34	—	—	£0.33	£0.43	£0.59	£1.08	—	—	—
2200	£0.27	£0.55	£0.70	—	—	£0.53	£0.66	£1.11	£1.55	—	—	—
3300	—	£0.94	—	—	—	—	—	—	—	—	—	—
4700	£0.67	£1.05	—	—	—	£0.86	£1.11	—	—	—	—	—

We carry a large range of capacitors in stock, including: Ceramic Mini Disc, Dipped Ceramic Multilayer, Dipped & Boxed Polyester, Mylar Film, Polystyrene, MKT Polyester, Tantalum Bead, Sub-miniature Radial, 105°C Radial, Low Leakage Radial, Non Polarised Radial, PCB Con Electrolytics, Polypropylene & Ceramic Trimmers and Tuning, Dilecon & O Type Variable capacitors. Full technical details available.

Resistors - Please State Value Required

per 100 of one value only

⅛W Carbon Film 5%	E12 Series	10Ω-1M0	£0.02 Each, £0.80 per 100
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Single Gang ¼" Shaft, 25mm Dia.	470Ω-2M2 Linear	£0.49 Each
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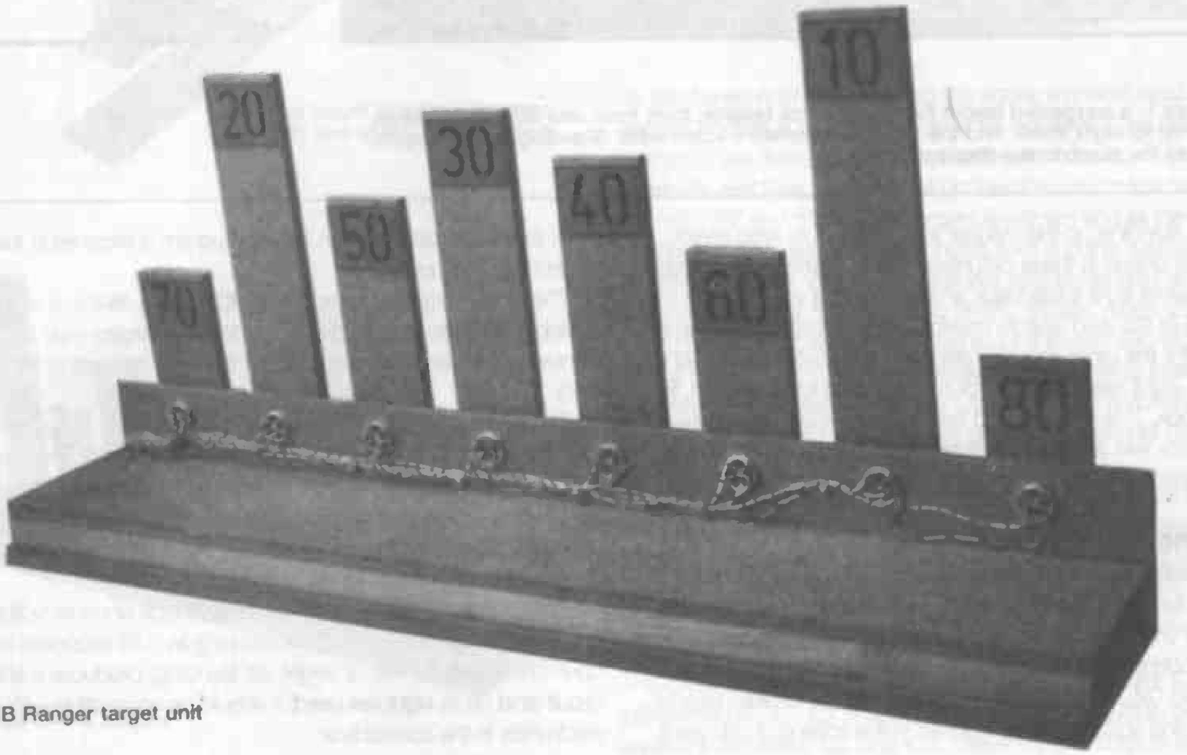
BB Ranger

This is a combination of an eprom-driven control box, a custom-built fall-down target and an LED scoreboard for BB and other lightweight pellet guns, by Bob Noyes



The BB Ranger target unit

This project was designed as an electronic scoreboard for a BB shooting range. Both of my sons have gone through the BB gun fad, starting with small, lightweight, very low power guns and working up to quite accurate pieces, some of which look similar to real guns although their plastic appearance ensures they can't easily be confused with the real things.

For target practice and in order for the boys to pit their skills against those of their friends I decided that some kind of electronic score board was required to give an instant read-out of the accumulated score. There was nothing on the market that would do so this project, BB Ranger, was born.

For those of you not familiar with BB guns, they are, in many ways, similar to air guns, using a powerful spring or puff of air, or both, to propel a small 6mm round plastic pellet - originally it was a small ball bearing, hence "BB". Unlike real guns, there is no explosive element in BB guns and licences aren't required for ownership; they are not lethal weapons although, as a precaution, eye protection should always be worn by everyone around when the guns are in use. This project is suitable for air guns as well as BBs, but air rifles are too powerful and may damage the targets.

Although a bullseye type target would have been preferable, it was not easy to construct one on which switches could be mounted to detect the score. As a convenient compromise, instead of a conventional target with the smallest ring being the highest score and the larger rings the lowest, we used separate individual fold-back targets (**figure 1**). There are eight targets, with scores ranging from 10 to 80 points. It goes without saying that the smaller ones carry higher scores. In the prototype, the 80-points score target measured 25mm high by 63.5mm wide; 70 points, 51mm by 63.5mm, each target thereafter being 25mm taller than the one before but scoring 10 points less, until the 10-points target, which was 203mm high. These eight targets were mounted in a straight line, but you can choose whether to mount them in ascending order, or all mixed up with a gap of about 38mm between each one. As can be seen **in figure 2**, they are mounted in such a way that, when hit, they fall backwards.

Out of sight behind the body of the assembly, a magnet is mounted in each of the targets. The type used was a door switch like those used in alarm systems - it is readily available and easy to mount, as a flange with countersunk holes is built into the magnet and the reed switches.

The magnet is mounted into the fall-back part of the target, and the reed switch into the body of the target assembly, so that when

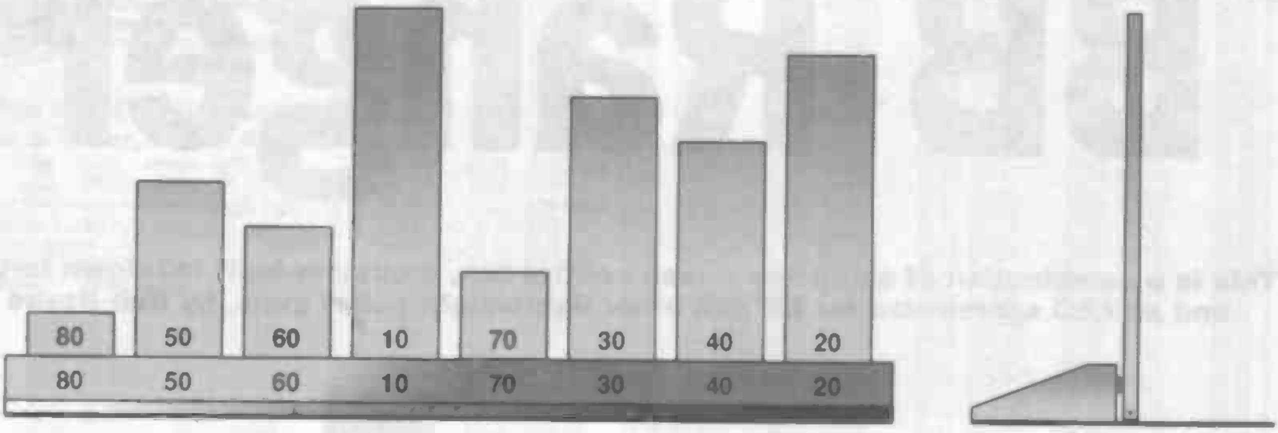


Figure 1: a suggested layout for the fall-back targets, from front and side. Each player has up to eight shots, and the highest cumulative score wins. Standing up the targets resets the score in the display.

the target is standing up the magnet is in range of its reed switch. The switch is closed in these circumstances but when the exposed part of the target is hit it falls back and the magnet mounted on it is out of range of the reed switch, making an open circuit. The same is repeated for the other seven targets. A 9-way cable was used to connect the eight reed switches, plus a common to all of them, to the control box. This cable should be several metres long to keep the control box well away from the target area. A plug and socket was used to connect the cable to the control box.

Board and paint

You don't have to construct eight fold-back targets if you don't want to. So long as the ones used score in the range 10, 20, 30, 40, 50, 60, 70 and 80 the circuit will work, although wire links must be used to connect the unused connections permanently from the control box to 0V. This just kids the control that the unused targets are still standing and don't play any part in the scoring. If you want more than eight targets, then a new program is required in the control box. See below.

The whole target is made out of MDF board as this is readily available and reasonably priced. The finished targets may be painted or varnished to protect them from the ravages of time (and kids).

The exposed parts of the target were covered in sticky-backed foam, the sort of stuff that pipes can be covered with. This absorbs the impact of the pellet hitting the target and helps prevent it rebounding to the firing position. The front of the body of the target assembly slopes back, again to deflect the pellet. This surface is used to show the score for each target.

This Ranger project is just one possible type of construction. Any similar type may be built, and so long as a hit produces an open circuit and a miss, or target still standing, produces a short circuit (and up to eight are used) it should be compatible with the electronics in the control box.

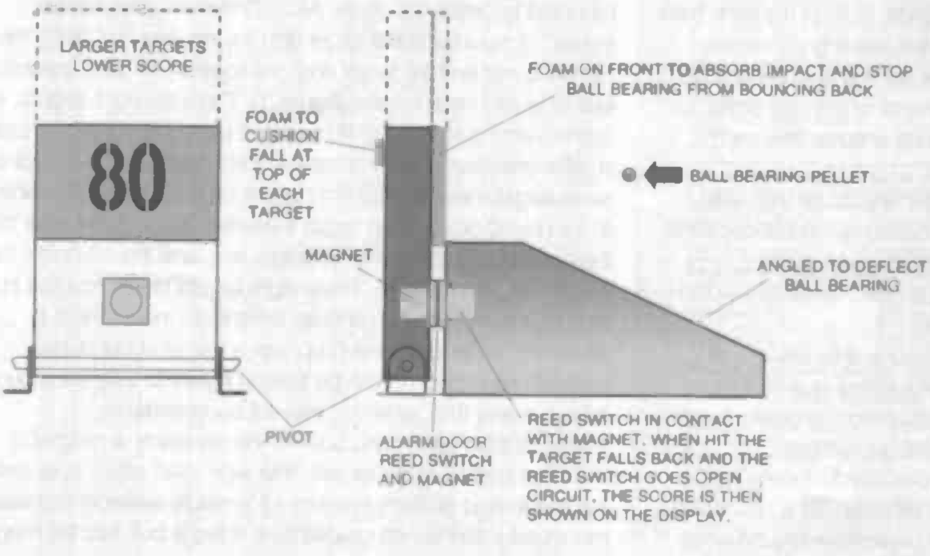


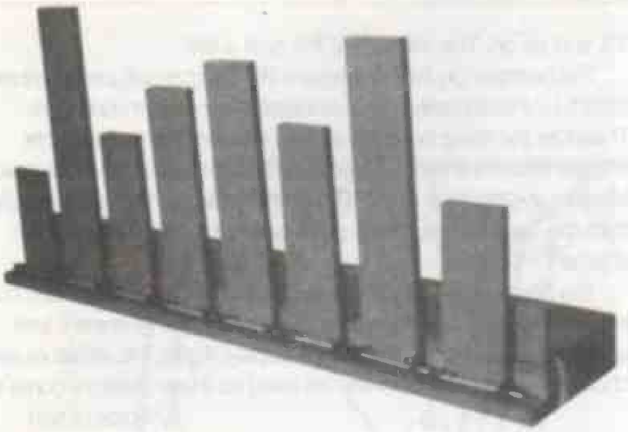
Figure 2: how the fall-back target was constructed

A very large cardboard cover was made to go over the target assembly in order to trap the pellets so they could be used again. The original was well over a metre long, 53cms high and 53cms deep, which allowed enough room to reset the targets, that is, to stand them up again. It also retained about 95 percent of the pellets used. The inside of the box was covered with canvas from an old tent to stop the pellets embedding themselves into the soft cardboard. I used wallpaper paste to stick the canvas to the cardboard. To reset the display, just stand up all the fallen targets and it will read zero.

The 2716 eprom

At the heart of the control PCB is an eprom or erasable programmable read only memory. The one used is the 2716, which is the smallest in the 27xx range

The target unit from the rear, with two of the targets down



The rear of the targets

of eproms, and can be picked up very cheaply as surplus stock. Larger memories such as 2732 and 2764 can be used so long as their control signals and extra address lines are catered for. However, the PCB in this project is designed for the 2716 only. **(See figure 3.)**

For some reason, eproms are often considered only as a part of a computer system containing software for the operating system, but it is just another component with a specification. In this case we are using its memory, even when the power is removed, to hold every combination of score from the eight targets. There is a total of 256 combinations of score from all targets up, that is, no score or zero to all eight targets down and a score of 36 points. The eight inputs from the targets' reed switches go to the 8 lowest address lines of the eprom, that is, the "10" goes to A0 (note A0 not A1), "20" goes to A1, "30" to A2 and so on. The remaining address lines, A8, A9 and A10 are connected to zero. If a larger 2732 is used, A11 must also be grounded. Now every combination of score sets its own address, i.e. with the "10" and "20" and "30" down but all the others up the address is as follows:

A7	A6	A5	A4	A3	A2	A1	A0
0	0	0	0	0	0	0	0

At this address a score of "6" is stored in the memory; this takes the form of D0, D1, D2, D3 which holds the tens or next most significant decade:

D0	D1	D2	D3
1	2	4	8

so data stored is:

D0	D1	D2	D3
0	1	1	0

and D4, D5, D6 and D7 hold the most significant decade:

D4	D5	D6	D7
1	2	4	8

As can be seen when adding up the score, the least significant decade or units is always zero, so does not have to be held in memory. Only the most significant and next most significant, or hundreds and tens, must be held in memory. So, in the case where the "10, "20" and "30" points targets are down and all the others are up, the most significant digit holds zero and the next most significant holds 6. With the permanent zero in the least significant decade, a score of "60" will show on the display. When you buy the 2716 eprom, it will either be blank, or, if it has been reclaimed from a circuit, it will contain a useless program. In that case the old program must be removed with a UV eraser. The eprom is usually exposed to UV light for 10 minutes or so, which should blank the eprom's memory.

The program for this project can then be loaded in via an eprom programmer, or a ready-programmed 2716 can be obtained ready me, for £16 including postage and packing (see the end of this article). The program is listed in **figure 4.**

The circuits

The circuit diagram of the BB Ranger appears in **figure 5.** The information in D0 - D7 is decoded by two 4511 BCD to seven-segment decoders, IC2 and IC3. These ics give outputs suitable for switching on the separate elements in the seven-segment LED displays. If only a small readout is required, DIL1 and DIL2 supply the current limiting resistors required for the two decades of common cathode displays. The third least significant decade display is wired so that all segments but the "g" segment are on, so that it reads zero. This takes the form of 6 x 270n resistors from each segment: a, b, c, d, e and f connected to +5V, and the common connected to 0V. Any small seven-segment common cathode displays will do, but they all have different pin outs. The pin

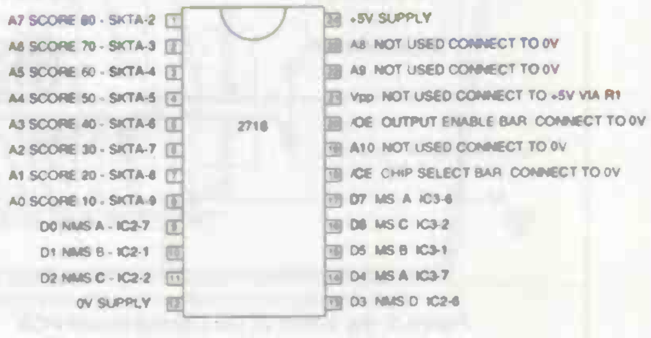
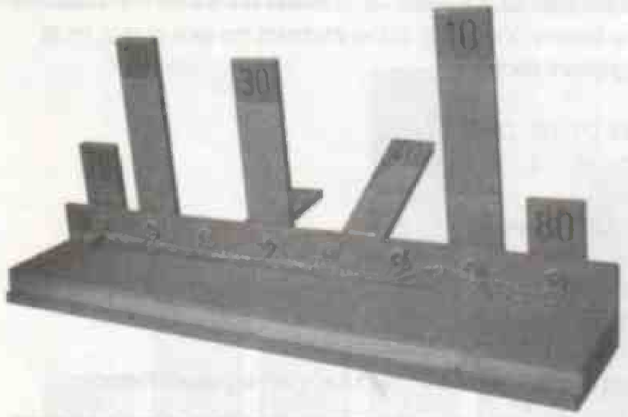


Figure 3: the 2716 eprom pin-outs



The target unit from the front, with two of the targets falling

out must be obtained for the ones used, and the common connected to 0V. The problem with these small LED displays is that they have a very limited readability range. To see the display from several metres away, larger displays are required.

As can be seen from the PCB layout in **figure 6**, although it is supplied with 12 volts, the circuit works from 5 volts via the on-board 104 regulator, which must be compatible with the eprom. 5 volts presents a problem with larger displays, as it only allows two round 5mm LEDs to be wired in series as each drops around 2.2 volts. In order to build up a larger display, 4 x 5mm LEDs are used to make each segment of the three seven-segment displays. Having four LEDs in series, each dropping around 2.2 volts, requires a supply in excess of 10 volts to allow for the LEDs plus the darlington voltage drop, and so on. To switch each of these segments on, DIL power darlingtons are used, one for each active decade: the most significant or hundreds decade and the middle display or tens decade. The units decade is again permanently wired to read zero. If you are going to build a larger display, DIL1 and DIL2 can be linked across, that is, pin 1 to pin 14, pin 2 to pin 13, and so on. This will reduce the cost a little.

TENS & HUNDREDS	UNITS 0	1	2	3	4	5	6	7	8	9
0	0	1	2	3	3	4	5	6	4	5
1	6	7	7	8	9	10	5	6	7	8
2	8	9	10	11	9	10	11	12	12	13
3	14	15	6	7	8	9	9	10	11	12
4	10	11	12	13	13	14	15	16	11	12
5	13	14	14	15	16	17	15	16	17	18
6	18	19	20	21	7	8	9	10	10	11
7	12	13	11	12	13	14	14	15	16	17
8	12	13	14	15	15	16	17	18	16	17
9	18	19	19	20	21	22	13	14	15	16
10	16	17	18	19	17	18	19	20	20	21
11	22	23	18	19	20	21	21	22	23	24
12	22	23	24	25	25	26	27	28	08	09
13	10	11	11	12	13	14	12	13	14	15
14	15	16	17	18	13	14	15	16	16	17
15	18	19	17	18	19	20	20	21	22	23
16	14	15	16	17	17	18	19	20	18	19
17	20	21	21	22	23	24	19	20	21	22
18	22	23	24	25	23	24	25	26	26	27
19	28	29	15	16	17	18	18	19	20	21
20	19	20	21	22	22	23	24	25	20	21
21	22	23	23	24	25	26	24	25	26	27
22	27	28	29	30	21	22	23	24	24	25
23	26	27	25	26	27	28	28	29	30	31
24	26	27	28	29	29	30	31	32	30	31
25	32	33	33	34	35	36	-	-	-	-

Figure 4: the BB Ranger eprom program 0 - 255 for the 2716 eprom

The heatsink on the prototype is RS (Electromail) part number 263251. Unfortunately, this is not available in single quantities. Therefore the fitting holes have been left undrilled so that other suitable heatsinks can be used. The heatsink must have solderable tabs, to give support to the IC. Drill the holes for the tabs carefully from the copper side, taking great care not to cut through the adjacent PCB track.

The power darlington ics are ULN and 2003A. These have built in base resistors, but 100n resistors are required to current limit each of the segments of the large display. Again, DIL resistors were chosen. Here, 16-pin sockets are used as these resistors come in a choice of two packages: although the circuit only required the 14-pin package, the 16-pin package will also fit. Care must be taken when wiring up the display PCB to the control PCB, because although they share a common 0V, their power supplies are different. The +12 volts of the display board must not be connected to the +5V on the control PCB. A table of the control board connections follows:

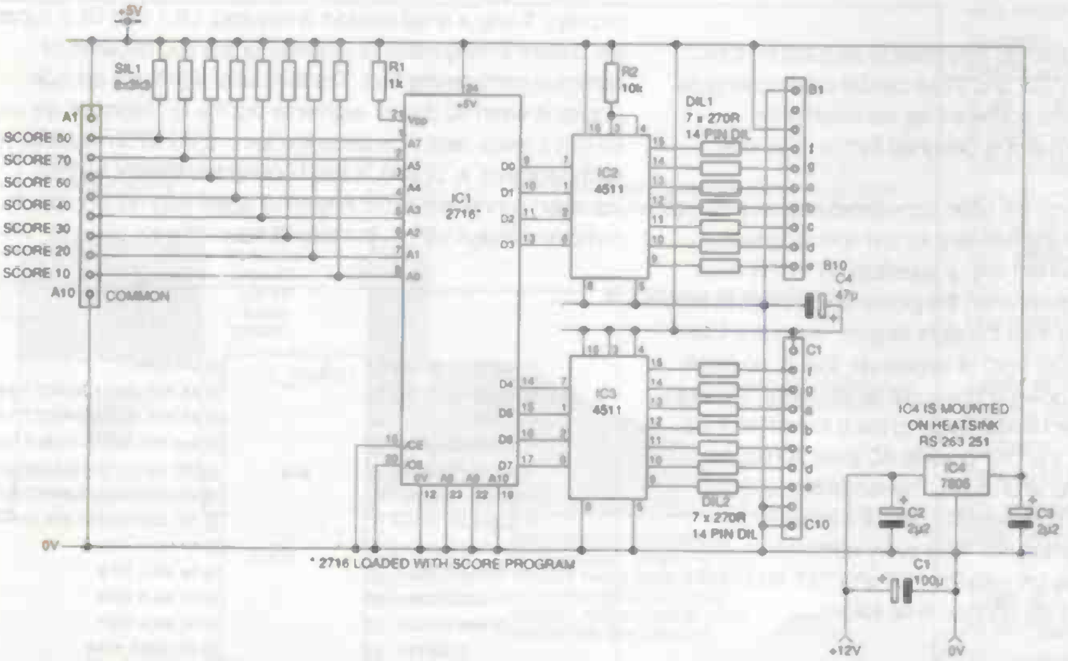


Figure 5: the circuit of the Control Board PCB

A Inputs
To targets
1 +5V
2 Score 8
3 Score 7

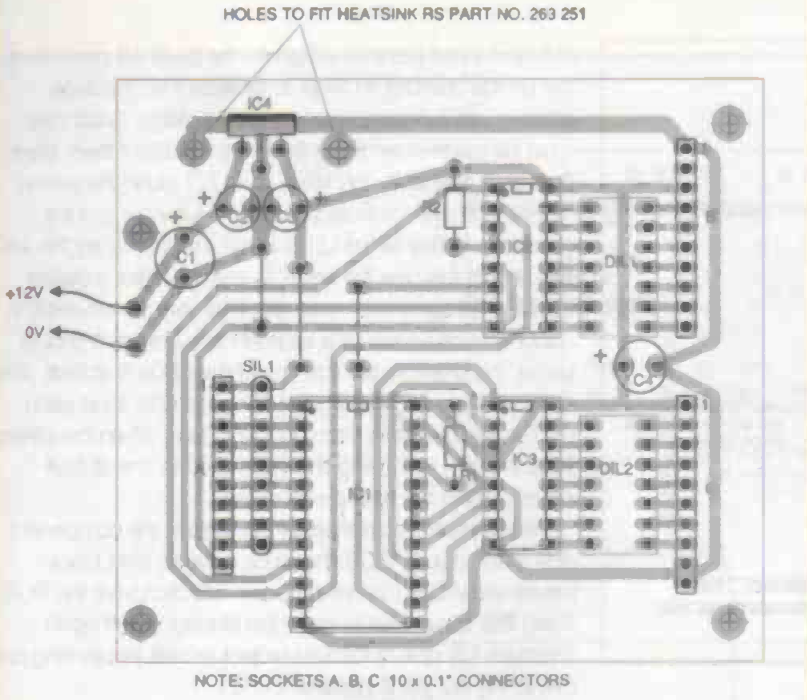


Figure 6: the component layout of the Control Board PCB

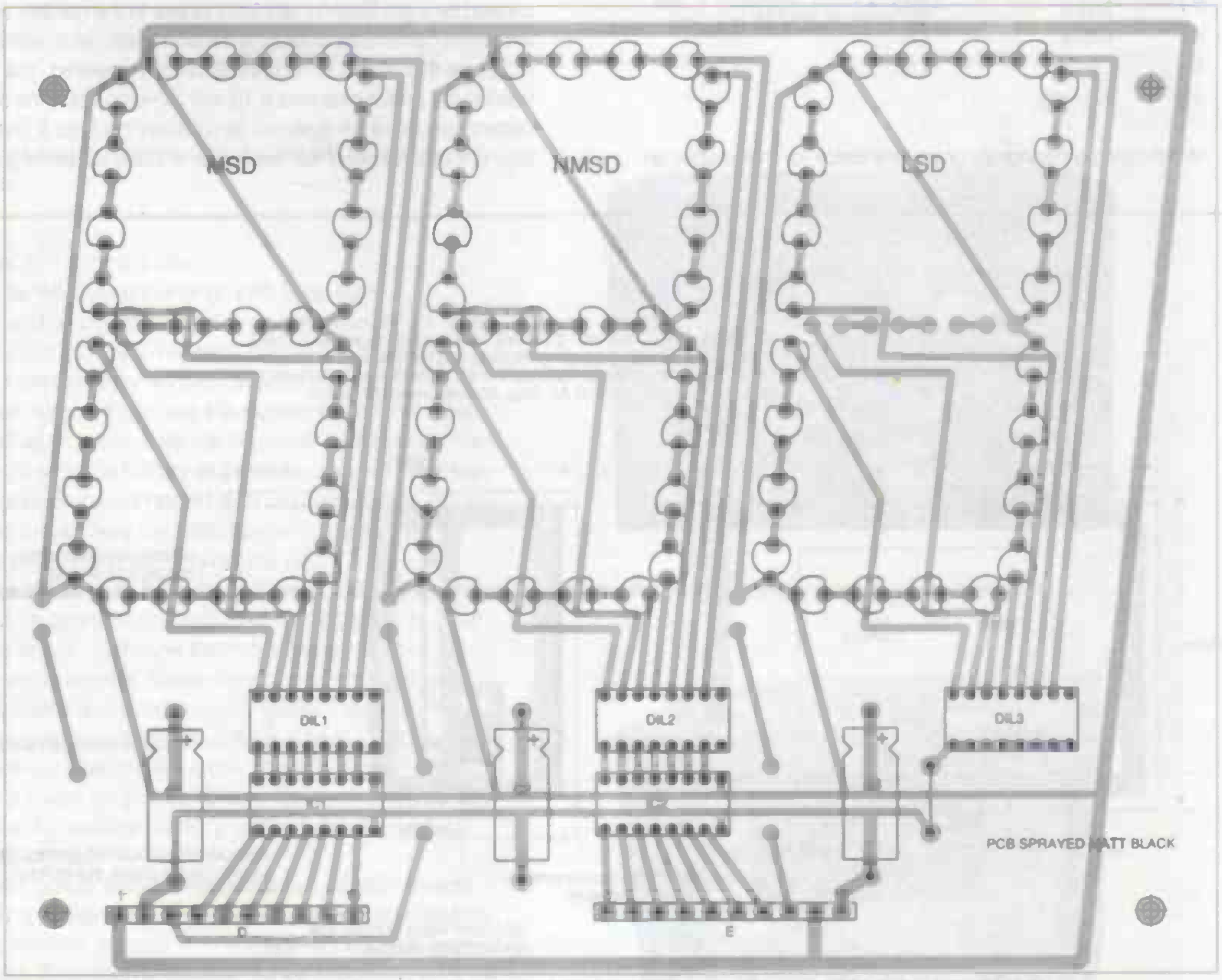
4	Score 6	
5	Score 5	
6	Score 4	
7	Score 3	
8	Score 2	
9	Score 1	
10	0V common	

Outputs
To large display

B	Function	To
1	0V	E10
2	Keyway	
3	+5V	
4	NMS f	E5
5	NMS g	E2
6	NMS a	E7
7	NMS b	E6
8	NMS c	E4
9	NMS d	E3
10	NMS e	D2

Outputs
To large display

C	Function	To



SOCKETS D AND E ARE 10-WAY 0.156" RIGHT-ANGLE PCB HEADERS   DIL 1, 2 AND 3 ARE 14 OR 16-PIN. ONLY 14-PIN REQUIRED FOR 100R RESISTORS.

Figure 7: the layout of the Display Board. The centre bar is not required in the lowest significant digit, as it always shows 0. 80 identical 0.2-in LEDs are used

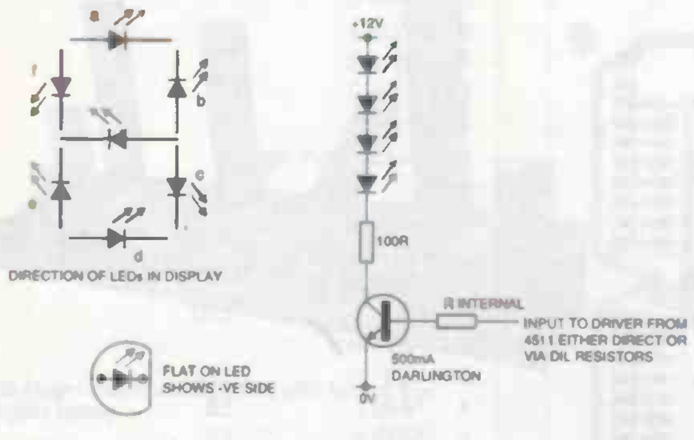


Figure 8: connecting up the LEDs for the Display Board. The lowest significant digit has the bottom of 100R grounded, as this always reads 0

1	+5V	
2	MS f	D8
3	MS g	D5
4	MS a	D10
5	MS b	D9
6	MS c	D7
7	MS d	D6
8	MS e	D4
9	0V	D2
10	Keyway	

When using a darlington, or any transistor for that matter, an inversion takes place as a high on the base will produce a low on the collector. In order to facilitate this, the large displays use a common anode configuration. Great care must be taken when fitting the LEDs - all 80 of them **(see figures 7 and 8).** It only takes one LED round the wrong way to stop the whole segment from illuminating. It's a good idea to buy all the LEDs at the same time, as this will ensure that they are the same type; it will make a clearer display than using odd ones, as LEDs vary considerably in colour and brightness. If a segment is out when it should be on, the chances are that one of the LEDs is at fault. The easiest way to find out which LED is out is to short each LED on the offending segment out in turn. When the others illuminate, the one being shorted out is the one at fault - either dead or the wrong way round.

To enhance the contrast of the display, the component side of the display PCB should be sprayed matt black before assembly; this prevents any reflection from the PCB. A red filter is required to cover the display, which again improves the look of the final project as well as blanking out everything but the illuminated LEDs.

The battery supply

The power supply to the display must be capable of producing in excess of 500mA, so a rechargeable battery is a must. Because this project can only be safely used out of doors, **it must not be mains powered for obvious reasons.** Too many accidents are caused by the misuse of electrical power in the garden, from excessive dampness to faulty extension leads, so to eliminate these problems this project is completely battery powered. The battery used in the prototypes was a 12-volt 2.3-amp hour, the sort of battery used in alarm systems as a battery backup. It goes without saying that it will need recharging, so a fused socket is provided for

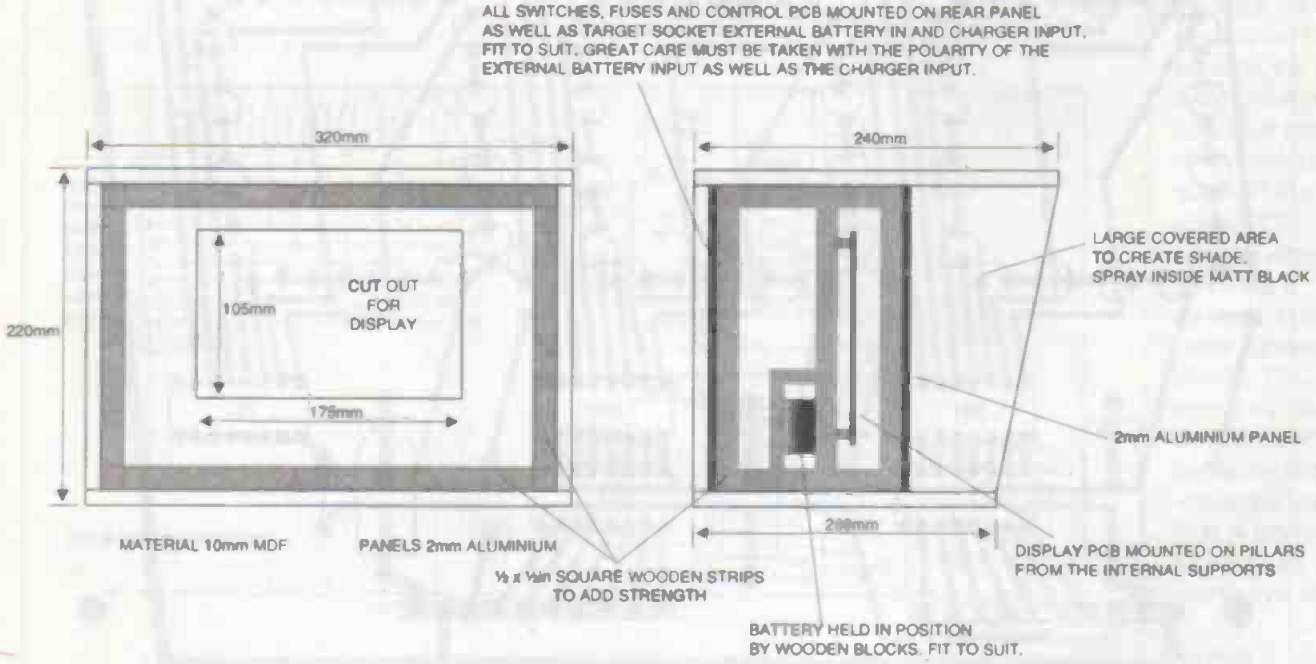


Figure 9: the structure of the Ranger control box

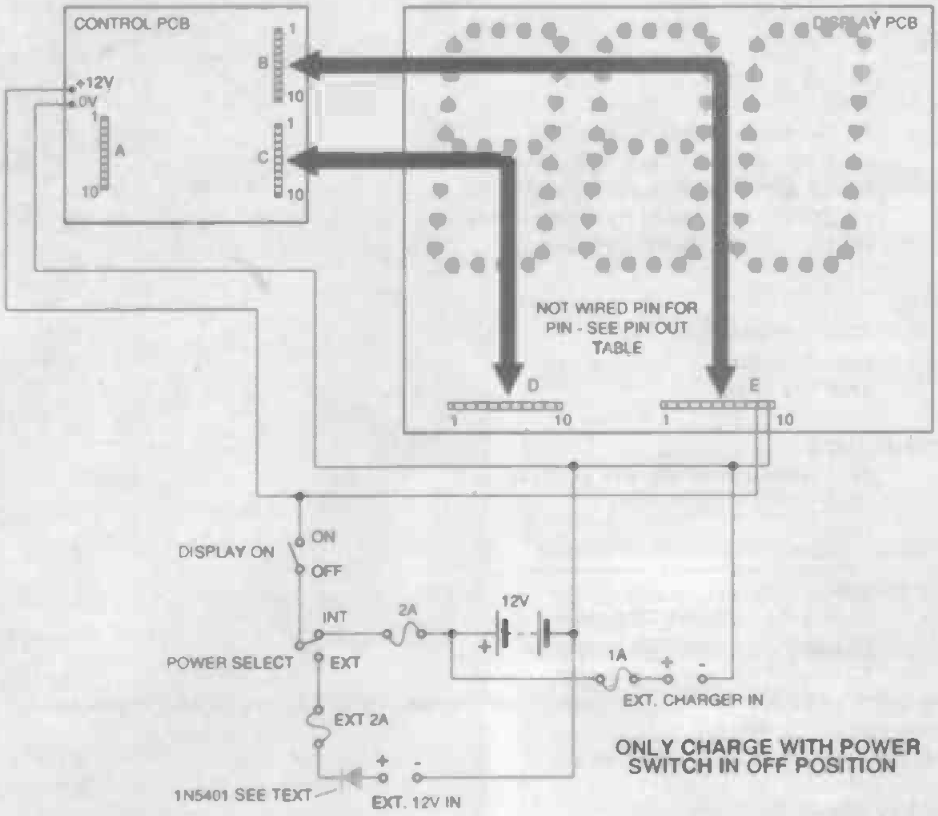


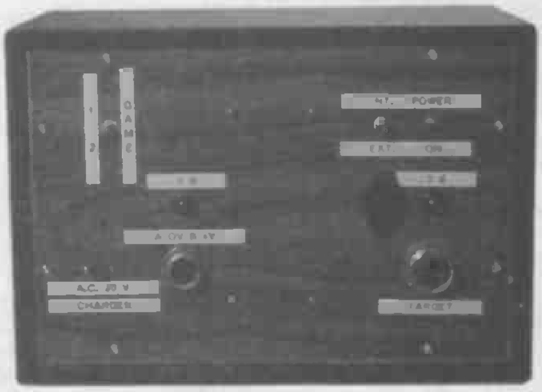
Figure 10: the external connections for the BB Ranger system

this on the rear of the control box.

The batteries will differ depending upon type, style, manufacturer and so on, so no precise charging currents or times can be given. Manufacturers' information must be followed. Although the internal battery will provide several hours of continuous use, for prolonged use it is recommended that a car battery is used as an external source of power. This must be fused at 2 amps as close to the battery as possible, using an inline fuse holder. If it is going to be connected by a plug and socket, the lead from the battery must have shrouded female contacts. This eliminates the possibility of shorting out the pins.

A selector switch should be used to make sure that this external battery cannot be connected across the internal battery, as great damage may result. Only one battery source can be selected at any one time. Great care must be taken to ensure the polarity is correct, as, although fuses are fitted, a lot of damage can result before a fuse blows. A diode can be fitted in series; this must be the 1N5401 type. Although it will add a 0.7-volt drop, this should be compensated by the fact that a 12-volt car battery, when fully charged, is well above 12 volts.

The control box is also constructed out of MDF board (**figure 9**). The design should include a lip over the display to provide a shaded area so that the display can be seen in bright daylight. The size of the box is not important so long as it is large enough to contain all the parts: the main control PCB, the large display and the battery. Again, only recommendations are given as the type of battery and other details will differ from one to another. The power set-up for



The control box from the rear, showing connections

The control box from the front, showing the score display

PARTS LIST for the BB Ranger

The Control Board

Resistors

R1	1k
R2	10k
SIL1	8 x 3k3 single-in-line resistor unit
DIL1	7 x 270R 14-pin dual in line resistor unit OR 7 x 270R one-third watt resistors
DIL2	7 x 270R 14-pin dual in line resistor unit OR 7 x 270R one-third watt resistors

Capacitors

C1	100uF 16V radial
C2, C3	2u2 16V radial
C4	47uF 16V radial

Semiconductors

IC1	2716 programmed eprom - see text
IC2, IC3	4511
IC4	7805

Miscellaneous

SKTA	10-way 0.1 vertical PCB header
SKTB	10-way 0.1 vertical PCB header
SKTC	10-way 0.1 vertical PCB header

The heatsink on the prototype was RS (Electromail) part number 263251. Other suitable heatsinks can be used if holes are drilled - see text.

Suitable casing (see text); link wire, solder, etc.

The Display Board

Resistors

DIL1, 2, 3 14- or 16-pin 100R dual in line resistor units of 7 or 8 100R resistors. Only 14 pins are required, but 16 pins will fit.

Capacitors

C1,C2,C3	100uF 16V

Semiconductors

IC1, IC2	ULN 2003A

LEDs: 80 x 0.2-in red LEDs: all the same type to make an even display

Miscellaneous

Sockets D, E: 10-way 0.156 right-angled PCB headers

Matt black paint for PCB and pellet-retaining cowling.

Wire, solder, etc.

The Target

10-mm MDF board for construction; door-alarm type reed switch and magnet combinations for each fall-back target; 8-way cable to connect reed switches; small pivots for individual fall-back targets; sticky-backed foam strip (see text); insulated connection wire; strong cardboard to make pellet-retaining cowling.

Batteries

Internal or external rechargeable battery source. Fuses, fused socket, selector switch etc. as appropriate for batteries (see text).

the Ranger is shown in **figure 10.**

Since the original was built a couple of years ago, the control box has found other uses. One, for instance, was used in a Roll the Ball game at a fete where light-dependent cells were used under holes in the game. When a ball lodged in the hole, it shut out the light to the LDR and a score was registered on the display. Again, there were eight holes with scores 10 - 80; the object was to roll five balls down a short runway and get them to lodge in the various holes, the winner to score 210 points and win a prize.

For a pre-programmed 2716 send a cheque or postal order for £16 to me, Bob Noyes, 13 Bowfell Close, Tilehurst, Reading RG31 6QR.

Blank 2716 eproms from Farnell Electronic Components: Canal Road, Leeds, LS12 2TU. Tel 0113 263 6311 or other sources. Second user ICs are often available as salvage from Greenweld Electronic Components Tel. 01703 236363.

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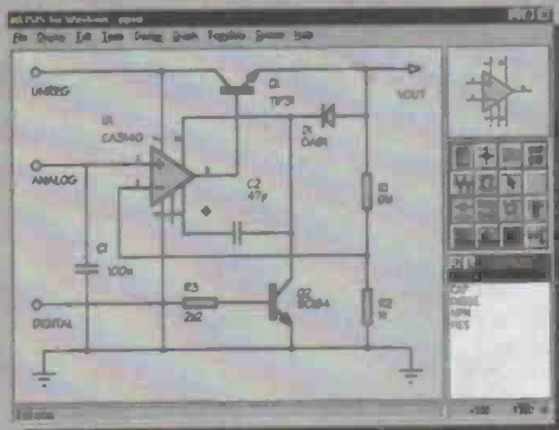

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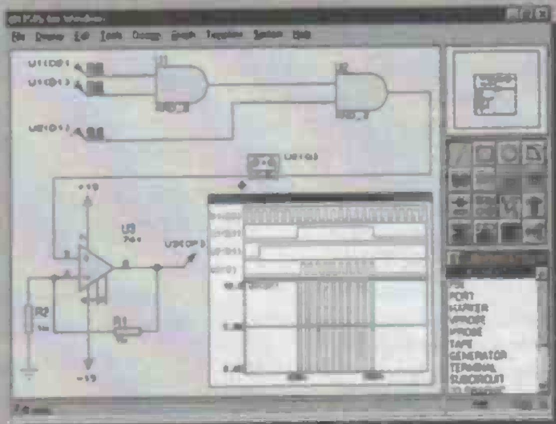

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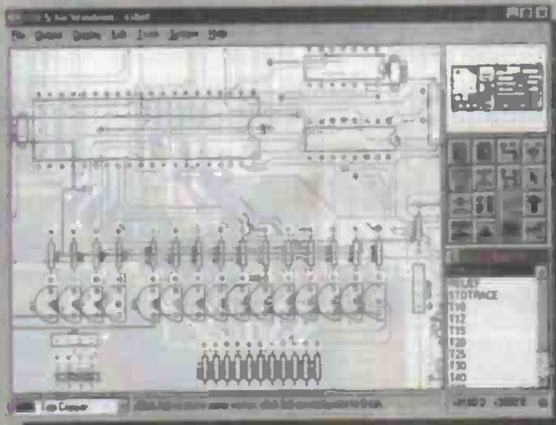

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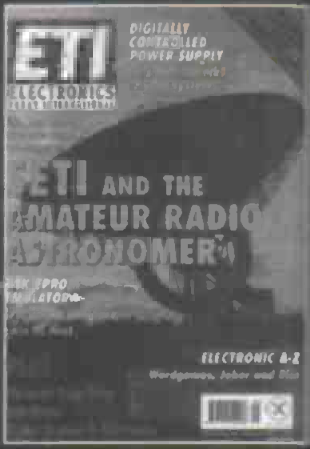

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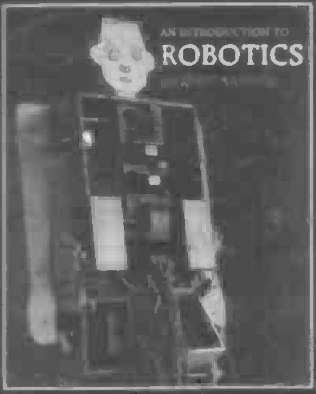

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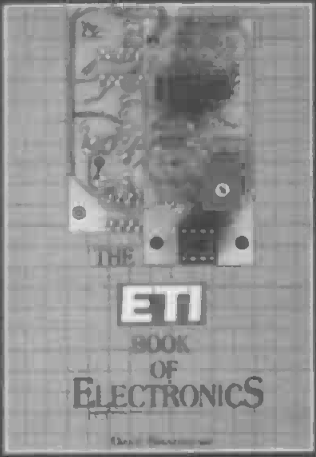

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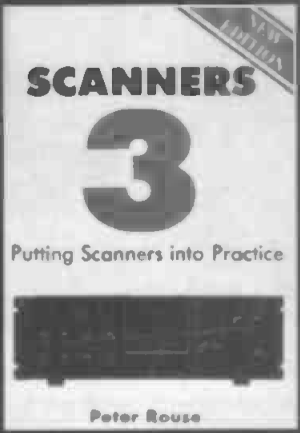

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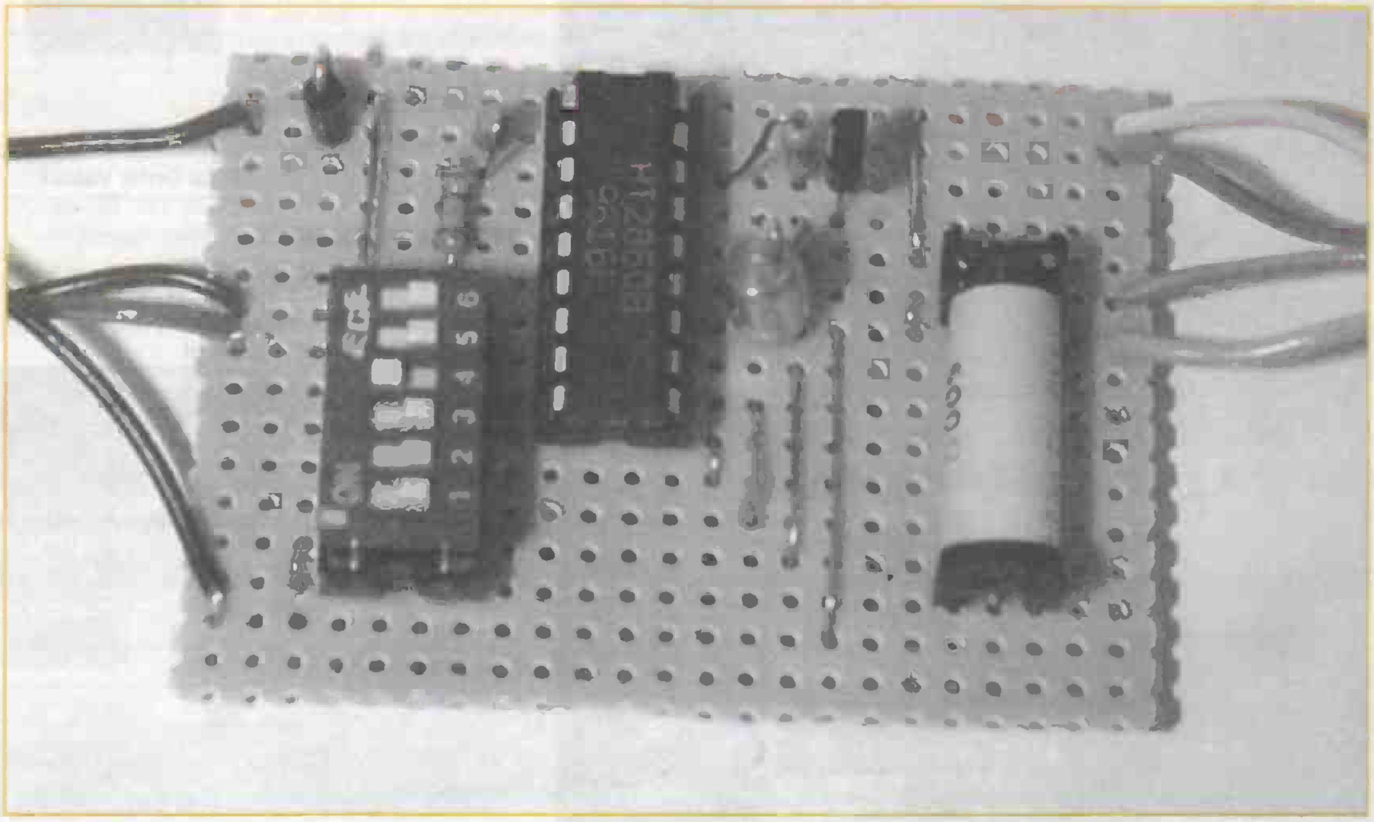
GCSE Grounding

Sound Effects Module

Terry Balbirnie continues a series of adaptable circuits for GCSE projects with a module based on the HT2860, a three-oscillator sound effect chip



B In this series we are describing some electronic modules which could be useful to students of GCSE Technology or similar courses at school or college. The circuits may be used in whole or in part for practical projects. All circuits have the potential for further investigative work built in, which could be useful for the more adventurous student. But you can use the circuits as they stand or with only "cosmetic" modifications.

All the designs are laid out on Veroboard. This has the advantage of being similar in layout to the circuit diagram. Some students find PCB layouts difficult to relate to the circuit diagram. Such details as exactly what the circuit is to be used for and how it will be housed are left to the constructor.

Just for effect

The circuit this month is a Sound Effects Module. This will provide a effects of four alarms plus a horn and an ambulance sound, and the effect is determined by the setting of a set of miniature switches on the circuit panel. An external push-button or other type of switch is then used to activate the circuit and the sound will be given as long as it is operated. Alternatively, the unit can be operated by some other circuit or system using a reed relay to provide isolation between the parts. In this way, no particular care need be taken to make the two sections "match" - for example, if the two circuits use different supply voltages. Any source of between 5 and 12V and capable of giving 10 to 20 milliamps will be sufficient to drive the coil of the reed relay and hence operate the new circuit.

The Sound Effects Module may be made into part of a toy or a game. It could be used to provide a different sound with each aspect of the game, or for different functions of a toy. It

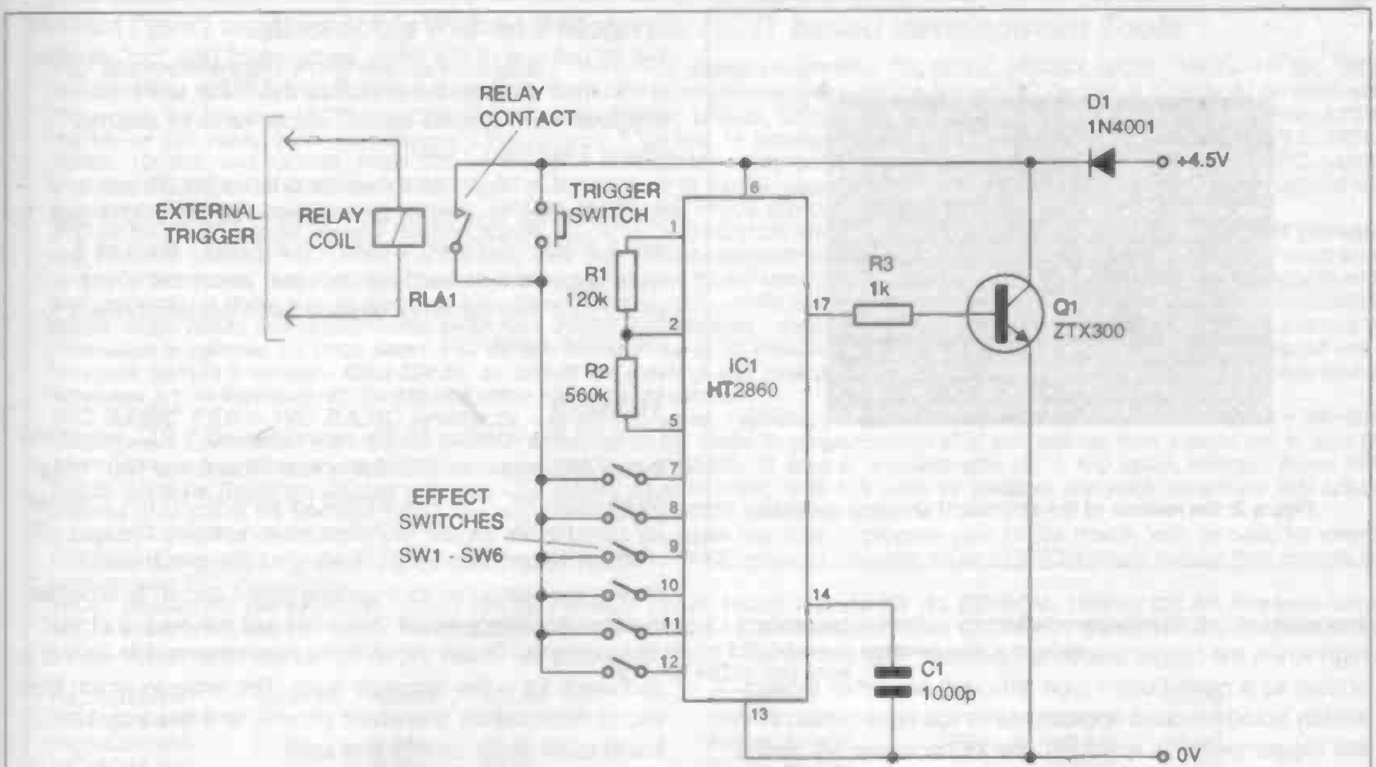


Figure 1: the circuit of the Sound Effects Module

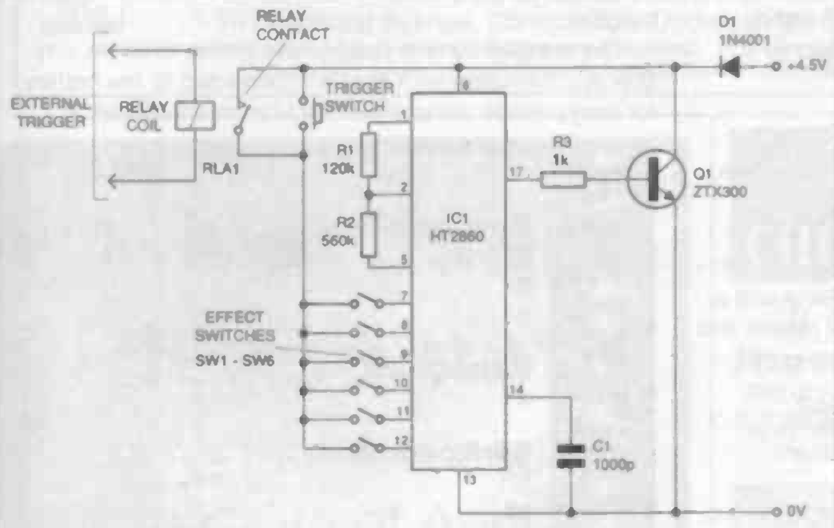


Figure 2: the stripboard layout of the Sound Effects Module

may be that, once the sounds have been heard, a little imagination could be used. They could be called "laser gun" or "phaser missile" for example! By adding a suitable amplifier, the module could be used as the basis for a burglar alarm system or another high-powered warning device.

Circuit description

The circuit for the Sound Effects Module is shown in figure 1. The circuit requires a supply voltage between 3V and 4.5V. Here, it is provided by three "AA" size alkaline cells in a suitable holder, giving a nominal 4.5V. Diode D1 provides protection to the circuit should the battery be connected in the wrong polarity, since then it would not conduct and no current would flow. In fact, the voltage applied to the circuit is only 3.8V or thereabouts due to the forward voltage drop of this diode.

The circuit centres on IC1, which is a sound effects chip. The effects are pre-programmed into it, so very few additional components are needed to make a working system. The quality of the sounds are controlled by three built-in oscillators (referred to as OSC 1, 2 and 3) and these require two external resistors and one capacitor to make them work. R1 is connected between pin 1 (OSC2) and pin 2 (OSC 1). The other resistor, R2, is connected between pin 2 and pin 5 (OSC3). The capacitor is connected between pins 13 (the 0V "negative" supply input) and 14. Pin 4 could be used to operate an LED while the system is working, but there did not seem to be any point in using it. In addition, the ic has several "test" pins (3, 15, and 16) and, again, these are not used. The positive of the supply (connected via diode D1) is applied to pin 6. The output signal is provided between pin 17 and the 0V line but it can only give a small current. Some students might like to try a piezo transducer connected to these pins direct. However, most people will wish to use a small loudspeaker. This needs a simple amplifier to provide sufficient current to operate it. This is the purpose of transistor Q1. Current from pin 17 enters its base via current-limiting resistor R3. The much larger collector current then flows through the speaker. Note that the speaker must be of the high impedance type as specified. Do not use an 8-ohm speaker which is the most common type. Note that, even with the amplifier, the sound will not be very loud but should be sufficient for many purposes.

The required effect is obtained by making one of the "effect pins" 7, 8, 9, 10, 11, or 12 high (that is, connecting it to supply positive). This is achieved by pre-selecting it using one of the miniature switches, SW1 to SW6 ("effect switches"). These switches are in a plastic case exactly the same shape as an

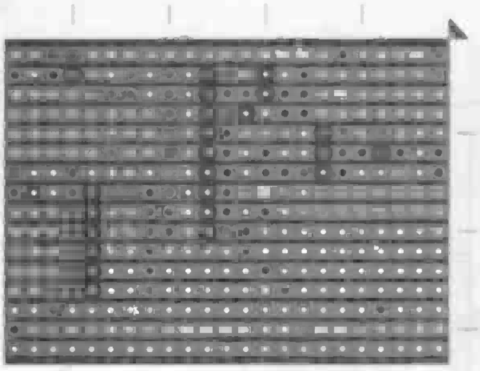


Figure 3: the reverse of the stripboard showing cut-outs

integrated circuit. The required effect pin will then be made high when the trigger switch is operated. This switch is shown as a push-button type although any other type of switch could be used appropriate to the application. When the trigger switch is actuated, the loudspeaker will sound with the desired effect. Some students will wish to provide individual connections to the effect pins so that different switches can be used to give the various effects.

The alternative triggering method is via the "make" contacts of reed relay, RLA1. Its "make" (normally-open) contacts, connected in parallel with the "trigger" switch works in the same way. Its coil could be energised by a signal from another circuit as described earlier.

Construction

If the circuit is going to be triggered by an external switch, there is no point in including RLA1. Use this only if the circuit is to be operated by some other system.

The topside stripboard layout (component side view) is shown in figure 2. There are several inter-strip links and a number of track breaks needed. Make the track breaks first then solder the link wires in place. If the circuit does not work at the end, it is almost certainly due to a strip not being properly broken, a break or link wire being left out or a blob of solder or sliver of copper bridging adjacent copper tracks - you have been warned!

Solder the ic sockets (one for IC1 and one for the effect switches) and all other components in position. The switches could be soldered to the PCB direct but it is better to use a 12-pin dil socket for them. This size of socket is not readily available. However, it is an easy matter to file a 14-pin unit to size. Alternatively, a 14-pin socket could be simply soldered to the PCB with the extra two pins at the bottom left unused as shown in the photograph. The reason for using an ic socket for the effect switches is because all strips to the left-hand side of them are connected together using a piece of bare copper wire on the copper strip side of the circuit panel. While soldering this wire, considerable heat will be generated and this could damage the switches. Using an ic socket disperses the heat and avoids any likely damage. When soldering this wire, make sure it does not touch anything else and cause a short circuit. Take care to mount diode D1 and the transistor with the correct orientation. Solder the PP3-type battery connector to the "+4.5V and the "0V" points.

Solder short pieces of wire to the trigger ("trigg") positions. Set all but one of the effect switches off (the "on" direction is clearly shown on the switch body). If the unit is to be triggered from another circuit, solder wires to external trigger ("ext trigg") points.

Insert IC1 taking care over its orientation. This is a CMOS device and could be damaged by static charges. To avoid problems, touch something earthed - such as a water tap - before handling the pins. Insert the effect switches if they have not already been soldered direct to the circuit panel.

Testing

Connect the speaker to the wires marked "LS1". Insert the three "AA" size cells into the holder. Touch the two "trigg" wires together. A sound should be emitted by the speaker. Try using other trigger switches while keeping the rest off.

There is an interesting property of the circuit which shows itself when more than one effect switch is on when the circuit is triggered. If this is tried, it will be found that the effects for which the switches are responsible sound in sequence for a few seconds each. The order in which they sound depends on an in-built priority, and this may be found quite easily by trial and error.

More adventurous candidates may wish to try increasing the volume emitted by the speaker by splitting the supply into 4.5V to the actual circuit and a higher voltage for the transistor section. It would also be possible to add an integrated circuit power amplifier or to use an external amplifier.

The standby current requirement of this circuit is only 8uA approximately so it may be connected to the battery for long periods without the need for an on-off switch.

PARTS LIST for the Sound Effects Module

Resistors

R1	120k
R2	560k
R3	1k

Capacitors

C1	1000pF

Semiconductors

IC1	HT2860
D1	1N4001

Miscellaneous

SW1-6	Set of six SPST sub-miniature PCB-mounting switches
LS1	Miniature 60 - 70 ohm loudspeaker
RLA1	Reed relay with SPST contacts and 5V 500 ohm coil - if required (see text)

0.1 in matrix stripboard; holder for three "AA" cells and alkaline cells to fit; PP3-type battery connector; 18-pin dil socket; socket for PCB-mounting switches if required - see text.

IC1 and all other components are available from Maplin. The reed relay is order code JH12N.

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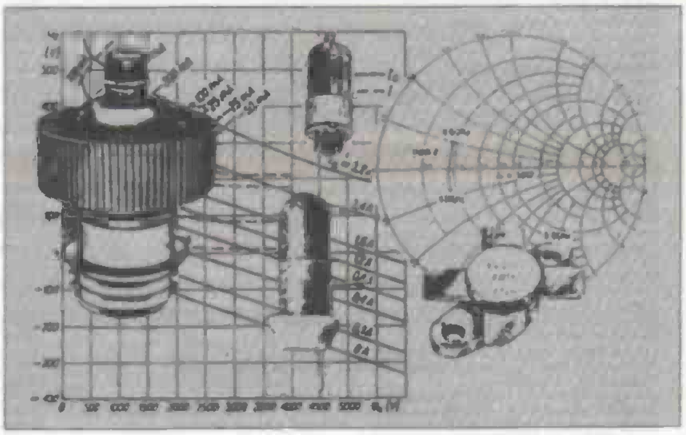

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The Orphan Decibel

Power variations are better represented in a logarithmic rather than a linear manner. This is accomplished by the use of the decibel - but what is a decibel?

By E.Chicken MBE FIEE

"Decibel" clearly means one tenth of a bel, but have you wondered why one never hears of a "bel", or for that matter a millibel, megabel or kilobel? Well, the truth is that they do not exist. This is not quite the truth, perhaps, because in theory the "bel" is still out there somewhere but its story is rarely told - or perhaps that should be "tolled", as the bel lost one "l" when it first appeared more than 70 years ago. The lone bel was doomed to disappearance because of its inconvenient dimension, somewhat like (and likewise despite its eminent inventor) the farad.

Named after Alexander Graham Bell, inventor of the telephone, the bel replaced in 1924 the 'transmission unit' which had been introduced the year before into the field of line telephony by the American Telephone and Telegraph Company (ATT). The bel was intended to equal 10 of ATT's 'transmission units'.

The 'transmission unit' itself had replaced an even earlier concept based on the ratio between the decrease in signal power produced by a given telephone cable and that produced in one mile a of standard cable. In 1924, an international advisory committee on long distance telephony in Europe, in cooperation with American representatives of the Bell telephone system, agreed to recommend the adoption as standard of either the *bel* or the *neper*, both of which were loosely referred to as units.

The bel was to be a unit based on logarithms to the base 10, while the neper (named after Napier) would be based on Naperian logarithms to the base 2.71828. The neper was later used to some extent in Europe, but is not often met today. Both units were intended as a means of expressing power ratios, and gain or loss of power-related quantities such as voltage and current. But in practice, one bel was too large, so it was scaled down some 5 years later to one tenth of a bel, becoming the *decibel*, abbreviated to *dB*. (And in retrospect, it looks remarkably like the equivalent of the earlier 'transmission unit' that it sought to replace.). But since then, the decibel (dB) has become a very useful and much used mathematical tool, particularly in electrical engineering and acoustics, although I will only consider the former here.

Power

Strictly speaking, the original mathematical expression for bel relates only to power ratios. Two powers (say P1 and P2) are said to to differ by N bels (where N is a number), when:

their power ratio $P_1 / P_2 = 10^N$

which when converted into logarithm form becomes:

$\text{N bels} = \log_{10} (P_1 / P_2)$

and because 1 bel = 10 decibels , this becomes :

$\text{N decibels} = \text{N dB} = 10 \log_{10} (P_1 / P_2)$

It is important to note that this expression defines a *number* of decibels, not the decibel as a *unit*, so, strictly speaking, one can refer to *a* decibel or to *one* decibel, but not to *the* decibel. Nor is decibel a metric unit of measurement or quantity, which is why it does not appear in the Systeme International d'Unites or SI System. In that metric system, the product or quotient of any two quantities is the unit of the resultant quantity: for example, volt x ampere = watt, each of which can be expressed in decimal multiples or sub-multiples such as mega-, milli-, and so on.

Decibel however , cannot be multiplied or divided by any SI Unit to produce another SI Unit, nor can it adopt other decimal multiples or sub-multiples in place of deci-. It is an orphan in the field of electrical engineering measurement, because it is really no more than a mathematical tool (as is the logarithm), whereby the products or quotients of large numbers can be more simply handled by the addition or subtraction of dB quantities. Examples of this are given later.

Note that a ratio such as 2/1 produces a positive number of decibels, whereas a 1/2 ratio would produce a negative logarithm and a negative number of decibels. Positive decibels add to simulate multiplication, whereas negative decibels subtract to simulate division , for example:

$(+10\text{dB} -3\text{dB}) = (\times 10/2) = \times 5 = 7\text{dB}$

But for convenience of use, rather than referring to power ratios, it is better to refer to power gain or loss. In which case, +dB represents a power gain, and -dB a power loss or attenuation.

Voltage

As said earlier, dB can also be applied to derivatives of power such as voltage and current, but using a slightly modified expression based on the relationship power $P = E^2 / R$, as follows:

$\text{N dB} = 10 \log_{10} (P_1/P_2)$

now re-written as:

$$\text{N dB} = 10 \log_{10} \frac{(E_1)^2/R}{(E_2)^2/R}$$

and cancelling the R/R $= 10 \log_{10} (E1)^2/(E_2)^2 = 10 \log_{10} (E_1/E_2)^2$

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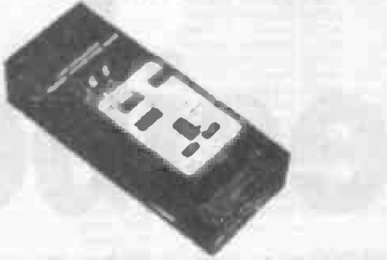

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which, by using the mathematical expression $\log_{10}(x)^2 = 2\log_{10}(x)$, can be re-written as:

$2 \times 10 \log_{10}(E_1/E_2)$

hence, in terms of voltage E:

$N\ dB = 20 \log_{10}(E_1/E_2)$

Current

Similarly in terms of current I, using the relationship power $P = I^2 R$, yields :

$N\ dB = 20 \log_{10}(I_1/I_2)$

Some examples follow. Note that all examples deliberately use approximated numerical values:

In power terms:

a power-gain of x2 (ratio 2/1), gives:
$N = 10 \log_{10}(2) = 10 \times 0.3 = 3$ dB

a power-gain of x5 (ratio 5/1), gives:
$N = 10 \log_{10}(5) = 10 \times 0.7 = 7$ dB

a power-gain of x10 (ratio 10/1), gives:
$N = 10 \log_{10}(10) = 10 \times 1.0 = 10$ dB

In voltage terms:

a voltage-gain of x1.4 (ratio 1.4/1), gives:
$N = 20 \log_{10}(1.4) = 20 \times 0.15$
$= 3$ dB

a voltage-gain of x2 (ratio 2/1), gives:
$N = 20 \log_{10}(2) = 20 \times 0.3$
$= 6$ dB

a voltage-gain of x3 (ratio 3/1), gives:
$N = 20 \log_{10}(3) = 20 \times 0.5$
$= 10$ dB

a voltage gain of x10 (ratio 10/1), gives:
$N = 20 \log_{10}(10) = 20 \times 10$
$= 20$ dB

Applying the above dB values to obtain an acceptably near approximation of power or voltage gain:

Example 1: Power-gain of 33dB is here converted to its numerical power gain.

33dB = 10dB + 10dB + 10dB + 3 dB
= 10 x 10 x 10 x 2
= power gain of x2000 (cf x1995 true)

Example 2: Power-gain of 67dB is here converted to its numerical power gain.
67dB = (10+10+10+10+10+10+7) dB
= (10x10x10x10x10x10 x5)
= power gain of 5×10^6 (cf 5.01×10^6)

Example 3: Voltage-gain of 36 dB is here converted to its numerical voltage gain.

36dB = 20dB + 10dB + 6dB = 10 x 3 x 2
= voltage gain of x60 (cf x63.1 true)

Example 4: Voltage-gain of 126dB is here converted to its numerical voltage-gain.

126dB = (20+20+20+20+20+20+6) dB
= (10x10x10x10x10x10x2)
= voltage-gain 2×10^6 (cf 1.995x106 true)

It is clear from the above that:

In terms of power:

3 dB means a multiplication by 2, ie twice the original power
10dB means a multiplication by 10, ie ten times the original power

Similarly, a negative dB figure implies division:

-3dB means a division by 2, ie half the original power
-10B means a division by 10, ie one tenth the original power

And in terms of voltage:
6dB means a multiplication by 2, ie twice the original voltage
20dB means a multiplication by 10, ie ten times the original voltage

Similarly , a negative dB figure implies division:

-6dB means a division by 2, ie half the original voltage
-20dB means a division by 10, ie one tenth the original voltage

In amateur electronics and radio, decibel usage leans more to power and voltage and rarely to current. Now, bear in mind that to produce a two-fold increase in received radio-signal voltage (considered by some to be = one S-point) requires not just doubling , but quadrupling of transmitted power (=+3dB+3dB)! It is then obvious that 1dB (= x1.26 power or x1.2 voltage) and even 2dB (= x1.6 power or x1.3 voltage) represent not very significant gains/losses either in power or voltage terms, hence can be ignored for many practical purposes, especially if only approximate values are sought.
In this case, it is possible to 'guesstimate' quite easily the power or voltage gain/loss equivalent to a given number of dB, by committing to memory the following six relationships:

Power:
3dB = multiply or divide by 2
7dB = multiply or divide by 5
10dB = multiply or divide by 10

Voltage:
6dB = multiply or divide by 2
10dB = multiply or divide by 3
20dB = multiply or divide by 10

Example 5:
Antenna gain of 16dB:
=(power) 10dB + 3dB + 3dB
= x 10 x 2 x 2 = x40 gain (cf 39.8 true)

or:
= (voltage) 10dB + 6dB
= x 3 x 2 = x6 gain (cf 6.3 true)

Example 6:
Power gain of 47dB
= 10dB+10dB +10dB+10dB+7dB
= x10 x10x10x10 x5
= $5x10^4$ (cf $5.01x10^4$)

Example 7:
A coaxial cable is quoted as having attenuation of 6dB per 100metres at 100MHz. This means a power loss of 6dB/100m = (-3dB-3dB)/100m = (2¯2)/100m = ¯4/100metre. Signal power is thereby reduced progressively by cable losses, to one quarter of its former value for each 100m of the cable's length, or to one half power per 50m of cable, and so on.

Absolute power , voltage, or current

The previous section showed decibel or decibels as applying to power or voltage ratios, that is, to relative power or voltage, and not to absolute values in watts or volts.

This difference is important in practice. For example, if a radio amateur were to say "I have increased my power by 20 watts", that would be of no significance if his original power was 1000W, but very significant if he had increased from 1watt to 21W. Similarly, a 3dB increase in power could mean a change from 2watts to 4watts, or from 4kW to 8kW, so to be meaningful in absolute terms one would need to also state the original reference power level. There is however a way around this, and that is to express the ratio in +/-dB relative to some arbitrarily chosen datum or ' zero level'. Datum levels have been internationally adopted to suit different purposes, three of which are given below as being of direct interest to the radio amateur:

dBm = dB relative to one milliwatt (mW) of electrical power, whereby 0dB = 1mW
dBW = dB relative to one watt (W) of electrical power, whereby 0dB = 1W
dBd = dB power or voltage gain (typically of a beam antenna) relative to a half-wave dipole antenna.

Note that dBd as applied to antenna gain is still only relative, in that it does not provide an absolute power in watts or level in volts. It implies an increase in power or voltage over whatever is expected from the major lobe of a dipole antenna in a similar location, and that applies equally to either reception or transmission.

Example 8
33dBm = power increase of x2000 above 1 milliwatt = (1/1000 W) x 2000 = 2 watts
-33dBm = power decrease of ¯2000 below 1 milliwat = (1/1000W) ¯ 2000 =0.5 microwatt
33dBW = power increase of x2000 above 1 watt = (1W) x 2000 = 2000 watts
-33dBW = power decrease of ¯2000 below 1 watt = (1W) ¯ 2000 = 0.5 milliwatt
26dBW = power increase of x400 above 1 watt = (1W) x 400 = 400 watts
16dBd = power gain of x40 relative to main lobe of dipole antenna
16dBd = voltage gain of x6 relative to main lobe of dipole antenna

In electrical engineering, 0dBm is taken as being 1milliwatt into 600 ohms (hence 0dB=0.775V rms pd), whereas in radio it is more likely to be 1mW into 50 ohms (hence 0dB = 0.224V rms pd). This is important, for example when using a signal generator the output attenuator of which is calibrated in dB , and you might wish to convert that into microvolts pd to determine the sensitivity of a receiver.
Some other dB terms of radio interest are:

dBV = +/-dB relative to 1 volt
dBuV = +/-dB relative to 1 microvolt
dBi = antenna gain relative to the theoretical "isotropic" (equal response in all directions) radiator
dBc = dB relative to carrier level, for use in spectrum analysis to quantify noise, spurious signals and distortion products such as harmonics

Other applications of dB in radio include the measurement of receiver sensitivity, adjacent channel selectivity, squelch sensitivity, intermodulation rejection, image rejection and S-meter linearity.

Power v voltage gain

Voltage (or current) gain of an amplifier can correctly be quoted in dB, even if the input and output impedances are not equal. If however the input and output impedances really are equal, then voltage dB will numerically equal power dB and vice-versa, that is, 3dB voltage-gain = 3dB power-gain, but only when Zin = Zout. That is because there can only be a direct relationship between voltage dB and power dB if the impedances across which the voltages are measured are equal, to cancel out in the previously stated dB formula based on P=E2/R. But in real life, amplifier voltage-gain is often quoted in dB, even when the input and ouput impedances are unequal, so it must be treated with due care.

Antenna gain is often quoted in dB. This is an example of where Zin = Zoutt because the feed impedance is a constant, so that the dB figure applies equally to power-gain or voltage-gain.

Example 9:
A 16dB gain antenna would produce:

a power-gain of 16dB = (10dB+3dB+3dB)
= (x10 x2 x2) = x40

or,

a voltage-gain of 16dB = (10dB+6dB)
= (x3x2) = x6.

Conclusion

It is useful for all radio and electronics enthusiasts to have at least a basic understanding of decibels, even if only to appreciate the meaning of those mystical figures that appear in antenna adverts and equipment reviews, or to translate into watts the 26dBW given as permitted transmitter output power in the UK Amateur Radio Licence. Of course, the full utility of decibels really comes into its own in complex calculations such as those for radio link-paths for earth-moon-earth or meteor-scatter communications. But whether it be for simple or complex calculations, a pocket scientific calculator makes light work of conversion from numerical gain or loss into +/-dB and vice-versa, by using the log key when converting from gain to dB, and the inv. log key for dB to gain - not forgetting of course to multiply or divide by 10 for power and 20 for voltage.

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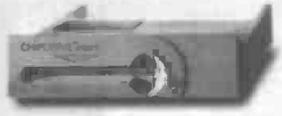

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SPICED CIRCUITS

Circuit simulation with software, by Owen Bishop. This month, part 7 - Logic simulation and a maths package.

In the previous part (Vol 27 Issue 1) we looked at simulation of logic circuits by conventional SPICE-based simulators. But even SPICE cannot be expected to be all things to all designers. It was written for designing integrated circuits. Subsequently it has been very useful in numerous applications relating to discrete analogue circuits, but it has limitations with logical circuits. When we describe a logic circuit, we do it in terms of gates, and assemblies of gates (such as flip-flops, counters and registers). Logical analysis is based on truth tables.

When we simulate a logical circuit using SPICE, the nature of SPICE makes it operate at a more fundamental level, calculating the currents through the transistors and resistors that go to make up each gate. Analogue analysis is based on Ohm's Law, Kirchhoff's Laws and transistor output characteristics, plus a great deal more. This is slow if the circuit contains more than a few dozen components. Logic gates usually consist of several transistors and other components, so that they perform in a very robust and repeatable way. Analysing them by analogue methods involves many time-consuming calculations for which, in practice, there is no need.

For instance, if the voltage at the input of a CMOS gate is greater than half the supply voltage, it rates at a high input. With a 5V supply, it does not matter if the voltage is 3V, 4V, or 5V or something in between. So there is no point it making the simulator iterate around a resistor/transistor gate circuit to calculate the voltages to 12 decimal places. A logic gate can be taken as a black box; given certain inputs, it gives a predicted output, with various but small and dependable time delays. The whole approach to modelling digital circuits is different.

The completely SPICE-modelled gate has uses for simulating mixed-mode circuits but the time that this takes limits the number of gates that can be included in a circuit. And we are talking about gates, which is still a long way from modelling logic circuits with counters, shift-registers, arithmetic units, and even further from LSI and VLSI devices. There is another reason why SPICE is inherently unsuitable for simulating logic circuits. Logic gates change state in a few nanoseconds but, once changed, may remain in the same state for microseconds or milliseconds. These are periods several thousand or million times longer than the period of change. It makes no sense to repeatedly calculate voltages and currents for these static periods. The simulator must be event-driven, leaping from one voltage change to the next. The iterating procedures of SPICE do not fit in with logic gate timings.

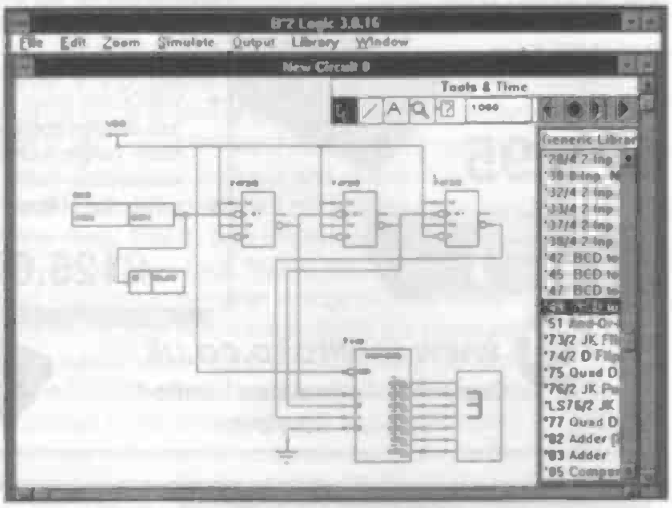


Figure 1: this version of the JK ripple counter uses a 7449 decoder and a 7-segment display to read the output states

Simulators such as SpiceAge, on which we based the first five parts of this series, minimise these disadvantages by breaking away from SPICE in certain respects. SpiceAge has recently added logic gate primitives and other function blocks to its range of 'components'. It also has algorithms for automatically calculating the size of the time step, to produce longer time steps when feasible and so decrease analysis time. Going even further, some simulators have started again from scratch and use a purely logic-based approach to digital analysis. One such simulator is described below.

B2 LOGIC, V3.0

B2 Logic 3.0 is published by Beige Bag Software, of Ann Arbor, Michigan, who also publish the analogue simulator B2 SPICE which we looked at in the previous article. B2 LOGIC is available in Windows and Macintosh versions, and is an impressive piece of software which is very easy to use.

The first stage in setting up a logic circuit is to draw its schematic on the screen. As a simple demonstration, we set up a ripple counter, one of the logic circuits that we analysed last month. Logic elements are selected from the device library (right of screen in **figure 1**, though it can be moved around). There is a very extensive library including everything from a plain inverter gate, through all kinds of registers and

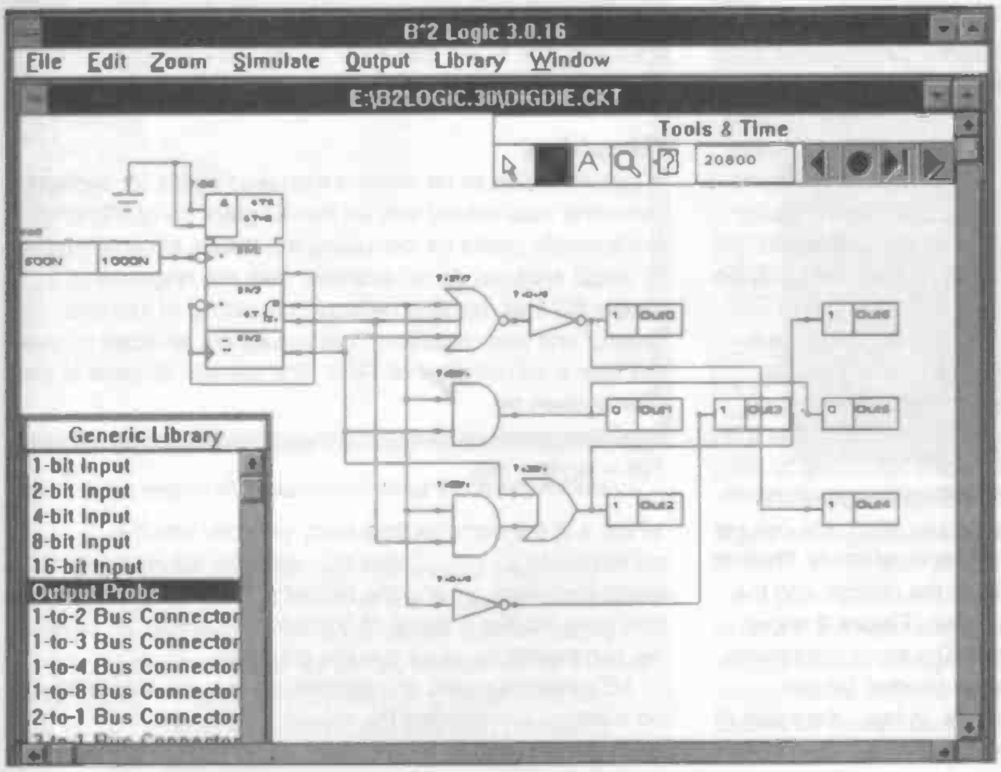


Figure 2: a simulation of one of many possible simulations of a digital die. The operator has just 'thrown' a five

flip-flops to a 74646 octal bus transceiver and register. The devices are displayed as standard IEC (International Electrotechnical Committee) symbols. There are several libraries to choose from, including Generic devices, TTL, LSTTL and CMOS technology. For this analysis we selected from the Generic library and built a three-stage ripple counter (it was two-stage a few months ago, but we can be a bit more ambitious with a dedicated digital simulator). B2 Logic has a useful set of input and output devices. The high voltage device (Vcc) provides logic high to inputs that need it, such as the J, K and reset inputs. Another device, a clock, is set to have a period of 80ns, with a pulse width (length of time for which it is high) of 40ns.

A probe is a handy device for reading output levels. We attached one to the clock and set it to display '0' for logic low and '1' for logic high (you can also make it display 'L' or 'H'). We could have done the same with the outputs from the counter but, if we have a ready-to-use 7449 decoder handy, why not use this instead? The 7449 is a BCD to 7-segment decoder and the library also has a 7-segment LED display which is easily attached (by dragging it with the cursor - simulation has that big advantage over real life). All we have to do now is to run the simulation and watch the display. The 'Tools and Time' window has buttons like those on a tape player for reset to zero time, stop, single step forward, and continuous run. Single-stepping (for presettable time intervals) shows the clock alternating between high and low and the 7-segment display goes through this sequence repeatedly:

0 1 (0) 2 3 (2) (0) 4 5 (4) 6 7 (6) (4) 0 1 etc

With 10ns steps, the numerals in brackets are displayed for a relatively short time. They are the glitches on a ripple counter that we explained last month. A continuous run makes the glitch periods so short that you can hardly notice them and the counter appears to be running correctly. At the end of the run we can ask for a trace, which plots the levels detected by probes. To examine these we first need to attach probes to the three counter output lines. The 10ns delay in each flip-flop is then clearly seen. Alternatively we can call up a table of probe logic levels at preselected time intervals during the run.

This circuit demonstrates how a counter can be built up from flip-flops and then analysed. If you need counters in other circuits, you would dig into the Library and use complete counter devices ranging from the 7493 binary ripple counter to the 74169 synchronous up/down binary counter with parallel load.

The ultimate simulation

In the world of simple circuits there are probably more designs for egg-timers than for any other function. Second on the list comes the digital simulation of rolling a die, with LEDs displaying a random count from 1 to 6 when you press the stop button. **Figure 2** is a simulation of one of the many digital die circuits. This is a simulation of a simulation - but it works. The circuit is driven by the clock we used in figure 1 but this time its output goes to a counter, a model of the 74LS92 counter wired to count repeatedly from 0 to 5.

The output is decoded by various logic gates, to which seven probes are connected. We have arranged these so that, if you look for the '1's, they produce the conventional patterns of spots on the face of the die. The number of gates is fewer than would usually be the case because it would be uneconomic to use four different kinds of gate, when building a real circuit. We would probably manage it just with NANDs and NORs and the simulator could be used to check out the slightly more complicated logic involved.

To start the die rolling, click on the continuous run arrow. When you click on stop the display shows the score. In the figure, the pattern of 'ONs' displays 'five'. Here we must reluctantly leave B2 Logic, which has in fact shown us the last simulation of this series, and move on to something entirely different.

MEXPRESS 1.1

This is one of the newer maths packages, and has a lot to offer the electronics designer. The simplest way to use it is as an on-screen calculator. For example, type 25 * sin (1.2) + 3.27 at the prompt, press ENTER, and back comes the result, 26.570. It can handle imaginary numbers too. For example 3.4 + 0.2i multiplied by 2.1 - 5.67i gives the result, 8.274 - 18.858i, although entering the calculation is slightly more involved. The package has a range of over 250 functions, including matrix algebra, statistical functions and equation solving. Another strong feature of this package is its flexible system of plotting graphs, both 2D and 3D, and its ability to produce real-time animations. Before we look at its graphics we will consider how the mathematical functions can be of use to the electronics designer. Although MExpress probably could simulate whole electronic circuits, we are not likely to use it for this purpose because it would take too long to set up the equations and plotting routines required. Regular simulators have all the required functions built in already. But there are numerous instances of design calculations that we need to perform over an over again, yet are that bit more complicated than can be handled easily on an ordinary calculator.

To take one very simple example as an illustration, we often need to find suitable resistor values for a potential divider. For instance, there is a need for this when we are trying to bias a transistor. You can, of course just make this a one-off calculation, type in the variables according to the formulae and obtain the results. But MExpress goes one better (actually two better, as we shall see later). We can set up the calculation plus a few frills in a special .X file. Then all we do it type the name of the .X file at the prompt and the routine is automatically called into action. **Figure 3** shows the notepad with the routine entered. The input statements ask the user to key in the three values needed for the calculation. Then the routine calculates 'outres', the value of the output resistor, and also the current through the network. After printing a heading, the calculated values are displayed. The contents of Notepad are then saved in a file called potdiv.X.

Figure 4 shows the outcome when, back in MExpress, we type the file name 'potdiv' and press Enter. We are asked to enter the values of input and output voltage and also the intended total resistance of the chain. The displayed results show that the output resistor should be 2.2k and the other resistor 7.8k. Probably the nearest E24 value, 7.5k?would be acceptable. Current through the network is 9mA. To recall the routine for another calculation, simply press the cursor 'up-arrow' key a few times until the original 'potdiv' command reappears at the prompt. Key 'Enter' and repeat the calculation with new values.

This is only the barest routine. Several refinements are possible, including routines to select the nearest E24 values. As an illustration of what can be done we have added a 'message screen'. This comes up on the screen as a typical Windows message, to warn you if by accident you have typed in the input and output voltages the wrong way round. The message screen can be tailored to fit your needs. This one has a bold exclamation mark on it and an 'OK' button for acknowledging the message.

We said we could go two better, and the next step could be to compile the potdiv routine to produce a free-standing program. You need a C++ compiler for this. MExpress translates your .X file into C++, to which you can add any C++ code of your own, and compile the lot to produce your faster-running and more sophisticated potdiv software. Whether you compile or not, you can quickly write a number of variants of the potdiv routine. Another variant could ask for voltages and network current and calculate both resistor values. Another could ask for both resistor values and input voltage and calculate output voltage. Then, turning your attention to the 555 timer ic, there are several more routines which would be very useful to have handy.

Graphics

A picture is said to be worth a thousand words (or perhaps a thousand data values) and so the 3D graphics of MExpress are specially useful for portraying the results of certain types of circuit analysis. As an example, take the response of a simple RC lowpass filter network, consisting of just one resistor and one capacitor. Their values are selected to give the filter a cut-off point of 1kHz. The transfer function of the filter is given be:

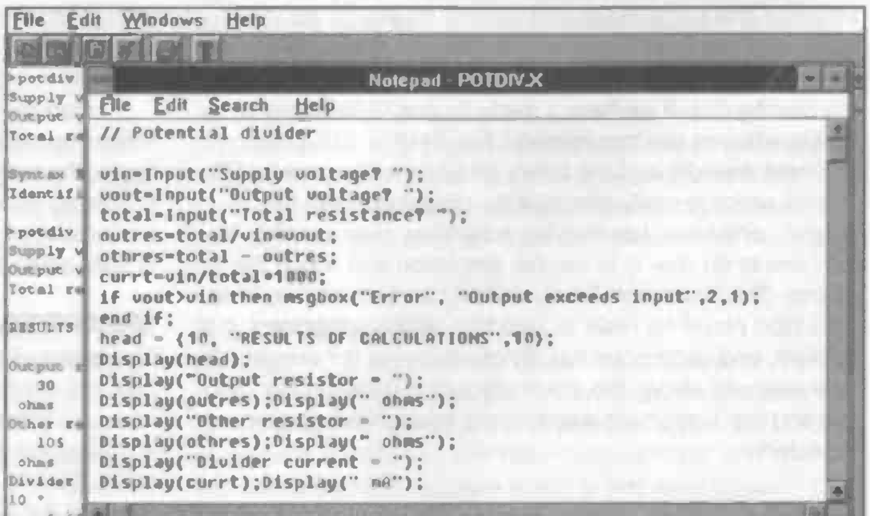
$$F(s) = \omega_0/(s + \omega_0)$$

where s is the complex frequency variable, which is equivalent to $(\sigma + j\omega)$. These two variables are measures of signal frequency (ω) and the rate at which amplitude is changing (σ). For a signal of constant amplitude, σ= 0, and we can substitute $j\omega$ for s in the equation.

MExpress is based on matrices, so the first step is to set up a matrix s containing the values of s for which we want to plot values of F(s). This will be a 2-dimensional matrix with rows for each value of σ and columns for each value of $j\omega$ (actually $i\omega$ because MExpress uses the symbol i instead of j). Values of σ are 0 to -8000 in steps of 2000, and values of $j\omega$ from 0i to 3i in steps of 1i. We then form a matrix t, holding of values of F(s) by using the command: t=abs(6283/(s+6283));. The term 'abs' gives the absolute value of the expression, since we are concerned here only with the amplitude of the output signal, not its phase. The value ω_0 = 6283, is obtained from:

$$\omega_0 = 2\pi f_0$$

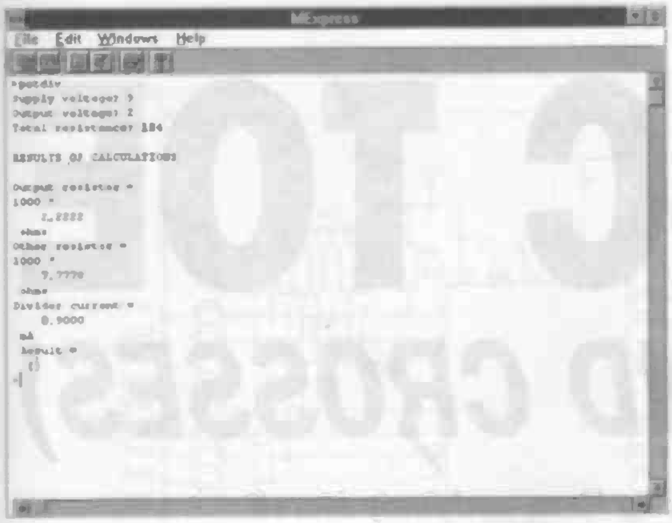
when f_0=1kHz. All that remains is to type MPlot(t), to obtain the 3D graph shown in **figure** 5. The axis running off to the left is frequency ($j\omega$) and the axis running to the right is the



```
// Potential divider

vin=Input("Supply voltage? ");
vout=Input("Output voltage? ");
total=Input("Total resistance? ");
outres=total/vin*vout;
othres=total - outres;
currt=vin/total*1000;
if vout>vin then msgbox("Error", "Output exceeds input",2,1);
end if;
head = {10, "RESULTS OF CALCULATIONS",10};
Display(head);
Display("Output resistor = ");
Display(outres);Display(" ohms");
Display("Other resistor = ");
Display(othres);Display(" ohms");
Display("Divider current = ");
Display(currt);Display(" mA");
```

Figure 3: In MExpress, users can type often-used routines into Notepad and save them for instant use later. This is 'potdiv', a routine useful for calaculating values for transistor biasing resistors



```
>potdiv
Supply voltage? 9
Output voltage? 2
Total resistance? 1E4

RESULTS OF CALCULATIONS

Output resistor =
1000 *
     2.2222
 ohms
Other resistor =
1000 *
     7.7778
 ohms
Divider current =
     0.9000
 mA
 Result =
  ()
>|
```

Figure 4: the results of a calculation using the potdiv routine

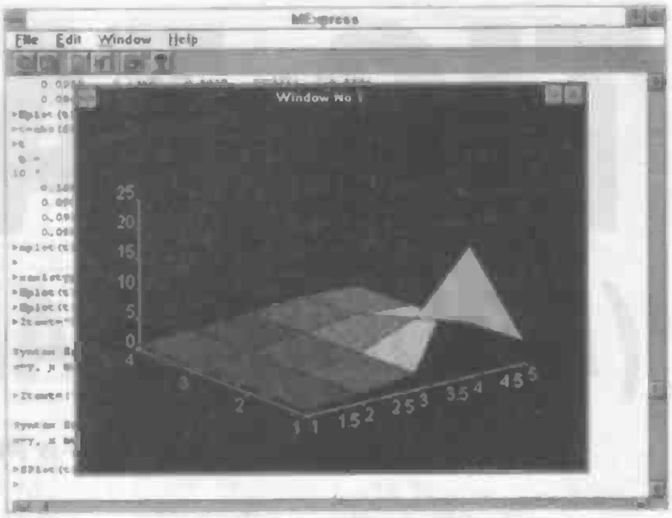


Figure 5: the gain of a lowpass RC filter plotted against frequency and rate of change of amplitude

rate of change of amplitude (σ). The vertical axis is the transfer function, or gain, (F(s)). At the origin (centre front) the gain is 1, as is expected for a DC signal. Running along the left-hand edge of the plot we have the response of the filter to increasing frequency at constant amplitude - the usual plot of gain against frequency. Gain falls with increasing frequency, as would be expected in a low-pass filter, but this does not show up on the graph because the vertical scale is too large. The reason for this is the tall peak we have discovered at the point where s = -6000 + 0i. Substituting this value into the equation gives F(s) = 6283/283 = 22.2. If we made s equal to 6283, the result would be infinitely large, and project infinitely upward. We call this a pole. The pole and its surrounding region represents a set of conditions at which the filter enters a resonant state, perhaps briefly, and its output voltage exceeds its input voltage by a considerable amount. Looking for poles is an important aspect of design because, if there is a chance of the circuit operating in the region of a pole we can expect severe distortion. Plots such as **figure 5** can help in locating poles.

This ends our brief survey of software useful to the electronics designer. New programs are coming onto the market all the time, but we hope that the examples we have used here will help you think clearly about simulation and to choose one most suited to your needs.

TIC TAC TOE
(NOUGHTS AND CROSSES)

A game-in-a-box with a PIC, by Rose and Andy Morell

This is an electronic game of Noughts and Crosses which allows you to play against the 'computer', that is, the PIC 16C64 microcontroller.

The PIC contains a long program designed to allow one or two players to play the game. The source code is available (see below). The 16C64 is the "intelligence" of the unit, and the playing board consists of nine 5mm tricolour leds (LED1 to LED9). In this way, the lights can be either green or red when selected, depending on whose turn it is, as the colour changes automatically. There are also two further leds, LED10 and LED11), which indicate whose turn it is. The eventual winner is heralded by a tune, which plays when a game has been won (or lost!), while the winning line flashes on and off. There are ten pcb-mounted push switches, including one reset switch. The position of the buttons corresponds to the position of the tri-colour leds, that is, it is a 3 x 3 matrix.

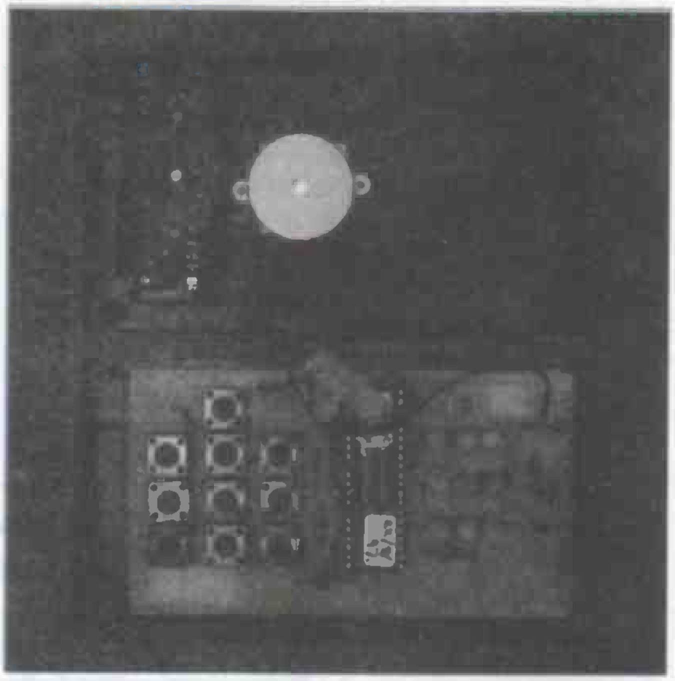
How to play

With the power on, select either push-switch 1, push-switch 2, or push-switch 3. To play against an opponent, select switch 1, and to play against the computer, select switch 2 or switch 3. Switch 3 will allow the computer to make the first move, and Switch 2 leaves you to make the first move. After that, you can press any one of the nine switches to commence play and make your move. Should you opt to play against the PIC, be prepared for a rapid response!

If there is stalemate in the game, you will have to press Reset to start a new game. If, on the other hand, you or the PIC should win a game, you will hear a tune (exactly which one depends on your choice of the sound generator chip during the construction stage). No further moves will be possible once the winning move is made. To stop the tune and start a new game, press 'reset'.

How the software works

There are nine memory locations representing the nine leds. On reset or power-up, the nine memory locations are filled with the number '8'. The software uses this information to determine what move to make. Now the game is being played, and you have just made the first move. Next, it's the PIC's turn, so the computer scans all three rows of leds, followed by the three columns, and lastly, the two diagonals, looking for a 'good move'!



It does this by looking at the nine memory locations that represent the nine leds. Once a move has been made, the PIC puts a '1' in the chosen location for an 'X', or a '2' for an 'O', while a space remains an '8'. (The microcontroller is always the 'O'.) On subsequent moves, the computer scans the memory locations and adds up the numbers in each row, column, and diagonal, looking for a line that contains two 'O's to win , or two 'X's so that it can block the third 'X' and at least not lose. To summarise:

1) A win in one move: the PIC only has to put its 'O' in the appropriate space to win.
2) A lose in one move: the PIC must block the 'X's' next move to avoid losing.
3) Neither is possible yet: the PIC will check the centre led to see if it has been occupied. If it has, it will look for 'any space', and if not it will bag the centre led!

For the 'computer' to find a win in one move, there must be three consecutive locations resulting in a total count of '12 decimal', that is, two 'O's , and one space: 2 + 2 + 8 = 12. Therefore, if any row, column and diagonal totals 12, a win in

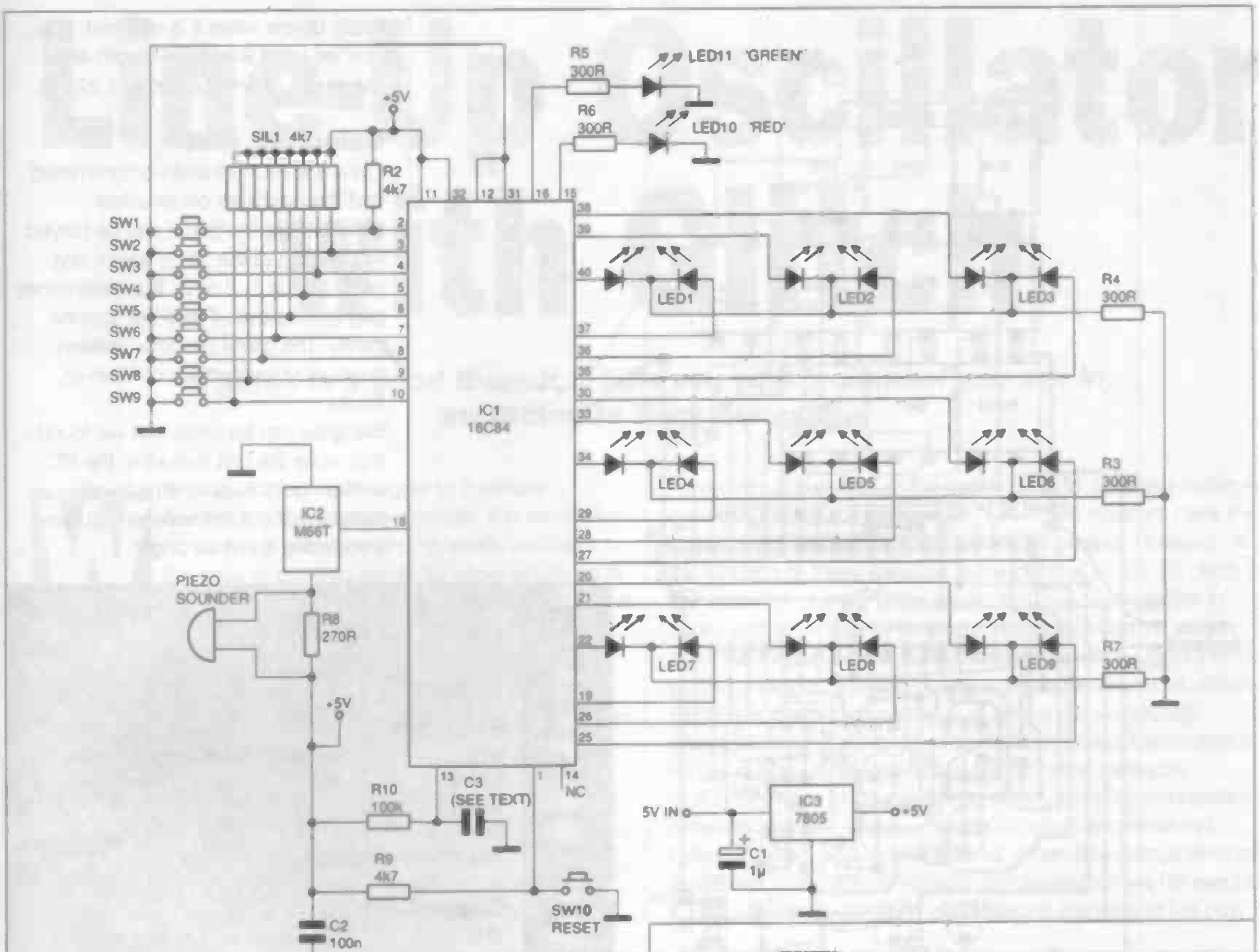


Figure 1: the circuit of the Tic Tac Toe

one move is possible, and the computer only needs to put its 'O' mark in that space to win - and celebrate by turning on the appropriate led. Flashing the winning line, it then loops away until Reset is pressed, or the power is interrupted.

Should no total of '12' be found in any one of the eight possibilities, then it will scan again, this time looking for a count of 1 + 1 + 8 = 10 decimal. This is 'may lose in one move', and as before the corresponding space will be taken up with the computer's 2, to block that move.

If the computer cannot find a place to put the first 'O', it will check the address that represents the middle led, to see if it has been taken. If not, then it puts its 2 or O in the centre or, if it has already been taken, it just takes any space it can for the first move only.

A check is made at the end of every move to find a possible winning row, column or diagonal.

Construction

The following should be sufficient for any hobbyist to build their version of Tic Tac Toe with the pcb and software provided.

There are a number of links, which should be fitted first. After that, fit the 40-pin dil socket, taking care not to bend the pins. Next, fit the single-in-line resistor (SIL1), taking care to put the 'dot' at the 5V pin on IC1, followed by R2-R8. This in turn is followed by the ten key-switches, SW1-SW10, and the leds LED1 to LED11, ensuring that the side with the flat edge/short lead (cathode) is inserted correctly. Next, carefully insert the

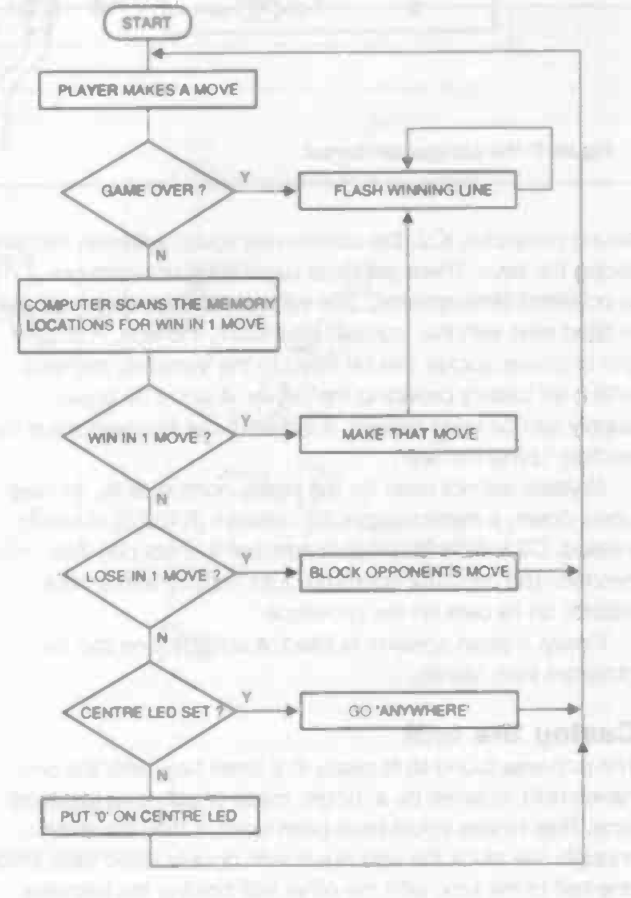


Figure 2: a flow diagram shows how the game program progresses

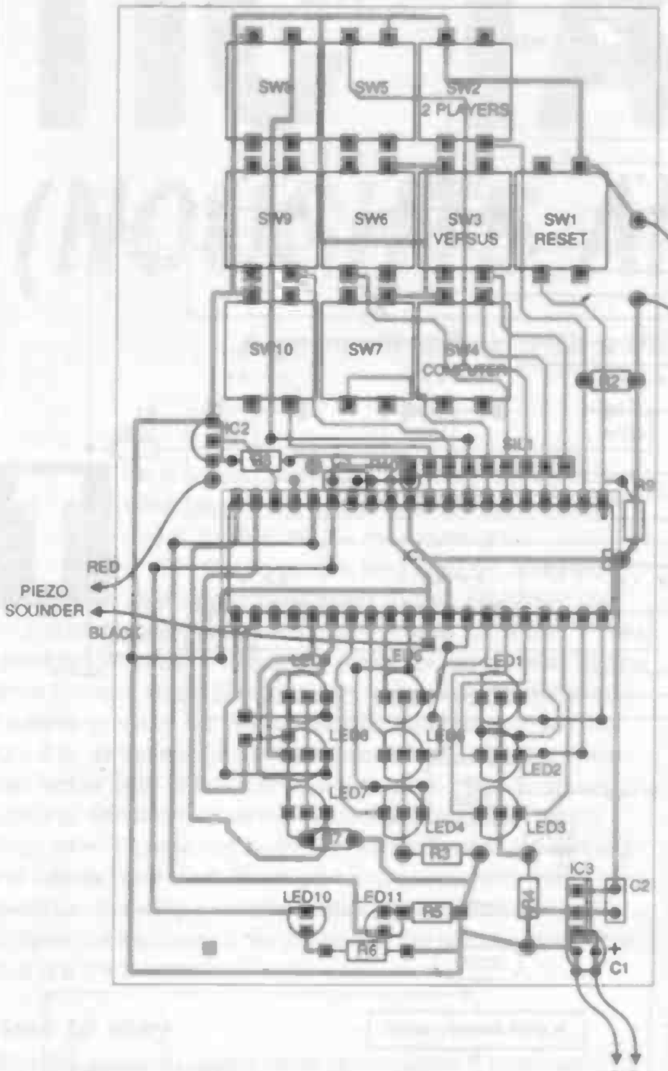


Figure 3: the component layout

sound generator, IC2, the correct way round with the 'flat' side facing the keys. There are three capacitors, of which one (C1) is polarised (and optional). The voltage regulator (also optional) is fitted next with the 'curved' side facing the leds. A battery clip or power socket can be fitted to the Veropins, perhaps with a 9V battery providing the power. A good dc power supply can be used instead, if required, but please consult the section 'Using the unit'.

Crystals are not used for the timing components. To keep costs down, a resistor/capacitor network (R10,C3) is used instead. C3 is from 20 pF upwards, but it is not definitely needed. The oscillator operated quite happily with a 100k resistor on its own on the prototype.

Finally, a piezo speaker is fitted. A suitable one can be obtained from Maplin.

Casing the unit

The pcb was found to fit neatly in a small box, with the two halves held together by a 'hinge' made of adhesive electrical tape. Real hinges could have been used, if they are small enough. We stuck the pcb down with double sided tape inside one half of the box, with the other half holding the batteries (side by side), and the piezo sounder stuck there also. So the components are then protected from damage, and the box easily opens when it is required. The box we used was from Maplin and measured 145mm x 80mm x 32mm.

Using the unit

Once the PIC has been programmed and the hardware constructed satisfactorily, the game can be played. At the start of the game select one push-switch 1, 2 or 3. This determines play (see above). Press the buttons gently. The game provides endless hours of enjoyment for children or adults.

Batteries can be used, but we found that while the unit (including the PIC) worked quite happily on a 3-volt battery, without the voltage regulator, the display is not so bright.

PARTS LIST for the Pic Tic Tac Toe

Resistors

SIL1	4k7 sil resistor, Maplin RA29G
R2,R9	4k7
R3-R7	300R
R8	270R
R10	100k

Capacitors

C1	(see optional regulator below)
C2	100 nF capacitor, ceramic.
C3	See text

Semiconductors

IC1	PIC 16C64 (see below) Write for prices
IC2	Sound generator chip: choice of music chips from Maplin (M66T Series, eg GX55K)
LED1-LED9	5mm tri-colour LEDs (common cathode)
LED10	3mm red led
LED11	3mm green led

Miscellaneous

Z1	Piezo sounder PCB, battery clip, battery box, solder, wire, Vero-pins.

Optional (for regulator)

C1	1uF 16v elect radial
IC3	7805 100mA voltage regulator

A 3.5-inch disk containing the source code is available for £5 (inc. postage and packing) payable to A J Morrell, 12 Boscobel Road, Winchester, Hants SO22 6RY. Postal only - please do not call. Programmed PICs may be available if demand is sufficient - please write (enclosing an SAE) and enquire.

Line-Up Oscillator with Glitch

A glitch is a good thing if it tells you which channel you are in, according to Tony Sercombe.

When sending an audio signal to a remote destination, or to a tape recorder, it is necessary to know the average sending levels, and also, in the case of a stereo signal, to know which leg is stereo right and which is left. The following circuit fulfils both these criteria.

The circuit is intended to be included within existing audio equipment, and as such a separate power supply is not provided, since its requirements are very modest, and it can be run from various voltages.

The circuit

The oscillator consists of a single transistor, working at 1 kHz. The output is fed to Q2, which is an N-channel fet connected as a buffer. This is necessary to prevent loading of the oscillator, which would lead to severe distortion of the waveform. The output of the buffer is fed to a resistor network consisting of three resistors. The two series resistors have the same total value as the single resistor in parallel. However, at the junction of these resistors is the point at which the glitch in the output of one leg takes place. The 220 uF capacitor in series with a P-channel fet and a 1k2 resistor form a switch from this output feed to earth, controlled by IC1. Under non-glitch conditions, the two output resistances are equal. When a glitch is applied, the resistance of the fet Q3 is reduced, effectively reducing the signal by the potential divider action of R12 and R11, the resistance of the fet being negligible.

IC1 operates in the astable mode. R7 and R8, connected between pins 8, 7 and 6, charge C6, which is connected between pins 2 and 6, and ground. When this charge reaches two-thirds of the supply voltage, C6 discharges via R8 into pin 7. The standing voltage on pin 3 feeding the gate of Q3 now

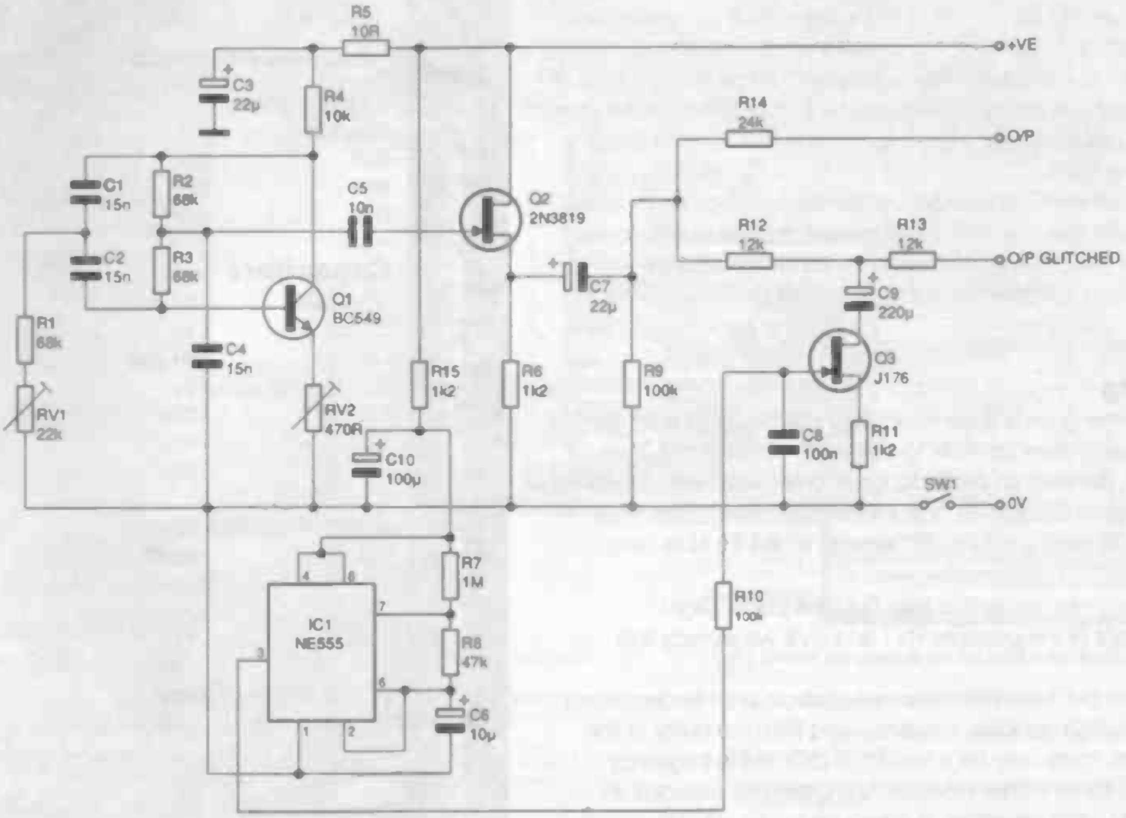


Figure 1: the circuit of the Line-Up Oscillator with Glitch

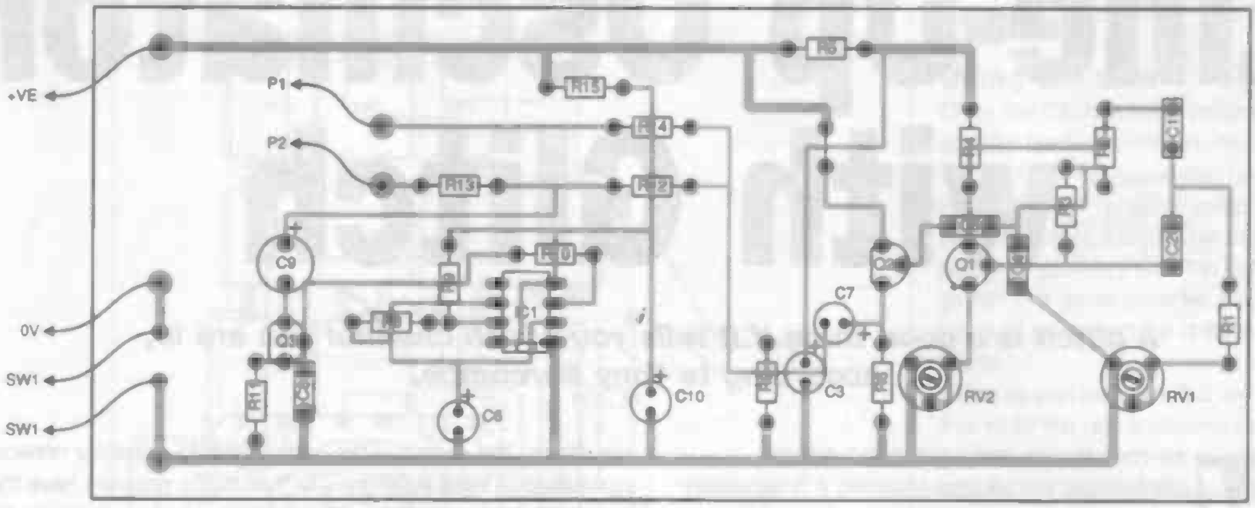


Figure 2: the component layout of the prototype

ramps low-switching Q3 to the low (resistance) state, thus producing the glitch. The IC is a standard NE555 timer. The somewhat heavy decoupling on pins 4 and 8 prevents disturbance on the supply line. The component values shown at IC1 provide for a half-second glitch every 10 seconds. If desired, these times may be modified to suit individual needs, and the values changed accordingly. However, the values shown seemed to be about right in the prototype. It is important that the glitch should not take place too frequently, otherwise the frequent repetition may interfere with the line-up procedure.

In the prototype the signal output level was 150 millivolts, measured as 146 mV with a 15-volt supply, dropping to 130 mV with a 9-volt supply. The outputs should be fed to a load of 10k. Much less than this will produce a disturbance of the un-glitched output. If this is unavailable, you may have to resort to buffer amplifiers.

A circuit layout is provided. When construction is complete, it is a good idea not to fit the ic immediately, so that the oscillator may be adjusted more conveniently. I always recommend the use of ic sockets, so that this is a minor matter.

Testing

After checking for any construction mistakes, dry joints, etc., set the two preset controls to their midway positions. If possible, connect an oscilloscope to one of the outputs. Failing this, a pair of medium to high impedance headphones may suffice. Connect a voltage of between 9 and 15 volts, and switch on.

At this point, oscillation may not take place. Slight adjustment of the presents RV1 and RV2 will remedy this situation.

Remember here that these two controls are interdependent, and since RV1 sets the frequency, and RV2 the purity of the waveform, there may be a small compromise in frequency accuracy to be made. However, the prototype provided an extremely good waveform at a frequency of 1.02 kHz. In any event, a precise value is not of paramount importance, but rather a well-defined waveform. If listening on headphones, check for the purest-sounding note.

Once this has been completed, the glitch can be checked. Remove the supply and put the ic into its socket. After restoring the supply, the glitch should be noticed as a sharp dip in output of half a second, every 10 seconds.

PARTS LIST for the Line Up Oscillator

Resistors

R1,R2,R3	68k
R4	10k
R5	10R
R6,R11,R15	1k2
R7	1M
R8	47k
R9,R10	100k
R12,R13	12k
R14	24k
RV1	22k
RV2	470R

Capacitors

C1,C2,C4	15n poly
C3,C7	22u
C5	10n poly
C6	10u
C8	100n
C9	220u
C10	100u

Semiconductors

IC1	NE555
Q1	BC549 (or 108/9, etc.)
Q2	2N3819
Q3	J176*

Miscellaneous

This project is designed to be fitted in existing equipment. PCB, ic socket, wire, solder, etc.

*The J176 can be obtained from Cirkit Distribution Ltd., Park Lane, Broxbourne, Hertfordshire EN10 7NQ. Tel°01992 448899 stock no. 59-02176, or another suitable P-channel device may be used.

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PHILIPS PM5193 Programmable Syn Func Gen 0.1MHZ-50MHZ	£1500
PHILIPS PM5192 Programmable Syn Func Gen 0.1MHZ-20MHZ	£1000
H.P. 3325A Syn Function Gen 21MHZ	£1250
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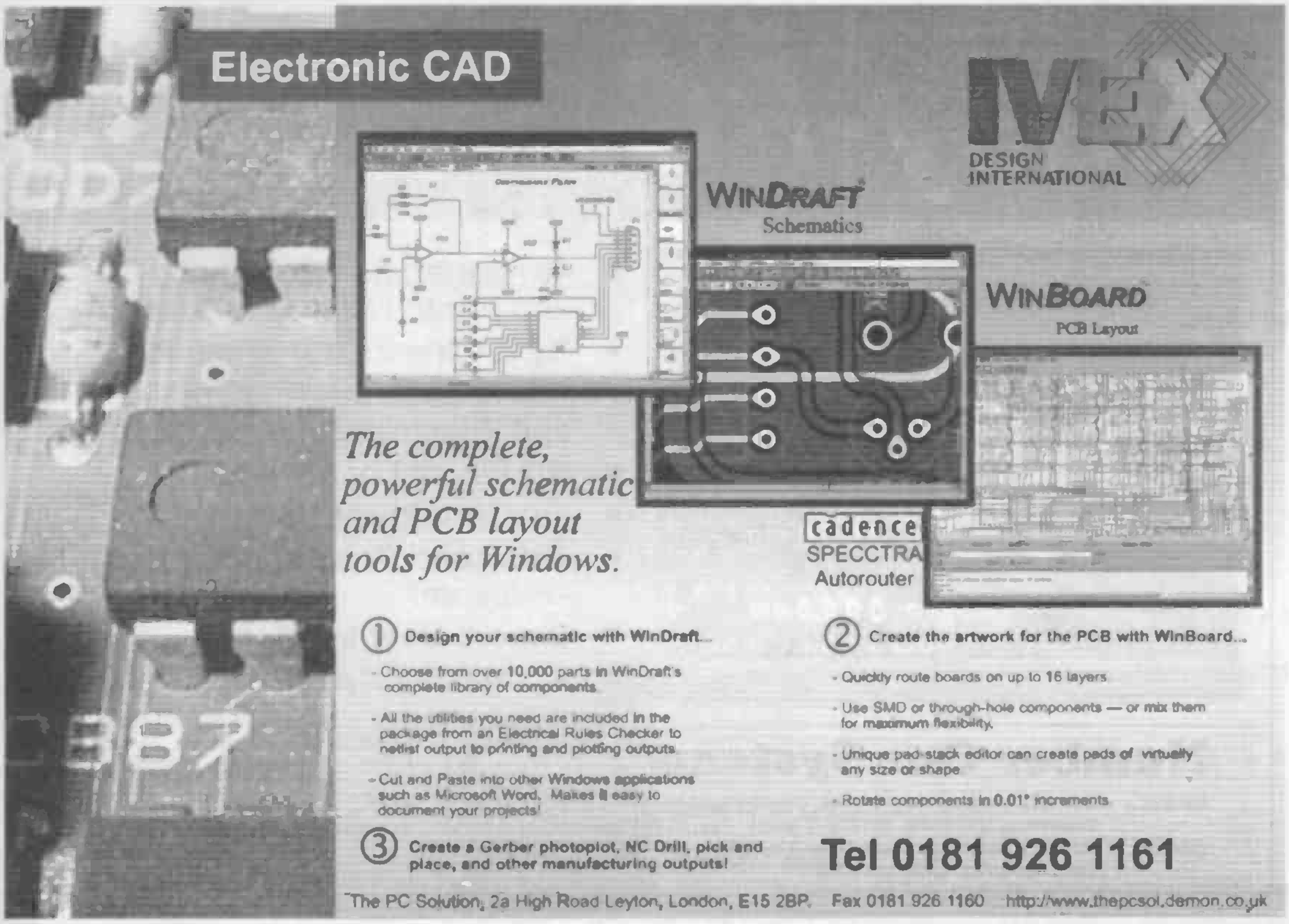

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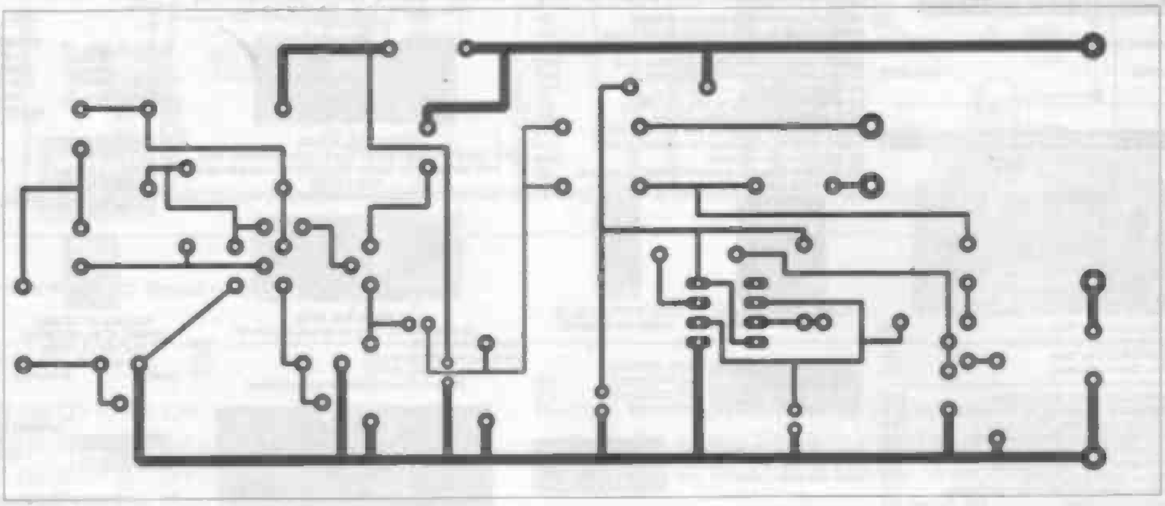
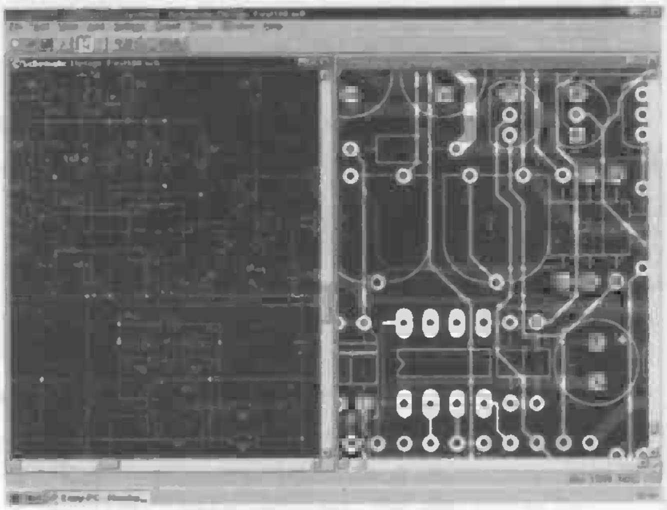


Line Up Oscillator with Glitch



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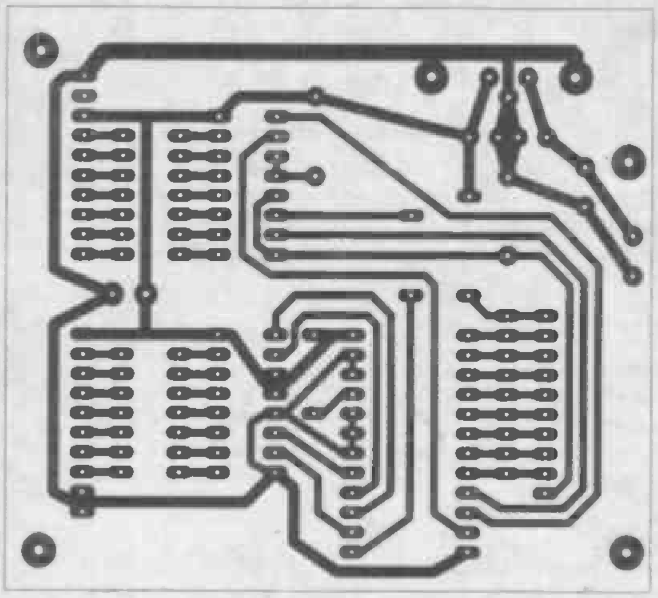
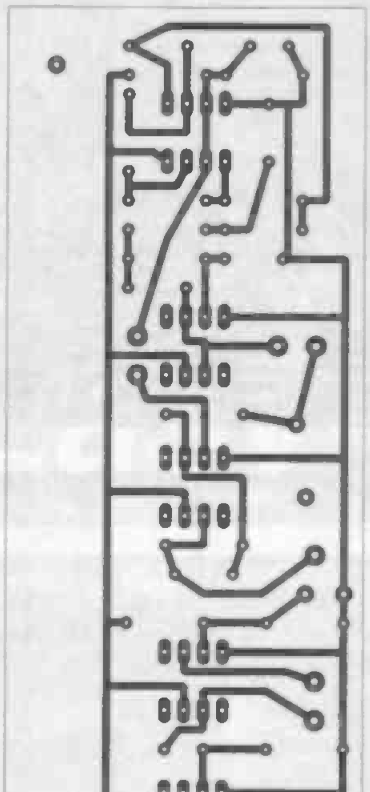


BB Ranger Control Board



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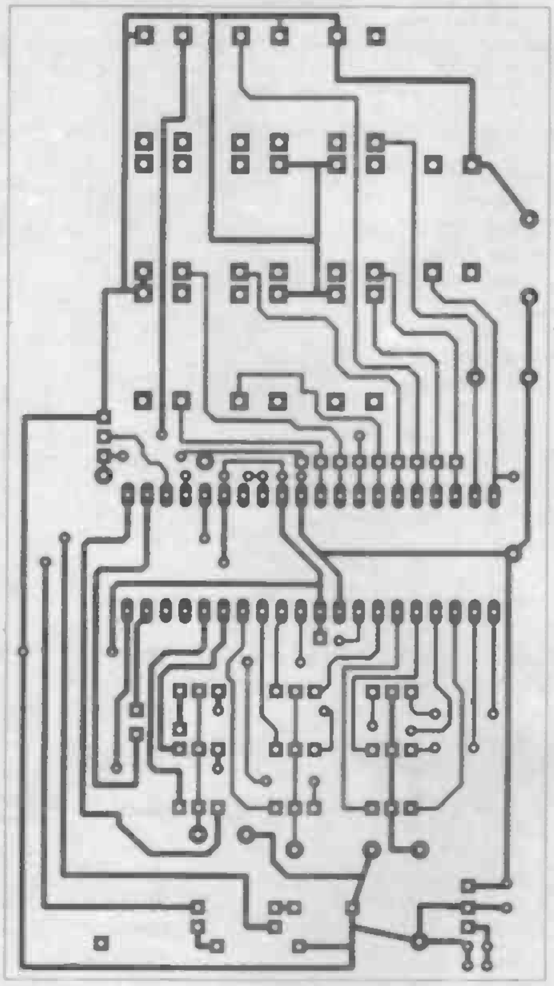

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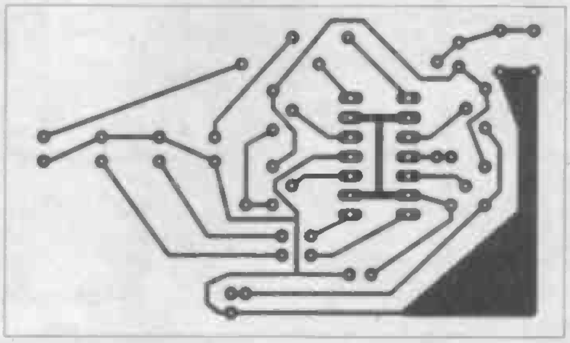

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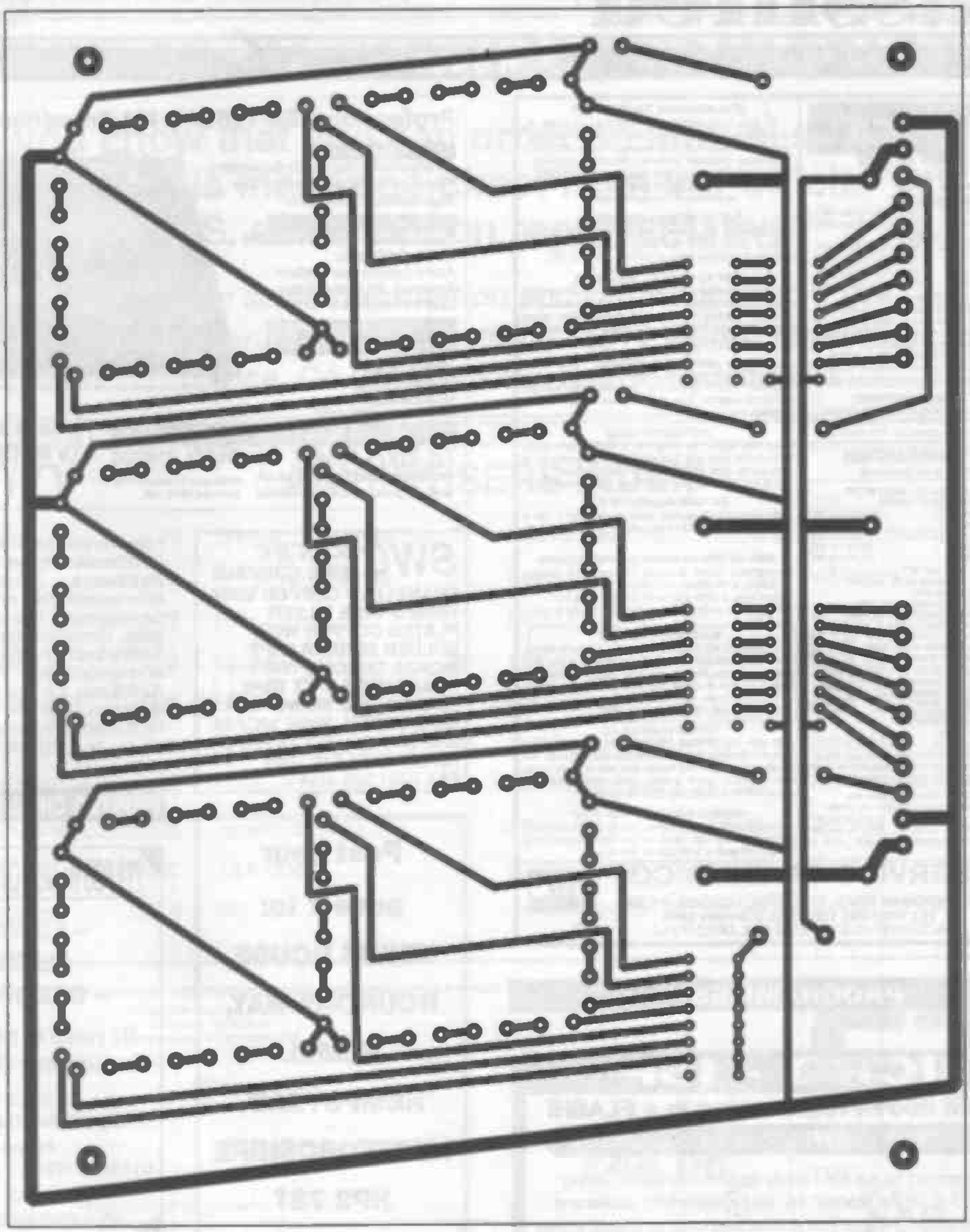

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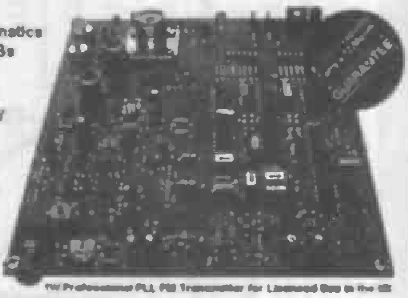

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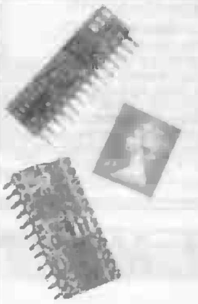

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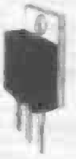

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ETI REVIEW

Peak Electronic DCA50 Component Analyser

A neatly made analyser than can identify transistors, diodes and LED and give the pin-outs quickly and without fuss.

The DCA50 is an analyser designed to identify discrete semiconductors and their connections. It can test a variety of two-terminal or three-terminal devices, chiefly diodes, mosfets and bipolar transistors. Three-terminal diode networks can be tested for the presence of diode junctions, and the individual junctions can be identified.

The analyser has three leads - in red, green and blue for quick identification - each terminated in a miniature crocodile clip. The readout is a two-line liquid crystal dot matrix display. The heart of the instrument is a PIC16C64.

Components are tested simply by connecting each of the two or three connections of the component to the crocodile clips in any order and operating the one button on the front panel. For a couple of seconds, the unit displays the message "DCA950 Component Analyser (R1010)", and then the analysis, such as "NPN Transistor RGB=>BEC Hfe=460", appears. This message was displayed when testing a BC109 transistor. The second time I tested the same device, the Hfe reading came up as 445.

The tester can identify signal diodes, rectifier diodes, zeners and also identify the terminals of a light emitting diode, and flash the component for a visual indication that it is functioning (regardless of which way round it is).

At more length, the main components that can be tested are P- and N-channel enhancement mosfets; NPN and PNP transistors; diodes and diode networks, and LEDs. It can indicate Hfe for bipolar transistors in the range 5 to 955, with an error of 5 Hfe and +/- 4 percent of the reading. Darlington transistors can be tested, but are likely to exceed the maximum range of measurement, in which case a reading of 955 is displayed.

The DCA50 cannot, apparently, test depletion mode mosfets and junction fets (which are inevitably depletion devices, and therefore not supported. They are, in any case, not in such widespread use as they used to be) but it will indicate the anode and cathode of any diode junctions, which effectively identifies the gate, and determines whether the device is N-channel or P-channel. The same method is used to read faulty transistors (if they are readable at all). If the current gain is very low or non-existent, the DC50 should be able at least to identify one or both diode junctions. Some diode-protected transistors cannot be accurately identified.

The analyser's crocodile clips are small, but they are not small enough to make easy contact with the thin wires of TO92 transistors. Surface mount devices are even harder to connect to.

It is very useful in that it can identify the pin connections of unknown devices, including the determination of which is the collector and which the emitter in junction transistors. It is easy enough to identify the base by using an ordinary multimeter on the diode test range, but to identify collector and emitter automatically saves a lot of effort.

Black and blue

The black case feels robust enough for general use, and fits neatly in the hand. The stylish metallic blue lettering on the case is more eye-catching than easy to read, but this may actually be an advantage, as it does not distract from the display.

The unit is specifically for examining components out of circuit, and includes a warning against trying to test components in a powered circuit, as damage to the analyser and possibly the test circuit may occur.

It will be a useful aid in replacing components in equipment which incorporates discrete semiconductors, particularly semiconductors with indecipherable markings. It will also help in making sure that semiconductors are connected up correctly in prototypes.

In operation, it is handy and trouble-free. You simply connect it up to the component, press the single button, and it gives you a readout. The readout is clear, and as long as you have read the instruction booklet to make sure that you understand the correspondences on the readout, you should know at once which leads are the collector, base and emitter, or cathode (k) and anode (a), depending on the kind of readout given.

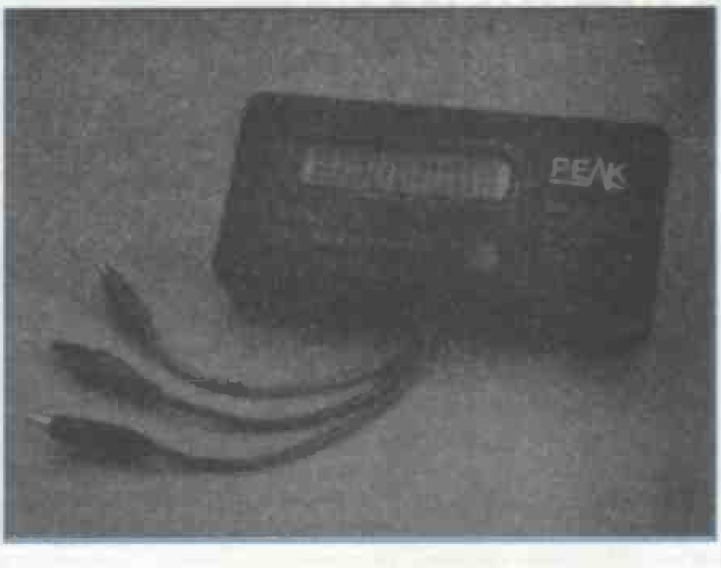
The instructions give a table of testable component types and the parameters within which they can be tested accurately. The makers say that the analyser is optimised for the vast majority of supported component types; a minority will fall outside the required operating conditions.

Maintenance on the component analyser amounts to making sure that the PP3 or equivalent battery is changed at least every 18 months to guard against inadvertent battery leaks. A battery warning appears when the battery is nearing the end of its life.

Although it may be more than the hobby user would spend in order to identify the occasional recalcitrant transistor, the DCA50's basic list price of £49 is good for a PIC-driven instrument with this much functionality, and is well worth considering if there is much component identification to be done. We found it particularly useful for quick-testing diodes from the diode box before using in displays or prototypes.

The 8-page instruction booklet is easy to follow and clearly illustrated, and includes the parameter list for components capable of being tested accurately.

For information, prices etc. contact Peak Electronic Design, 70 Nunsfield Road, Buxton, Derbyshire SK17 7BW, UK.



Around the Corner

Fine lines and slim salaries

A team of graduate students from the University of Texas in the USA, working with DuPont Photomasks Inc., has made a major breakthrough in semiconductor production design in a way that nobody thought possible with the current technology.

The student team, led by chemistry and chemical engineering professor Grant Willson, produced a semiconductor wafer print etched with features 0.08 micron in width, the thinnest etching yet achieved, and not expected before around 2008. Further, the etching was achieved with the 193-nanometre wavelength of light, rather than the much finer beams used in more experimental research. It had been expected that technology still in very early stages of development, such as extreme ultraviolet or x-ray lithography, would be needed to achieve such small lines, but instead it has been done with the same sort of optical technology used for the current generation of 0.25 micron semiconductors.

It is not yet known whether this will turn out to be a commercially viable process, and it is likely to be several years before this is determined. One interesting things is that, using the 193-nanometre wavelength of light, the features etched are effectively finer than the etching beam used.

But beside this dramatic progress, in the USA, as in the UK, there is a shortage of technical skills. American companies have asked the government to increase the number of foreign workers who can be given temporary visas. Companies as reputable as Microsoft, Cypress Semiconductor, and Texas Instruments are all reported to be lamenting the skills shortage.

Texas Instruments' Stephen Leven is reported to have found evidence that the image of high tech workers is distinctly uncool with American youth. "Recently, I was shown a drawings by children asked to envision someone in the high technology industry," said Leven. "Their images of the folks who work in our companies are unflattering ... men with pocket protectors, crooked glasses and rumpled clothing ..." Dilbert rules.

Too often it seems that the engineering image in Britain is even more comic. The difference is that the American response has been to offer higher salaries to attract the people who are available, while in Britain, although salaries are not too bad for technical people, they are not in the same range. As an example, $40,000 (about £25,000) was offered for graduates with a very modest bachelor's degree from an average college.

Britain's attitude is compounded by some of the great and the good who think that the ability to understand anything technical means an inferior intellect. There is certainly a difference in outlook between engineers and politicians. As we know, engineers tend to regard facts as reasonably fixed and verifiable, while politicians sometimes seem to regard them as infinitely mutable.

The attitude is typified by an MP on the first day TV cameras were used in the House of Commons. The interviewer asked whether he would watch his performance on video afterwards, and he replied, with pride ringing in his voice, that although they had a video recorder, neither he nor his wife knew how to operate it.

This was an extreme indication of the ignorance of the true economic significance of science and technology. Despite, or perhaps even because of this, governments the world over react slowly to most technological advances.

Speaking of which, we hope to have an ETI page on the World Wide Web soon. The url will be published as and when it is set up. If you try a search engine, you may get a preview before the magazine containing the url is published.

Next Month

Volume 27 no. 4 of Electronics Today International will be in your newsagents on 24th April 1998 ... Geoff Pike GI0GDP's unusual UHF model radio controller looks set to take off ... Robert Penfold is working on a noise limiter for music systems ... Robin Abbott starts a new introduction to PIC programming with emphasis on more advanced microcontrol ... we have some more electronic games ... plus all the regulars, and more.

Contents are in preparation but are subject to space and availability.

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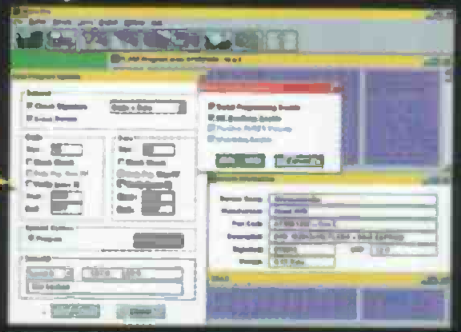

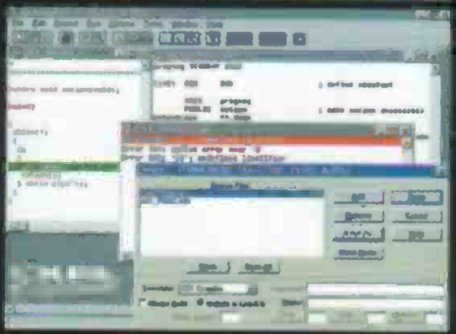

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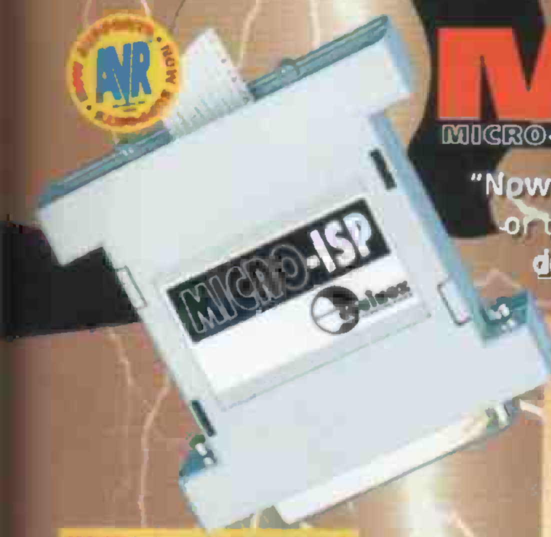

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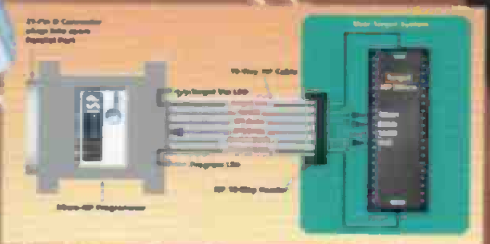

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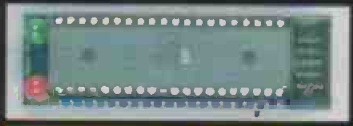

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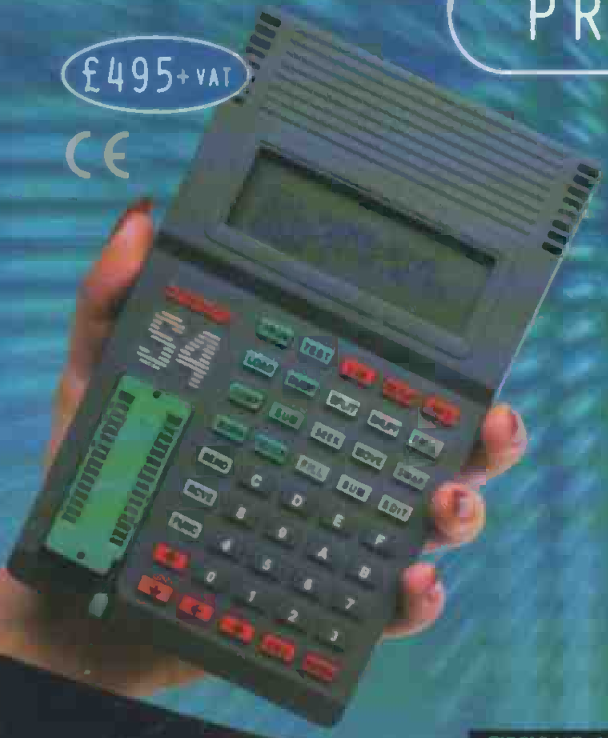

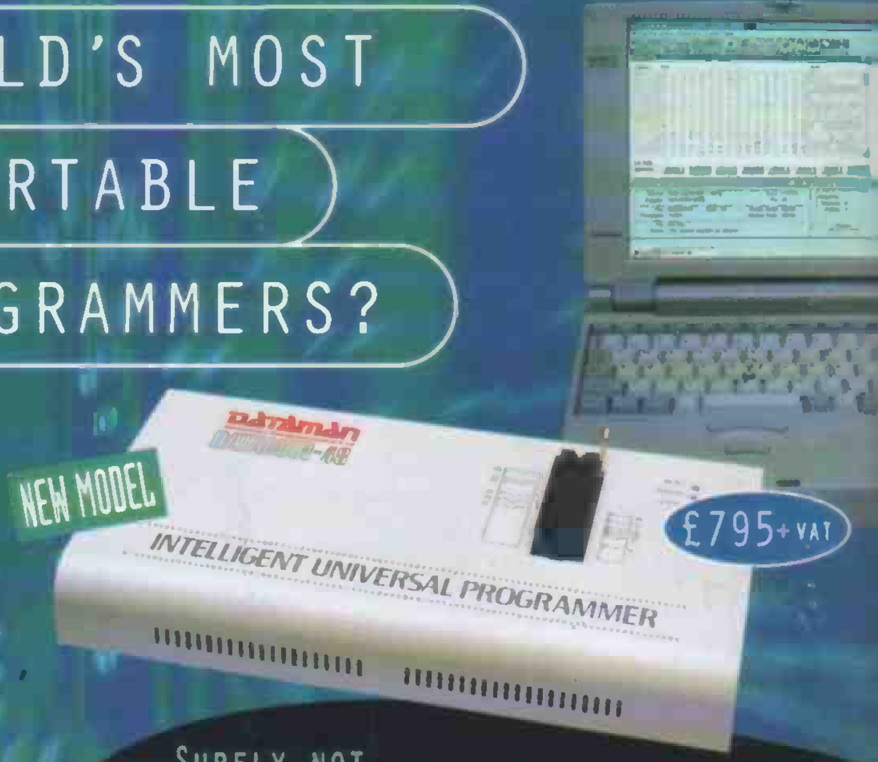

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