Electro Magnetic Levitation

Tomorrow’s flying trains

ETI Data Bus Monitor
“Off You Go” Press-to-Time Switch
Audio Squarewave Generator

Powerline Signal Controller
PIC16C54 Software Test Board
Integrated Schematic & PCB Design System

"extremely good value for money for such a comprehensive package"

Practical Wireless July 96

Quickroute 3.5 is a powerful, affordable and easy to use integrated schematic & PCB design system for windows. With its multiple button bars, 'tool tips', and 'parts bin' Quickroute helps you to get working quickly and efficiently.

Quickroute is available in 4 different versions (see Table) all of which offer great value for money. Quickroute is available with multi-sheet schematic capture, 1-8 layer auto-routing, copper fill, engineering change, and a range of popular file import/export features allowing connection to simulators and other software packages (details on request). Prices are Personal (£68), Designer (£149), PRO (£249) and PRO+ (£399). Please add P&P and V.A.T to total (see below).

THE 32 BIT AUTO-ROUTER WITH FLEXIBILITY & POWER

SMARTRoute 1.0 is a new 32 bit auto-router that offers amazing flexibility & power at an affordable price! Compatible with Windows 3.1/95/NT, SMARTRoute gives you total control over routing strategies including layers used, track & via sizes, design rules, etc.

SMARTRoute is completely compatible with Quickroute 3.5 and offers improved completion rates compared with Quickroute's built in auto-router (ask for details). SMARTRoute is available for £149 plus P&P and V.A.T. Special bundle pricing for Quickroute and SMARTRoute when purchased together.

MExpress is a powerful tool that can be used interactively to load, analyse and display data - or by using its powerful BASIC-like scripting language - you can create technical applications with buttons, menus, 2D & 3D graphics, and powerful numerical methods (ask for details).

MExpress is available in Standard (£99) and Developers Editions (£299). Prices exclude P&P and V.A.T. (see below). The Developers Edition includes tools for turning MExpress script files into C++ code. This can then be compiled by an MExpress compatible C++ compiler into a stand alone executable!
Features & Projects

Magnetic Levitation
Research continues in Japan, America and Europe into the “flying trains” that use controlled electro-magnetism to skim at high speeds over specially-designed guideways. Nick Hampshire reports on the state of the art, and adds an outline circuit for experimenters.

ETI “Camp Light”
Free this month with ETI, a PCB to build. This novel approach to portable lighting incorporates a 12V - 250V DC converter and uses a low-power-consumption mains lamp.

“Squarer”
John Linsley Hood has designed a good quality square-wave generator that can be used with his low distortion oscillator to give quick, accurate audio test results.

Data Bus Monitor
This ETI data monitor checks and digitally displays all 8 bits of binary data on an output port in decimal or hexadecimal format. Add flexibility to your system, and save hasty arithmetic. By Tim Parker.

Simple Power Line Signal Controller
A straightforward circuit for device control through house wiring that can be expanded or not as you need it. By Bart Trepak.

Process Timer and Controller (Part 3)
Tim Parker continue his PIC16C54 process timer project this month with a useful board to enable programmers to test the code of their interface software without having to connect up the controller.

Off you go
A self-timing switch by Terry Balburnie, for lights, alarms, computer monitors or anything where you need a quick time-out.

Pre-Hertzian Radio - the Needles and Fastnet System - Part 2
George Pickworth undertakes his own lake experiment to find out more about the single-cable marine communications system once used by the Needles lighthouse.

Regulars

News
PCB foils
Round the Corner
**THE RENOWNED MXF SERIES OF POWER AMPLIFIERS**

**FOUR MODELS:** MXF200 (100W + 120W) MXF400 (200W + 200W) MXF6000 (300W + 300W) MXF9000 (450W + 450W)

**ALL POWER RATINGS R.M.S. INTO 4 OHMS, BOTH CHANNELS DRIVEN.**

**FEATURES:**
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- Standard 775mV inputs.
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- Latest technology for stress free power delivery, two inputs into any load.
- Very low distortion.
- Angled sections.
- MXF200 & MXF6000 fast cooled with D.C. loudspeaker and thermal protection.

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**OMF200 200 WATT POWER OUTPUT 200 watts R.M.S. INTO 4 OHMS, FREQUENCY RESPONSE 100KHz -3dB, Damping Factor > 300, Slow Rate 50V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S/N -110 dB. Size 300 x 115 x 100mm.**

**PRICE £64.35 + £4.00 P&P.**

**OMF300 300 WATT POWER OUTPUT 300 watts R.M.S. INTO 4 OHMS, FREQUENCY RESPONSE 100KHz -3dB, Damping Factor > 300, Slow Rate 50V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S/N -110 dB. Size 300 x 175 x 100mm.**

**PRICE £81.75 + £5.50 P&P.**

**OMF400 450 WATT POWER OUTPUT 450 watts R.M.S. INTO 4 OHMS, FREQUENCY RESPONSE 100KHz -3dB, Damping Factor > 300, Slow Rate 50V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S/N -110 dB. Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay, Size 422 x 300 x 125mm.**

**PRICE £119.00 + £12.00 P&P.**

**OMF900 1000 WATT POWER OUTPUT 1000 watts R.M.S. INTO 4 OHMS, FREQUENCY RESPONSE 100KHz -3dB, Damping Factor > 300, Slow Rate 50V/uS, T.H.D. typical 0.002%, Input Sensitivity 500mV, S/N -110 dB, Fan 422 x 300 x 125mm.**

**PRICE £475.00 + £35.00 P&P.**

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**TYPE 'E963° 60WATT Ell8-410TC (TWIN CONE) HI-FI. MULTI-ARRAY DISCO ETC.**

**PRICE C73.34 + £3.50 P&P.**

**PRICE C125.00 PER PAIR.**

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**PRICE C15.10**

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**MXF400 W19 x113.3 (3U)s012"**

**MXF600 W19 x113.3 (4U)s134"**

**COLORS:- BLACK**

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386/486 etc £10.99 ref PCK80 for £65

PC KEYBOARDS PS2 connector top quality suitable for 286/386/486 etc. £12 ref LOT81

GAS HOBS AND OVENS Brand new gas appliances. perfect for you self sufficient in electricity £3.50 each ref EP69.

WIRELESS VIDEO BUG KIT With all accessories and a miniature CCTV camera (included) to any standard television! All the components including a PP3 battery will fit into a cigarette packet with the lens, requiring a hole about 3mm diameter. Supplied with a telescopic aerial but a piece of wire about 4" long will still give a range of up to 100 metres. A single PP3 will probably give more than 1 hour use. £9.99 ref EP70 (locally not licensed)

CCTV CAMERA MODELS 4x700cm 30grms. 12v 1000mm effective range. £2.10 ref CSB2.

LIFE ASIATIC RANGER COMPASS Oil filled capsule. strong foilblanket reflects more than 90% of body heat. Also suitable for the hypothermia space blanket £6.99 ref LS7.

TALKING BOX STRIPPER COMPLETE with coin slot mechanisms originally made to ret£7 each. these units are designed to operate on any telephone line into a payphone. The units have the loops keeping and sometimes broken links. However they can be adapted for their original use or used for something of a more commercial nature.

BIG BROTHER PSU Cased PSU. 2A output, 2m op lead. 1.5v 50cm dia 86gm £10.99 ref 0/X604

TELEVISIONS 21" 250w 900nm wavelength. 28vdc 600hz pulse frequency The units have two semi conductor lasers and motor drive units for alignment. Each unit has two gallium Arsenide injection lasers, 1 x 9 waft, 9 watts, 2 x 5 watts, 10 watts, 2 x 1 watt, 20 watts, 2 x 3 watts, 60 watts, 2 x 10 watts, 200 watts, 2 x 20 watts, 400 watts.The units are designed to read standard credit cards, they have 3 wires with 5053.5 and £1 coins DC operated. price just £7.99 ref BAR27.

RETURN TO THE LAST FEW TO CLEAR AT £4.99 SAVE €3.00 ref LOT61

TALKING COINBOX STRIPPER COMPLETE with coin slot mechanisms originally made to ret £7 each. these units are designed to operate on any telephone line into a payphone. The units have the loops keeping and sometimes broken links. However they can be adapted for their original use or used for something of a more commercial nature.

PLUG IN POWER SUPPLY SALE FROM £1.60 Plugs into TV or video. £1.60 ref EP47.

SOLAR POWER LAB SPECIAL You get TWO 6'x6' 6v 130mA components £4.99 for FIVE ref SA26

GAS LEAD ACID BATTERIES Two sizes currently available this month 12v 15AH lead/acid BATT1 for £18 and 10AH (suitable for emergency lights up to 70% of load) for £15.99 ref LS6.

MIXED COMPONENTS 2 line.

CALLING ALL WANTED ORDERS 2150x150x85mm complete with switch, flyleads and IEC socket. 12v 2watt £9.99 ref SA25.

YUASA SEAL LEAD ACID BATTERIES Two sizes currently available this month. 12v 15AH lead/acid BATT1 for £18 and 10AH (suitable for emergency lights up to 70% of load) for £15.99 ref LS6.

EIO ref L0T99

LED RADIOLUX STRIPPER DRIVES ideal for striping. lots of useful guidelines including a small case and lots of components. SALE PRICE JUST £9.99 FOR FIVE ref SA36

SOLD OUT

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MIXED COMPONENTS 2 line.

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SOLAR POWER LAB SPECIAL You get TWO 6'x6' 6v 130mA components £4.99 for FIVE ref SA26.
Flexible current chaser

A flexible ac current probe specially for irregular-shaped conductors with difficult access is available from all Professional Instrument Distributor Association (PIDA) members. The LEM-flex ac current probe is compatible with any digital multimeter, chart recorder or oscilloscope. The compact, portable probe has back-on-itself flexibility with two standard current ranges to each unit, a wide bandwidth, 1% accuracy and electrical isolation with rugged durability. Standard models are available in lengths of 61, 91 and 122 cm, with dual ranges of 0-30/30-300A, 0-300/3000A and 0-60/600-6000A. Flexible air-core toroidal current transformers have overcome the limitations of iron-core current transformers, particularly with regard to rigidity.

Apart from their ability to go around multiple odd-shaped conductors in tight positions, ideal applications are said to be in large variable-speed drives, phase currents in motor drives and UPS systems, output check of MG sets in standby power supplied, power semiconductor failure, current measurement of diodes or SCRs in power rectifiers on a test or permanent basis, and as front-end probes for power monitoring, harmonic analysis and data logging.

For information Tel Fred Hutchinson at Quiswood Ltd. 01756 799737.

486 microcontroller

The compact, multi-function PCA-6144V CPU card in the photo is a fully-featured 486DX2/DX4 industry-grade CPU card with on-board VGA display capability.

The local bus VGA controller has a Windows accelerator and 1MB of display memory. The card supports up to 64MB of on-board dram with a secondary level cache of 128K.

Other on-board features include an enhanced IDE hard disk interface, floppy disk controller, PC/104 interface bus connector allowing modular expansion of the board, two high speed i6C550 buffered serial ports (one RS232 and one RS-232/485), an enhanced bi-directional parallel port and a PS/2 mouse connector.

The card also has on-board power management to the "green function" standard, accessed via the BIOS, which provides three power-save modes: doze, sleep and suspend.

There is a 63-level on-board watchdog timer for fault-critical applications, allowing automatic reset in the event of a software failure. The board operates from a single 5V supply and is designed to run reliably between 0 and 60 degrees C.

The PCA-6144V is available from Integrated Measurement Systems (IMS), 305-308 Solent Business Centre, Millbrook Road West, Southampton SO15 0HW. Tel 01703 711143 Fax 017703 704301.
**Tinner is lead-free**

Intertronics have a lead-free soldering-iron tip-tinner in two sizes.

Modern self-cleaning solder does not entirely remove the problem of oxide deposits clogging the soldering bit and lowering its efficiency. IC lead-free tip tinner is designed to prolong bit-life and increase soldering efficiency, and being lead free helps to keep polluting by-products of soldering to a minimum.

The Tip Tinner is packaged in an ESD-safe metal container with an adhesive pad for fixing to the workbench.

The two packages are priced at £5.88 and £10.41.

Information from Intertronics, Unit 9, Station Field Industrial Estate, Banbury Road, Kidlington, Oxon OX5 1JD

**National Microelectronics Institute**

Nine major semiconductor companies have banded together to found the National Microelectronics Institute (NMI) in the UK. Motorola, NEC, National Semiconductor (UK), Seagate Microelectronics, Siemens Microelectronics, Fujitsu, Newport Wafer Fab, Philips Semiconductors and GEC-Plessey will own the Institute, based on the campus of the Heriot-Watt University, collectively and will be working in partnership with the Department of Trade and Industry, the Scottish and Welsh Offices, and the Government Office for the North East.

The NMI will aims to provide a focus for coordinating the training, supply and research infrastructure for the semiconductor manufacturing industry in the UK. An important initial priority will be to focus on the availability of skilled technicians and engineers for the industry.

Launching the new Institute on July 8th, Ian Lang, President of the Board of Trade in the UK, said:

"Semiconductors are a key enabling technology for the creation of the Information Society, providing the means for the processing and storage of vast quantities of data.

The growth rates in this sector during 1995 were amongst the most remarkable on record for a major industry during peacetime. I am glad to say that the UK has secured a significant share of this expanding industry.

"This is an industry that requires ever-closer links with educational institutions and local agencies, and with its suppliers."

For information contact Sam McEwan Tel 0141 228 2299.

**Modern transformers for ancient valves**

A range of transformers specially designed to meet the needs of the regrowth in the valve market has been launched, aimed especially at electronics and amateur radio enthusiasts. The new VTM range is made by Variable Voltage Technology to traditional requirements but using modern methods and materials, including high grade annealed copper wire and high quality grain-oriented lamination. VTM transformers have been designed to give a low flux density to ensure reduced magnetic fields. The meet the requirements of the EMC and low voltage directives. CE marking is available where appropriate. The transformers can be specified for either frame or vertical mounting, and are designed particularly for:

- mains transformers for HT circuits with or without filament windings
- filament transformers
- mains smoothing chokes
- output transformers with biode or pentode connections, or for use in ultralinear mode. EL34 and EL84 valve types are catered for, and various loudspeaker impedance tapings are available.
- grid coupling transformers, fully screened, single ended or push/pull.

VVT is a specialist transformer designer and manufacturer that can customise its standard range transformers to meet non-standard requirements. Variable Voltage Technology Ltd., Unit 24, Samuel Whites Estate, Medina Road, Cowes, Isle of Wight PO31 7LP Tel 01983 280592 Fax 01983 280593.
Limited quantities of this 2nd supert, ultra small desktop unit. Fully tested and guaranteed with keyboard, 4 M of RAM, SVGA monitor output, 256 colour and 640x480 resolution. Fully tested and guaranteed. Fully expandable and integral 120 Mb IDE drive with single 1.44 Mb 3.5" floppy disk drive. Fully featured with standard simm connectors 30 & 72 pin. Supplied condition complete with enhanced keyboard, 640k + 2Mb RAM, with battery backup is provided as standard. Supplied in good used drive & Integral 40Mb hard disk drive to the front. Real time clock. LIMITED QUANTITY only of these 12Mhz HI GRADE 286 systems.

31/2" CONNER CP3024 20 mb IDE I/F (or equiv ) RFE. Dual 8" cased drives with integral power supply 2 Mb.
31/2" SEAGATE ST -238R 30 mb RLL I/F Refurb.
31/2" MINISCRIBE 3425 20mb MFM I/F (or equiv.) RFE.
51/4" HP C3010 2 Gbyte SCSI differential RFE tested.
EA' CDC 94205-51 40mb HH MFM I/F RFE tested.
534" WESTERN DIGITAL 850mb IDE I/F Brand New.
51/4" INTEGRAL 120 Mb IDE (or equiv) RFE.
31/2" CONNER CP3044 40mb IDE I/F (or equiv ) RFE tested.
51/4" MITAC 4151 80mb MFM I/F Brand New.
Attention all old Keithley instruments!

TO celebrate its 50th anniversary, Keithley Instruments is sponsoring a contest to find the "oldest Keithley instrument" still in working order. A new Keithley Model 2000 digital multimeter will be awarded as first prize to the organisation (or, presumably, to individual owners, if there are such) that can locate the oldest working Keithley instrument. The winner will be able to demonstrate that the instrument can still collect data as it was originally designed to do. Keithley Instruments was founded in 1946 by Joseph F Keithley in Cleveland, Ohio, USA and the company's first product was the Phantom Repeater. This was an amplifier with high input impedance and low output impedance, used to boost signals from low-level transducers and circuits so that they could be measured by the oscilloscopes and voltmeters available at the time.

In the 1950s, the Phantom Repeater was followed by electrometers, piooammeters and DC voltmeters that used many of the vital design features of the Phantom. Today, Keithley products, hardware and software, are used all over the world for electronic test and measurement, data acquisition and semiconductor characterisation. Anyone who works in an industrial research laboratory, engineering development department, quality control area, university or production line should start looking to see if they are using or simply storing a vintage Keithley Instrument that is still working as it was designed to do. "They are second to none in providing highly accurate and reliable data related to the electrical, temperature and periodic phenomena they test and measure", say Keithley of their instruments, and some were second to none in getting there first, too. If you know one of these instruments, send details of the model and serial number with a photograph of the working unit to Mr. Nick Challacombe, MD, Keithley Instruments Ltd., The Minster, 58 Portman Road, Reading, Berks RG30 1EA, UK, before 18th October 1996. We gather that the winner will be treated to a winner's welcome sometime in November.

Adapt to 73kHz

Following the Radiocommunications Agency's proclamation of a new amateur radio frequency (71.6 to 74.4 kHz), Cambridge Kits have put together the information to enable constructors to adapt the Cambridge 60 kHz Receiver for 73 kHz. Adding a variable capacitor (which can be re-used from an old broadcast receiver) to the superheterodyne receiver and retuning it enables it to tune to 70 to 75 kHz. The internal antenna can receive time signals from HBG in Switzerland on 75kHz. The receiver also has provision for an external antenna. The 60 kHz receiver (which is also part of Cambridge Kits' MSF clock kit) is £35.30 including case, decoding details, Basic listings, modification details and P&P. The new amateur band was issued by the Radiocommunications Agency in response to requests from amateurs who wish to experiment with propagation through the ground by transmitting from underground caves, and is available for transmiling to 'A' licence holders investigating LF propagation. Transmitting on the band needs a licence variation, and applications for stays under three months, where amateurs can operate abroad for more than three months. Countries that have implemented the appropriate CEPT Recommendation will issue on request mutually recognised HARECs to those who have passed a relevant national exam. In the UK, Class B HARECs will be issued to anyone who has passed the RA, and Class A HARECs to anyone who has passed the RA and the RSGB's 12 wpm Morse test. Any individual who currently holds or has ever held a full UK licence will be eligible to apply, whatever their original qualifications. Requests for a HAREC should be addressed to the RA accompanied by a current UK licence or proof of an RAe pass (and Morse test pass where appropriate). Foreign or British citizens who have equivalent foreign qualifications can obtain a full UK licence on presenting a HAREC issued by another recognised CEPT administration. Enquiries to RA general enquiry point 0171 211 0211 or your national radio organisation. CEPT Recommendation T/R 61-01 will continue for stays under three months, where amateurs can operate under the authority of their UK licence.

Shorts

The following statement about the Trafficmate navigation system on 433.92MHz has been issued by the Radiocommunications Agency. "Trafficmaster are operating the Trafficmate system on 433.92MHz at present and the system is required to comply with the spectrum management parameters of MPT 1340. This is a temporary frequency allocation and an alternative frequency has now been found for the Trafficmaster network. All Trafficmaster transmitters and receivers will be required to operate on the new alternative frequency after the 31st December 1996." The Radio Society of Great Britain has been in discussion about the overlap of certain new allocations in the traffic area with amateur radio bands (in this case in the 70 cm band) for much of the last year. The Radiocommunications Agency has also launched a new scheme to simplify application for a foreign radio licence for UK radio amateurs who wish to operate abroad for more than three months. Countries that have implemented the appropriate CEPT Recommendation will issue on request mutually recognised HARECs to those who have passed a relevant national exam. In the UK, Class B HARECs will be issued to anyone who has passed the RAe, and Class A HARECs to anyone who has passed the RAe and the RSGB's 12 wpm Morse test. Any individual who currently holds or has ever held a full UK licence will be eligible to apply, whatever their original qualifications. Requests for a HAREC should be addressed to the RA accompanied by a current UK licence or proof of an RAe pass (and Morse test pass where appropriate). Foreign or British citizens who have equivalent foreign qualifications can obtain a full UK licence on presenting a HAREC issued by another recognised CEPT administration. Enquiries to RA general enquiry point 0171 211 0211 or your national radio organisation. CEPT Recommendation T/R 61-01 will continue for stays under three months, where amateurs can operate under the authority of their UK licence.

MODS MODS MODS MODS

ETI August 1996 Simple Distribution Amp: The component layout on page 33 shows D1, D2, D3 and D4 reversed. The circuit diagram on page 32 is correct.

Overseas Readers

Tel To call UK telephone numbers, replace the initial 0 with your local overseas access code plus the digits 44.

Do you have a requirement for any of the following services:
- PCB Assembly (Conventional and Surface Mount)
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- Product Design/Consultation
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- PCB Artwork Manufacture
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**TECHSCOPES**

- **Tektronix 2213** - 60MHz Dual Channel: £250
- **Tektronix 468** - 100MHz D.S.O.: £450
- **Tektronix 454** - 150MHz - 2 Channel: £600
- **Hitachi V650F** - 60 MHz Dual Channel: £300
- **Hewlett Packard 182C** - 4 channel - 100 MHz: £1500
- **Hewlett Packard 4275A** - LCR Meter (Multi-Frequency): £2000
- **Hewlett Packard 4126A** - 10MHz - 18GHz: £4500
- **Hewlett Packard 2223A** - 250MHz 4 ch: £4000
- **Hewlett Packard 2222B** - 500MHz 4 ch: £6000
- **Philips 9042A** - 1GHz - 18GHz: £8000
- **Philips 9043A** - 18GHz - 40GHz: £10000

**SPECIAL OFFER**

- All goods sold on a 30 day guarantee.
- Protocol Analyser £4500
- Protocol Analyser with 30 day guarantee £4750

**POWER SUPPLY**

- **Hewlett Packard 6560A** - Power Supply 20v - 50A £450
- **Hewlett Packard 6561A** - Power Supply 20v - 50A £425
- **Hewlett Packard 6562A** - Power Supply 20v - 50A £400
- **Hewlett Packard 6563A** - Power Supply 20v - 50A £375
- **Hewlett Packard 6564A** - Power Supply 20v - 50A £350

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*SEND LARGE S.A.E. FOR LIST OF EQUIPMENT*
Nick Hampshire takes a look at how magnetism is being used to enable a transport system of the future to whisk along at 500km per hour barely 10cm from the ground.

And the Trains of the Future
We have probably all had those dreams where one floats effortlessly across the surface of the earth. Some mystics even claim to be able to do it, although no-one has actually seen them floating through the countryside, and their techniques seem to rely more upon the effects of excessive ascetic zeal or drug taking than on science. But then we all know that gravity ensures that, barring the use of a great deal of energy, or of helium-filled balloons, or various aerodynamic effects, we will always be firmly placed upon the earth's surface. And, as we all know from painful experience of falling down, gravity is a force to be reckoned with. Anti-gravity devices may be beloved of science fiction writers and film makers, but they are totally outside the range of our current knowledge. So how is it that at various experimental sites across the world there are devices weighing many tons that can float a few centimetres above the ground without the aid of jet engines, helium, or aerodynamic surfaces? The answer lies in the use of magnetic fields to generate repulsive forces to create levitation. It is the well known effect that we discovered as kids playing with a couple of magnets, the fact that like poles repel and opposite poles attract. The force of this repulsion and attraction is sometimes so strong that it is virtually impossible to push two like poles together.

### Floating on magnets

The forces of repulsion and attraction between two magnets or between a magnet and a piece of iron can be enormous, capable of lifting many times the weight of the magnet itself. We only have to think of the electromagnetic grabs used in scrap yards to lift and move tons of scrap iron. In a reverse manner it is therefore reasonable to think of using magnetic repulsive force to lift: or, in other words, float quite heavy objects. You can prove this in a simple experiment: if you place two bar magnets with like poles together in a tube of sufficiently small dimensions to keep their ends in alignment the top magnet will 'float' above the bottom magnet. You can then add a considerable weight to the top magnet before the 'float' gap is closed completely.

This type of observation goes back hundreds of years, long before electricity was discovered, and it is not surprising therefore that the concept of using magnetic repulsion in some form of transport system is equally old. However, any attempts to put these ideas into practice using conventional permanent magnets were doomed because of the inherent instability of magnetic fields. Note that in the above experiment we had to keep the two magnets in alignment using a tube (see Box 1 for an explanation of the instability problem). This means that without severely constraining movement it is impossible to build, say a "maglev" - the term used by magnetic levitation researchers all over the world for many years now - train, using conventional permanent magnets.

With the discovery of electromagnetism there was renewed interest in the concept, but all attempts were again doomed to failure by the same problems of instability. Nevertheless, at the same time, engineers and scientists managed to harness the forces of magnetic repulsion/attraction in the electric motor. Here, a number of electromagnets built into the rotor are alternately switched in polarity using a commutator, so that the rotor electromagnets alternately repel and attract the poles of a fixed permanent magnet, the resultant forces generating a rotation of the rotor. In an electric motor the instability problem does not arise because the entire structure is fixed in position using bearings on the rotor shaft.

The development of electronics meant that the mechanical assembly of commutator and brushes used in conventional electric motors could be replaced by electronic switching techniques. An example of this is the stepper motor. But, for
the developers of maglev transport systems, this also meant that it was possible to use the electric motor principle to generate linear motion. Linear motion systems were developed in the early 1960s (primarily in the UK) by simply opening out the electromagnetic coils in a motor to produce a linear sequence of magnets, forming what was called a linear motor. By electronically switching these coils in the same type of sequence used in an electric motor it was possible to move a magnetic object along the line of coils, floating just above them. Reverse the sequence and the object would move in the other direction. This was the first practical step towards a maglev train, it demonstrated all the key requirements for such a system: levitation above a track, and motion along the track with controllable direction and speed.

**The Japanese approach**

The British pioneered the technology in the 60s and early 70s, but all funding was cut off in an ill-judged bout of Government cost-cutting during the early 70s. But, despite this setback, there has been ongoing research in both Japan and Germany for the last 30 years as we said before (see Table 1 for a history of Japanese maglev development). Of these two countries Japan has made by far the biggest commitment to research and development of a full commercial maglev train.

Japanese engineers working on this project at RTRI have developed a system which uses a combination of superconducting magnets and the old British developed linear motor technology. Using this combination they have built and designed a series of prototype maglev vehicles that fulfil the designers' aims of super high-speed, high safety factors, high reliability, low environmental impact and minimum maintenance.

The research and development program for Maglev (the name given to the project which combines superconducting technology and linear motors) has been underway at RTRI since 1970. The first few years were spent on laboratory tests to verify the feasibility of running such a train at speeds of up to 500km/h. The success of these early tests led in 1975 to commencement of the construction of a 7-km test track. This facility was opened in April 1977 and has subsequently enabled...
the engineers to test full sized prototypes. The Miyazaki test track is located in Miyazaki Prefecture. It has a length of 7km and minimum radius curvature of 10,000m. On this test track in 1979, an early prototype model, the ML-500, attained 517km/h using an inverted-T shape guideway. The guideway was modified to U shape in the next year. A manned two-car vehicle, the MLU001, first ran in November 1981, and registered a speed of 400.8km/h in 1987.

The latest vehicle, the MLU002N, was unveiled in 1993 and is running on the Miyazaki test track today. It reached a speed of 431km/h last January. One of the main aims behind the current development work being conducted by RTRI is enhancement of the reliability and durability of the superconducting magnet (SCM). The SCM suffers from external magnetic disturbances caused by the presence of the ground coils and from mechanical vibrations generated by vehicle dynamics. These disturbances cause quenching troubles, or the sudden disappearance of magnetomotive force of the SCM. RTRI’s engineers have been studying these problems with a comprehensive range of test studies, and have, as a result, developed countermeasures such as stiffening the SCM and decreasing the total current density of superconducting coils. Besides the problems associated with the SCM the designers are also working on a whole range of developments, such as aerodynamic brakes that use the aerodynamic drag of panels on the car roof; disc brakes for high-speed running; ground coils which consist of sidewall levitation coils and double-layer propulsion coils; a high-power supply system for pulse width modulation (PWM) inverters using gate turn-off (GTO) thyristors, and turnouts for high- or low-speed passing.

The success of the Maglev project prompted the Japanese Government to increase funding in 1990, and at the same time authorise the construction of a new test line which should allow the designers to take development right up to the final design of the first Maglev systems for public use. The new test line named Yamanashi Maglev Test Line is now under construction. The Yamanashi test line is being built in the Yamanashi Prefecture and it is expected that the first test run will start in spring, 1997. Two trains will be able to run at a speed of about 500km/h (the target speed is over 550km/h) on the Yamanashi test line which has a curve section (minimum radius curvature of 8,000m), a steep-slope section (maximum gradient of 4%), a tunnel section, and double-track section (5.8m between track centres). In addition, the track site will incorporate a planned facility for performing operational simulation tests that involve vehicles, power conversion stations, train control systems, guideways, and environmental considerations.

**How does a Superconducting Maglev actually work?**

The current Japanese development work on a maglev train is based upon the use of both linear motor technology and superconducting magnet technology. These are combined into a very complex system which has some components mounted in the track and others in the moving train. Mounted in the track bogie units are the superconducting magnets, and in the walls of the U-shaped track is a sequence of figure eight shaped electromagnetic coils that are linked under the track, or guideway, as it is more commonly called.

We can divide the operation of the system into three distinct areas: magnetic levitation, lateral guidance and propulsion. The levitation height is about 10cm, with similar gaps between the train and the guideway side walls, and as we have already seen the design speed for the system is up to 550Km/hr. These are design tolerances and speeds that have pushed the technology to the limit (we will be looking at some of these design problems later on in this article).

Magnetic levitation (figure 1) depends upon the interaction of the coils mounted on the guideway walls and the bogie mounted superconducting magnets. The figure-eight shaped levitation coils are installed on both the side walls of the guideway in a position so that when the on-board superconducting magnets pass at high-speed they are several centimetres under the axes of these coils. The result of having a superconducting magnet passing each pair of coils is that an electric current is induced within the coils, which then temporarily act as electromagnets.

The coils thus generate two magnetic forces which act at the same time, on the one hand pushing the superconducting magnets upwards, and on the other hand pulling them upwards, thereby levitating the maglev bogie. With such a small gap between the guideway side walls and the maglev vehicle lateral guidance is extremely important. At very high speeds even a slight scraping of the vehicle against one wall due to, say, the pressure of a side wind, could be catastrophic. This means that it is important that the control system is as foolproof, simple, and completely automatic as possible. The technique which the Japanese team have employed certainly meets these criteria. What the designers have done is to connect the two levitation coils facing each other (figure 2), forming a circuit loop. When a maglev vehicle with its superconducting magnets is displaced laterally, an electric current is induced in this loop, with the result that a repulsive force acts on the levitation coil near the bogie and an attractive force acts on the other levitation coil that is farther apart from the bogie. The two forces thus automatically pull the train back towards the centre of the track.

Forward or reverse propulsion of a maglev train is achieved by using the linear motor technique (figure 3). This means that a repulsive force and an attractive force induced between the bogie mounted superconducting magnets are used to propel the vehicle in the desired direction. To provide the required magnetic repulsion and attraction the propulsion coils located on the guideway side walls are energised by the three-phase alternating current from a tracksix substation.

These propulsion coils create a shifting pattern of magnetic fields on the guideway, the control of which can determine not only direction but speed. Faced with this shifting pattern of magnetic fields, the bogie mounted superconducting magnets are both attracted and pushed by the shifting field, thus propelling the maglev train.

**Design considerations for a commercial maglev system - Aerodynamic Issues**

High-speed (500Km/h) trains using magnetic levitation have a whole host of unique design problems which must be overcome prior to the development and use of commercial systems. One of the most important of these is the aerodynamics of the vehicle.

The technological success of high speed maglev vehicles, like most aerospace systems, hinges upon a good aerodynamic design - a very large part of the design process is influenced by aerodynamic considerations. Such considerations have a major role in determining propulsion techniques, structural design, and control system
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requirements, not to mention the manufacture of the vehicle, its unit cost, and its life cycle cost. The aerodynamic problems involved in the design of maglev vehicles differ greatly from that of aircraft and conventional trains. The most important of these problems is the need to minimise the aerodynamic drag. At proposed speeds of 500km/hr or more, which in aircraft terms is the same as 0.4 times the speed of sound (Mach 0.4) aerodynamic drag will be the largest component of drag. At lower speeds it is magnetic drag which is predominant. Of course aerodynamic drag on a maglev vehicle will not affect vehicle range (as is the case for aircraft) since power is derived through the guideway. However, lower drag will mean less energy expended and therefore lower operating cost.

Unlike an aircraft, the suspension and control on a maglev vehicle is performed using magnetic and not aerodynamic forces. This means that at cruise conditions the vehicle weight is primarily supported by magnetic lift. From the design point of view this means that there is no need to try and maximise the value for aerodynamic lift. Instead, the aerodynamic design must ensure that ground effect forces do NOT create any conditions which will degrade system performance. Ground effect is a very important force in high speed vehicles travelling on, or very close to the ground.

It can produce a suction force (negative lift) due to the higher velocity underbody airflow. On Formula 1 racing cars, for example, maximisation of this suction force is one of the aerodynamic design goals, as it gives them greater stability. However, ground effect will degrade the performance of a maglev system because it will decrease the levitation effect of the magnetic field and increase the levitation requirements, and the energy used.

The reverse type of aerodynamic force is the positive lift that is used by aircraft to achieve flight. This could be used to augment the magnetic levitation system, but at just a few centimetres above the ground it is too unreliable.

The designers of maglev transport systems are therefore aiming to counterbalance lift and ground effect to create a vehicle with zero lift. A zero lift design will minimise induced drag and therefore ease magnetic propulsion requirements. On aircraft, aerodynamic moments are used to reorient the lift vector thereby manoeuvring the plane, however, maglev vehicles simply follow their guideway. This means that on maglev vehicles aerodynamic moments will need to be counteracted with magnetic coupling forces and minimised in order to lessen magnetic control requirements. As far as aerodynamic shape is concerned it is very important that maglev vehicles are insensitive to crosswinds. It should be remembered that a 30m long vehicle with 5cm lateral guideway clearance can sustain only a 0.2 degree yawing angle with the guideway before making contact. Since yawing moment diverges with side slip angle, crosswinds will make the maglev vehicle highly susceptible to excessive lateral displacements. A good aerodynamic design will minimise this sensitivity, and thus reduce the cost for lateral directional control.

Design considerations for a commercial maglev system - The environment

The fact that the guideway used by maglev vehicles will be on average no more than 10m above the ground brings with it additional aerodynamic design problems. Along most of the guideway's length the vehicle will be travelling at 500km/hr, with the guideway going through urban and residential areas. This means that the vehicle must also be designed to minimise its aerodynamic disturbance on the surroundings. A maglev train travelling at high speed has the potential to generate a lot of noise.

Noise is derived from strong vortices and pressure waves produced by the airflow over the vehicle and through the vehicle/guideway clearance gap. This means that poor aerodynamic design could cause maglev to be an unwelcome environmental intrusion in many locations.
Noise also becomes an issue as a result of the close proximity to the ground. Aerodynamic noise is generated from the vehicle’s turbulent boundary layer, trailing vortices, and wake. In the US a noise limit of 73 dB at 15 meters from the vehicle centreline was set by the US Federal Railroad Administration. In addition to this, the design must avoid pooling of rain water, dirt, and debris in undesirable areas such as the air intake for the ventilation system. The shape of the vehicle and, to a greater degree, that of the track and the region of interaction, must be laid out to avoid susceptibility to snow accumulation.

**Design considerations for a commercial maglev system - Manufacture and economics**

Because of the high technology involved, the enormous importance of aerodynamics, and the necessary tight manufacturing tolerances, maglev transportation systems are increasingly being viewed as a good business opportunity by aerospace companies looking to broaden their activities into other areas of commercial transportation, a factor which will undoubtedly give the newly revitalised US work on maglev a considerable advantage. Only the aerospace companies have the capability to handle the requirements for complex aerodynamic surfaces with their curvature continuity and smooth transitions, surfaces which tend to be very difficult to manufacture.

The expertise of such companies in the use of different manufacturing processes ranging from riveted aluminium to advanced composite materials will be very important. These requirements will affect the cost of production. More expensive materials will be needed, and surface smoothness and tighter tolerances will be more difficult to produce, and therefore also increase costs. However, high unit should be counterbalanced by low running costs and by the efficiency exhibited by such systems in moving people and goods rapidly over long distances.

**Is there a future for maglev?**

The great advantage of using magnetic levitation to “float” something, such as a train, is that it virtually eliminates all the problems arising from friction in any system where surfaces are in contact with each other, like wheels on a track. This means much higher speeds, at lower energy consumption, lower mechanical wear, and fewer problems with heat derived from friction - indeed the virtual elimination of most moving parts.

In theory, a maglev train which has no physical contact with the ground should be capable of very high speeds, speeds which rival those of aircraft. Indeed, aerodynamics are a very important consideration in the design of maglev transport systems. Current developments in Japan, now the world’s leaders in maglev research, have demonstrated speeds of up to 500 km/hr with a full sized prototype. Besides a capability to travel at high speed, a maglev train should be extremely energy efficient since losses due to friction, heating etc are minimised.

With research currently concentrating on the use of superconducting magnets the efficiency should be even greater. Furthermore, compared with aircraft there will be no consumption of energy in order to climb to a cruising altitude. The operational efficiency and economic potential of maglev transportation systems in an era of Impending energy shortage and concern about the environment has meant that the technology has started to attract a lot of attention in the last year or so.

**Why not use a permanent magnet suspension system?**

The difficulties involved in achieving stable suspension or levitation are derived from an inverse square law that relates force and distance.

This was first examined by the Victorian scientist William Earnshaw in his classic paper published in 1842, he shows mathematically that it is impossible for a pole placed in a static field of force to have a position of stable equilibrium when an inverse square law operates. This fundamental calculation is known as Earnshaw’s theorem.

In the late 1930s the German scientist Braunbeck performed a similar analysis on unvarying magnetic and electric fields, and deduced that suspension or levitation is only possible when materials have a relative permeability, \( \mu_r < 1 \) or \( \epsilon_r < 1 \).

(The to prove this, suspension has been achieved using diamagnetic materials, and as a result of the effect of currents in the suspended objects.)

It thus follows from both Earnshaw’s theorem and Braunbeck’s analysis, that stable suspension or levitation is
impossible with a system of permanent magnets (or fixed current electromagnets) unless, of course, part of the system contains either a diamagnetic material ($\mu_r < 1$) or a superconductor ($\mu_r = 0$). It also follows that it is completely impossible to achieve levitation in electrostatic fields since there are no known materials with $\epsilon_{\text{linen}} < 1$.


**Magnetic levitation circuitry - of the DIY type**

The problem, from an amateur experimenter's point of view, with superconductivity projects is the requirement for buckets of liquid helium. Pretty nasty stuff, and not that easy to obtain, not to mention the fact that it evaporates faster than you can use it. So, by and large, superconductivity experiments are a no-go area until we can all get cheap samples of high temperature superconductors that only need cooling in liquid nitrogen. This means, of course, that constructing a superconductivity maglev train in your back garden is out of the question.

However, do not despair, for there is a way in which we can achieve this type of levitation effect without superconductivity. It involves the use of an ingenious feedback system to create an electromagnetic system that behaves in much the same way as a superconducting magnet, a magnet that will repel BOTH ends of any bar magnet and can thus be used to 'float' such a magnet.

Such a device is actually quite simple to build, and it works at room temperature. The main component is an electromagnet. You could use a surplus one, but it is generally far easier to make your own. For the core use some 0.25-inch iron rod (a bolt will do) at least an inch long. To make the coil you need to first of all construct a suitable electromagnet's core (hold it in position with some tape or Blu-Tak).

Glue it all firmly in place before winding the coil. For this size of electromagnet the coil needs about 300 turns of 30 swg wire (use good quality enamelled copper wire, or even coated wire-wrap wire). Such an electromagnet will generate a fairly strong magnetic field given a supply voltage of around 9 V.

For a circuit (see figure 4 for example) you will need two power supplies, one with +9V and GND, and the other with -9V and GND. Both share a common ground (batteries could be used if operated for very short periods). The two power supplies are needed to generate the polarity reversal within the electromagnet. The electronics are fairly straightforward, though make sure that the transistors arid diodes are capable of handling the voltage as well as the current through the coil.

The Hall effect switch is the sort that is widely used in alarm systems (they are available from Maplin). The Hall effect switch is not mounted with the rest of the components but is positioned on one end of the electromagnet's core (hold it in position with some tape or Blu-Tak).

When the unit has been assembled and the power applied, the end of the iron core on which the Hall effect switch is mounted should repel any bar magnet, irrespective of polarity, that is brought close to it - the basis of any magnetic levitation system. Instability means that a single unit cannot be used to levitate a bar magnet. To do that you will probably need about six units mounted with their core ends (and attached Hall effect switches) at about 45 degrees to the horizontal and pointing towards each other, creating a magnetic 'trench' in which the bar magnet can 'float'. Two parallel rows of these coils and circuits will act as a simple maglev railroad track allowing a bar magnet to float along above them if it is gently pushed between the rows (figure 5). A circuit of this type operates in the following manner: when power is applied to the circuit the Hall switch is on and voltage is applied to the coil in a particular direction so that the tip of the coil's iron core to which the Hall switch is attached becomes a north pole. However, the Hall switch is positioned on the core so that this polarity of magnetic field turns the switch off. When the switch is off, the direction of voltage is reversed. This means that the tip of the core becomes a south pole, and as a result the Hall switch turns back on. Of course this results in polarity switching back again. The result is that when this circuit is running the Hall switch turns on and off very rapidly, and the magnetic field rapidly switches back and forth.

This means that effectively each pole of the electromagnet exhibits an average zero magnetic polarity. But if we bring another magnet close to the Hall sensor then the situation changes, with feedback trying to keep the zero polarity. This means that when no magnet is near the coil, the coil's average polarity is zero, but when a magnet is placed near the sensor the Hall switch adjusts the magnetic field to keep the sensor at zero polarity. This is exactly what happens in a superconductive magnet; it creates zero magnetic field inside itself and thus repels either pole of a permanent magnet. In other words our circuit is replicating the behaviour of a superconducting magnet, and not a drop of liquid helium in sight! In this circuit the coil-assemblies will therefore repel a bar magnet regardless of whether it is an N or an S pole. When an N pole approaches the Hall sensor, the circuit will send a current through the coil more in one direction than the other, which makes the coil's pole become "N" rather than zero, and it repels the magnet. The two opposing magnetic fields thus cancel each other to zero between the magnet and the coil, the position of the Hall effect switch. Unfortunately the circuit exhibits slightly negative stability. This means that small movements in the suspended bar magnet trigger the compensating magnetic field after a small time delay, which in turn will trigger slightly larger movements. The resulting oscillations will magnify and eventually get so severe that they will throw the magnet out of the device after a few seconds. The only way to stop this problem is to make sure that the magnet is not moving initially. Oscillations will then build up very slowly or not at all.

Oscillations in the magnet can also be damped down by putting a thick copper bar just below the bar magnet. The induced current and electrical resistance of the bar will generate a small amount of mechanical damping to the changing magnetic fields. The result is a dampening of the magnet's motion, and the oscillations should decline in magnitude. However, the only real way to overcome the problems of instability and oscillation is to use a more complex form of feedback circuitry which will eliminate the loop delay which causes the oscillation.

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<td>SP11</td>
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### SOLDERING ACCESSORIES

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### DESOLDERING AIDS

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<th>Description</th>
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<tr>
<td>8 way Preprogrammed Universal Remote Control</td>
<td>8WPRG</td>
<td>1450p + VAT</td>
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This can be done by using an analogue Hall sensor connected to an amplifier, and the signal from the Hall sensor can then be used to generate the required damping.

**The US starts to take an interest**

The Federal Railroad Administration (FRA) and the US Air Force (USAF) have announced an agreement to develop magnetic levitation technologies for use in missile defence warhead testing as well as high-speed ground transportation. The Federal Railroad Administrator Jolene M Molitons said: "We are excited about the prospect of working with the Air Force on the development of multipurpose applications of this new technology. This partnership is an excellent example of the Clinton Administration's commitment to develop high technology projects that will yield maximum benefits, with both military and civilian applications. Magnetic levitation (maglev) trains have the real potential to help relieve congestion along our nation's already overcrowded highways and airways. "A maglev passenger train could cut the travel time from downtown Los Angeles to downtown San Francisco to about 1 hour and 30 minutes — today, it takes nearly 10 hours travelling by traditional rail service", she added.

Maj. Gen. Stewart E. Cranston, commander of the USAF Development Test Center, said: "Magnetic levitation technology will give the Department of Defence a capability to conduct realistic, hypersonic testing of warhead lethality and propulsion systems at an affordable price. We are pleased to work with the Federal Railroad Administration to develop commercial applications for this technology."

The "FRA's Deputy Administrator Donald M. Itzkoff has met with USAF officials at Holloman Air Force Base in New Mexico to discuss the construction of a maglev upgrade to the existing Holloman High-Speed Test Track. "By working with the Air Force to develop very high-speed maglev vehicle control capabilities, we believe we will also derive technology benefits applicable to future high-speed passenger train service", Itzkoff added. Maglev is part of the Department of Transportation's forthcoming assessment of high-speed ground transportation commercial feasibility. A demonstration of electromagnetic propulsion capability will also be developed and tested.

The USAF will use the track's guideway to test the effects of high-speed payload velocities and the FRA will determine potential safety and performance applications for high-speed trains. The project, as funded by the USAF, will test superconducting magnet design and fabrication, verification of computer codes which predict dynamic magnetic fields, effects of track irregularities and aerodynamic impact of velocities up to 300 mph on test vehicles. Maglev technology uses magnetic forces to levitate the vehicle and to either attract or repel for propulsion, for both suspension and guidance.

Maglev trains have the potential to travel at speeds in excess of 250 mph. Currently, Congress has provided the FRA with limited funding for maglev safety-related work. The FRA was, however, the lead agency in an interagency cooperative effort in 1991 with the Department of Energy and the US Army Corps of Engineers, concerning the viability of a US maglev transportation system. The results were published in the National Maglev Initiative (NMI) report. The NMI and the FRA's expertise in maglev will be utilised by the USAF as a resource as they further develop their research.

**History of maglev R&D in Japan**

1962 - Research for linear motor propulsion and non-contact run started
1970 - Study on electrodynamic levitation system using superconducting magnet started formally
1972 - LSM-propulsion experimental superconducting maglev test vehicle (LSM200) succeeded in levitated run and LIM-propulsion experimental (ML100) succeeded in levitated run
1975 - LSM-propulsion experimental superconducting maglev test vehicle (ML100A) succeeded in perfect non-contact run
1977 April - Miyazaki Maglev Test Center opened
1977 July - Test run of ML-600 inverted-T guideway started at Miyazaki Test Track 1979 Jan. Simulated tunnel run tested
1979 May - Run with helium refrigerator on board tested (ML-500R)
1979 December - 517km/h run attained
1980 November - Test run of MLU001 on U-type guideway started on Miyazaki Maglev Test Track
1981 November - 2-car unit test run started
1982 September - Manned 2-car unit test run started
1986 December - 3-car unit registered 352.4km/h run
1987 January - Unmanned 2-car unit attained 405.3km/h
1987 February - 400.8km/h run of manned 2-car unit attained
1987 April - Railway Technical Research Institute reorganised as a foundation, taking over the R&D work so far pursued by JNR
1987 May - Test run of MLU002 started
1988 December - Substation cross-over test carried out
1989 March - Aerodynamic brake system tested (MLU001)
1989 November - 394km/h run attained (MLU002)
1990 March - Test on traverser type turn out started
1990 November - Start of initial phase in construction of the Yamanashi Maglev Test Line celebrated
1991 June - Test run on sidewall levitation system started
1991 June - Test run energized by inverts started
1993 January - Test run of MLU002N started
1994 February - MLU002N attained 431km/h run

**Note:**

LSM: - Linear Synchronous Motor
LIM: - Linear Induction Motor

Pictures courtesy of RTRI, Japan
**Electro Value**

**Buying Guide 1996**

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Fax: 0161 432 4127

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**Analogue ICs**

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<thead>
<tr>
<th>Positive Amp</th>
<th>T2000</th>
<th>78090, +6v</th>
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**Digital ICs 74L**

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**Surface Mounted Transistors**

<table>
<thead>
<tr>
<th>Flash tubes</th>
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<td>He-Ne</td>
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**Silicon Diode Arrays**

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**Other SMd products available:**

- Ceramic & tantalum capacitors
- Ferrites
- Hall-effect devices
- Integrated circuits
- LEDS & Opto-couplers
- Resistors
- Temperature sensors

**Product Range**

- NICHICON Capacitors
- KEMET Capacitors
- Littium Batteries
- OHM Capacitors

**Cables and Connectors**

- QUICK REX CABLES
- QUICK REX CABLES 5.0mm²
- QUICK REX CABLES 7.5mm²
- QUICK REX CABLES 10.0mm²

**Quick Connectors**

- QUICK CONNECTORS

**Telephone:**

- OHM TELEPHONES

**Power Supplies**

- OHM POWER SUPPLIES

**Valves**

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Andrew Armstrong has developed a portable power 250-volt DC generator that he uses to power a low-consumption mains-voltage fluorescent lamp from a 12V car battery.

I normally work under a 3500K colour temperature low consumption lamp of the type intended to replace a conventional domestic lightbulb. The 18W model I use is specified to give out slightly more light than a 100W incandescent lamp. The colour temperature, being higher than most, gives a light with enough blue in the spectrum to tell, for instance, the difference between red and purple on a resistor colour code easily. It also make most things look a little brighter - in short, it is ideal for a situation in which there never seems to be enough light because there are no walls and ceiling to reflect it back to you. An interesting fact about the low consumption lamps intended for use with this project is that they contain all the necessary electronics to drive a fluorescent lamp, but they are designed to work on 240V AC. However, what they do is to rectify the mains when it is first fed in, so they can run just as happily on DC. All that is needed is a DC supply of the average level on the capacitor which follows the rectifier in the fluorescent lamps. I found that 250V works well on a range of lamps, so this project is to provide a nominally 250V DC supply to run a low consumption mains lamp.

Many of you will have seen designs for 12V to fluorescent tube converters. Normally these use a blocking oscillator driving a transformer made on a ferrite pot core. This transformer steps the 12V supply up to a high enough level to run a fluorescent tube. However, low consumption lamps operate differently because of the higher supply voltage.

A normal mains fluorescent luminaire employs a choke in series with the fluorescent tube to limit the current once it has struck. When a fluorescent tube is conducting, the voltage...
The schematic

Instead of rectified mains as shown in figure 1, we use a DC supply generated by the circuit shown in figure 2. This design employs a Linear Technology switched mode converter chip, the LT1170, in a voltage-boosted flyback converter configuration.

Flyback converters operate by storing energy in a magnetic field, usually contained in a defined airgap in a magnetic component, and then discharging that energy into a load at a different voltage from that at which it was fed in. The maximum power output available from a given flyback converter is limited by how much magnetic energy can be stored in the magnetic component before it saturates, and how rapidly the energy can be stored and transferred. This circuit works at 100kHz, which is a respectable though not technologically difficult frequency for a flyback converter. The frequency is set by the on-chip oscillator of the LT1170.

The energy storage is provided by a ferrite E-core transformer with a gap in the centre limb. The component chosen is an EFD20, which is a 20mm-square “easy flat design” transformer using a ferrite suitable for frequencies of several hundred kilohertz.

At room temperature the 15mm-square transformer, which can store about half the energy of the 20mm-square one, is adequate for the job. However, allowance has to be made for the fact that the transformer core material is ferrite. The mechanism of magnetisation of ferrite is different from that of iron, with pairs of opposed magnetic moments of unbalanced strength, so that the difference between the two allows for a net magnetisation. The practical upshot of this is that ferrite saturates at lower flux densities than iron, its Curie point (the temperature at which it ceases to be magnetic) is lower, and across it does not rise significantly as current increases, so without an external limiting component the current would rise to a destructive level and the lamp would be useless.

The choke contains a substantial iron core, and is inconveniently large and heavy.

Low consumption lamps use the same principle, but use a much smaller choke in conjunction with a higher frequency to give the required current (because the impedance of an inductor is $2 \pi f L$ where $L$ is the inductance and $f$ is the frequency). What they do is to switch a DC supply at a high frequency and use the result to drive the fluorescent lamp. The principle, omitting the control circuitry, is shown in figure 1.

![Figure 2: the circuit of the 250V DC source](image)

![Figure 3: switching waveform on IC1 pin 4](image)

![Figure 4: the switching waveform expanded to show a switching spike](image)
Figure 5: the switching waveform on IC1 pin 4 but without the ferrite bead

its saturation flux density decreases as it warms up.

To allow for heat dissipation in the unit and still permit correct operation, the EFD20 is the smallest suitable transformer.

The structure of the circuit is largely conventional. Starting at the power input, J1, there is a filter to stop interference getting out down the input wire, and a diode to protect against reverse battery connection. C2 provides local decoupling. A specially low esr (equivalent series resistance) capacitor is used to minimise noise and maximise efficiency.

IC1 contains all the active electronics including the switching device. R1 and C3 provide a fairly low frequency pole for the feedback loop, aiming more for absolute stability than for rapid response to step changes of load (which are not expected to occur). In this type of converter the switching device will inevitably be subjected to some degree of switching spike caused by the leakage reactance of the transformer. To protect the chip from damage caused by such spikes, the maximum voltage is clamped by zener diode D1, with D2 being provided to prevent D1 from conducting when the switching device is on. The switching waveform is shown in figure 3, with the spike being very apparent. As can be seen, under the load conditions for which this trace was taken (21-watt lamp load) the switch is on for just over 4 microseconds, and then the transformer transfers energy to C5 for approximately 3 microseconds. After that there is approximately 3 microseconds when both D3 and the switching device are not conducting. Figure 4 shows an oscilloscope printout of the detail of the spike on IC1 pin 4. In this trace it can be seen that the first ring has a flattened top, where D1 conducts and limits the size of the spike. In the absence of the zener diode, the spike would go to approximately twice this voltage. One item not always seen in flyback converters is the ferrite bead L2. This is necessary to limit the rise of switch current during the first few tens of nanoseconds if the switching device turns on at or near the peak of one of the oscillatory cycles that occurs in the transformer once it has finished discharging energy into C5. To illustrate the effect of the ferrite bead, the waveform at the junction between L2 and T1 is shown in figure 5. Here, there is a -4V spike at the point of switch-on. With a slightly different amount of load, so that the switch-on occurs at or near the peak of the cycle rather than, as here, more than half way down, the spike can exceed 10V. In practice, what happens without L2 is that at some specific levels of load the control chip switches on for only about 100 nanoseconds on some cycles, when it switches at the peak of a ring. This alters the phase of the switching so that the next cycle can usually switch successfully. The switching jitters, and the efficiency drops. You will note that there is a significant period where the transformer is ringing and not either being charged or discharged with magnetic energy. This is necessary for two reasons: the control law is different if the converter operates in continuous mode, i.e. when either the switching device or the diode are conducting at all times. The second reason is that, if the switching device turns on while the diode is still conducting, then there is a significant switching loss in the diode which reduces the efficiency. Therefore, T1 has been designed so
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that the converter will not run into continuous mode at any rate of load. By the way, the effectiveness of the input filter is illustrated by the waveforms of figures 6 and 7. Figure 6 shows the interference waveform on the top of C2 at 1V per centimetre, while figure 7 shows the interference on J1 at 200 mV per centimetre. The peak interference voltage is reduced to approximately one-fifth by the addition of L1 and C1.

Building the transformer
In order to make this project work well, the transformer must be built just as shown. Any variation from the designs shown here may result in unreliability. For example, one more turn on the primary could send the system into continuous mode conduction at higher load levels, which might cause the failure of D3.

First of all, one of the 40-turn secondaries must be wound (it does not matter which one). It must be connected between the two pins as shown in figure 8, the transformer pin diagram. It is vital that all the windings are done in the same direction, so that if you have started winding, say, clockwise at one side of the transformer, all subsequent windings must start at the same edge and go in the same direction.

After the first winding has been put on, a layer of tape should be placed over it. Ideally, thin Mylar tape should be used, but if this is not available, any thin non-conducting tape may be used. The enamel insulation on the wire is supposed to be adequate for the voltages in use, but the slightest scratch in assembly can impair this quality, so a layer of tape is very desirable as an extra protection.

The next layer to be wound is the 8-turn primary. To keep the windings as flat as possible, the same wire thickness is used for the primary as for the secondaries, but, because of the increased current in the primary, two wires are wound side by side to make this winding. A length of wire at least twice as long as required to go round the bobbin 8 times should be folded in half and the folded end looped over one of the pins to which the primary is connected. If necessary, because two wires join this pin, a little of the insulation at the point in contact with the pin should be scraped off to enable extra heat to get through to the self-fluxing insulation.

A single twist should be put in the wire to hold it tightly onto the pin, and then the paired wire should be wound carefully 8 times round the bobbin in the same direction as the winding already put on. It is preferable to space the turns roughly evenly over the length of the bobbin. When 8 turns have been applied, terminate the pairs of wires at the other primary connection pin. It is desirable to scrape a little of the insulation off both wires at this point to make sure that solder contacts them both and to avoid the possibility that only one of the two wires may end up properly connected.

Then apply a further layer of tape, and wind the final 40-turn secondary, again making sure to do it in the same direction as the other two windings. Then solder the wires to the pins, making sure that the solder contacts the wire through the self-fluxing insulation. A hotter-than-normal soldering iron temperature is desirable for this process.

The layering of the tape and windings is illustrated by the cross-sectional view in figure 9.

When the winding has been done and its conductivity checked with a meter, assemble the cores and clips as shown in figure 10. The transformer is now made and is symmetrical, so it can fit into the board either way round.

Assembly of the board
If the specified components are used, they should all fit on the pcb with no difficulty. Do NOT fit IC1 until you have read the sections on assembly. See the component overlay in figure 11.

The printed circuit board will be mounted, with only a moderate clearance, to the inside-lid of the metal case, so it is important that the component legs are cut fairly short and are soldered neatly (figure 12, shown board-up with the lid upturned).

When clipping the resistor legs, be sure to keep one to thread through the ferrite bead that forms L2, and a second
Mounting IC1

The IC is mounted on a heat-spreader plate (figures 13 and 14) which has captive bolts that will be located through the side of the case from inside and have the nuts put on from outside (see the box assembly diagram, figure 15). This is quite a fiddly process and, in the prototype, several of the legs broke off the essential IC1 after the lid had been taken on and off about a dozen times. I then clipped the legs of the IC somewhat shorter and connected them up with flexible wires that have shown no tendency to break. You may choose to do it either way, depending on whether you anticipate having to remove the lid often once the unit has been built. It is useful to figure out which way you prefer to connect the IC before carrying out the testing in the next section.

To test the equipment, IC1 needs to be connected up with its heatsink mounted, to prevent it from getting too hot too fast. The heatsink is the heat-spreader plate that will also be part of the mounting for the PCB in the case, therefore it is best to cut the heat-spreader plate, to drill it and the casework accurately at this stage, and fit the captive bolts into the spreader plate, so that once it is mounted on IC1, it does not have to be removed again for assembly.

A piece of aluminium 2mm thick by 20mm wide by 70mm long is suitable as a heat-spreader plate with the case used here. When the plate has been cut, clamp it to the inner side of the case, so that it is also located against the base (NOT the lip) of the case, and drill through it and the case two fixing holes, one towards each end of the spreader plate (this is just to keep the bolt-holes clear of IC1, which will be bolted separately to the centre part of the spreader plate). These holes should be drilled with a 2.5mm drill, then the plate should be unclamped from the case, and the holes in the case should be drilled out to 3.5mm diameter, which will allow an M3 bolt to pass through easily.

The heatspreader plate needs captive bolts (bolts which do not drop out when the nut is removed), so you must file out the 2.5mm holes in the plate until they are just large enough to permit an M3 bolt to be forced into the plate with a screwdriver, cutting its own thread as it goes. When the bolt is almost screwed home, a tiny drop of Superglue should be placed on the inside of the head (do NOT get glue on the remainder of the thread, which will be needed later) and then it should be tightened down thoroughly. Once the Superglue has set, the bolts will in effect be part of the spreader plate.

Now that the position of the heat spreader plate is known, it is necessary to get an accurate measurement of where the hole for the IC should be drilled in the plate. The next step, therefore, is to mount the PCB onto the lid of the box, temporarily, but using the correct bolts and spacers. Mark and drill four holes to match the mounting holes in the PCB. Drill these to a diameter of 3mm and countersink. Then bolt the board into place using two of the bolts, diagonally placed, with their spacing washers.

Temporarily hook a piece of clipped component leg into the middle hole of the PCB where IC1 is to fit. Align the side of the lid with the side of the box, and carefully mark the rim of the box against where the component leg is. This marks the centre of IC1 when mounted, and is the vertical line on which the hole for IC1 needs to be drilled in the heat spreader plate. Locate the heat spreader plate into its mounting-holes on the box, and mark onto it a vertical line matching the position-mark on the rim of the box.

Figure 11: the component overlay
Figure 12: assembly of the pcb into the lid of the case

Then, place IC1 onto the heat-spreader plate with its mounting-hole centred on the line, and with the tab downwards and almost lined up with the BOTTOM EDGE of the heat spreader plate (remembering that the pcb hangs upside-down in relation to the box). Mark the centre of the IC hole, and drill the heat-spreader plate at the marked point to a diameter of 3mm. Countersink this hole from the side away from the IC and make sure it is countersunk to sufficient depth that the head of the bolt does not protrude at all, as the finished heat-spreader plate must lie flush with the wall of the box to spread the heat properly. Mount IC1 to the heat spreader plate using a countersunk bolt with, if possible, a smear of heatsink compound between the IC and the plate. An insulating washer is not needed, because the tab of the chip is grounded. Now connect IC1 to the pcb, either by means of flexible wires or by mounting it directly. If it is to be mounted directly, then it may be best to locate the IC to the board without soldering it before the board is unbolted from the lid, and line it up so that the heat spreader plate bolts locate with the holes in the case. Then you may judge the position of the chip and solder it in the best angle to locate with the mounting hole. If flexible wires are used, the only note of caution is to make sure that all the wires go to the right holes. Whichever connection method is used, the pcb should be unbolts from the case for IC1 to be soldered. The unit should then be tested before fitting it into its case.

Testing and final assembly
First of all test the item using a dummy load resistor - 3.3k 20 watt would be ideal, but working on the principle that if it works properly at a low power it would normally be safe to try it on its normal load, a 47k 2-watt resistor would serve. Connect the load resistor,
connect a voltmeter to the output, and connect a 12V supply, capable of giving at least 4 amps without hitting current limit, to the input. The unit should give approximately 250V DC output and show no signs of distress. If all is well so far, connect a lamp-holder and plug in a low-consumption fluorescent bulb of the electronic variety at a rating of up to 23 watts. The lamp should light within about 1 second.

Please note that lamps containing a mains-frequency ballast choke, such as the Thorn 2D lamps, will not work with this, and may be damaged by it. This unit can only just fit the aluminium case chosen for it, but it is a neat and tidy case and the next size up is clumsy and unnecessarily large.

The real problem is the height, but the cases in the catalogues with a greater height also have about twice the area. To make use of every millimetre of height, but pcb is catalogued with a greater height also have about twice the area. To make use of every millimetre of height, but pcb is catalogued with a greater height also have about twice the area.

First of all, mount the pcb onto the lid of the case using all four countersunk bolts and the 3mm spacers. Then, thread the wires through the grommets leaving only a small amount of slack. Then position the lid so that the bolts from the heat spreader plate locate through the holes in the case.

Be careful, as the weight of the heat spreader plate inevitably places some strain on the legs of IC1 at this stage. Screw the nuts a few turns onto the bolts so that they do not pull out again, then bolt the lid onto the case with its countersunk screws. Then tighten up the nuts on the heat spreader plate bolts. Needless to say, if you want to open the unit again, remember to remove the nuts that secure the spreader plate to the case BEFORE before trying to remove the lid, or the hinging force will be borne by IC1. For safety reasons, it is desirable to fit an in-line fuse in the positive connection to the unit. The unit may be turned on and off by clipping and unclipping the wire to the battery terminals, but if the lamp is not used or alternatively a switch may be mounted on the case and attached in series with the positive connection. This may necessitate the use of an in-line screw connector inside the case. Clearly, it is not sensible to put a switch in the 250V output connection to the lamp, so just connect the lampholder securely to the end of wire.

Please note that this unit has been very carefully designed to use the parts specified and is expected to work dependably if built exactly to the design. However, this sort of design places unusual demands on the components in use, and the use of substitute components may cause failure, and destruction of other parts of the circuitry.

In use
The unit generates a certain amount of heat in running, and the box may be expected to get warm but not too hot to touch. The electronics of the low-consumption lamp also generates a certain amount of heat, but again this should not reach a dangerous level.

Do be aware however that the wiring to the low-consumption lamp should be regarded as mains wiring, and treated with the caution accorded to any mains appliance wiring. This unit, and particularly any low-consumption lamp that may be used with it should not be operated if it has been subjected to significant amounts of rain or other source of damp. Low consumption mains lamps are meant for use indoors, and may therefore not be waterproof.

Suppliers of specified parts:
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Electromail (part of RS Components) P O Box 33, Corby, Northants NN17 9EL Tel 01536 204555
Cirkit Distribution Ltd. Park Lane, Broxbourne, Hertfordshire EN10 7NQ Tel 01992 471314
Maplin Electronics P O Box 3, Rayleigh, Essex SS6 8LR 01702 554161

![PARTS LIST](image)

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R1 470R
R2 220k
R3 220k
R4 2k2

**Capacitors**
C1 100u
C2 100u 20V Electromail stock no. 188 3288
C3 4u7 Electrovalue stock no. LL4.750
C4 22u 350V Electrovalue stock no. 5022350

**Semiconductors**
D1 BZX75C56 Electromail stock no. 283-819
D2 UF4006 Electromail stock no. 264-282
D3 UF4006 Electromail stock no. 264-282
D4 1N5820 Electromail stock no. 183-7667
IC1 LT1170CT Electromail stock no. 299-711
T1 - to be wound by hand. See separate parts list below

**Miscellaneous**
L1 4.7uH Cirkit stock no. 34-62178
L2 Ferrite bead
T1 8x0.40
J1, J2 2 pin 0.2" screw connectors
Aluminium case. This MUST BE aluminium for proper heat dissipation. Plastic or steel will not work correctly. The case used in the prototype is a DCM5003 from Maplin, no. GU62
Small piece of 2mm cut aluminium for the heat-spread plate
4 off 3mm spacers
5 off 3mm bolts, counter sunk, 10mm long
2 off 3mm bolts, panhead, 12mm long

**Transformer Parts List**
All the parts are from Electrovalue
EFD CORE B66417 U100K187 EFD20
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A circuit for a very low distortion oscillator based on a two-lag loop was shown in the January 1995 issue of ETI. The major attractions of this design are its very low distortion - rather less than 0.001% at 1KHz - and its ability to switch from one frequency to another without any amplitude 'bounce'. (This amplitude unsteadiness is an unwanted characteristic of most low distortion signal generators, and it can be irritating if it is wanted to carry out tests over a range of frequencies.) However, for the oscillator to be really useful in an electronics workshop involved, for example, in audio amplifier design, it is desirable that the instrument should also offer a good quality square-wave output, with a rapid, overshoot-free rise and fall time and a flat, droop-free, plateau between the high and low level transitions, of the kind shown in Fig. 1a.

The value of such a test waveform in audio work is that, used in conjunction with an oscilloscope, preferably DC coupled, it can give a very rapid indication of the performance of the circuit under test, as in that, for example, the waveform shown in Fig. 1b, would suggest a relatively poor degree of stability in an amplifier using loop negative feedback - a condition which could be explored using a selection of alternative output loads.

A more easily overlooked fault of the same kind is shown in Fig. 1c, and could be due to capacitative feedback between input and output wiring in an amplifier with a wide frequency response bandwidth. Whether such wide bandwidths are a good thing is debatable, but if the circuit permits them, it is equally necessary that they don't leave the circuit prone to RF instability, which could burn out expensive LS 'tweeter' units, the square wave generator circuit should provide an output waveform which is droop-free between the rise and fall transitions, so that waveforms of the type shown in Figs. 1d and 1e - indicating respectively poor LF and poor HF response - can be properly interpreted. Fortunately, this is quite an easy requirement to meet.

Square-wave generator design
Quite a range of circuits exists which will convert an input sine-wave into a flat-topped square-wave output, such as a CD4066 quad bilateral switch, actuated by a squared off input waveform, and used to switch an output between, say, a pair of +5V and -5V supply rails. Alternatively, a fast voltage comparator could be used, effectively acting as an amplifier which is driven into overload by its input signal, though such an arrangement would not necessarily

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Continued from P. 32

provide the desirable glitch-free rise and fall characteristics desired. Since the "high level" output of the oscillator is 5V RMS, which is quite adequate to drive CMOS logic elements fed from +/-5V rails, the simplest, and most economical system would be to use a CMOS Hex Schmitt Trigger, such as the CD40106 (74C14) for which the circuitry and associated sine/square waveform switching is shown in Fig. 2. Since the internal circuitry of the Schmitt trigger causes it to "latch" on one or the other of two states, in which its output is either logic '1' (+5V) or logic '0' (-5V), the requirement for a droop-free plateau between the rise and fall transitions is met, while the internal circuitry of the device generates rise and fall times which are typically 50nS in duration - which is less than 0.1% of the duration of the on- and off-times of a 10KHz square-wave. The input diodes, D1 and D2, and the input resistor R2, are included to protect the IC chip from an excessive input voltage swing, and the input bias resistor, R3, serves both to ensure that the input of the IC is clamped to the logic '0' (-5V) level when the circuit is switched out of use, and also to equalise the output 'mark to space' ratio. A pair of low power IC voltage regulators is used to provide low impedance voltage reference levels, and the last two gates of the CD40106 are also paralleled to reduce its output impedance.

**Output attenuator**

This is a three step section of a constant impedance attenuator, having a characteristic impedance, as seen at any point, of 600 ohms and an attenuation at each step (apart from the first which is a divide-by-five) of ten times, to give outputs either of 0-5V, on the high-level output socket, or a choice of four switched output...
maxima, on another output socket, covering the range 0-1mV up to 0-1V. The attenuator requires some rather awkward resistance values, e.g. 733, 5940 and 660 ohms, and these are provided, with quite a reasonable degree of accuracy, by the parallel connection of 820/6k8, 6k8/47k and 1k5/1k2 resistors, respectively, as shown in Fig. 2.

At normal room temperatures the thermal noise associated with the 600 ohm output impedance will be a shade less than a microvolt for a
100KHz measurement bandwidth - i.e. about -60dB, with respect to 1mV - and this should be allowed for in low signal level noise measurements.

**Range switching resistors and capacitors.**
These are assembled, for convenience, between the lags of the respective 3- and 4-way switches.

**Power supply unit**
This is a conventional design with its output +/-15V lines stabilised by 7815 and 7915 IC voltage regulators, as shown in Fig. 3. The stabilised +/-5 volt lines for the squarer circuit are provided by a pair of 78L05 and 79L05 ICs mounted on the squarer unit PCB.

**PCB layouts**
These are shown in Figs. 4 and 5 and the completed instrument, enclosed for good screening in a 222mm x 146mm x 55mm diecast box (Deltron type 450-0070), is shown in Fig. 6.

---

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To Perfect PCB's
How many times have you tried to check the bit states of an 8-bit output port using either a multimeter, oscilloscope or even an LED soldered on two lengths of wire, and then had to work out the value, adding them up something like 1+2+4+8...etc.?

Here's a project which should help to overcome all of these 'pains in the neck' for you, by displaying digitally the whole 8 bits in decimal or hexadecimal format. There are some display driving ICs available which accept BCD (binary coded decimal) inputs and convert this to seven segment outputs. These are fine if you only want to display a single number from 0 to 9, but how often is that? There was even an IC available some years ago which accepted 4 bit binary data and displayed this in hexadecimal, so you could always have used two of these, but these were expensive, and I don't know if they're still available. Even so, if they are, you would still be limited to hexadecimal readout only. What is strange is that, even from the beginnings of digital computers, no manufacturer has produced a readily available IC which will accept and convert 8 bit binary data, and certainly not one which gives a decimal readout as well.

For educational purposes this format is a must for demonstrating the differences between the two codes. The circuit diagram of figure 1 shows how simply this can be achieved using the PIC16C55 microcontroller. Because speed is not an important factor in this design, the lower priced RC version of the PIC is used, and the oscillator frequency is set by the values of R1 and C1, which can be altered if you wish, but to stay within the manufacturers recommendations, don't reduce C1 much below 20pF or R1 below 2K2.

As is usual with designs of this nature, there is little to explain about the circuit diagram, since all of the work is carried out by the program within the microcontroller itself. The binary code is applied to port B (which is programmed for input only) and is converted to seven segment display codes. All of the corresponding segment connections of the three displays are paralleled together, but only one is accessed at any time. The digit data for each display is applied in turn to port C, and then the strobe line for the currently selected display - RA1 to RA3 - is pulled low for a predetermined length of time to light it up.

The display is then turned off again and the sequence is repeated for the two remaining ones. A point to bear in mind is that each display must be turned off at the end of the light-up period before moving on to the next digit, otherwise display 'ghosting' will occur. This is a most irritating effect where the previous digit data appears superimposed very dimly on the currently active one. The unwanted data is only present for as many clock cycles that it takes to set up the next digit data on port C, but because the displays are refreshed so rapidly, and continuously, the 'ghosting' appears to be occurring constantly, even thought it isn't. The jumper link JP1 and momentary switch SW1 can be closed to signal to the program to display the data on port B in decimal format, rather than the default hexadecimal. The switch can be pressed or released at any time, for switching briefly between display formats, ideal for quick conversion references and educational uses.

Continued on P. 41

Figure 1: The circuit diagram of the Data Bus Monitor: simple, but practical.
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Programs/ Features PIC EEZE 1 PIC EEZE 2 PIC EEZE 3

| 16C54,65,66,67,68 | YES | YES | YES |
| 16C62,63,64,65 | YES | YES | YES |
| 16C71,73,74 | YES | YES | YES |
| 16C84 | YES | YES | YES |
| 16C620,621,622 | YES | YES | YES |
| Serial Eeproms | YES | YES | YES |
| In Circuit Emulation | - | - | YES |
| Expansion Port | YES | YES | YES |
| BASIC compiler | - | - | YES |

Price (built and tested)
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Upgrading is simple, just order the required system firmware and pay the difference.

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The jumper link, on the other hand, when fitted, provides long-term viewing in decimal format only, thereby removing the need to keep the switch pressed all the time. You will see from the circuit diagram that the decimal point (dp) has been connected to P1C0 on IC1. This has been done for completeness of connections to the LED displays, although these segments are not driven by the listed software, but that's not to say they cannot be. In fact, these types of displays have pin connections to both left and right hand decimal points, but it's the right hand one that has been used here. Although the connections to port B are labelled 'Binary Input/Output', in our application they are only used for input. The reason for such labelling is because the port could be programmed for output, and the program modified slightly to output binary codes at timed intervals on this port which correspond to the digital displays, although connected to RCO on IC1. This has been done for long term viewing in decimal format only, thereby removing the chance of getting them the wrong way round, unlike some other types which can easily be inserted upside down by mistake. Be careful when soldering the displays in place. There is only a fine gap between the pads and the copper tracks which run in between them. If, when you power up the board, you get strange digits displayed - particularly if they appear in all three of the displays - then the chances are that you've got an unintentional solder bridge across two or more adjacent tracks.

Don't forget the single wire link at the top of IC1, and take care with the direction of the SIL resistor network RN1, as these are very easy to solder the wrong way round. The pin 1 marker dot points towards the top of the board. A regulated +5V power supply can be applied to the board either via the two-way terminal block, or via the binary input/output pin header. Whether you use, make sure it's connected in the correct polarity. If the board is to be used in educational establishments - schools and colleges etc. - it might be a good idea to apply power only to the terminal block, and to remove the top pin from the pin header so as to prevent the possibility of shorting out the power supply connections. Don't remove the bottom (OV) pin, as this will be required for a ground reference to any other equipment to which the board is linked, and also for shorting to the other binary code input pins to alter the input code. Once you're satisfied with the construction, insert a programmed PIC16C55RC/P into the IC socket (pin 1 upwards) and power up the board. With no inputs connected and with JP1 removed, the value 'FFH' will appear in the display. The two left hand digits are the value being read from the input port in hexadecimal. The right hand digit will always display the letter 'H' when hexadecimal display format is selected, in just the same way it is written on paper to clarify that the value is in hex. This might seem unnecessary at first, especially since decimal readouts don't contain letters anyway. But it would not be so clear if the two hexadecimal digits happened to be numbers.

Press and hold down SW1 to display the value in decimal format. The display now changes to '255'.

**Figure 2: The components layout and pin connections to each of the LED displays.**

**Figure 3: The components as laid out on the PCB.**

Continued from P. 39

...
This is the decimal equivalent to FF in hexadecimal. Releasing SW1 will return once more to displaying the value in hexadecimal format. Now try shorting some of the input lines D0 to D7 - to OV. The display will adjust according to the changing values being read. In decimal mode, leading zero blanking is used to remove any unwanted '0's in the left hand displays. This means the value of (say) four is displayed as ' 4 ' (with two leading blanks), rather than '004', which is the way it would be written. In hexadecimal mode, the zero's are not suppressed at all, and even the value of nought (usually pronounced like 'zero zero hex') is displayed as '00H', which, again is the way it would normally be written to prevent confusion.

Software
The listing as presented is the complete program, as blown into the pre-programmed PIC16C55RC/P available for this project. From the size of it you will realise there is more than enough program memory remaining to include further routines of your own.

LIST P=16C55, N=38, C=132, R=DEC
TITLE 'ETI DATA BUS MONITOR'
******************************************************************************
* DATA BUS MONITOR
* Copyright 1996 DTE MICRO SYSTEMS
* For use on the DTE DATA BUS MONITOR board
******************************************************************************

* WARNING. THIS PROGRAM MAY NOT BE SOLD, *
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******************************************************************************

; Define the general registers and I/O port addresses
RTCC EQU 01 ; Real Time Clock/Counter register address
PC EQU 02 ; Program Counter address

; Status register address
STATUS EQU 03

; File Select Register address
FSR EQU 04

; I/O Port A (lower 4 bits only available)
PORTA EQU 05

; I/O Port B (all 8 bits available)
PORTB EQU 06

; I/O Port C (not fitted on PIC16C54/56)
PORTC EQU 07

; Assign labels to programming constants used in PIC assembly language.
W EQU 0 ; Destination register
F EQU 1 ; Destination register

; Assign basic pin labels to the bit numbers for I/O port A.
RA0 EQU 00 ; Port A I/O bit 0
RA1 EQU 01 ; Port A I/O bit 1
RA2 EQU 02 ; Port A I/O bit 2
RA3 EQU 03 ; Port A I/O bit 3

; Assign basic pin labels to the bit numbers for I/O port B.
RB0 EQU 00 ; Port B I/O bit 0
RB1 EQU 01 ; Port B I/O bit 1
RB2 EQU 02 ; Port B I/O bit 2
RB3 EQU 03 ; Port B I/O bit 3
RB4 EQU 04 ; Port B I/O bit 4
RB5 EQU 05 ; Port B I/O bit 5
RB6 EQU 06 ; Port B I/O bit 6
RB7 EQU 07 ; Port B I/O bit 7

; Assign basic pin labels to the bit numbers for I/O port C.
RC0 EQU 00 ; Port C I/O bit 0
RC1 EQU 01 ; Port C I/O bit 1
RC2 EQU 02 ; Port C I/O bit 2
RC3 EQU 03 ; Port C I/O bit 3
RC4 EQU 04 ; Port C I/O bit 4
RC5 EQU 05 ; Port C I/O bit 5
RC6 EQU 06 ; Port C I/O bit 6
RC7 EQU 07 ; Port C I/O bit 7

; Assign labels to the various bit values of the STATUS register (03h)
CARRY EQU 0 ; carry bit
DCARRY EQU 1 ; digit carry bit
ZERO EQU 2 ; zero bit
PDOWN EQU 3 ; power-down bit
WATCHDOG EQU 4 ; watchdog time-out bit

; Assign labels to the various (RAM) data file registers used
ORG 08 ; Set base address for RAM

COUNT1 EQU 01 ; General purpose counter
DECIN1 EQU 02 ; for 1s digit
DECIN2 EQU 04 ; for 10s digit
DECIN3 EQU 05 ; for 100s digit
DIGIT1 EQU 06 ; display data
DIGIT2 EQU 07 ; display data
DIGIT3 EQU 08 ; display data
HEXLO EQU 09 ; middle digit (LSh)
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Continued from P. 42

```
GETDATA
  MOVF PORTB, W ; GET DATA ON PORT B
  MOVF IPBUFF ; STORE IT IN 'IPBUFF'
  ; Convert 'IPBUFF' into Hexadecimal
  ; values in 'HEXLO' and 'HEXHI',
  ; and into Decimal values in
  ; 'DECIM1', 'DECIM2' and 'DECIM3'

CONVERT
  CLRF DECIM1 ; CLEAR RIGHT DIGIT
  CLRF DECIM2 ; CLEAR MIDDLE DIGIT
  CLRF DECIM3 ; CLEAR LEFT DIGIT

; Hexadecimal conversion routine
  MOVF IPBUFF, W ; GET NIBBLE SWAPPED
  "IPBUFF" IN 'W'
  ANDLW H'OF' ; MASK OFF THE LEFT
  NIBBLE
  MOVF HEXHI ; AND PUT IT IN 'HEXHI'
  (MSB)
  MOVF IPBUFF, W ; GET 'IPBUFF' IN 'W'
  ANDLW H'OF' ; MASK OFF THE LEFT
  NIBBLE
  MOVF HEXLO ; AND PUT IT IN 'HEXLO'
  (LSB)

; Decimal conversion routine
  MOVF IPBUFF, W ; IS 'IPBUFF' ZERO?
  BTFS C STATUS, ZERO
  NO - THEN WORK OUT THE
  VALUE
  RETLW 00 ; YES - LEAVE 'DECIM's AT
  ZERO
  CONV3
  INCF DECIM3 ; ADD 1 TO LEFT DIGIT
  CONV4
  DECSZ IPBUFF ; SKIP IF 'IPBUFF' HAS
  REACHED ZERO
  GOTO CONV3 ; OTHERWISE GO ROUND
  AGAIN
  RETLW 00 ; EXIT

; Now convert the digit values into display codes
  MOVF DIGIT1, W ; GET RIGHT
  CALL GETCHAR ; CONVERT TO
  DISPLAY CODE
  MOVWF DIGIT1 ; AND PUT IT
  BACK
  MOVF DIGIT2, W ; GET MIDDLE
  CALL GETCHAR ; CONVERT TO
  DISPLAY CODE
  MOVWF DIGIT2 ; AND PUT IT
  BACK
  MOVF DIGIT3, W ; GET LEFT
  CALL GETCHAR ; CONVERT TO
  DISPLAY CODE
  MOVWF DIGIT3 ; AND PUT IT
  BACK
  RETLW 00 ; EXIT

; Get a display character bit
; pattern by converting 'W' to display code
  GETCHAR
  ADDWF PC, F ; USE 'W' AS AN OFFSET
  FOR 'PC'
  RETLW B'11101110' ; RETURN WITH 'O' DISPLAY CODE
  RETLW B'00100100' ; RETURN WITH '1' DISPLAY CODE
  RETLW B'10110110' ; RETURN WITH '2' DISPLAY CODE
  RETLW B'11011010' ; RETURN WITH '3' DISPLAY CODE
  RETLW B'01110100' ; RETURN WITH '4' DISPLAY CODE
  RETLW B'11101110' ; RETURN WITH '5' DISPLAY CODE
  RETLW B'11001110' ; RETURN WITH '6' DISPLAY CODE
  RETLW B'10100100' ; RETURN WITH '7' DISPLAY CODE
  RETLW B'11111100' ; RETURN WITH '8' DISPLAY CODE
  RETLW B'11111010' ; RETURN WITH '9' DISPLAY CODE
  RETLW B'01011110' ; RETURN WITH 'A' DISPLAY CODE
  RETLW B'01011111' ; RETURN WITH 'B' DISPLAY CODE
  RETLW B'11001010' ; RETURN WITH 'C' DISPLAY CODE
  RETLW B'00111110' ; RETURN WITH 'D' DISPLAY CODE
  RETLW B'11011010' ; RETURN WITH 'E' DISPLAY CODE
  RETLW B'11011000' ; RETURN WITH 'F' DISPLAY CODE

; Refresh the displays. The "DIGIT"s
; finally contain the bit patterns
; ready for displaying the characters
; require for Hex or Decimal readout.
; If display is Decimal then blank
; out any leading zeros except right digit.

DISPLAY
  BTFS PORTA, RAC ; SKIP IF DECIMAL MODE
  SELECTED
  GOTO DISP3 ; ELSE DISPLAY DATA IN
  HEX FORMAT

; Display data in Decimal format
  MOVF DECIM1, W ; GET RIGHT DIGIT
  CALL GETCHAR ; CONVERT TO DISPLAY CODE
  MOVWF DIGIT1 ; PUT IT IN RIGHT DIGIT
  MOVF DECIM2, W ; GET MIDDLE DIGIT
  DECIMAL DATA
  CALL GETCHAR
  MOVWF DIGIT2 ; PUT IT IN MIDDLE DIGIT
  MOVF DECIM3, W ; GET LEFT DIGIT
  DECIMAL DATA
  CALL GETCHAR
  MOVF DECIM3 ; PUT IT IN LEFT DIGIT
  MOVF DIGIT3
  NOW blank off any leading zeros
```
```assembly
MOVF DECIM3.W ; GET LEFT DIGIT DECIMAL DATA
BTFSS STATUS,ZERO ; BLANK IT OUT IF ZERO = '0'
GOTO DISP4 ; NOT ZERO - LEAVE IT ALONE
CLRF DIGIT3 ; CLEAR ALL BITS IN LEFT DIGIT
MOVF DECIM2.W ; GET MIDDLE DIGIT DECIMAL DATA
BTFSC STATUS,ZERO ; LEAVE IT ALONE IF NOT ZERO
CLRF DIGIT2 ; OTHERWISE BLANK IT OUT
GOTO DISP4 ; LEAVE RIGHT DIGIT ALONE ANYWAY

; Display data in Hexadecimal format

DISP3
MOVF HEXH.W ; GET MSB OF HEX VALUE CALL GETCHAR
MOVWF DIGIT3 ; PUT IT IN LEFT DIGIT MOVF HEXLO.W ; GET LSB OF HEX VALUE CALL GETCHAR
MOVWF DIGIT2 ; PUT IT IN MIDDLE DIGIT MOVWF B'01111100' MOVWF DIGIT1 ; PUT 'H' IN RIGHT DIGIT - 'DIGIT1'

; 'DIGIT's contain the required display codes, now light up the displays

DISP4
MOVF DIGIT3.W ; GET LEFT DIGIT DATA MOVWF PORTC
BCF PORTA,RA3 ; LIGHT UP THE DISPLAY CALL DELAY
BSF PORTA,RA3 ; AND TURN IT OFF AGAIN MOVF DIGIT2.W ; GET MIDDLE DIGIT DATA MOVWF PORTC
BCF PORTA,RA2 ; WAIT FOR LIGHT-UP PERIOD PERIOD
BSF PORTA,RA2 ; AND TURN IT OFF AGAIN MOVF DIGIT1.W ; GET RIGHT DIGIT DATA MOVWF PORTC
BCF PORTA,RA1 ; LIGHT UP THE DISPLAY CALL DELAY ; WAIT FOR LIGHT-UP PERIOD
BSF PORTA,RA1 ; AND TURN IT OFF AGAIN

; The program now falls through back to the 'START' routine

; Beginning of the main program (entry point) *

START
MOVLW 255
MOVF PORTA ; SET ALL PORT A OUTPUTS HIGH TRIS PORTB ; SET PORT B FOR INPUT MOVLW 01 ; SET RA0 FOR INPUT CLRW MOVWF PORTC ; START WITH ALL DISPLAY BITS OFF TRIS PORTC ; SET PORT C FOR OUTPUT CALL GETDATA ; READ AND CONVERT DATA ON PORT B QOTO DISPLAY ; DISPLAY IT AND GO ROUND FOREVER

; Set up the reset vector for the type of processor used.
; This varies between devices but is at 1FFh on the 16C54
ORG H'1FF'
GOTO START
ZZZ ;END OF PROGRAM MARKER

PCB

The DTE 'Data Bus Monitor' printed circuit board can be purchased separately for £4.50.

A complete kit of parts for this project, which INCLUDES the PCB, a pre-programmed PIC16C55RC/P and everything else listed above, is available from the author by mail order only from:

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A SIMPLE POWERLINE SIGNAL REMOTE CONTROL

By Bart Trepak

The advantages of being able to switch appliances on and off anywhere in the house from a central controller or computer are many and apart from the convenience can be used to improve energy usage and security. In the past, the obvious way to do this would have been to lay control cables from the central controller to each appliance, but the thought of running cables around the house to the various units with the prospect of chasing out walls, re-plastering, lifting carpets and floorboards etc. was enough to put anyone off the idea of the computer controlled home.

Of the systems now available for remote control, infra-red and ultrasonic controls are unsuitable as their range is limited to the confines of a single room.

This leaves only radio and direct wiring. Of these, radio is of course far more flexible allowing the positioning and re-positioning of appliances anywhere in the building but suffers from complexity of receivers and the necessity to use certain frequencies usually in the UHF band which makes setting up or fault finding extremely difficult without sophisticated (and expensive) test equipment. On top of this, approval and a licence is required for this form of communications as there is the difficulty of restricting the transmission to a single flat, house or building.

This leaves only the direct wiring method with all the disadvantages mentioned above. To overcome these, many designers have devised systems for utilising the existing mains wiring for sending the control signals and since most appliances will need to be mains powered and therefore situated reasonably close to a mains outlet, this would not seriously impair the flexibility of the system.

With all systems of this sort, there is always the temptation on the part of the designer to add more and more "features" as he thinks of them and a basically simple project grows and grows until the cost and effort in building it and getting it to work, let alone in teaching your granny how to use it, almost rivals the upheaval of the installation of separate control wires to each appliance. With personal identification numbers, the ability to control 32 different appliances, security codes in case Mrs Jones in Madia Vale has a similar system which may interfere with the smooth running of your computerised house and programming switches to identify each appliance, each receiver now consists of five or six ICs which, together with the power supply and coding switches, occupy a box about the size of a toaster and almost certainly surpassing it in complexity. As if this were not enough, an infra-red remote control is often also incorporated into the system to remotely control the remote controller!

All this may be necessary if one were designing a system to run a factory or hotel complex but in the home most people would be hard pressed to find half a dozen appliances which they needed to control remotely let alone 32 or more.

There is little point, for example, in being able to switch the TV on and off from another room (unless you just want to annoy the other members of your family) or to control the lighting in four or five rooms in the house independently to give the impression that the house is occupied when one or perhaps two lights would be enough.

This reasoning, together with many requests from people who simply wanted say, to only switch an electric blanket on early without having to go upstairs especially to do this, or have the morning coffee ready when they come downstairs, prompted this design. The circuit is however, easily modified to provide a limited number of other extra "channels" if required.

Coding

The mains wiring is not a particularly good medium for the transmission of signals. As well as having a 230V 50Hz sine wave on it, there are also all sorts of pulses and transients, caused by equipment being switched on and off, superimposed on it. As well as this, any signals which are transmitted along it tend to be attenuated to a greater or lesser degree by the various appliances which are connected to it. To enable the control signals to be distinguished from these much larger amplitude signals, it is necessary to transmit them on a relatively high frequency carrier (compared to 50Hz) but not so high that losses due to capacitance of the cables or other appliances cause a severe attenuation of the signal.
The best frequencies to use seem to be between about 80 and 150kHz and this system runs at approximately 100kHz. The normal domestic supply consists of three wires: Line (or Live), Neutral and Earth. In theory, the signals could be sent between any two of these.

Neutral and Earth would appear to be the most attractive since the voltage between them is not usually very large and certainly not the 230V ac which exists between L and N and the reason for this is that the Neutral is earthed at the substation and sometimes at the point at which the supply enters the house. This can effectively "short out" the signal, limiting its range and giving highly variable results. For this reason, the signal in this system is connected between the Live and Neutral. Obviously, any system with more than one channel needs to be coded so that each receiver can be switched on and off without affecting the status of the others.

In this circuit this is achieved by modulating the 100kHz carrier with a tone or, more simply, by switching it on and off at a lower frequency.

This makes both the transmitter and receiver very simple as no fancy digital encoders and decoders are required. The use of a tone sensitive integrated circuit in the receiver simplifies the design considerably and removes the need for any adjustments which makes the circuit particularly attractive to the hobbyist who may not have access to an oscilloscope or frequency meter.

The small number of parts also make it possible to make the receiver unit very small enabling it in many cases to be built into the appliance which you want to control. Alternatively, it could be fitted into a "plug box" of the type used for calculator power supplies so that the unit can also function as the mains plug with the added advantage that it can be removed and reconnected to other appliances as required.

**Operation**

The operation of the system is probably best understood by referring to the block diagram. We will consider first the receiver and in particular the operation of the tone decoder IC used in this circuit as this is central to the system operation and defines to a large extent the kinds of signals required and hence the circuits used to produce them at the transmitter.

The tone decoder IC is almost purpose made for this application (although it was originally designed as a whistle switch for use in those "answer back" key fobs which were so popular a few years ago) and contains an amplifier, tone decoder and an output bistable stage.

The centre frequency is not set by the usual resistor-capacitor network or a tuned circuit but by a single resistor which in fact sets the frequency of an internal clock oscillator. The circuit then responds to input frequencies of between 1/10 and 1/15 of this clock signal and produces an output by changing the state of the bistable latch each time it receives 256 cycles of a signal in the required frequency range.

The receiver therefore consists of a 100kHz input filter to recover the carrier signal from the much larger amplitude 50Hz carrier.
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mains voltage followed by an amplifier and demodulator to reproduce the transmitted tone. This is fed to the tone decoder - bistable IC - and is followed by an output stage which drives a relay. A dc power supply block to provide a low voltage supply to the circuit from the mains voltage completes the requirements for the receiver. On the transmitter side we clearly require an oscillator to produce the 100kHz carrier signal which is coupled to the mains. Since the carrier is to be switched on and off, the oscillator is controlled, via an OR gate, by two further oscillators which produce the two tones.

Normally, these two oscillators would be connected directly to the push button switches which would enable the relevant oscillator causing it to switch the carrier oscillator on and off at the required frequency.

If this were done in this case, the final state of the receiver would depend on how long the transmission lasted. If the carrier oscillator was switched on and off less than 256 times, the receiver would not switch at all, while if the transmission lasted for more than 512 cycles, the receiver would change state and then switch back again giving effectively the same end result.

One way around this would be to count the oscillator cycles at the transmitter and disable it after 256 cycles had been completed. In practice this did not prove to be necessary and a simpler approach of using a monostable was chosen. This is arranged to enable the oscillator for a period long enough to produce 256+ cycles but less than 512 cycles irrespective of how long the push button is pressed.

The block diagram for the transmitter which is also shown in figure 1 therefore consists of a 100kHz oscillator together with two low frequency tone generators which are enabled by monostables triggered by two push button switches. A simple mains supply completes the requirements for the transmitter.

The receiver

The complete circuit for a receiver is shown in figure 2, and as can be seen it is quite a simple affair and the various stages shown in the block diagram can easily be identified. The high frequency signal from the transmitter is passed via C1 to the transformer T1 which has its secondary tuned to the 100kHz carrier by C2 and forms the input filter.

The circuit is arranged so that transistor TR3 is normally turned on by base current flowing via R1 which ensures that TR2 is turned off and so its collector remains at the supply voltage which is about 5 Volts.

As soon as a signal is received at the base of TR3, this transistor will be turned off and since the signal consists of bursts of 100kHz, TR2 switches on and off at 100kHz during these bursts and remains on when the burst stops.

This causes TR2 to switch on and off during each burst quickly discharging C4 and as this capacitor can only charge up relatively slowly via R2, the voltage at the collector of TR2 remains "low" for the duration of the burst.

When the 100kHz signal stops at the end of the burst, the collector voltage rises again to the supply rail resulting in the original modulating waveform being reproduced at the collector of TR2 while the 100kHz carrier is removed. This signal is then fed via C5 to IC1.

IC1 is the frequency selective circuit which switches the output on and off alternately each time 256 cycles of a signal of between 1/10 and 1/15 are received where f is the oscillator frequency set by resistor R4. Since this is quite a wide frequency range no special tuning of the receiver or transmitter
is required although it does mean that the number of possible channels is limited. The output of IC1 is used to switch the relay RL1 via transistor TR1 with D2 protecting the transistor against possible damage due to the back emf generated by the relay when it is switched off. The power for the circuit is obtained by the low loss "dropper" C7 with resistor R7 being included to prevent the capacitor from shorting the high frequency carrier signal.

R8 discharges C7 when the plug is removed from the mains socket to prevent any charge stored from giving anyone a shocking experience! The ac voltage is rectified by the diode bridge, limited to 12V by zener diode D3 and smoothed by C6 to provide a dc supply for the relay. IC1 and the amplifier require a 5 Volt supply and this is provided by R5 and the zener diode D1.

### Construction

With so few components, construction should not cause any problems provided reasonable care is taken. The use of a printed circuit board is recommended as it will make the construction easier, safer and the finished unit smaller. A suitable layout is given in figure 3.

Remember that the circuit operates at mains voltage, so make sure that components do not touch each other and that there are no solder splashes between track which could cause a lot of damage to the circuit when power is applied.

The ic is a MOS device and therefore sensitive to static. Touching the pins should therefore be avoided and the device mounted in a socket if possible. Take care also to insert the diodes correctly especially the zeners which tend to have very small markings to identify their voltage.

Testing the finished unit will obviously have to wait until the transmitter has been constructed and this will be dealt with next month.

For the sake of completeness, the mains connections to the assembly are shown in figure 4.

The L and N are interchangeable as far as the circuit is concerned although it is more usual to switch the L line (as shown), with the load connected on the N side. If the unit is to be mounted in a plug box, a separate in-line fuse should be fitted in the L line as shown but if the receiver is mounted in a separate box with a socket for plugging the appliance into, the fuse could be that fitted in the mains plug used with the device. The final assembly of the circuit into its box should be postponed until the complete system has been tested.

If required, two receivers could be built with different value resistors fitted in position R4. These should be chosen so that the frequency of the receivers does not overlap, which could result in both units swithcing together. If more channels are required, further receivers with different R4 values can be built but the transmitter would also need to be modified to enable more tones to be generated.

In this case, R4 is best replaced by a preset and the value determined by trial and error. Once this has been done, the preset may be replaced by the nearest value fixed resistor.

Suitable alternative values for other frequencies will be given next month. Next month's article will deal with the construction of the transmitter and the testing of the complete system.

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ELECTRONICS TODAY INTERNATIONAL

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Having presented the main Process Timer/Controller and its associated power supply, we continue this month with a small but useful board, which enables programmers who are writing their own interface software for the main board to test out their code without having to connect the controller to their proposed target interface.

When writing programs for microcontrollers which will eventually have control over a particular interface, whether it be for automotive applications, light and motor control, or, dare we say, the proverbial central heating controller (oh dear, how those words have been worn thin over the years!), the resulting code must be perfect in its operation if the microcontroller is to perform the designated tasks correctly.

There's nothing worse than discovering that something's wrong once the main controller is connected to the target interface and powered up, and all manner of inexplicable things start happening.

The art of programming is to write, test and debug small sections of the program at a time, but as our confidence in writing software grows, it's easy to get so engrossed in what we're doing that we get "on a roll", and decide to carry on regardless, writing more and more code, almost instinctively believing that the program will work, and that we know exactly what will happen once the controller is connected to the interface.

But it doesn't, and it's frustrating enough that the outputs alone might not do what you thought you had programmed them to do, but this becomes doubly frustrating when these outputs are interacting with various input conditions which themselves, when applied, inaugurate further irrational behaviour in perhaps both the controller board and the programmer.

This is obviously no use at all if the interface is already connected to various output devices, which by now each seem to have a mind of their own, doing things that you didn't even expect them to, let alone what you want them to. Even worse, no matter which buttons you press, or what input signals you try to simulate, you cannot override or significantly influence the actions of the controller, and things usually go from bad to worse. The most commonly used button in these situations is marked ON/OFF.

Experienced programmers will know that all of this could be the result of just one single incorrect instruction in the program code - but which?

Perhaps not so strangely, at this point we return to the program, split it up into 'chunks' and start testing the code in sections to find out where it's going wrong, as we should have done in the first place. In these situations it's useful to have some means of testing the code prior to connecting the devices you intend to control. Basically, all that is needed is something that will visually indicate the state of each output bit, and provide the means to simulate the required (or expected) input signals. This is just the intention of the project presented here.

The circuit
This must be one of the most simple circuit diagrams there is,
but the usefulness of the board just goes to show how some of the simplest designs can also be some of the best, and it could get more use than some of your final interface designs themselves. The seven bits available on the Process Timer expansion bus output port are fed to the inputs of a 7-stage Darlington driver, IC1, which in turn is used to drive the seven LEDs connected to its outputs. These provide high/low status indicator lights for the expansion bus output port. When an LED is lit the corresponding output bit is high, and when an LED is off the output bit is low. Rather than connecting the LEDs directly to the outputs of the 74LS74 (IC3) on the main controller, they are powered from the regulated +5V supply, and IC1 is used to minimise the load on the expansion bus.

This allows the Software Development Board to remain in place while other interface boards are also connected to the expansion bus, which is extremely useful if your desired interface isn't doing what it should, because you can see what signals are being sent to it. An additional LED provides a power on indicator (LED8) and resistors R1 to R8 limit the current through each LED. The expansion bus input port is connected to two sets of switches. The first set is formed by seven of the 8-way DIP switch SW1, the second set is made up of miniature PCB pushbutton switches PB1 to PB7. By using both types it is possible to use the pushbuttons for simulating momentary input signals, whilst the DIP switches provides long term or permanent input signals. When a switch is closed or pressed, the corresponding input bit on the expansion bus is pulled low to GND. When a switch is open or released, the input bit is pulled high to +5V by the resistor network RN2 on the main controller board.

The eighth pushbutton and DIP switch position provides control of the Output Enable (OE) line of the expansion bus. In most cases this will not be needed but has been included on this board for completeness of signal access. The OE signal was explained in part 1 of this series of projects, so a full explanation will not be repeated here, but basically, if you want to demonstrate the switches related to this signal (DIP switch 8 and PB8), together with their effect on the output status LEDs, then

**Figure 1:** the basic requirements for access control using an automatic gate controller

**Figure 2:** simplified flowchart for the automatic gate controller program. The main objective is to keep the gate closed at all times when it is not required to be open, but priority is given to vehicles exiting the driveway, even if the gate has started on the closing phase, but not yet shut.
you must place the jumper link JP1 on the main controller in the EXT (right hand) position. With the switch closed or pressed the LED indicators are enabled. When the switch is open or released the LEDs are disabled.

**Construction**
This is very easy, very straightforward. No static sensitive devices, no special handling precautions required. Make sure IC1 faces the right way, and don’t forget the five wire links. The DIP switch can be fitted either way around, depending on whether you want the switches to close on the downward or upward stroke, but generally these types of switches are numbered 1 to 8, and the PCB is designed to use these numbers to correspond to the bit numbers of the input port, so for this they should read left-to-right as normal.

**Connection and testing**
In common with all other boards in this series, this one plugs directly into one of the board edge connectors of the expansion bus ribbon cable.

If you are using non-polarised connectors on your ribbon cable then ensure the board is plugged in the right way around. Testing the board is simply a case of plugging it in and writing some software to turn the LEDs on and off, and to read the state of the pushbuttons or DIP switches.

The followingshort routine, while not doing anything practical, will test the individual operation of each switch and LED. The operation of the software is very simple; close a DIP switch or press a button and the corresponding LED for that bit will light up.

Remember though, if any of the DIP switches are closed (ON) then its equivalent pushbuttons will have no effect.

**Listing 1**
A simple test routine for the software development board

```
END OF PROGRAM
```

**Built-in test routine**
Here’s a well kept secret (up until now, that is). The programmed (darkroom timer) PIC16C54 available for this project has a built-in test routine of it’s own, which is far more comprehensive than the above listing. Not only does it provide pushbutton, LED and OE line testing, but also makes use of all four display digits to show what value is being read from the expansion bus input port, and what value is being written to the expansion bus output port.

To enter this test mode, first start with no power to the board, all DIP switches open, all pushbuttons released and the OE jumper on the process timer set to the EXT (external) position. Now hold down the bottom left hand RESET button on the process timer whilst powering up the board.
check the display again, it might just be that you have hexadecimal digits in this way it's very easy to mistakenly read segment left blank (off), and if you're not used to viewing top horizontal segment), whereas the letter 'b' has this very similar. The '6' makes use of display segment 'a' (the very availability of typographical characters it's important not to confuse the number '6' with the hex letter 'b', since they look the same.

A word of caution here. Whenever 7-segment displays are used to display hexadecimal values, because of the limited availability of typographical characters it's important not to confuse the number '6' with the hex letter 'b', since they look very similar. The '6' makes use of display segment 'a' (the very top horizontal segment), whereas the letter 'b' has this segment left blank (off), and if you're not used to viewing hexadecimal digits in this way it's very easy to mistakenly read it as '6'. So if you think your readings are wrong, then just check the display again, it might just be that you have misinterpreted the digit.

The development board together with the built-in test routine could double up as an educational demonstration of different types of code formats, since the pushbuttons produce inverse binary codes, the status LEDs are driven using positive binary codes and the digital displays on the Process Timer show both these codes in hexadecimal format, which is one of the most preferred types used by programmers in general.

Table 1: single pushbutton results

<table>
<thead>
<tr>
<th>BUTTON</th>
<th>DISPLAY READINGS</th>
<th>LED STATUS INDICATORS 1 = ON</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>FF:00</td>
<td>00</td>
</tr>
<tr>
<td>PB1</td>
<td>Fd:02</td>
<td>10</td>
</tr>
<tr>
<td>PB2</td>
<td>Fb:04</td>
<td>01</td>
</tr>
<tr>
<td>PB3</td>
<td>F7:08</td>
<td>00</td>
</tr>
<tr>
<td>PB4</td>
<td>EF:10</td>
<td>00</td>
</tr>
<tr>
<td>PB5</td>
<td>dF:20</td>
<td>00</td>
</tr>
<tr>
<td>PB6</td>
<td>bF:40</td>
<td>00</td>
</tr>
<tr>
<td>PB7</td>
<td>7F:80</td>
<td>127</td>
</tr>
</tbody>
</table>

Note: DIP switch 8 or pushbutton PB8 must be closed in order for LED indicators to light.

The software for this is complete in its functionality, but is very basic and by no means exhausti...
Comprehensive PIC solutions from FED

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Visit our Web page at http://www.ibmpcug.co.uk/gmviewer/led.htm
With programs that are very short, or at least with very simple specific tasks, there is usually no need for a flowchart. But with more ambitious designs it’s almost a necessity as the starting point to writing a reasonably structured program, to ensure you don’t take up valuable memory space by writing masses of repeated code which perform the same function. The program presented performs a power-up test of the piezo transducer, the 7-segment displays and the two LEDs (6 and 7) used to indicate the status of the limit switches. Plus, it carries out all of the tasks in the flowchart, AND shows messages in the displays of the Process Timer board relating to the status of the gate at any time.

When assembled, the whole program takes up a fraction more than just half of the available program memory of a PIC16C64 - 246 bytes to be precise, so there’s plenty of room left for adding your own modifications.

In order to drive the gate motor, detect the limit switches, ground loop and keypad operations, 4 inputs and 2 outputs of the expansion bus are used by the program.

The brackets below show which LEDs are used to indicate the outputs, and which pushbuttons to press to simulate the inputs, they are:

- **O/P1 (LED1)** Output for driving the gate opening relay. Turn on this relay to connect the +V power rail to the gate actuator motor, at the same time, turn off the gate closing relay to connect the power GND rail to the opposite motor pole.

- **O/P2 (LED2)** Output for driving the gate closing relay. Turn on this relay to connect the +V power rail to the gate actuator motor, at the same time, turn off the gate opening relay to connect the power GND rail to the opposite motor pole.

- **I/P1 (PB1)** Normally Open (N/O) limit switch input for gate open. This input goes low when the gate reaches the full travel of its open limit.

- **I/P2 (PB2)** Normally Open (N/O) limit switch input for gate closed. This input goes low when the gate reaches the full travel of its closed limit.

- **I/P3 (PB3)** Normally Open (N/O) keypad relay output. This input receives brief, low going pulses each time the code or card swipe is accepted.

The duration of the pulse is usually programmable at the keypad by the installer, and could be anything between 10 milliseconds and 20 seconds.

- **I/P4 (PB4)** Normally Open (N/O) ground loop detector relay output. For our purposes we will assume that this input is low at any time there is a vehicle within the detection range of the ground loop, but, as with the keypad, this is usually programmable at the detector for different configurations by the installer.

If both O/P1 and O/P2 are in the same state - high or low - the motor will not be driven, since the same voltage will be present on both poles of the motor.

No damage will result to the motor, but it is always best to keep the poles held to GND when no movement is required, such would be the case in a power-fail situation when both of the motor driving relays would de-energise and drop out. With permanent magnet motors this actually has a strong braking effect, because the magnetically induced current acts upon the low resistance of the armature winding and feeds the current back onto itself.

This, however, only works with motors which do not have a pre-armature speed control, so most of the small cassette player motors used these days won’t be suitable, since they generally have an adjustable speed control fitted inside the motor housing, which renders them non-reversible. If you want to use this type of motor you will have to dismantle it, remove the speed control section and connect the supply wires directly to the connectors of the armature brushes.

### Method of operation

**Obviously the Process Timer expansion bus cannot be connected directly to relays and motors etc. without adding a suitable interface board (see next part), but the explanation of how it operates remains the same, and the functions do work correctly when you simulate the various input conditions via the pushbuttons or DIP switches on the software development board.**

The default objective of the program is to keep the gate closed until such times that it is required to open. When a low signal is detected from the keypad or ground loop detector, caused by the correct code being entered or a vehicle entering the detection range of the ground loop respectively, the gate will open fully.

Once open, it is held there for a minimum of 10 seconds to allow the vehicle to pass through the gateway.

As long as the ground loop is clear after the 10 second hold time, the gate will attempt to close again. However, as a safety measure, if the ground loop is still active after this period, the gate will remain open and the Process Timer will emit a few beeps every second, until the vehicle moves out of the detection range.

If the keypad or ground loop are activated during the gate’s closing phase, the gate will stop for 2 seconds, and then reverse the motor to the opening phase. Once the gate has begun opening, it must be allowed to open fully, until it hits the open limit switch. There is no way to override it in the same way as the closing phase. The meanings of the various messages which will appear in the displays are as follows:

- **SHU** The gate closed limit switch is made, so the gate is assumed to be shut.

- **run** The gate motor is running in the Open direction (the gate is opening).

- **runC** The gate motor is running in the Close direction (the gate is closing).
STOP The gate was closing but either the ground loop detector or keypad input was activated, signalling the gate to open, so to prevent excess strain or damage the gate motor has been stopped for 2 seconds prior to reversing its direction.

HOLd The gate open limit switch is made, so the gate is assumed to be open, and is now on hold. In order for the vehicle to pass through the gateway it is now held open for at least 10 seconds before any attempt is made to close it.

LOOP The gate is attempting to close after being on HOLd, but there is something on the ground loop preventing it from doing so.

The gate will be held open until the obstruction is removed, after which the gate will begin to close immediately.

When displayed, the LOOP message flashes every second, and is accompanied by a two-tone bleep sound from the transducer.

Using the program

With the software development board plugged into the ribbon cable, set all DIP switches to the off position, the OE jumper link on the Process Timer to INT (left hand), and power up. There will be a few bleeps, followed by 88:88 in the displays and the two right hand LEDs lit on the software development board. This is the start up piezo, display and LED test routine.

From now on there is no need to touch the Process Timer, as everything is controlled from the software development board. After a couple of seconds runO will appear in the displays, and O/P2 LED will light. Because the processor receives a high signal from the gate closed limit switch it assumes the gate is open and is now trying to close it by turning on the gate close relay output bit.

Simulate the action of the gate closed limit switch by holding down pushbutton PB2. From the low input signal the processor assumes the gate has now closed, so the relay output bits are turned off, the limit switch indicator LED7 lights and the message SHUt appears in the displays. Releasing PB2 will simply reinstate stage 1 once more.

Simulate a keypad entry or ground loop detector signal by pressing PB3 or PB4 respectively. If PB2 is still held down (gate shut), the message runO is displayed and O/P2 LED lights. If not, then the message STOP appears for 2 seconds prior to runO being displayed.

The gate open limit switch input is high and the processor turns on the gate open relay output bit to open the gate. At this point you can release PB2, because the processor is now only looking for the gate open limit switch.

Press PB1 to simulate the action of the gate open limit switch. The gate is now put on hold for 10 seconds to allow the vehicle to pass through the gateway, and HOLd appears in the display during this period.

Release all buttons and the gate will close after 10 seconds. If, after the 10 second hold period, you still have PB4 pressed (loop active) the gate will remain open and LOOP flashes in the display, together with bleep sounds from the piezo. As soon as you release PB4 the gate will close and the whole process starts again.

The 5-page listing will appear next month if there is sufficient demand; otherwise, this listing, together with the simple Expansion Bus test routine and the main Darkroom Timer program of part 1 is on the software disk for this project, which is available from the author.

Still to come...

As we mentioned in part 1 of this series, the Process Timer/Controller does not have to be restricted to just timing applications. The ability to interface it via the expansion bus makes it suitable for a whole range of projects, and, as you may now realise, is not limited to small or simple designs just because it uses the low-end PIC16C54 device.

The next part of the project is a full blown I/O interface board which provides the means to connect the Process Timer expansion bus to the outside world.

On-board features will include changeover relays, open collector outputs and adjustable sensor inputs capable of handling up 50V on each input channel.

Some software examples will be supplied, and we will look at implementing a model of the automatic gate controller program on the board.

Kits and bits available

A complete kit of components for the Process Timer Software Development Board, which includes everything in the parts list, is available from the author by mail order only at the following address:

DTE Micro Systems
112 Shobnall Road
Burton on Trent
Staffordshire DE14 2BB

Complete kit for the Software Development Board (All components - including the PCB) £11.00

The PCB can be purchased separately if required £5.50

The programmed PIC16C54 is available separately at £8.50

Fully documented source code text on 3.5 inch disk (The complete source code + various other files) £8.50

All prices are inclusive, but please add £2.50 to the total order value to cover carriage and handling charges. If ordering from overseas, payment must be in pounds Sterling (£). Cheques, bank drafts or money orders etc. must be drawn on a British bank. Goods will normally be dispatched within five working days from receipt of order (subject to cheque clearance and availability), but please allow up to 28 days for delivery.

<table>
<thead>
<tr>
<th>Resistors</th>
<th>Capacitors</th>
<th>Semiconductors</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 - R8 470R (8 off)</td>
<td>C1 100nF Ceramic or Polyester</td>
<td>LED1-8 5mm high efficiency red LED (8 off)</td>
<td>SW1 8-way SPST DIP Switch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IC1 ULN2003 - 7 Stage Darlington driver</td>
<td>PB1-8 6 x 6mm miniature PCB switch (8 off)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Links 1/0.6 tinned copper wire (6&quot;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCB DTE Process Timer Software Development Board</td>
</tr>
</tbody>
</table>

PARTS LIST

ELECTRONICS TODAY INTERNATIONAL 59
OFF YOU GO!

Terry Balbirnie's automatic shut-down switch

Do you ever leave your computer switched on all day so that you can return to it at odd times? Do the children forget to switch it off after having used it to play games? If the answer to either of these questions is yes, then this project could be useful to you.

Worthwhile savings
It may be inconvenient to shut down the computer itself especially when several programs are running. However, there would be no such problem if only the monitor were to be switched off at the end of a session. Doing this would represent a worthwhile saving. A typical monitor is rated at about 120 watts. If it was left switched on for 8 hours, it would consume almost 1 kWh or electricity. Most people would not bother to switch off the monitor themselves. The Off you go! circuit has therefore been designed to cut off its supply automatically when there is no user present. It does this by interrupting the mains feed after a preset time between 10 and 40 minutes unless a push-button reset switch has been operated. Whenever the button is pressed, the timing begins again. Towards the end of the cycle, a buzzer begins to bleep. The button must now be pressed within a few minutes or the supply will be disconnected.

Dozing off
This circuit should not be used to switch off the computer itself. However, it could be used to switch off the TV in a child's bedroom or elsewhere. It could also be connected to a bedside reading light or radio. This would be handy for anyone who regularly goes to sleep with appliances left switched on. Note that it should not be used where any memory would be lost due to total disconnection of an appliance from the mains. Certain TVs “lose” the stations and need to be re-tuned if they are disconnected for more than a few hours. The maximum load is 2A corresponding to about 500W on 240V mains. The circuit will therefore accommodate a wide variety of low-power appliances. The unit may be left plugged into the mains continuously. This is because at the end of the timing period, the supply to the circuit

Figure 1: the block diagram of the shut-down switch

- FAST MONOSTABLE
- BINARY COUNTER
- LOGIC GATES
- RELAY

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itself is switched off so there is no current drain. The Off you go circuit is housed in a metal enclosure. There is the push-button reset switch referred to above and a further mains on push-button switch on the front panel. (see photograph). A flashing LED indicator, also on the front, shows when the circuit is operating. On the back there is a pair of 3-pin mains connectors. The lead which would normally carry the supply to the monitor is connected to one of these. A new lead is then taken from the other one to the monitor.

How it works
A block diagram of the system is shown in figure 1. The circuit comprises four sections in addition to the power supply: a fast astable (pulse generator), a binary counter, a system of logic gates and a relay which switches the mains supply to the load (e.g. a computer monitor). A detailed circuit diagram is shown in figure 2. The astable section consists of integrated circuit timer, IC1, and associated components. Assuming a supply exists, a continuous stream of pulses will be provided at the output, pin 3. The pulse repetition frequency is determined by the values of fixed resistors R1 and R2, preset potentiometer RV1 and capacitor C1. With the values specified, the preset may be used to adjust the frequency between 2.5 and 10 Hz. approximately (that is, 2.5 to 10 pulses per second).

The pulses from the astable are applied to the clock input, pin 10, of binary counter, IC2. Thus, as successive pulses are registered, the outputs ("twos", "fours", "eights", "sixteens" and so on) go high in various combinations to provide the binary count. Most of the outputs are unconnected but the highest three ("1024s", "2048s" and "4096s") plus the "8s" are used. The final two ("2048s" and "4096s" at pins 2 and 3 respectively) are connected to IC3 pins 4 and 5. IC3 is a triple 3-input NAND gate (that is, there are three separate 3-input gates in one package) and pins 4 and 5 are two of the inputs to one of the sections (IC3a). The third input (pin 3) receives a signal direct from IC1 output. Most readers will be familiar with a two-input NAND gate. The characteristics of the 3-input variant are simply an extension of this. Here, there will be a high output (in this case, pin 6) unless all three inputs are high, whereupon it will be low (figure 3 shows the truth table with the inputs labelled A, B and C and the output labelled X).

Not there yet
Towards the beginning of the cycle, IC3 pins 4 and 5 will be low because counting has not progressed sufficiently far. The output of IC3a will therefore be high irrespective of the state of pin 3. Pins 4 and 5 will both go high when the count has progressed sufficiently for the "2048s" and "4096s" outputs to be high simultaneously - that is after counting 4096 + 2048 or 6144 pulses. Suppose the astable is set to its lowest rate of 2.5Hz. To reach a count of 6144 would take about 40 minutes. At the highest frequency of 10Hz it would take some 10 minutes. When these pulses have been counted, the output of IC3a, pin 6, will pulse high at the clock frequency reflecting the behaviour of pin 3. This is because as pin 3 becomes high, all three inputs will be high so the output will be low. As pin 3 becomes low, the output will be high. The output from IC3a is inverted by IC3c which is a further 3-input NAND gate. To understand how this comes about, refer once again to the truth table. Since two of the inputs - pins 11 and 12 - are connected together, they must have the same logic state. Meanwhile, the other input (pin 13) is made permanently high by connecting it direct to the positive supply line.

It will be seen that if the output from IC3a is low, pins 11 and
12 will also be low. The output of IC3c - pin 10 - will then be high (shown by line 2). If IC3a output is high, pin 10 will be low (shown by line 8). The pulses obtained from IC3c pin 10 then operate buzzer, BUZ1. At the lower clock speed there will be a rapid bleeping. At the higher one the pulsing will be so fast that the buzzer will produce a warbling tone.

**Relay energised**

Now look at the remaining 3-input NAND gate, IC3b. While any of its inputs are low, the output (pin 9) will be high. At the beginning of the timing sequence, Darlington transistor Q1 will therefore receive base current via resistor R5. Consequently, current will flow in the collector circuit and relay, RLA1, will be energised. The normally-open ("make") contacts will be closed and the monitor and transformer, T1, will receive current. Diode D1 bypasses the high voltage pulse which appears across the relay coil when it switches off. Without it, semiconductor components in the circuit could be destroyed. Note that the high output state at IC3b pin 9 enables IC1 by making pin 4 (reset input) high.

IC3b output, pin 9, will remain high until all three inputs (pins 1, 2 and 8) go high simultaneously and this will occur when IC2 outputs '4096s', '2048s' and '1024s' are all high. This corresponds to a count of 4096 + 2048 + 1024 which is 7168 pulses (or 1024 pulses more than was needed for the buzzer to sound). At the slowest clock speed this will take about 48 minutes and at the highest one, 12 minutes. When this happens, the current flowing into the base of the Darlington transistor is interrupted and there will no longer be any current in the relay coil. The "make" contacts will open and the appliance and transformer will be switched off. Additionally, IC1 pin 4 is made low and the astable disabled.

To summarise, at the slowest clock speed the buzzer will begin to bleep after 40 minutes and the mains will be disconnected after 48 minutes. At the highest clock frequency, the buzzer will begin to bleep after 10 minutes and the supply will switch off after 12 minutes. Any time before the supply is cut off, the sequence may be re-started by making IC2 reset input, pin 11, high for an instant. This is the purpose of push-to-make switch, SW1. Normally, pin 11 is maintained in a low state through resistor R3 and this prevents false resetting due to possible pick-up of random signals along the wiring. Capacitor C2 holds pin 11 high for an instant on powering-up the circuit and this ensures that the counter is reset (that is, begins from zero). To show that the circuit is operating, IC2 '8's' output (pin 7) operates light-emitting diode, LED1 via current-limiting resistor, R4. The LED will flash at one-eighth of the clock frequency and this will be useful when checking the circuit since these pulses are sufficiently slow to be counted.

**Power supply**

The power supply is derived from the mains using a conventional arrangement of transformer T1 having a centre-tapped secondary, twin rectifier diodes, D2 and D3 and smoothing capacitor C3. No stabilisation is required because the astable frequency does not depend on the input voltage to any great extent. Also small changes in frequency, and therefore in the timing period, are not thought to be important.

When the circuit has timed out, the relay "make" contacts will be left open. To activate the circuit, push-to-make switch SW2 is
operated for an instant. This allows current to flow to the transformer primary which establishes a supply to the circuit. IC2 then begins counting and the relay is immediately energised. The ‘make’ contacts now take over in maintaining the supply and SW2 may be released. Note that since this switch also directs current to the load until the relay contacts “make”, it is important for it to be suitable for mains use and have an adequate current rating (see components list).

Construction

Construction is based on a single-sided printed circuit board (PCB) and the component overlay is shown in figure 4. First drill the four mounting holes (one is in the large copper area below C3 position). Mount the IC sockets and the two sections of screw terminal block, TB1 and TB2, as indicated. Add the five link wires and follow with the resistors (including preset, RV1) and capacitors taking care over the polarity of C3.

Solder the three diodes, the Darlington transistor and the buzzer in position taking care over the polarity of these components. The diodes have a grey band round the body to denote the cathode (marked “k” in each case). The polarity of the buzzer is also marked on the body. Solder the relay in place. Adjust RV1 fully anti-clockwise as viewed from IC1 position. This will provide minimum timings which will be convenient for testing purposes. Solder 15cm pieces of light-duty stranded connecting wire to the free pads labelled “SW1” and “LED1”.

Testing

The circuit panel should now be tested using a battery before the mains power supply is constructed. In this way, basic checks and setting-up may be carried out safely.

Attach the positive (red) PP9 connector to one of the terminals labelled “ac” (it does not matter which) and the negative (black) one to the terminal labelled “gnd”. Insert the ics into their sockets observing the orientation. Since these are static-sensitive devices they could be damaged by charge which might exist on the body. It would therefore be wise to touch something which is earthed (such as a water tap) before handling the pins. Carefully twist the “LED” wires to the LED indicator observing the polarity. Alternatively, use a plain LED. The slightly shorter lead is the cathode (negative) one. Make sure that these wires and those for SW1 are not left touching.

Connect the battery. The relay will be heard to click and the LED should begin to flash at about once per second. After 10 minutes, the buzzer should begin to give a warbling sound and after a further 2 minutes the relay should click off and the LED go out. These timings are approximate but will act as a guide. Touch the “SW1” wires together momentarily to reset the circuit. Allow timing to proceed until the buzzer begins to sound. Touch the wires together again. The buzzer should be silenced and the timing should start again. Adjust RV1 for the required period (although this will not be known exactly until after a few days of use). I suggest that a short time is used for most purposes.

Getting prepared

If all is well, attention may be given to the enclosure and power supply. Prepare the case by making holes in the rear panel for the input plug, output socket and transformer (see photographs). It is vital to understand that the mains output (monitor feed) appears at the socket so that it is impossible to touch the pins.

Drill holes for the two push-button switches and LED indicator (or a mounting clip for a plain LED) in the front panel. SW1 should be chosen to have a very light action. Hold the circuit panel in position, mark the mounting holes on the base of the box and drill them. Also drill the hole for the fuseholder and attach it. Mount the transformer including a solder tag on its upper fixing. Attach the mains plug and socket. Note that the output socket should be mounted to the left of the input plug (as viewed from inside the case) - see figure 5. The neutral pins will then be adjacent to one another. Attach the circuit panel using 10 mm long plastic stand-off insulators on the bolt shanks. Check that the underside copper tracks and joints on the PCB remain several millimetres clear of the base of the box. Check especially that the relay contact connections cannot, under any circumstances, touch the metalwork. Provide additional insulation as necessary. Attach the LED indicator. Refer to figure 5 and complete the internal wiring. All mains connections (shown in bold type) must be made with mains type wire of 5A rating minimum. Note the earth connection which is made to the solder tag. This grounds the case and transformer and is an essential safety requirement. The connections to the plug and socket should be made using insulated spade receptacles. Do not solder wires direct to the tags because the plastic body easily melts. Note also that SW2 connections must be insulated using heat shrinkable sleeving or an insulating boot. The transformer secondary leads (blue in the prototype) are connected to the terminals labelled “ac in”. The centre tap (black) lead is connected to the terminal labelled “gnd” via fuse FS1. Small cable ties were used in the prototype to keep the wiring tidy. If the plug on the mains input lead is of the 13A UK pattern, fit a 2A or 3A fuse. If the plug is not fused, a separate one must be included in the live (L) mains feed inside the case. Assemble the case and stick self-adhesive feet on the base to protect the work surface. Make up a lead for the monitor and connect it up. Plug the unit into the mains and check the circuit under working conditions. Note that when the mains supply cuts off, capacitor C3 keeps the timing circuit operating for a few minutes until it discharges. To avoid any problems with the circuit failing to trigger, make a habit of pressing SW1 (reset) before operating the mains on switch when the unit has timed out.

Safety precaution:

If the timing needs to be re-adjusted, unplug the unit from the mains before removing the lid of the case. RV1 should then be turned a little at a time and the lid replaced before plugging in. This procedure will avoid any possibility of touching live mains connections.

Figure 3: truth table for the 3-input NAND gate

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>A B C</td>
<td>X</td>
</tr>
<tr>
<td>0 0 0</td>
<td>1</td>
</tr>
<tr>
<td>0 0 1</td>
<td>1</td>
</tr>
<tr>
<td>0 1 0</td>
<td>1</td>
</tr>
<tr>
<td>0 1 1</td>
<td>1</td>
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<td>1 0 0</td>
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<tr>
<td>1 1 0</td>
<td>1</td>
</tr>
<tr>
<td>1 1 1</td>
<td>0</td>
</tr>
</tbody>
</table>

Buylines

The buzzer must be loud enough for the purpose. The unit used in the prototype was obtained from Maplin order code: KU56L. The box and relay were also obtained from Maplin order codes: XY43W and JM177T respectively. Other components are freely available.
Figure 4: The component layout of the shutdown switch

Resistors
- R1, R5: 10k
- R2: 220k
- R3: 47k
- R4: 1k
- RV1: 1M sub miniature vertical preset

All 0.6W 1% metal film.

Capacitors
- C1: 220n min. metallised polyester 5mm pin spacing
- C2: 10n min. metallised polyester 5mm pin spacing
- C3: 470m radial electrolytic 16V

Semiconductors
- IC1: ICM7555
- IC2: 4020
- IC3: 4023
- Q1: MPSA14
- D1, D2, D3: 1N4001
- LED1: Red LED indicator (or plain LED and mounting clip)

Miscellaneous
- FS1: 20mm chassis fuseholder and 200mA fuse to fit.
- BUZ1: 3V to 24V dc buzzer - 90dB at 12V.
- SW1: Push to make switch - see text.
- SW2: Push to make switch with 3A mains rated contacts.
- RLA: Relay with 6V 100W coil and 5A mains rated contacts.
- PL1/SK1: IEC (Euro-style) 3-pin chassis plug and socket
- T1: Miniature mains transformer with 6-0-6V centre tapped secondary rated at 250mA (3VA)
- TB1: 2-way PCB mounting screw terminal block - 5mm pin spacing
- TB2: 3-way PCB mounting screw terminal block - 5mm pin spacing

Circuit panel: 8-pin dill socket, 14-pin dill socket, 16-pin dill socket. Plastic stand-off insulators, small nuts and bolts, heat shrinkable sleeving, solder tag. PP9 battery and connectors (for testing). Metal box for project.

Figure 5: Wiring up the unit
George Pickworth sets up an experiment to measure the success of Willoughby Smith's cable-less telegraphy system of a hundred years ago

Following Willoughby Smith's small scale trials with a rowing boat on a lake as described in the first part of this article, and the granting of a patent for the single cable system, the Telegraph Construction Company accepted the invitation from Trinity House to go ahead with the Needles project in 1892.

According to the writer J.J Fahie, the submarine cable entered the sea at Alum Bay, but there is some evidence that it eventually entered the sea near the pier at Totland, and that the complementary electrode was attached below low water mark to the legs of the pier; this would be logical (see figure 3a). The cable terminated at a mushroom shaped copper electrode lying on the sea bed 60 yards from the rock. The electrode also served as an anchor for the cable.

The secondary electrodes, aligned radially with the distant primary electrode, were securely anchored below low water mark on opposite sides of the rock, as in figures 8b and 9.

However, my experiments showed that if iron-sheathed submarine cable was used, the sheathing would have to be insulated from the water, or else it would provide a low resistance return path to the complementary electrode and virtually short-circuit the system. More about this later.

Two-way communication
Despite the great difference in the spacing of the primary and secondary electrodes, the system was used for two-way communication. Operation proved entirely satisfactory and for the first time reliable communication with the lighthouse was maintained under all weather conditions. The lighthouse equipment was essentially the same as that used on land (see figure 10).

Interestingly, the original sender chopped DC into high frequency pulses that produced a tone in the distant receiver's earpiece. The advantage of the tone system was that it was almost immune to galvanic currents generated by the action of sea water on the electrodes.

However, the lighthousemen, accustomed to signalling with flags, preferred a mirror type galvanometer which deflected a beam of light across a screen (speaking galvanometer). This had a simple adjustment to compensate for variations in Galvanic currents.

A further refinement was to install a call system: employing a relay which rang a bell to attract attention, avoiding having to have someone constantly on duty watching the meter.

Fastnet lighthouse
Standing on a rock 80 feet high, 360 feet long and 150 feet wide, situated about 6 miles from the south west corner of Ireland, the Fastnet lighthouse was in one of the most exposed and inaccessible sites in the British Isles. Like the Needles lighthouse, it had been impossible to maintain communications with a continuous cable, as the cable was frequently broken.
where it came ashore. Poor visibility frequently prevented signalling with lamps or flags, often at those times when communication was most urgent, so, in 1892, the Needles system was adopted. According to Fahie, the shore end of the cable came ashore near Galley Cove, a few miles from Crookhaven Post Office, while the distant end terminated at a 500-pound mushroom-shaped copper electrode lying under 11 fathoms of water 100 feet from the rock.

The cable had a copper conductor weighing 107 pounds per nautical mile and was covered with 150 pounds of gutta percha per nautical mile. Its complementary electrode was placed in the haven itself, as in figure 11a. The alignment of the secondary electrodes is shown in figure 11b. Because heavy seas periodically swept over the rock, the wires leading from the electrodes to the lighthouse were placed in deep grooves chased into the rock and filled with Portland cement.

The secondary electrodes consisted of a number of copper rods inserted into 2.5-inch diameter sloping holes drilled through the rock so as to emerge into the water 20 feet below low water mark where they were not subjected to wave motion, as in figure 12. Installation was a difficult and costly operation. The signalling equipment was essentially the same as that used at the Needles lighthouse (figure 10). However, according to Fahie, ten large Leclanche cells (15V)** were used on the rock, and the current in the secondary circuit when sending signals was 1.5A, while the galvanometer at the shore end of the primary circuit registered 150 microamps.

**Iron sheathing**
The iron sheathing round the cable was dispensed with for the final 100 feet and replaced by a thick covering of rubber sheathed with copper wire and covered with more rubber. The whole assembly was protected by glass rings. Fahie said that these drastic measures were to prevent Galvanic effects between the iron sheathing and the copper electrode, but I believe the main reason was to avoid a low resistance path to the complementary electrode.

**Willoughby Smith's lake experiment**
The four electrodes in use each consisted of aluminium tubes 20mm in diameter and 1.25m long. Plastic-covered automotive cable was used as the submersible cable to the distant primary electrode, which was placed on the lake bed in 2 metres of water 150 metres from the bank. The electrode was kept in a vertical position by means of a weight and a plastic bottle. The vertical position of the primary electrode corresponded with the secondary electrodes; the plastic bottle served as a marker showing its precise position (see figure 13). The complementary primary electrode was laid in shallow water near the bank. The primary circuit was energised with 6 volts, and the current was measured at 125mA. The secondary electrodes were suspended in the water from the bow and the stern of a 2.5m GRP (fibreglass) dinghy and were connected to a microammeter with a resistance of 1500 ohms.

**Bamboo cane**
To enable the distance separating the primary and secondary electrodes to be maintained within close limits over 360 degrees, a bamboo cane with a plum-bob attached to the far
Figure 10: the Needles telegraphy equipment. The same type of equipment was used on the rock and on shore.

Figure 11a: the Fastnet system, showing the position of the submarine cable.

Figure 11b: the Fastnet system, showing the alignment of the electrodes. Not to scale.

end was extended from the bow of the dinghy. During measurements, the dinghy was manoeuvred so that the plumb-bob was directly over the bottle marking the position of the primary electrode. When the distance separating the primary and secondary electrodes was 1.5m, the meter registered 130 to 150 microamps as the dinghy swung around the primary electrode (figure 14). However, the current fell rapidly as the dinghy was incrementally moved away from the primary electrode and was negligible at 10 metres.

Figure 12: A sketch of Fastnet, showing how the electrodes were attached to the rock.
High resistance
Because the meter had a fairly high resistance it behaved as a voltmeter and therefore indicated a potential across the secondary electrodes.
A high resistance valve-voltmeter would have been more appropriate, but I used the microammeter to simulate a galvanometer.
Similar results were obtained when the secondary circuit was energised and the meter connected to the lake-side end of the primary circuit; this demonstrated that the system could be used for two way communication.
The meter reading fell dramatically when a length of galvanised iron wire, to simulate the effect of iron sheathing of a submarine cable, was laid alongside the insulated wire leading to the distant electrode; this substantiated my belief that the cable’s sheathing would either have to be removed or be insulated from the water.
I wish to record my thanks to the proprietors of the Mill Marina, Thrapston, Northants, for allowing me to conduct these experiments on their lake.

Figure 13: Willoughby Smith’s lake experiment reproduced by the author.

Figure 14: A plan view of the lake experiment, showing microamps generated through the secondary circuit with electrodes aligned at 90, 180, 270 and 360 degrees to the base-line.

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Next Month

In the November 1996 issue of Electronics Today International we continue Tim Parker’s Process Timer and Controller. Terry Balbirnie’s sound-effects circuit imitates the sound of a telephone ringing, and can be put to a number of uses from drama to discouraging intruders. If you are suffering from a noisy environment, Robert Penfold has developed a variable-effect background sound generator to help fade traffic noises and so on into the background. We have the second and final part of Bart Treap’s mains signal controller.

We are working on a bench PSU specially designed for valve equipment, and a PIC-controlled data logger. We have some news about software for electronics students and designers, and Douglas Clarkeson continues his series on alternative energy source.

Around the Corner

There is a growing disparity between what the electronics hobbyist can do and what the professional can manage. There is always some difference between facilities available to professionals and amateurs in any field, but in electronics in recent years it has been growing faster than most.

Of course, I can still wire a few components together to make a simple, useful circuit - a simple preamplifier, for example, for my sound card so that I don’t have to get so close to the microphone to generate vocema! This is a minimalist project, but not something you can buy easily or cheaply, and the ability to assemble it rapidly as needed is a great advantage.

But - look at it from another angle: how many amateur projects use surface mount components? The few which do normally use only the largest resistors and capacitors (1206), while in industry, a straw poll shows that half to three quarters of pcb’s now use smds (surface mount devices) and that 0805 components are beginning to give way to 0603 (which are 1.6mm by 0.8mm).

The designations refer to the size in inches - 0605 is 0.08 in by 0.05 in. I find 0603 difficult but far from impossible to use for prototypes - but these prototypes are on a hot air levelled pcb with solder resist. But I suspect that 0402 may prove a stumbling block, while 0201, which is already a reality in Japan, will only ever be machine assembled.

There are compensations, though. For instance, PIC programming is now well within the reach of amateurs: It has reached a stage when anything that need not run too fast, and uses more than a few standard logic devices, can be done conveniently in a PIC. Board size is reduced, and revisions do not normally need cut tracks and wire links, but just a few code changes. Perhaps PALs (programmable array logic) and even MACHs (an array of four PALs with extra I/O) will soon be accessible to amateurs as well.

But to return to traditional components: even these can present problems. I could only find the magnetic components for this month’s cover project with Farnell Electronic Supplies, who have a minimum order of £25. Even small production runs face problems because, unless a distributor carries an item as permanent stock, you can get hold of two samples from Japan in three weeks, or multiples of 20,000 on order, but nothing in between. Even for a pot-core-halving 20p in quantity this is a snag.

Luckily a supplier was found for the transformer core, and if you look far enough there is often a source for a suitable component, although it is quite frequently not the one you would, ideally, have preferred.
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