FREE ENTRY COMPETITION!

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

Vol.32 No.12

EVERYDAY PRACTICAL ELECTRONICS

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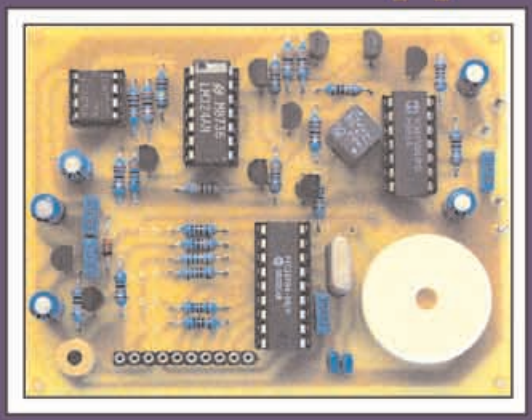
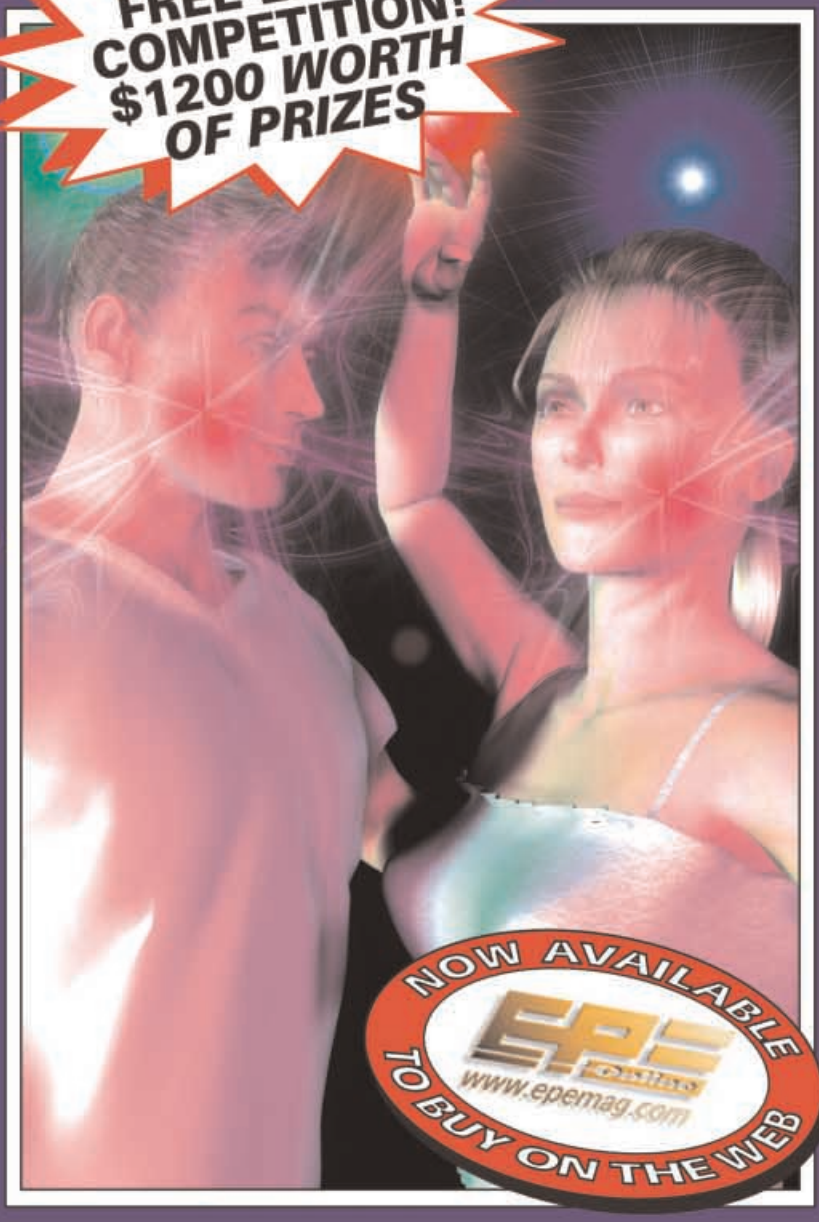
CHRISTMAS CHEEKS
Party time body adornment

PIC VIRUS ZAPPER MkII
Improved Experimental Infection Zapper



NIM MACHINE
PIC Controlled Game

FREE ENTRY COMPETITION! $1200 WORTH OF PRIZES



PLUS

TEACH-IN 2004 Part 2 - TRANSISTOR CIRCUITS
RADIO CIRCUITS · THE SUPERHET

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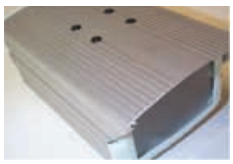
Colour CCTV camera, 8mm lens, 12V d.c. 200mA 582x628 Resolution 380 lines Automatic aperture lens Mirror function PAL Back Light Compensation MLR, 100x40x40mm. Ref EE2 £69

Built-in Audio .15lux CCD camera 12V d.c. 200mA 480 lines s/n ratio >48db 1V P-P output 110mm x 60mm x 50mm. Ref EE1 £99



Metal CCTV camera housings for internal or external use. Made from aluminium and plastic they are suitable for mounting body cameras in. Available in two sizes 1 – 100 x 70 x 170mm and 2 – 100 x 70 x 280mm. Ref EE6 £22 EE7 £26 multi-position brackets. Ref EE8 £8

Excellent quality multi-purposeTV/TFT screen, works as just a LCD colour monitor with any of our CCTV cameras or as a conventional TV. Ideal for use in boats and caravans 49·7MHz-91·75MHz VHF channels 1-5,168·25MHz-222.75MHz VHF channels 6-12, 471.25MHz-869·75MHz, Cable channels 112·325MHz-166·75MHz Z1-Z7, Cable channels 224·25MHz-446·75MHz Z8-Z35 5" colour screen. Audio output 150mW. Connections, external aerial, earphone jack, audio/video input, 12V d.c. or mains, Accessories supplied Power supply, Remote control, Cigar lead power supply, Headphone Stand/bracket. 5" model £139 Ref EE9, 6" model £149. Ref EE10

Self-cocking pistol plcr002 crossbow with metal body. Self-cocking for precise string alignment Aluminium alloy construction High tec fibre glass limbs Automatic safety catch Supplied with three bolts Track style for greater accuracy. Adjustable rear sight 50lb drawweight 150ft sec velocity Break action 17" string 30m range £21.65 Ref PLCR002

Fully cased IR light source suitable for CCTV applications. The unit measures 10 x 10 x 150mm, is mains operated and contains 54 infra-red LEDs. Designed to mount on a standard CCTV camera bracket. The unit also contains a daylight sensor that will only activate the infra-red lamp when the light level drops below a preset level. The infra-red lamp is suitable for indoor or exterior use, typical useage would be to provide additional IR illumination for CCTV cameras. £49. Ref EE11

Mains operated and designed to be used with any CCTV camera causing it to scan. The clips can be moved to adjust the span angle, the motor reversing when it detects a clip. With the clips removed the scanner will rotate constantly at approx 2·3rpm. 75 x 75 x 80mm £23. Ref EE12

Colour CCTV Camera measures 60x45mm and has a built-in light level detector and 12 IR LEDs 0.2 lux 12 IR LEDs 12V d.c. Bracket Easy connect leads £69. Ref EE15

A high quality external colour CCTV camera with built-in infra-red LEDs measuring 60 x 60 x 60mm Easy connect leads colour Waterproof PAL 1/4in. CCD 542 x 588 pixels 420 lines 0·05 lux 3·6mm F2 78 deg lens 12V d.c. 400mA Built-in light level sensor. £99. Ref EE13

Colour pinhole CCTV camera module with audio. Compact, just 20x20x20mm, built-in audio and easy connect leads PAL CMOS sensor 6-9V d.c. Effective Pixels 628x582 Illumination 2 lux Definition >240 Signal/noise ratio >40db Power consumption 200mW £35. Ref EE21

A small colour CCTV camera measuring just 35 x 28 x 30mm. Supplied complete with bracket, microphone and easy connect leads. Built-in audio. Colour 380 line resolution PAL 0·2 lux +18db sensitivity. Effective pixels 628 x 582 Power source 6-12V d.c. Power consumption 200mW £36. Ref EE16

Complete wireless CCTV sytem with video. Kit comprises pinhole colour camera with simple battery connection and a receiver with video output. 380 lines colour 2·4GHz 3 lux 6-12V d.c. manual tuning Available in two versions, pinhole and standard. £79 (pinhole) Ref EE17, £79 (standard). Ref EE18

Small transmitter designed to transmit audio and video signals on 2·4GHz. Unit measures 45 x 35 x 10mm. Ideal for assembly into covert CCTV systems Easy connect leads Audio and video input 12V d.c. Complete with aerial Selectable channel switch £30. Ref EE19

2·4GHz wireless receiver Fully cased audio and video 2.4GHz wireless receiver 190x140x30mm, metal case, 4 channel, 12V d.c. Adjustable time delay, 4s, 8s, 12s, 16s. £45. Ref EE20

The smallest PMR446 radios currently available (54x87x37mm).These tiny handheld PMR radios not only look great, but they are user friendly & packed with features including VOX, Scan & Dual Watch. Priced at £59.99 PER PAIR they are excellent value for money. Our new favourite PMR radios! Standby: – 35 hours Includes: – 2 x Radios, 2 x Belt Clips & 2 x Carry Strap £59.95 Ref ALAN1 Or supplied with 2 sets of rechargeable batteries and two mains chargers £84.99. Ref Alan2

Beltronics BEL55O Euro radar and GATSO detector Claimed Detection Range: GATSO up to 400m. Radar & Laser guns up to 3 miles. Detects GATSO speed cameras at least 200 metres away, plenty of time to adjust your speed £319. Ref BEL550

TheTENS mini Microprocessors offer six types of automatic programme for shoulder pain, back/neck pain, aching joints, Rheumatic pain, migraines headaches, sports injuries, period pain. In fact all over body treatment. Will not interfere with existing medication. Not suitable for anyone with a heart pacemaker. Batteries supplied. £19.95 Ref TEN327 Spare pack of electrodes £5.99. Ref TEN327X

Dummy CCTV cameras These motorised cameras will work either on 2 AA batteries or with a standard DC adapter (not supplied) They have a built-in movement detector that will activate the camera if movement is detected causing the camera to 'pan' Good deterrent. Camera measures 20cm high, supplied with fixing screws. Camera also has a flashing red l.e.d. built in. £9.95. Ref CAMERAB

INFRA-RED FILM 6" square piece of flexible infra-red film that will only allow IR light through. Perfect for converting ordinary torches, lights, headlights etc to infra-red output only using standard light bulbs Easily cut to shape. 6" square £15. Ref IRF2 or a 12" sq for £29 IRF2A

GASTON SEALED LEAD-ACID BATTERIES

1·3AH 12V @ £5 REF GT1213
3·4AH 12V @ £8 REF GT1234
7AH 12V @ £8 REG FT127
17AH 12V @ £18 REF GT1217

All new and boxed, bargain prices. Good quality sealed lead-acid batteries

SOLAR PANEL 10 watt silicon solar panel, at least 10 year life, 365 x 26mm, waterproof, ideal for fixing to caravans, boat, motorhomes etc. Nicely made unit with fixing holes for secure fittings. Complete with leads and connectors. Anodised frame. Supplied with two leads, one 3M lead is used for the o/p with two croc clips, the other lead is used to connect extra panels. Panels do NOT require a blocking diode, they can be left connected at all times without discharging the battery. £84.99. REF PAN

8A solar regulator 12V, 96 watt, 150mm x 100mm x 25mm. £28. REF SOLREG2

High-power modules (80W+) using 125mm square multi-crystal silicon solar cells with bypass diode. Anti-reflection coating and BSF structure to improve cell conversion efficiency: 14%. Using white tempered glass, EVA resin, and a weatherproof film along with an aluminium frame for extended outdoor use, system Lead wire with waterproof connector. Four sizes, 80W 12V dc, 1200 x 530 x 35mm, £287. REF NE80. 123W 12V d.c., 1499 x 662 x 46mm, £439. REF NDL3. 125W 24V, 1190 x 792 x 46mm, £439. REF NEL5 and 165W 24V, 157 x 826 x 46mm, £593.

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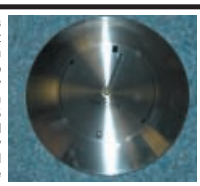
THE TIDE CLOCK. These clocks indicate the state of the tide. Most areas in the world have two high tides and two low tides a day, so the tide clock has been specially designed to rotate twice each lunar day (every 12 hours and 25 minutes) giving you a quick and easy indication of high and low water. The Quartz tide clock will always stay calibrated to the moon. £21 REF TIDEC



LINEAR ACTUATORS 12-36V D.C. BUILT-IN ADJUSTABLE LIMIT SWITCHES. POWER COATED 18in. THROW UP TO 1,000lb. THRUST (400lb. RECOMMENDED LOAD). SUPPLIED WITH MOUNTING BRACKETS DESIGNED FOR OUTDOOR USE. These brackets originally made for moving very large satellite dishes are possibly more suitable for closing gates, mechanical machinery, robot wars etc. Our first sale was to a company building solar panels that track the sun! Two sizes available, 12in. and 18in. throw. £29.95. REF ACT12, £34.95 REF ACT18.

POWERSAFE DEEP CYCLE BATTERIES
12V 51AH. NOW ONLY £29.95 EACH
YUASA 6V 100AH NOW ONLY £19 EACH

BRAND NEW MILITARY ISSUE DOSE METERS (radiation detectors). Current NATO issue. Standard emergency services unit. Used by most of the world's military personnel. New and boxed. £69. REF SIEM69

NIGHT VISION SYSTEM. Superb hunting rifle sight to fit most rifles, grooved for a telescopic sight. Complete with infra-red illuminator. Magnification 2·7x. Complete with rubber eye shield and case. Opens up a whole new world! Russian made. Can be used as a hand held or mounted on a rifle. £99. REF PN1

These Samarium magnets measure 57mm x 20mm and have a threaded hole (5/16th UNF) in the centre and magnetic strength of 2·2 gauss. We have tested these on a steel beam running through the offices and found that they will take more than 170lb. (77kg) in weight before being pulled off. With keeper. £19.95. REF MAG77.

Peltier Effect heat pump. Semiconductor thermo-electric device which works on the Peltier effect. When supplied with a suitable electric current, can either cool or heat. Also when subject to an externally applied temperature gradient can produce an electric current. Ideal for cooling or controlling the temperature of sub assemblies. Each module is supplied with a comprehensive 18-page Peltier design manual featuring circuit designs, design information etc., etc. The Peltier manual is also available separately. Maximum watts 56·2 40 x 40mm Imax, 5·5A Vmax, 16·7 Tmax (c-dry N2), 72. £29.95 (inc. manual. REF PELT1. Just manual £4 REF PELT2.

New transmitter, receiver and camera kit. £69. Kit contains four channel switchable camera with built-in audio, six IR l.e.d.s and transmitter, four channel switchable receiver, 2 power supplies, cables, connectors and mounting bracket. £69. Wireless Transmitter. Black and white camera (75 x 50 x 55mm). Built-in 4 channel transmitter (switchable). Audio built-in 6 IR l.e.d.s. Bracket/stand. Power supply 30m range Wireless Receiver 4 channel (switchable). Audio/video leads and scart adapter. Power supply and manual, £69. REF COP24.

This miniature Stirling Cycle Engine measures 7in. x 4¼in. and comes complete with built-in alcohol burner. Red flywheels and chassis mounted on a green base, these all-metal beauties silently running at speeds in excess of 1,000 r.p.m. attract attention and create awe wherever displayed. This model comes completely assembled and ready to run. £97. REF SOL!

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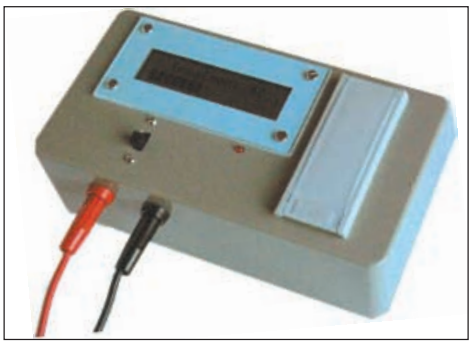

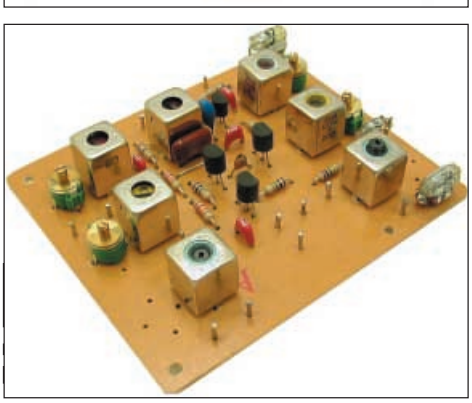

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NEXT MONTH

CAR COMPUTER

Cars are really useful, but owning one can be a pain! Maintaining one, keeping the engine in optimum condition and remembering all those important services dates is a nightmare – unless you live with a car mechanic, or use a log book. This PIC-controlled handheld Car Computer replaces and improves on the log book method. Each time the car is refuelled, the owner enters the amount of fuel added and the current mileage/kilometrage(!). With the aid of an in-built real-time clock, it calculates fuel consumption and can display any change in it over a monthly period. A drop in average fuel consumption can signal the onset of a problem, such as poor engine efficiency, signalling the need for a service or tune-up.

"Service points" can also be entered – reminders to take some kind of action, such as changing a timing belt, or have an in-warranty checkup, and so on. These events are typically time and/or distance based, and the Car Computer can be configured to track both and prompt the owner at the appropriate moment.

PIC WATERING TIMER

How to keep your plants in pristine condition before you PIC them! This timer module is designed around a PIC16F84A microcontroller to control a motorised water valve providing an automatic watering system for a greenhouse or garden. It is designed to control the water feed from a low pressure rainwater butt and is not intended for use on household mains water. With a little modification it can be used to control other devices.

One of the design constraints was that it should run on batteries with low power consumption. The prototype consumes only 1·7mA, mostly drawn by the l.c.d.

It has also proved to keep time well. During the growing season it watered the author's greenhouse tomatoes at regular intervals regardless of his presence. The only adjustment needed was to lengthen the "wet" time bit by bit as the summer got warmer (and the "perfect" tomatoes got bigger!)

GPS TO PIC AND PC INTERFACING

Global Positioning System (GPS) navigation handsets have been available inexpensively for some time and are in widespread use. Readers have been asking lately how they can be interfaced to PIC microcontrollers.

This article explains and demonstrates how such interfacing can be done with GPS handsets that conform to the NMEA 0183 standard. It also illustrates how they can be interfaced to a PC-compatible computer, using Visual Basic 6 (VB6). The techniques are extremely simple and the software examples given can be readily modified to suit a wide variety of applications.

PLUS

TEACH-IN 2004 – PART 3 OP.AMPS

RADIO CIRCUITS – PART 8: DOUBLE-CONVERSION SUPERHET

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We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £15.00
18VDC Power supply (PSU201) £5.95
Leads: Parallel (LEAD108) £4.95 / Serial (LEAD76) £4.95 / USB (LEADUAA) £2.95

NEW! USB 'All-Flash' PIC Programmer

USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows Software. ZIF Socket and USB Plug A-A lead not incl.
Kit Order Code: 3128KT – **£29.95**
Assembled Order Code: AS3128 – **£39.95**

Enhanced "PICALL" ISP PIC Programmer

Will program virtually ALL 8 to 40 pin PICs plus certain ATMEL AVR, SCENIX SX and EEPROM 24C devices. Also supports In System Programming (ISP) for PIC and ATMEL AVRs. Free software. Blank chip auto detect for super fast bulk programming. Requires a 40-pin wide ZIF socket (not included)
Kit Order Code: 3144KT – **£54.95**
Assembled Order Code: AS3144 – **£59.95**

ATMEL 89xxx Programmer

Uses serial port and any standard terminal comms program. 4 LEDs display the status. ZIF sockets not included. Supply: 16VDC.
Kit Order Code: 3123KT – **£29.95**
Assembled Order Code: AS3123 – **£34.95**

NEW! USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows software. See website for PICs supported. ZIF Socket and USB Plug A-A lead extra. 18VDC.
Kit Order Code: 3149KT – **£27.95**
Assembled Order Code: AS3149 – **£44.95**

Introduction to PIC Programming

Go from a complete PIC beginner to burning your first PIC and writing your own code in no time! Includes a 49-page step-by-step Tutorial Manual, Programming Hardware (with LED bench testing section), Win 3.11–XP Programming Software (will Program, Read, Verify & Erase), and a rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). Connects to PC parallel port.
Kit Order Code: 3081KT – **£14.95**
Assembled Order Code: AS3081 – **£24.95**

ABC Mini Microcontroller Board

ABC Mini Starter Pack

Currently learning about microcontrollers? Need to do more than flash a LED or sound a buzzer? The ABC Mini Starter Kit is based on ATMEL's AVR 8535 RISC technology and will interest both the beginner and expert alike.
Beginners will find that they can write and test a simple program, using the BASIC programming language, within an hour or two of connecting it up. Experts will like the power and flexibility of the ATMEL microcontroller, as well as the ease with which the board can be "designed-in" to a project.
The ABC Mini STARTER PACK includes everything you need to get up and experimenting right away. On the hardware side, there's a pre-assembled ABC Mini Board with parallel and serial cables for connection to your PC. Windows software included on CD-ROM features an Assembled, BASIC compiler and in-system programmer.
Order Code ABCMINISP – **£49.95**
The ABC Mini boards only can also be purchased separately at £29.95 each.

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have.
See website for full details. Suitable PSU for all units: Order Code PSU203 – **£9.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 TXs can be learned by one Rx (kit includes one Tx but more available separately). 4 indicator LEDs.
Rx: PCB 77x85mm, 12VDC/6mA (standby).
Two & Ten Channel versions also available.
Kit Order Code: 3180KIT – **£41.95**
Assembled Order Code: AS3180 – **£49.95**

Computer Temperature Data Logger

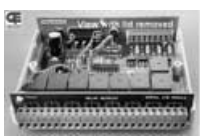
Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 38x38mm. Powered by PC. Includes on DS1820 sensor and four header cables.
Kit Order Code: 3145KT – **£22.95**
Assembled Order Code: AS3145 – **£29.95**
Additional DS1820 Sensors – **£3.95 each**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

NEW! DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12VDC.
Kit Order Code: 3140KT – **£39.95**
Assembled Order Code: AS3140 – **£59.95**

Serial Port Isolated I/O Module

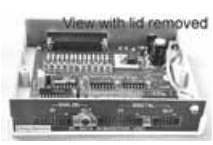


Computer controlled 8-channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Once programmed, unit can operate without PC. Includes plastic case 130 x 100 x 30mm. Power: 12VDC/500mA.
Kit Order Code: 3108KT – **£54.95**
Assembled Order Code: AS3108 – **£64.95**

Infra-red RC 12-Channel Relay Board

Control 12 on-board relays with included infra-red remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12VDC/0·5A.
Kit Order Code: 3142KT – **£41.95**
Assembled Order Code: AS3142 – **£59.95**

PC Data Acquisition & Control Unit



Monitor and log a mixture of analogue and digital inputs and control external devices via the analogue and digital outputs. Monitor pressure, temperature, light intensity, weight, switch state, movement, relays, etc. with the apropriate sensors (not supplied). Data can be processed, stored and the results used to control devices such as motors, sirens, relays, servo motors (up to 11) and two stepper motors.

Features

- 11 Analogue Inputs – 0·5V, 10 bit (5mV/step)
- 16 Digital Inputs – 20V max. Protection 1K in series, 5·1V Zener
- 1 Analogue Output – 0-2·5V or 0-10V. 8 bit (20mV/step)
- 8 Digital Outputs – Open collector, 500mA, 33V max
- Custom box (140 x 110 x 35mm) with printed front & rear panels
- Windows software utilities (3·1 to XP) and programming examples
- Supply: 12V DC (Order Code PSU203)

Kit Order Code: 3093KT – **£69.95**
Assembled Order Code: AS3093 – **£99.95**

Hot New Kits This Autumn!

Here are a few of the most recent kits added to our range. See website or join our email Newsletter for all the latest news.

NEW! EPE Ultrasonic Wind Speed Meter

Solid-state design wind speed meter (anemometer) that uses ultrasonic techniques and has no moving parts and does not need calibrating. It is intended for sports-type activities, such as track events, sailing, hang-gliding, kites and model aircraft flying, to name but a few. It can even be used to monitor conditions in your garden. The probe is pointed in the direction from which the wind is blowing and the speed is displayed on an LCD display.

Specifications

- Units of display: metres per second, feet per second, kilometres per hour and miles per hour
- Resolution: Nearest tenth of a metre
- Range: Zero to 50mph approx.

Based on the project published in Everyday Practical Electronics, Jan 2003. We have made a few minor design changes (see web site for full details). Power: 9VDC (PP3 battery or Order Code PSU203).
Main PCB: 50 x 83mm.
Kit Order Code: 3168KT – **£34.95**

NEW! Audio DTMF Decoder and Display

Detects DTMF tones via an on-board electret microphone or direct from the phone lines through an audio transformer. The numbers are displayed on a 16-character, single line display as they are received. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC via the serial port. The unit will not detect numbers dialled using pulse dialling. Circuit is microcontroller based.
Supply: 9-12V DC (Order Code PSU203).
Main PCB: 55 x 95mm.
Kit Order Code: 3153KT – **£17.95**
Assembled Order Code: AS3153 – **£29.95**

NEW! EPE PIC Controlled LED Flasher

This versatile PIC-based LED or filament bulb flasher can be used to flash from 1 to 160 LEDs. The user arranges the LEDs in any pattern they wish. The kit comes with 8 superbright red LEDs and 8 green LEDs. Based on the Versatile PIC Flasher by Steve Challinor, *EPE* Magazine Dec '02. See website for full details. Board Supply: 9-12V DC. LED supply: 9-45V DC (depending on number of LED used). PCB: 43 x 54mm.
Kit Order Code: 3169KT – **£10.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix)

FM Bugs & Transmitters

Our extensive range goes from discreet surveillance bugs to powerful FM broadcast transmitters. Here are a few examples. All can be received on a standard FM radio and have adjustable transmitting frequency.

***MMTX'* Micro-Miniature 9V FM Room Bug**

Our best selling bug! Good performance. Just 25 x 15mm. Sold to detective agencies worldwide. Small enough to hide just about anywhere. Operates at the 'less busy' top end of the commercial FM waveband and also up into the more private Air band.
Range: 500m. Supply: PP3 battery.
Kit Order Code: 3051KT – **£8.95**
Assembled Order Code: AS3051 – **£14.95**

***HPTX'* High Power FM Room Bug**

Our most powerful room bug. Very Impressive performance. Clear and stable output signal thanks to the extra circuitry employed.
Range: 1000m @ 9V. Supply: 6-12V DC (9V PP3 battery clip suppied). 70 x 15mm.
Kit Order Code: 3032KT – **£9.95**
Assembled Order Code: AS3032 – **£17.95**

***MTTX'* Miniature Telephone Transmitter**

Attach anywhere along phone line. Tune a radio into the signal and hear exactly what both parties are saying. Transmits only when phone is used. Clear, stable signal. Powered from phone line so completely maintenance free once installed. Requires no aerial wire – uses phone line as antenna. Suitable for any phone system worldwide. Range: 300m. 20 x 45mm.
Kit Order Code: 3016KT – **£7.95**
Assembled Order Code: AS3016 – **£13.95**

4 Watt FM Transmitter

Small, powerful FM transmitter. Audio preamp stage and three RF stages deliver 4 watts of RF power. Can be used with the electret microphone supplied or any line level audio source (e.g. CD or tape OUT, mixer, sound card, etc). Aerial can be an open dipole or Ground Plane. Ideal project for the novice wishing to get started in the fascinating world of FM broadcasting. 45 x 145mm.
Kit Order Code: 1028KT – **£22.95**
Assembled Order Code: AS1028 – **£34.95**

25 Watt FM Transmitter

Four transistor based stages with a Philips BLY89 (or equivalent) in the final stage. Delivers a mighty 25 Watts of RF power. Accepts any line level audio source (input sensitivity is adjustable). Antenna can be an open dipole, ground plane, 5/8, J, or YAGI configuration. Supply 12-14V DC, 5A. Supplied fully assembled and aligned – just connect the aerial, power and audio input. 70 x 220mm.
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1080KT – Liquid Level Sensor £5.95
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3006KT – LED Roulette Wheel £8.95
3074KT – 8-Ch PC Relay Board £29.95
3082KT – 2-Ch UHF Relay £26.95
3126KT – Sound-Activated Relay £7.95
3063KT – One Chip AM Radio £10.95
3102KT – 4-Ch Servo Motor Driver £15.95
3160KT – PIC16F62x Experimenter £8.95
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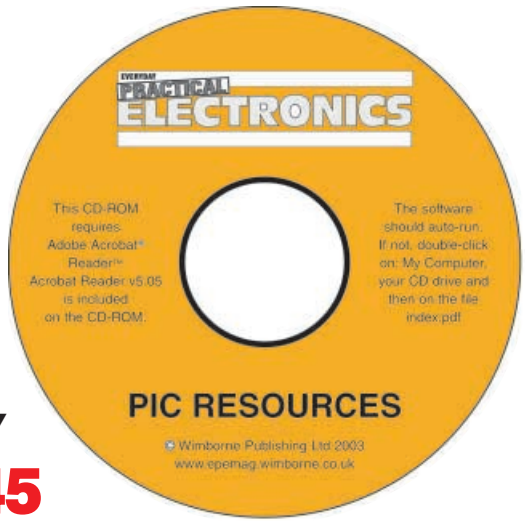
EPE PIC RESOURCES CD-ROM



A companion to the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)

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- EPE PIC Tutorial V2 complete demonstration software, John Becker, April, May, June '03
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- PIC Toolkit TK3 for Windows (software details), John Becker, Nov '01

Plus these useful texts to help you get the most out of your PIC programming:

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- Programming PIC Interrupts, Malcolm Wiles, Mar/Apr '02
- Using the PIC's PCLATH Command, John Waller, July '02
- EPE StyloPIC (precision tuning musical notes), John Becker, July '02
- Using Square Roots with PICs, Peter Hemsley, Aug '02
- Using TK3 with Windows XP and 2000, Mark Jones, Oct '02
- PIC Macros and Computed GOTOs, Malcolm Wiles, Jan '03
- Asynchronous Serial Communications (RS-232), John Waller, unpublished
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- Using Serial EEPROMs, Gary Moulton, unpublished
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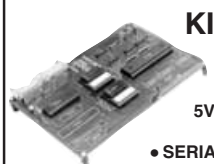

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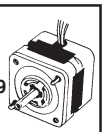

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Full set of top quality *NEW* components for this educational series. All parts as specified by *EPE*. Kit includes breadboard, wire, croc clips, pins and all components for experiments, as listed in introduction to Part 1.
**Batteries and tools not included.*

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

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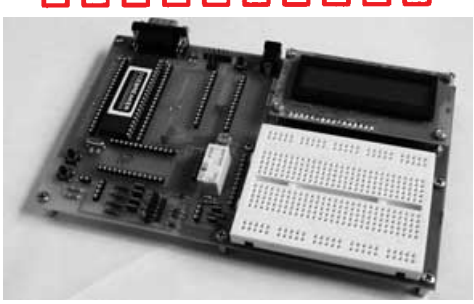

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- Windows™ (95+) Software included
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Programs can be written, assembled, downloaded into the microcontroller and run at full speed (up to 20MHz), or one step at a time.
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0-100mA	0Ω65
0-500mA	0Ω12
0-1A	60mΩ
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TIME WASTER?

Sometimes life seems fraught with difficulties, if it's not the email system clogging up due to massive spam files being sent to us, then it's the internal network on a go-slow tying up the system for what seems like an age, or important attachments for our artwork being removed by the virus scan. I often wonder if computers, the internet and email etc. do actually save us any time, or whether the hours we waste sorting out the problems or sifting through the junk that arrives on the system everyday takes longer than the time saved.

SPAM

Does the Nigerian gentleman with two million dollars left over from some government deal really think we will fall for his stupid scam and give him our bank details and some money to smooth its passage to our account? And does everyone really want to be forced to see all the adverts for pornography and the various enhancement drugs? It is high time the service providers who allow companies to use them to send out all this unrequested rubbish were made to clean up their acts and stop it at source. In my view, email would work in the way intended if all unsolicited advertising was banned. The problem is that it basically costs nothing to send your adverts to millions of people worldwide, so it only needs one poor soul to respond to make it worthwhile.

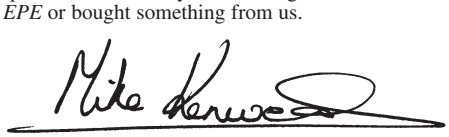
I suppose it is the price we pay for freedom of information, but it seems to be a price which one day might bring the whole worldwide system grinding to a halt.

At *EPE* we now pay for email filtering which does remove about 80 per cent of the worst offenders, at least we don't now have to watch disgusting images opening on-screen every morning, but it still lets about 20 unwanted messages through each day which we would be more than happy not to get.

FINE

No doubt greater minds than mine are working on the problem, but I can't help thinking that some legislation to fine the service providers for allowing their systems to send any form of spam – and surely if one email is going to thousands of addresses they should be aware – would make them take action. I guess something will be done when the systems crash and the world as we now know it comes to a standstill.

After that rant, let me assure you that we never pass on personal details of our customers to anyone, be they email or postal addresses or phone numbers, so you will not get a load of unsolicited junk because you have subscribed to *EPE* or bought something from us.



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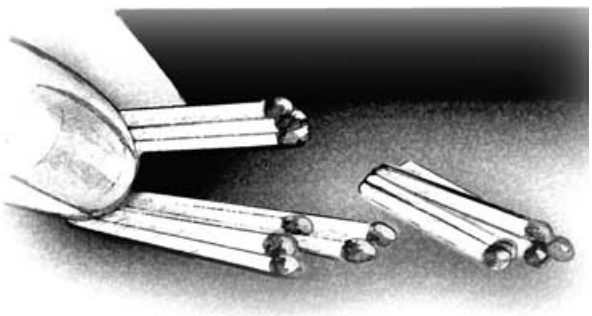
Constructional Project

PIC NIM MACHINE



DAVID COWARD

Nimbly PIC a winning pile!

NO-ONE knows quite when the game of NIM was invented. It is thought to be of Chinese origin, but named by the Germans.

The rules are very simple. A number of objects (pebbles, marbles, stones, coins, cards, but usually matchsticks) are placed into a number of piles. Each player takes it in turn to remove one or more objects from one and only one pile, applying simple binary logic. Whoever takes the last object wins.

NIM AND ELECTRONICS

NIM has had a long standing relationship with electronic devices. As early as 1940, Westinghouse displayed *Nimatron* at the *New York Trade Fair*. This one tonne machine won over 90% of the games it played against over 100,000 people! In 1951, an almost unbeatable robot called *Nimrod* was the star feature at the *Berlin Trade Fair*, where police had to be called to hold back the crowds who wanted to play it!

In more modern times, and in keeping with "Moore's Law", NIM was the sample game provided with the KIM1 6502 microprocessor evaluation board produced in the late 1970s. NIM is a popular topic for computer courses as the game logic is very simple, and a bit of practical maths should generate a winning strategy from almost every position . . .

Moore's Law, incidentally, defines the rate of increase of the number of transistors per square inch on an i.c. – current doubling about every 18 months.

PIC UPDATE

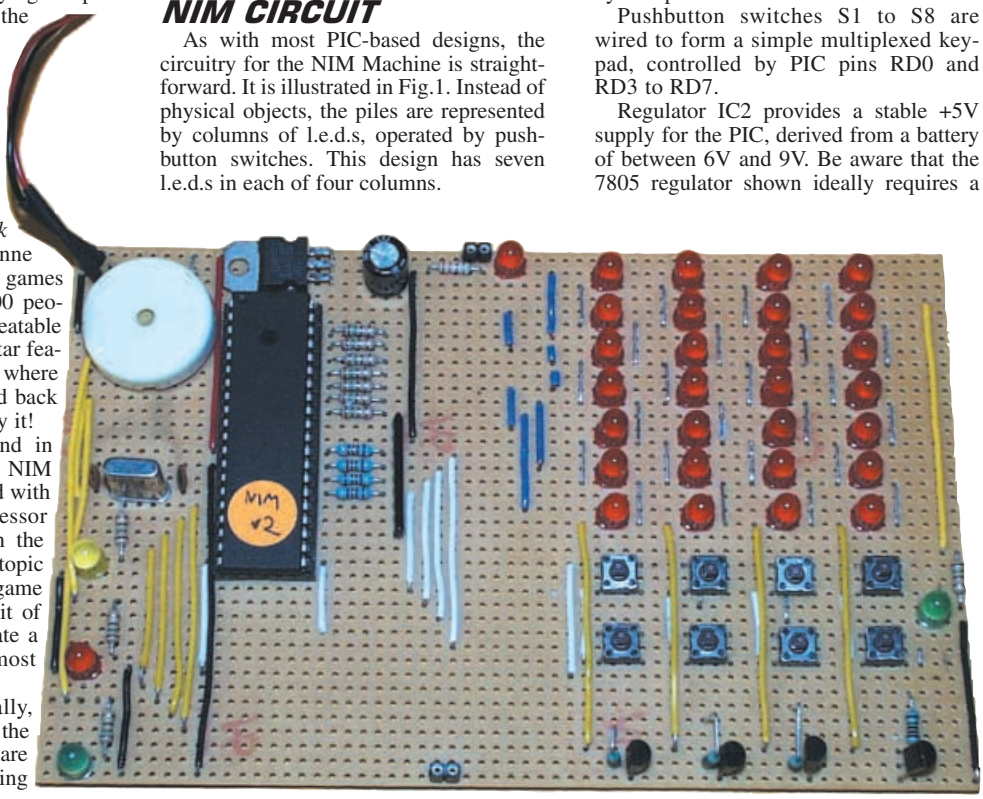
The author's own interest in electronics arose after seeing a NIM machine proudly exhibited by a sixth form member of the Electronics Club at a school open day in the early 1970s. Based on a design published in *Practical Electronics*, his marvelously noisy machine used pushbuttons, uniselectors and light bulbs to replace the clunky rotary switches and indicators of the original design.

It seemed natural and timely to bring the NIM/electronics relationship up to date, and deploy today's PIC technology to play this simple, but strategically challenging game.

The software, available as stated later, is written in C.

NIM CIRCUIT

As with most PIC-based designs, the circuitry for the NIM Machine is straightforward. It is illustrated in Fig.1. Instead of physical objects, the piles are represented by columns of l.e.d.s, operated by pushbutton switches. This design has seven l.e.d.s in each of four columns.



There's not much to say about the circuit! The PIC16F877 microcontroller, IC1, is operated at 20MHz, and drives the multiplexed 4 × 7 l.e.d. display (D1 to D28) via transistors TR1 to TR4 (column control via PIC pins RC0 to RC3), buffered by resistors R1 to R4, and resistors R5 to R11 (row control via PIC pins RB0 to RB6). An individual l.e.d. in the display is illuminated by turning on the individual row and column driver bits.

L.E.D.s D29 to D32 provide other game indicators, as discussed later, controlled by PIC pins RA1 to RA3 and RA5. The piezo sounder, WD1, provides audio feedback that a key has been pressed, and makes other noises from time to time, controlled by PIC pin RA0.

Pushbutton switches S1 to S8 are wired to form a simple multiplexed keypad, controlled by PIC pins RD0 and RD3 to RD7.

Regulator IC2 provides a stable +5V supply for the PIC, derived from a battery of between 6V and 9V. Be aware that the 7805 regulator shown ideally requires a 1·5V minimum differential between its input and output pins, and may not provide good regulation for 6V batteries that are less than fully charged.

It is worth noting that the PIC is capable of being powered directly at 6V, in which case IC2 could be omitted if preferred (provided the polarity of the battery is never reversed!).

COMPONENTS

Approx. Cost Guidance Only **£19** *excl. case*

See SHOP TALK page

Resistors

R1 to R4	1k (4 off)
R5 to R11, R16 to R19, R21	150Ω (12 off)
R12 to R15	4k7 (4 off)
R20	10k
R22 to R25	47k x 8 s.i.l. common-resistor module (see text)

Capacitors

C1, C2	22p ceramic disc, 5mm pitch (2 off)
C3	100μ radial elect. 16V

Semiconductors

D1 to D28, D31, D33	red l.e.d., 5mm (30 off)
D29, D32	green l.e.d. 5mm (2 off)
D30	yellow l.e.d. 5mm
TR1 to TR4	BC548 (or similar) *npn* transistor (4 off)
IC1	PIC16F877-20 microcontroller, preprogrammed (see text)
IC2	7805 +5V 1A voltage regulator

Miscellaneous

S1 to S8	push-to-make tactile switch, with shaft, p.c.b. mounting (8 off)
S9	s.p.s.t. min. toggle switch
WD1	active piezo sounder

Stripboard 39 strips x 63 holes; 40-pin d.i.l. socket; battery clip (see text).

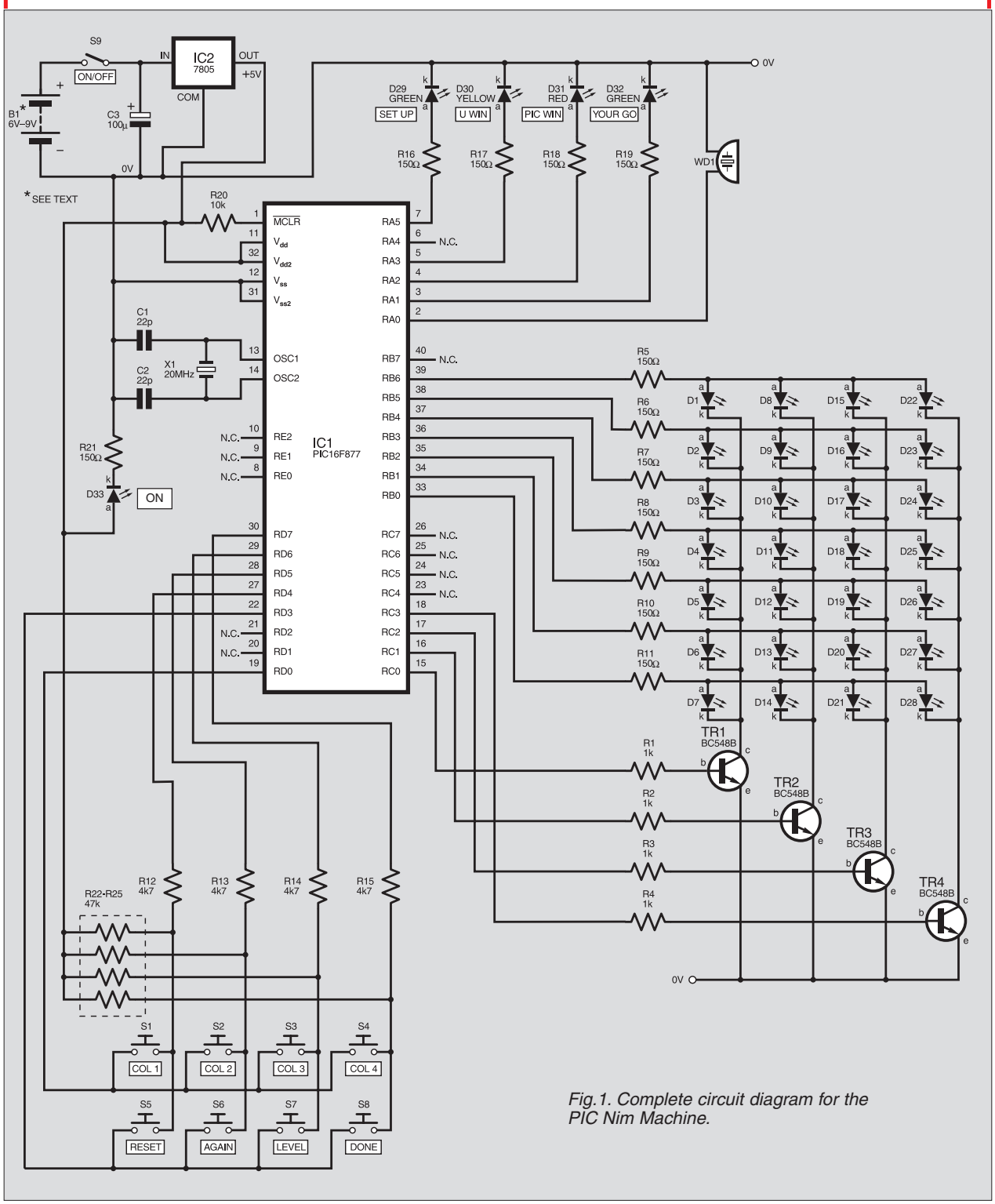


Fig.1. Complete circuit diagram for the PIC Nim Machine.

PIC NIM MACHINE – CIRCUIT BOARD

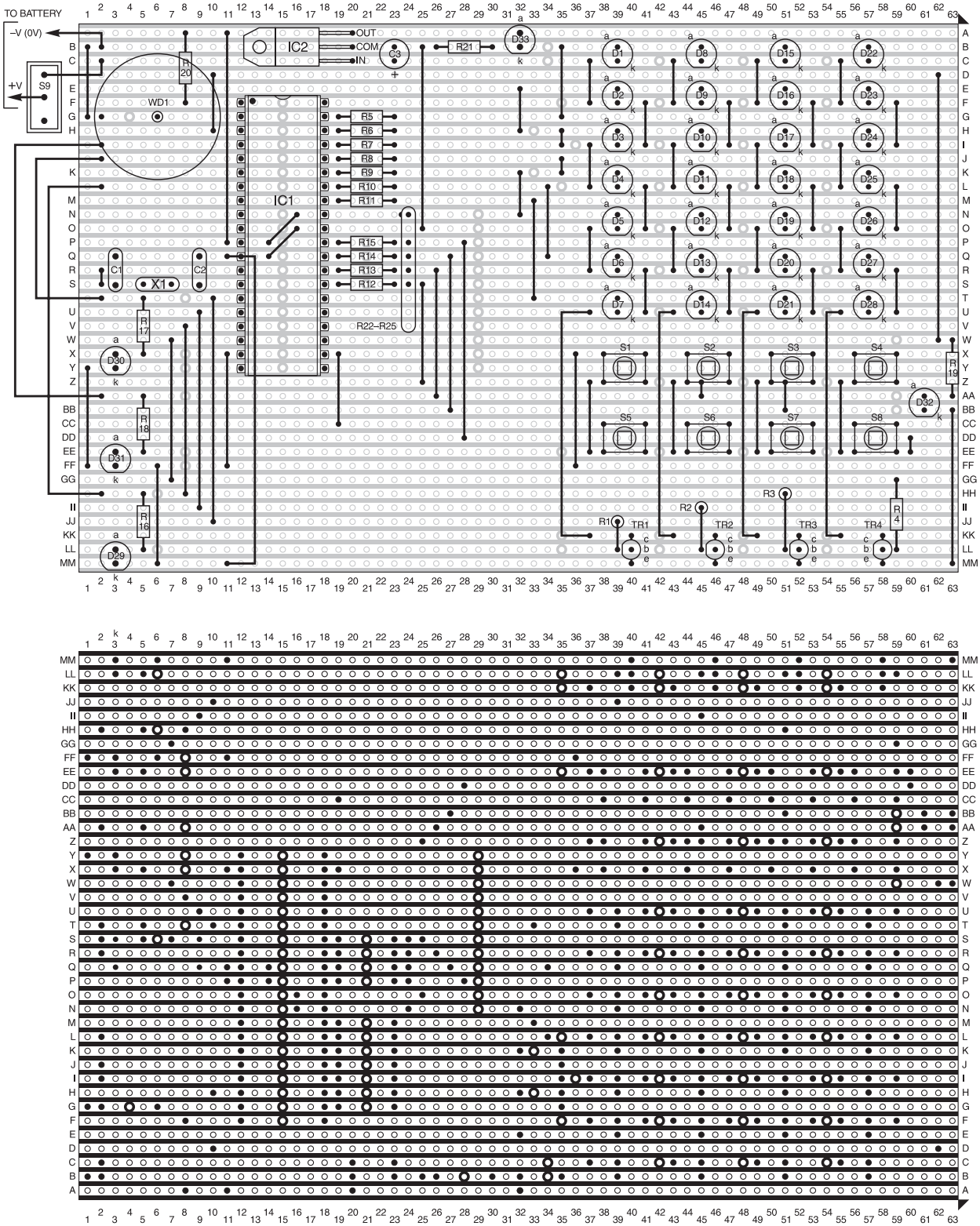


Fig.2. Stripboard component layout, link wires and details of breaks required in the underside copper tracks. Note that the unused pins of the s.i.l. resistor module (R22-R25) must not be connected to the board and it is advisable to snip them off.

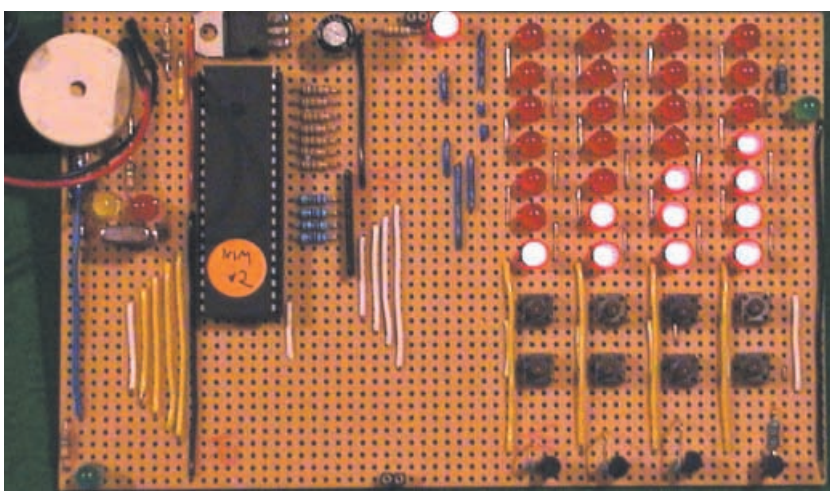
CONSTRUCTION

Construction is straightforward and, given the low main component count, stripboard is a perfectly viable alternative to a printed circuit board. Fig.2 illustrates the stripboard component layout used with the prototype.

Ensure that all the track breaks are made, preferably using the special stripboard cutter available. Next insert all the link wires, noting that two go under the IC1 position, followed by components in ascending order of size. A socket *must* be used for IC1.

Note that the s.i.l. (single-in-line) resistor module (R22 to R25) has only four of its eight resistors used and it is advisable to remove the module's pins for the unused resistors.

Ensure that all the l.e.d.s are inserted the correct way round, as must be the transistors and regulator IC2.



If the assembly is to be mounted in a case (the prototype was not), the l.e.d.s could be stood off the board, and the pushbutton switches replaced by appropriate panel mounted switches connected to the appropriate points on the stripboard.

Before applying power, thoroughly check that the assembly is correct and that the soldering is satisfactory.

It is advisable to test the matrix before inserting the preprogrammed PIC (correctly orientated!). This is easily achieved through the use of two small wander leads inserted into the Vdd socket pins (11 and 32). One of the leads is connected in turn to the socket pins on Port B, whilst the other is connected in turn to the column driver pins on Port C. One l.e.d. should light for each combination.

GAME THEORY

Many theories abound in respect of winning strategies. This design makes use of the XOR theory, which states that a winning position is one in which the bitwise XOR of the numbers of objects in each pile (expressed as a binary number) is zero.

By way of example, consider the situation in which the piles have one, two, three and four objects respectively:

PILE	OBJECTS	BINARY
1	1	0001
2	2	0010
3	3	0011
4	4	0100
–	XOR	0100

To use this theory, the computer chooses a pile and removes one object. It then calculates the XOR of the situation. If this is zero, the machine makes its move. If not, it takes another object away from the pile (if possible) and repeats the test. If it can't find a winning position by taking objects from the current pile, it moves on to the next. If it can't find a winning position at all, it makes a random move!

In the above example, on the hardest level, the machine will correctly deduce that a winning position can be achieved by removing all the objects in pile 4:

PILE	OBJECTS	BINARY
1	1	0001
2	2	0010
3	3	0011
4	0	0000
–	XOR	0000

In fact, this is the only situation where, from the starting position, the XOR is zero. After that, the machine is unbeatable, as it is impossible for the player to turn the situation into a winning position!

PLAYING THE GAME

The machine powers up in setup mode, indicated by flashing Setup l.e.d. D29. This allows the player to set the number of objects in each "pile" using the pushbutton switches under each column (S1 to S4). The example above and illustrated in the photograph shows a game with one, two, three and four objects in each column respectively.

The degree of difficulty can also be set. Pressing Level switch S7 once puts the machine into Difficulty mode, indicated by flashing the U Win and Setup l.e.d.s, D30 and D29, and then each subsequent press increases the difficulty level by one. Maximum difficulty means that the machine uses maths for every move. Minimum difficulty (which is the default) means that each move is random.

The level of difficulty is indicated by the number of complete rows illuminated. The Done switch, S8, exits Difficulty mode and puts the machine back into Setup mode.

Once setup is complete, pressing the Done button starts the game. The Your Go l.e.d., D32, will flash and the player makes a move by pressing the appropriate column button once for each object they would like to "remove".

When the player's turn is complete, the Done button requests the machine to take its turn. It is possible to force the machine to take its turn by pressing Done without making a move. This can be used to make the machine go first (it will still usually win with difficulty level 7), or to cheat! The machine is smart enough to realise that if there are no objects left in a column, it must be the other player's turn.

Play continues until the last l.e.d. is turned off. The machine indicates the winner appropriately by flashing either D31 (if the machine wins) or D30 (if the player wins).

When the game starts, the machine saves the opening position and difficulty level. This is recalled using the Again button, S6 – useful for those who want to have another go immediately from the same starting position! The Reset switch, S5, sets difficulty to minimum and turns on one l.e.d. in column 1.

SOFTWARE DESIGN

The software for the NIM Machine was written in C, it was produced using the FED variant of this language (V8.04) with an Application Designer front-end. C is a functionally based language well suited to the event oriented nature of an interrupt driven PIC environment.

The C source files provided allow readers with appropriate C programming resources to reconstruct the project in its entirety as a simulation, in which 7-segment displays are used instead of individual l.e.d.s.

An Application Designer was used to speed up the original design process for the NIM Machine. This allows components ("elements") to be connected to a PIC on-screen, and an application generated which takes care of the basic software utilities.

In this design the main saving was the use of a keypad element. When a key is pressed, the element responds with an "event" and a value that can be processed by C code written by the programmer. The Application Designer also takes care of all PIC Port initialisations, memory page management and provides events for timer overflows and other interrupts which trigger, for example, a scan of the display.

The major software challenge was to slow the action down sufficiently so that the player could see what move the machine had made. This was achieved by flashing the l.e.d.s as they are "removed" (turned off). However, implementing this on a multiplexed display whilst at the same time driving the piezo sounder was "interesting", but demonstrates effective use of the interrupt driven C language used.

RESOURCES

All software files for this design are available from the *EPE PCB Service* on 3·5in disk, for which a nominal handling charge applies. It is also available for *free* download via our home page at **www.epemag.wimborne.co.uk**. Pre-programmed PICs are also available as stated on this month's *Shoptalk* page.

For more information on NIM and its variants, do a search on "Game of NIM" via **www.google.com** – there are thousands of links!

So there it is! Not quite the one tonne of *Nimatron* (even with batteries), but plays a mean game nevertheless! □

Seedy CDs and Dodgy DVDs

How permanent is your home-recorded CD and DVD data? Andy Emmerson provides answers as well as questions.

NOBODY likes unwelcome surprises, not least with high-techery that has cost an arm and a leg. But a grasp of the technology that makes it work helps avoid disappointment, especially if you also understand the underlying "materials technology" that makes it tick.

Lately users of these new-fangled DVD recorders (I'm one of them!) have been suffering cold sweats when precious recordings vanished into thin air. Mini disc (MD) users have also suffered in the same way, so what's going on?

DISAPPEARING TRICK

Data disappears when it is inadvertently overwritten or when the storage medium deteriorates, and both can apply here. For some DVD and MD data loss the root cause is overwriting. In one popular brand of DVD recorder it appears that the laser optics were not fixed rigidly enough, with the result that when the laser beam shifted, previously recorded data effectively became "invisible".

Faulty software in the same machines meant that when you added a new recording to a part-used rewritable disc, it overwrote part of an earlier recording. After being alerted to this nasty feature (all right, bug) the manufacturer rewrote the operating software and arranged to repair at its own expense any machine displaying these faults (contact your dealer if you too have been affected).

CURING CORRUPTION

In the case of MDs the issue is slightly different and missing recordings are not so much lost as mislaid – so long as you take action immediately they "go missing". What happens here is that the audio is recorded but for some reason the "table of contents" or TOC that tells the player where to look on the disc for each recording has not been updated. This can happen when a disc is ejected or the machine is switched off before the TOC has been written.

Power cuts or mains surges are possible culprits too. The disc will claim to be empty when this happens and the crucial thing is to hold fire and make no further recordings.

Repairing a scrambled mini disc is not a do-it-yourself exercise but there are people who can help. For example, a website **www.esdl.co.uk/body/md_data_recovery/md_recovery.htm** gives some reassurance. And you might look at these pages too:

- **www.minidisc.org/test_mode_warning.html**
- **www.minidisc.org/tips_sec_3.html**
- **www.sonicstudios.com/tips.htm.**

Data can also go missing on CDs that you record yourself and fortunately there is a range of "data recovery" software you can use to retrieve missing tunes (or computer data for that matter). The programs cannot fix badly corrupted files but are said to have a high rate of success, so it's worth having a go, especially as some of these programs are freeware. Here are some sites to examine:

- **www.elpros.si/CDCheck/helplink.php?helpfn=overview**
- **www.smart-projects.net/isobuster/**
- **www.newfreeware.com/utils/617/**

You will also find helpful articles on data recovery on some of these sites.

OTHER REASONS

Assuming no error on your own part, why should data go missing on CDs and CD-Rs? People often assume that scratches on the under (or recorded) side of the CD are the culprit, but the opposite is the case. As Michael Biel, Ph.D., professor of radio and television at Morehead State University, Kentucky, states, the upper side is most vulnerable.

"It is the label side that needs to be protected from scratches, dents, holes and so on," he declares. "The reflective surface is right under this thin coating, and it is this side of the disc that needs to be treated very carefully to avoid permanent damage. Scratches on the thicker "reading" side (made of polycarbonate) can usually be removed without permanent damage."

Tests have shown that even manufacturers' names printed in paint on this upper surface can affect the data recorded directly underneath after a while. Unlike commercial mass-produced CDs (in which the digital information is actually moulded into the polycarbonate), the recordable CDs we use at home work by melting and deforming dye layers that are coated onto the blank grooved polycarbonate. These dye layers can be damaged by the heat of the machines that apply the brand names.

SUB-STANDARD MEDIA

By far the most common case of data loss, however, is sub-standard media (by which we mean blank CD-Rs, DVDs and MDs). Whilst truly awful recordable CDs have been all but banished from the marketplace, the higher cost of blank DVDs is creating a ready market for a product sold at pocket-money prices. Sadly most of this is of poor quality and frequently reject material that the big brands are not prepared to sell under their own name (but cannot afford to discard either).

In a recent Internet newsgroup posting, Fred Berney of **www.oldietv.com** offered a professional viewpoint, saying, "As a company that duplicates over 5,000 CDs a year and close to that many DVDs a year, I think I can speak from some experience. When the CD first appeared on the market, there were a number of manufacturers that were producing a product that failed after a few months. Many, many articles were written about this. Keep in mind that a CD-R as well as a DVD-R depends on dyes for recording. If the dyes do not hold their structure, then the information can be lost."

WORDS TO THE WISE

Leaving recordable CDs and DVDs in sunlight is a good way to "bleach" those dyes, so always put them away into their library cases. For DVDs the black plastic cases are the best place you can store them. It also pays to buy reputable brands.

Berney continues, "If you stick with major companies and mainly those that have a good reputation, your discs should last a good number of years. When I first started burning DVDs I bought some made by a company that was considered 'generic' by many. I'm now finding that some of those discs have failed.

"However, about two years ago, I decided to standardise by using only Verbatim and in some cases Mitsui DVD-R discs. I have never had one go bad on me. I probably pay twice as much for my Verbatim and Mitsui discs than if I were to purchase some off-brand disc, but the security is worth the extra money. Anyway, prices are coming down on even these brands."

BACK-UP LIFE

If long life of recordings is important to you, then it must make sense to buy recordable DVDs from a manufacturer that stipulates the life of its products and back this up with an unconditional guarantee. Verbatim Corporation is one and last year it stated its DVD-RW discs had a data life of more than 50 years, enabling information to be accessed millions of times (or replaced up to 1,000 times) without any deterioration in picture or sound quality.

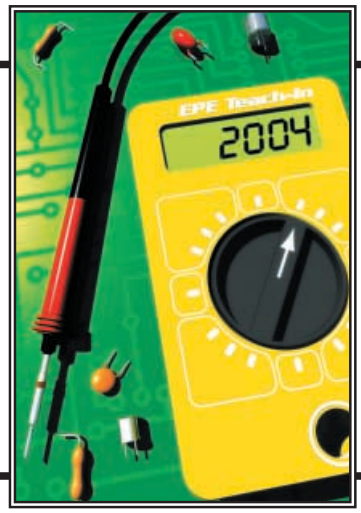
Even then, Ed H. Zwaneveld from the National Film Board of Canada advises caution, saying, "My advice would be not to buy media for content that requires any kind of medium-term or extended-term life expectancy unless the manufacturer has published Qualification Testing data that proves its ability to resist oxidation.

"It would in my opinion also be very risky to throw tapes away after transfer to these media, because they are in a high number of cases unlikely to afford even a fraction of the claimed 100-year life!"

EPE Tutorial Series

TEACH-IN 2004

Part Two – Transistor Circuits



MAX HORSEY

How to apply electronics meaningfully – the aim of this 10-part series is to show, experimentally, how electronic components function as part of circuits and systems, demonstrating how each part of a circuit can be understood and tested, and offering advice about choosing components

A TRANSISTOR is a current amplifier. Transistors can be used to increase the current available from a sensor to switch on an output device, such as a buzzer, lamp or motor, for instance.

In this part we first examine *bipolar* transistors – the common type to which such devices as the BC108 belong, for example. We then look at Darlington and MOSFET transistors.

BIPOLAR TRANSISTORS

The principle of the transistor is shown in Fig.2.1, which illustrates the transistor action by means of a water analogy. Of course, no analogy can provide the whole story, but it should provide a visual guide to the action.

The diagram in Fig.2.1a shows an imaginary valve. The water in the pipe labelled "collector" cannot flow into the body of the valve since it is blocked by the pivot arm. However, if water is forced in through the pipe labelled "base" the arm will be pushed and pivoted, so allowing water to flow down from the collector, as in Fig.2.1b.

The water from the base and collector now combine and flow out of the pipe labelled "emitter". If the pressure at the base is removed, the spring will close the pivot arm and the flow will stop.

Several points can be made from this analogy – and are helpful in understanding a real transistor:

- A small flow into the base can turn on a large flow via the collector and emitter. Hence the device can amplify the flow
- There is a degree of independence between the input (base) side, and the output (collector/emitter) side. Hence two circuits operating on two voltages can be interfaced by a transistor, e.g. a 5V logic circuit can control a 12V motor via a transistor
- A little pressure is needed at the base before any current will flow. In a real transistor this translates to the 0·7V turn-on voltage required at the base (assuming that the emitter is at 0V). (*Physics purists may dislike the suggestion that voltage is like pressure, but the link does help in understanding the action of the transistor*)
- Emitter current = base current + collector current

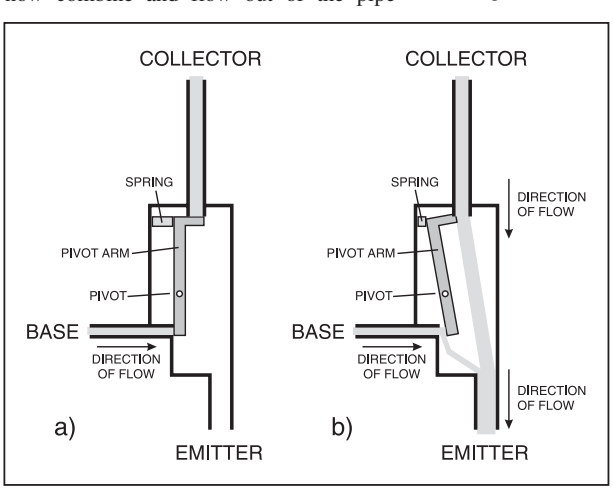


Fig.2.1. Using a water valve to illustrate the transistor principle, (a) valve closed, (b) valve open.

The symbol for a real transistor, a bipolar *npn* type, is shown in the circuit diagram of Fig.2.2, notated as TR1. The circuit also illustrates how a small current can be used to switch on a larger current. When you touch the "touch contacts" a very small current flows through your finger – far too little to activate a buzzer. But this tiny current is sufficient to activate the transistor, which amplifies the current sufficiently for the buzzer to sound.

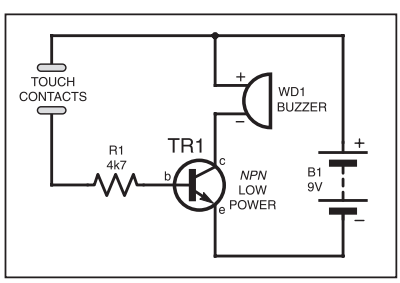


Fig.2.2. Illustrating how an npn *transistor can enable a small current to control a larger one.*

Any high-gain (high amplification factor) *npn* transistor will work in this circuit, such as type BC108 (or BC108B/C), or the popular BC549 or 2N3904. We look at transistor choices later.

Notice that a resistor, R1, has been included. This prevents damage to the transistor if you happen to bridge the touch contacts with metal (e.g. a ring on your finger).

If you want maximum sensitivity in this single-transistor circuit, use a 12V solid state buzzer of the type that are generally white, have leads and will typically work on supplies down to 3V or less. Buzzers designed for printed circuit board (p.c.b.) mounting tend to be less sensitive.

The circuit in Fig.2.2 can be used as a touch sensor, moisture sensor, breath sensor, or many other applications.

NPN AND PNP

The type of transistor shown in Fig.2.2 is an *npn* type (negative-positive-negative). It turns on when the voltage at its base (*b*) is sufficiently positive with respect to its emitter (*e*), about 0·7V for silicon *npn* types.

It is possible to obtain the opposite type, namely *pnp* (positive-negative-positive). This type turns on when the voltage at its base is *negative* with respect to its emitter. This is illustrated in Fig.2.3, and can be used in the same way as the circuit in Fig.2.2.

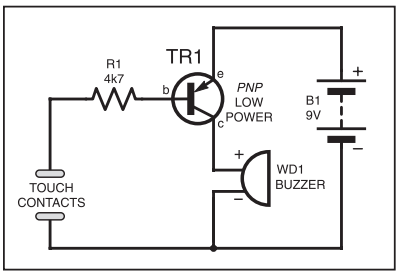


Fig.2.3. Using a pnp *transistor to perform the same function as shown in the* npn *circuit of Fig.2.2.*

If no current flows from the base, the transistor will be turned off. But if finger contact allows current to flow, the voltage at the base will fall. If it falls to 0·7V lower than the emitter (always denoted by the arrow) voltage, then the transistor will be switched on.

PUSH-PULL OUTPUTS

There is no real point in using a *pnp* transistor in a circuit like this, but there are occasions when *pnp* transistors can be useful when used in conjunction with *npn* types. For example, a "push-pull" arrangement is shown in Fig.2.4a, where a combination of *npn/pnp* transistors is employed to drive a loudspeaker in both directions. This arrangement requires a dual-rail power supply, which can be made using two batteries in series. Dual-rail supplies will be covered in Part 3 next month.

The circuit in Fig.2.4a might be the output stage of a power amplifier. We will see later how transistors can be employed to amplify voltage, but the present circuit is designed to increase the current available as needed by the loudspeaker.

Imagine a situation where an a.c. signal (such as an audio signal) is applied to the input. When the voltage at the input rises, current flows into resistor R1 and turns on *npn* transistor TR1. Hence current from the positive rail is pushed into the speaker making its cone move outwards.

When the voltage at the input falls, current flows away from the base of TR2 via R2. Hence the *pnp* transistor is turned on, and current is "sucked" from the speaker, making its cone pull inwards. If the a.c. voltages are quite high then the circuit will sound reasonable good.

A simple test circuit is shown in Photo 2.1. The transistors are TIP41A (*npn* type) and TIP42A (*pnp* type). A signal is obtained from the headphone output of a CD or cassette player, and an 8Ω speaker is used. Do not expect much volume or hi-fi!

Next month we will employ the same output device (i.e. loudspeaker) but using an op.amp instead of two transistors, with much better results.

The waveforms in Fig.2.4b indicate what happens when small voltages are applied at the input. Since TR1 turns on when its base is 0·7V *above* its emitter, and TR2 turns on when its base is 0·7V *below* its emitter, there is a "dead region" between –0·7V and +0·7V, where the speaker is not driven at all. Waveform *B* shows this.

The effect is known as "crossover distortion", and will degrade the sound quality. The solution is to apply negative feedback, by connecting point *B* in Fig.2.4a to the inverting input of an op.amp, as discussed next month.

Note that in a real amplifier it is important to use pairs of transistors fairly closely matched in terms of gain etc., and "complementary" transistors are available in most catalogues.

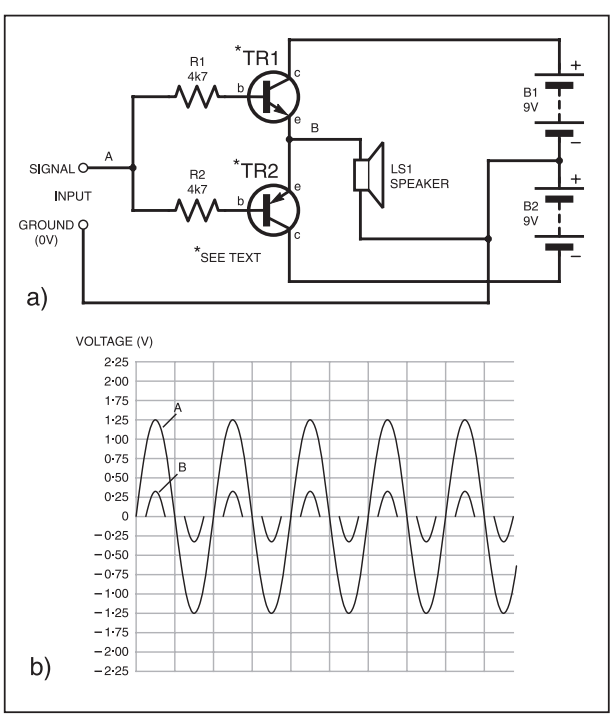


Fig.2.4. Example of a push-pull loudspeaker driving circuit (a), and (b) typical waveforms that might be associated with it (see text).

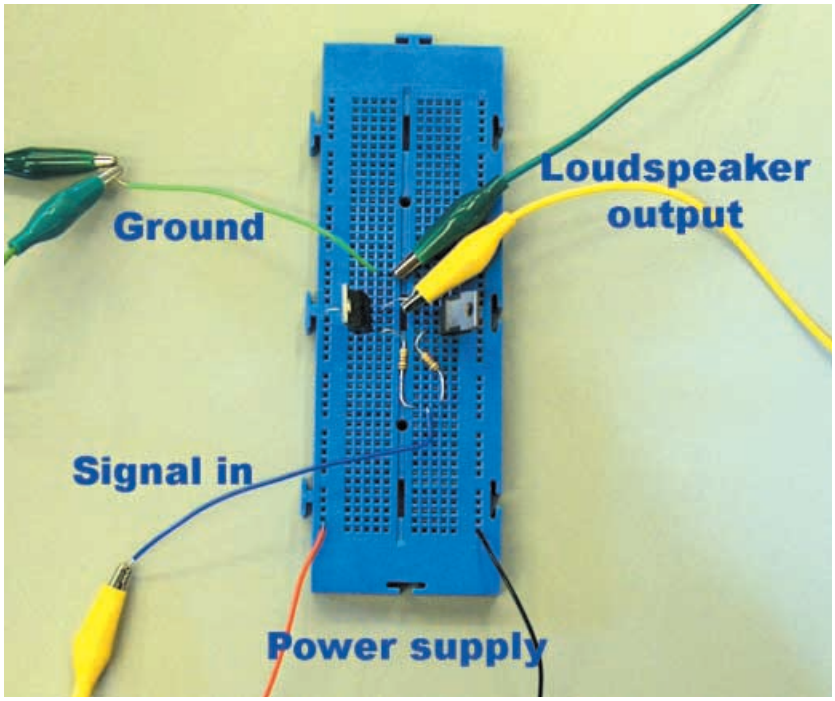


Photo 2.1. Breadboard assembly of the circuit in Fig.2.4a.

Table 2.1. A selection of transistor types.

***NPN* Low power, high gain**
BC549, BC548, BC184L, BC108, 2N3704, 2N3904

***NPN* Medium power**
BFY51, BFY52, ZTX1048A

***NPN* High power**
TIP41A. TIP122*

***PNP* Low power**
BC178, BC214L, 2N3702

***PNP* Medium power**
ZTX1147A

***PNP* High power**
TIP42A, TIP127*

Note that transistors marked with * are Darlington transistors and as such are a little different from "normal" transistors. They are described in the next section

SELECTING TRANSISTORS

The range of transistors available is huge – a few are listed in Table 2.1.

In virtually every case a substitute can be made, providing the transistor can handle the current required, and has a sufficient gain. Transistors are divided into low, medium and high power types, with current handling of typically, under 1A, 1A to 3A, and over 3A, approximately.

One of the most popular low power *npn* transistors is the BC108. This may also be sold as BC108B and BC108C. The BC108C has the highest gain, and is a better choice. A cheaper alternative with even higher gain is the BC184L. This is also sold as BC184 (without the L), but be cautious as the leads are arranged in a different order.

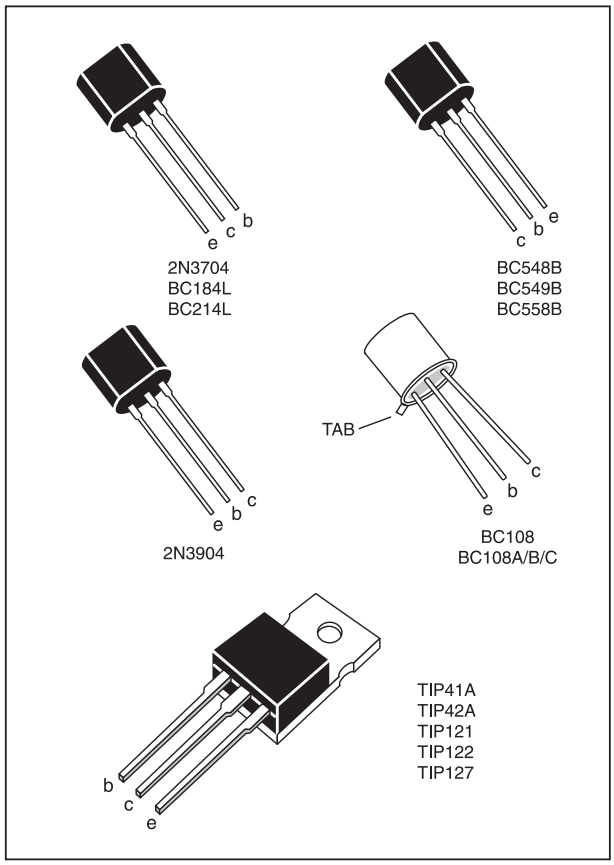


Fig.2.5. Some examples of transistor type pinouts.

Another popular choice is the BC549 or BC548. More alternatives include the 2N3704 and 2N3904. All these transistors have been tried in the circuits suggested in this series, and so select the most convenient.

Pinout details for a range of common types are shown in Fig.2.5.

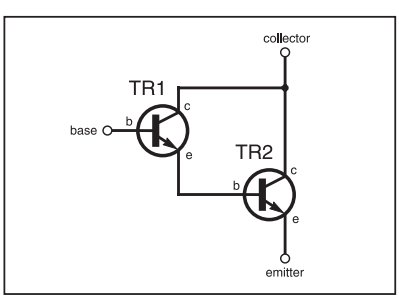
Many multimeters have a socket so that the gain of a transistor can be measured directly. You simply plug in the transistor, and the reading on the display indicates the gain.

DARLINGTON PAIR

A small low power transistor generally has a high gain. A large high power transistor has a low gain. The Darlington pair transistor combines the two, to produce a transistor with high gain and high power. Fig.2.6 shows the arrangement with two *npn* transistors.

Transistor TR1 is the low power type. When combined with TR2, a high power type, the total gain is given by:

Total gain = gain of TR1 × gain of TR2



Flg.2.6. Two npn *transistors used in a Darlington pair configuration.*

So if the gain of TR1 is 200, and the gain of TR2 is 15, then the total gain is 3000. The total power rating is equal to the rating of the larger transistor TR2. You really do get the best of both worlds!

One word of caution: the turn-on voltage for a normal transistor is a difference of 0·7V between emitter and base. Since there are two base-emitter junctions, the turn-on voltage for a Darlington pair will be twice 0·7V, i.e. 1·4V. This is rarely a problem, and can sometimes be an advantage.

USING DARLINGTONS

Many projects employ logic circuits, PIC microcontrollers, etc., and the output from the logic device may be required to switch on a motor, relay or solenoid, etc. These devices often require a significant current (an amp or more) and so the current – which may be just a few milliamps – from the logic device, needs to be amplified. A single high power transistor is unlikely to provide sufficient gain, and so a Darlington pair – with its high gain and high current – is ideal.

An example arrangement is shown in Fig.2.7. The symbol implies that TR1 is a single Darlington pair, i.e. with two transistors inside one casing, such as type TIP121. The current gain of the device is likely to be at least 1000, and so a current of just 1mA at the base should switch on 1A via the motor, solenoid etc.

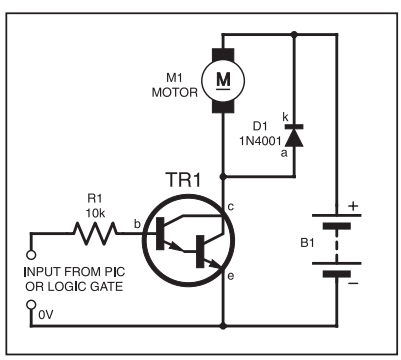


Fig.2.7. Using a Darlington transistor to interface a logic circuit to a high-current device, a motor in this instance.

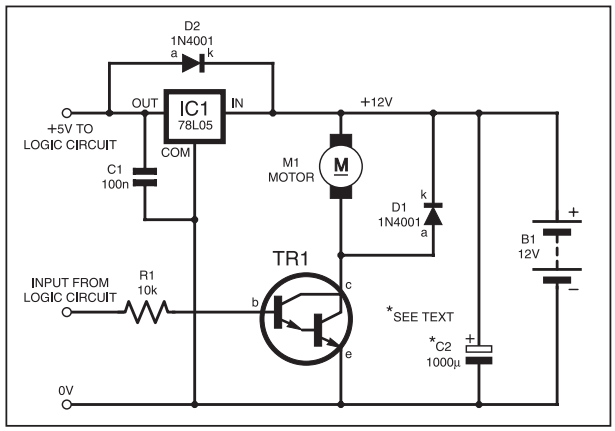


Fig.2.8. Adding a 5V regulator to the circuit of Fig.2.7.

Note that the Darlington is happy acting as an interface between a 5V logic circuit and another circuit powered by a higher voltage, such as 12V. Diode D1 removes any spikes (back e.m.f.) produced by the motor, which might damage TR1.

VOLTAGE REGULATION

You will probably want to drive the whole system from a single 12V supply, and so the circuit shown in Fig.2.8 can be employed. Here an inexpensive 5V regulator, IC1, is used to provide an accurate 5V supply for the logic circuit, leaving 12V for the output device. The regulator specified is type 78L05. This can provide 5V at a maximum current of 100mA. If you require more current for the logic circuit, use a 7805 regulator, which provides 5V at up to 1A.

Notice the addition of decoupling capacitors, C1 and C2, which help ensure a smooth d.c. supply free from ripples and spikes. The larger capacitor, C2, must be chosen according to the current used by the whole circuit – most of which flows through the output device. If in doubt, use a larger size; a value of 1000μF is suggested.

Diode D2 is optional, but required if there is any risk of the 5V supply remaining active after the 12V supply has fallen to zero. For example, if your logic circuit includes a large value capacitor, it is possible for the charge on that capacitor to remain for some time after powering down the circuit. Current will try to flow through regulator IC1 the wrong way, causing its destruction.

The inclusion of diode D2 will ensure that any such current will be shunted around the regulator. If in doubt, include D2 anyway since it will do no harm.

You may also want to protect against connecting the supply the wrong way round. There are two arrangements in common use, and these were outlined in Part 1 last month.

ALTERNATIVE TRANSISTOR ARRANGEMENTS

We have seen that the "load", e.g. motor, lamp, etc., is always placed on the collector side of the transistor, as shown in Fig.2.9a. You may have wondered why the load (LP1) is not placed on the emitter side, as shown in Fig.2.9b.

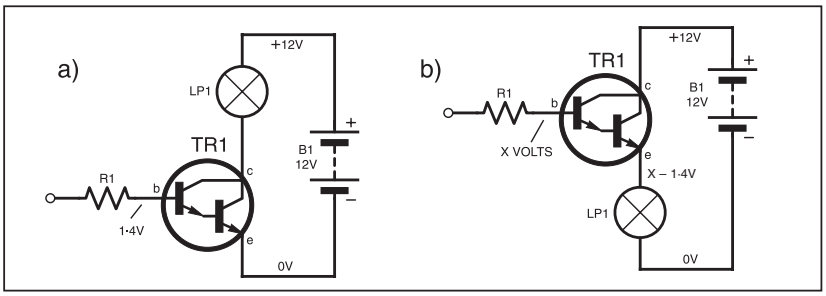


Fig.2.9. The load device (e.g. lamp) to be switched on and off should normally be connected in the transistor's collector path (a), not in the emitter path (b).

To understand that (a) is better than (b), remember that the purpose of the circuit is to allow a small current to switch on an output device at full power. So if you have a lamp rated at 12V 2A, you will achieve maximum brightness on a 12V supply if 2A is actually flowing through the lamp – you want your transistor to act like a switch, i.e. have virtually no internal resistance, and no voltage loss.

The circuit in Fig.2.9a virtually achieves this, since an input of, say, 5V will cause enough current to flow via resistor R1 to fully switch on TR1. Remember that its emitter is connected to 0V, and so only 1·4V is required at its base to "fully saturate" (fully switch on) the transistor. If a non-Darlington transistor is used, then the figure of 1·4V becomes 0·7V. Although the internal resistance of a transistor is not zero, it is low enough to switch on the lamp to almost full brightness.

Now consider Fig.2.9b. In order to saturate, the voltage between emitter and base must be 1·4V. But when the lamp is connected as shown, the voltage at the emitter will be higher than 0V. (It has to be higher than 0V, or no current would flow through the lamp, and it would not light at all.)

Now we have a problem. The highest voltage that can be applied to the base from our logic circuit is 5V. In order for the transistor to remain saturated, there has to be a voltage of 1·4V between its base and emitter. Hence the emitter voltage can be no higher than 5V – 1·4V i.e. 3·6V. So our 12V lamp has only 3·6V across it.

Consequently, the circuit of Fig.2.9b provides a rather dim outcome! Even if we could raise the input at the base of the transistor to 12V, we would still require 1·4V between base and emitter, and so the emitter voltage could not be above 10·6V.

Hence our conclusion is that Fig.2.9a provides the better solution – if you wish to use the transistor as a switch. This type of arrangement is known as a *common emitter* circuit, since the emitter is common to the input and output sides. However, the circuit in Fig.2.9b is very useful if you require a simple voltage controller. This arrangement is known as an *emitter follower*.

SIMPLE VOLTAGE CONTROLLER

When controlling the speed of a motor, or brightness of a lamp, some people consider using a variable resistor. So we will check out this approach, then show a much better solution. Consider the following problem:

You wish to vary the speed of a 12V 1A motor, or the brightness of a 12V lamp. The obvious answer seems to be to employ a variable resistor, as shown in Fig.2.10. You use Ohm's Law to calculate the resistance needed, and connect up. Unfortunately, the variable resistor becomes very hot. All the energy not required by the motor is being "lost" (i.e. converted into heat) by the variable resistor.

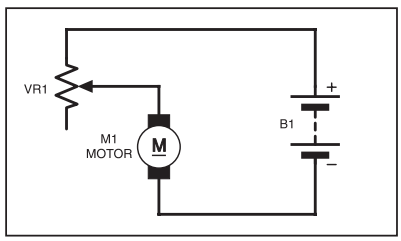


Fig.2.10. Using a variable resistor to control a motor is unsatisfactory (see text).

You may find that your variable resistor has become so hot that it burns out. So you buy a type with a higher power rating. It still becomes hot, but it is sufficiently large (and expensive) enough to cope. All is well, and you now try a smaller 12V 0·1A motor (or small lamp). You now find that the speed (or brightness) cannot be reduced. You re-calculate using Ohm's Law, and buy another variable resistor . . .

RHEOSTAT

The type of variable resistor used in this way is often referred to as a *rheostat*. Those readers of a sufficient age may have used rheostats as stage light dimmers. These were large, and produced enough heat to fry an egg. A smaller "lab" rheostat is shown in Photo 2.2.

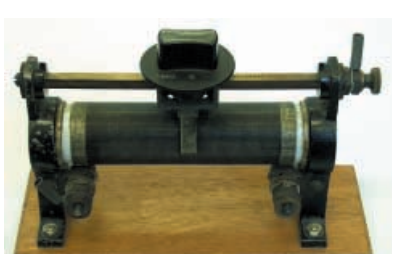


Photo 2.2. A small "lab" rheostat.

As explained, a rheostat works if its resistance is calculated for the particular device being controlled. Many years ago rheostats were used to control the speed of model trains and – at a very tender age – the author often measured the voltage across the rails of his train set. All seemed fine when the train was on the track, but as soon as the engine was removed, he was puzzled by the way in which the voltage zoomed up to 12V regardless of the setting of the rheostat.

Many years had to pass before it was realised that the current flowing affects the voltage lost across the rheostat. If the current is reduced to zero (by lifting the engine off the tracks), the voltage lost is reduced to zero, hence 12V remains across the rails.

The net result of all this is that a rheostat makes a very poor voltage controller, and modern electronics provides better solutions.

TRANSISTORISED VOLTAGE CONTROLLER

If we wish to use a variable resistor to provide an accurate output voltage, then the current flowing though the variable resistor must be constant. This is achieved by connecting the fixed part of the resistance across the power rails, as a potentiometer, as shown in Fig.2.11.

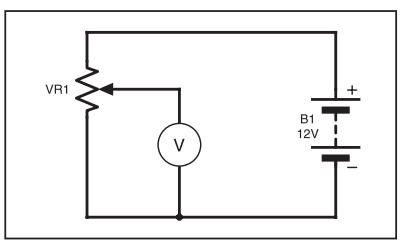


Fig.2.11. Monitoring the voltage on the wiper of a potentiometer.

The variable part – the *wiper* (shown as an arrow) – then "taps off" the required voltage. For example, if the wiper is at the top, the output voltage will be equal to the supply, 12V in this case. If the wiper is at the bottom, the output will be zero. If the wiper is half way, the output will be 6V, i.e. half the supply voltage.

If a voltmeter is connected to the wiper as shown, using a potentiometer of, say, 1kΩ or 10kΩ, the voltage at the wiper when at different settings can be monitored.

The system works very well, providing that no appreciable current flows out through the wiper. So if you tried to connect your motor or lamp to the wiper, the output voltage will be lower than predicted.

In practice, if using a small value potentiometer, the current available from the wiper is a few milliamps or less. But electronics comes to the rescue, and a Darlington transistor can be used to amplify this current by 1000 times or more.

A Darlington is very accomplished at maintaining a voltage difference of 1.4V between its base and emitter, providing it is saturated. Remember that the figure of 1·4V applies only to a Darlington. A "normal" bipolar transistor will work in the same way, except that the figure of 1·4V becomes 0·7V.

The circuit diagram in Fig.2.12 shows how the Darlington transistor is connected to the potentiometer. The theory is best understood by taking an example.

Suppose the wiper of the potentiometer (pot) is set to 6V. The Darlington drops out 1·4V between its base and emitter, fixing the emitter at 6V – 1.4V = 4.6V.

If you require a current of say 1A from the circuit to power the motor, then only 1mA will be needed at the base of the Darlington, assuming a gain of 1000. In practice the gain is likely to be higher, and so 1mA or less is required from the wiper of the pot.

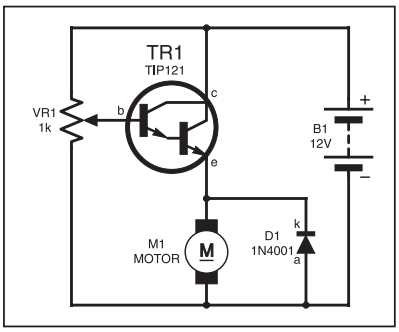


Fig.2.12. Motor speed can be controlled by a potentiometer used in conjunction with a Darlington transistor.

The current will be delivered to the motor from the power rail via the Darlington. The voltage will be set by the voltage at the base of the Darlington, less 1·4V. If your motor uses less than 1A, the change of current at the base of the Darlington is too small to create a significant error.

Notice that the emitter voltage "follows" the base voltage, hence the term *emitter follower*, as referred to earlier. So you have a voltage controller which, within reason, provides an output voltage which is unaffected by the current required.

WHAT POT VALUE?

There just remains one question mark – the best value to use for the potentiometer, i.e. what resistance is needed between the two fixed parts of the pot?

The "rule of ten" is useful here, namely, decide upon the maximum current needed from the wiper, multiply this by 10, and that is the current which must flow continuously through the fixed part of the pot.

Staying with our original problem, it was decided that 1mA would be the maximum current needed by the Darlington pair. Hence ten times this, i.e. 10mA, must flow through the pot from end to end.

On a 12V supply and using Ohm's law:

Resistance = Voltage / Current

Hence:

Resistance = 12V / 10mA = 12V / 0·01A = 1200 ohms = 1·2k ohms.

You cannot buy a pot with a resistance of 1·2k ohms, so the nearest acceptable value is 1k ohms.

Notice that a constant current of 12mA will flow through the 1kΩ pot; we must ensure that this does not cause excess heating. The power dissipated will be:

Power = Voltage × Current

Hence:

Power = 12V × 0·01A = 0·12W

Fortunately, a small preset pot is rated at around 0·12W, and a panel mounting linear rotary pot at about 0·2W, so all is well.

Finally, note that the continuously flowing current is wasted energy; hence you would be unwise to use the circuit with a battery (other than a car battery!), and a mains-driven power supply which provides about 12V d.c. is ideal.

Of course, the maximum voltage the circuit can supply is 12V – 1·4V = 10·6V. If this is insufficient, the d.c. supply must be increased to say 15V, which will allow the circuit to deliver 13·6V.

AMPLIFIER CIRCUITS

Transistors are current amplifiers, as we said earlier. We sometimes need a voltage amplifier – for example, to boost the small signal from a microphone to an acceptable level. Although an op.amp (described next month) provides the ideal solution, a simple one or two-transistor amplifier can be very useful, particularly if the quality of the signal is not important, e.g. to allow a microphone to activate another circuit such as a sound-switch or an audio driven light-chaser unit. A single transistor voltage amplifier is shown in Fig.2.13.

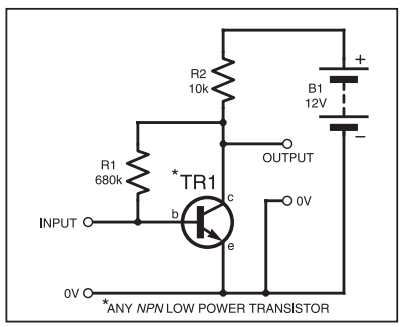


Fig.2.13. Using a transistor as a voltage amplifier.

The design of a quality transistor amplifier is extremely complex, so we will look at the principle of using this simple arrangement.

A transistor will *start* to turn on when the voltage at its base, in relation to that at its emitter, is at around 0·5V (never an absolutely predictable figure). If the base voltage is increased, the transistor will turn-on more (in other words the resistance from collector to base will fall), until it is fully turned on, or saturated, when its base voltage is around 0·8V (again never an absolutely predictable figure).

So if we move the voltage at the base from 0·5V and 0·8V, the effective resistance from collector to emitter of the transistor will fall from near-infinity to near-zero. The test circuit shown in Fig.2.14 helps to illustrate the effect.

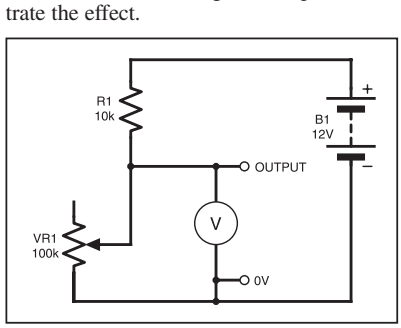


Fig.2.14. Monitoring the tapped voltage of a variable potential divider.

Set the wiper of VR1 to zero resistance (closest to the 0V power line) and the output voltage will fall to zero. Set the wiper to full resistance and the output voltage will rise to within a volt or so of the positive power supply. You can now adjust VR1 and make the output voltage rise and fall. A standard panel-mounting rotary potentiometer can be used to test the effect, or a preset may be more convenient, as shown in Photo 2.3.

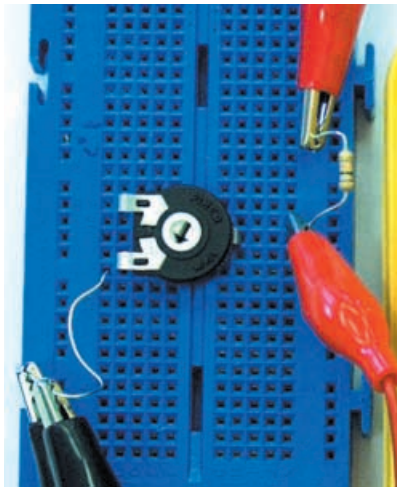


Photo 2.3. Breadboard assembly of the circuit in Fig.2.14.

Returning to Fig.2.13, the transistor acts like a variable resistor, but instead of using a pot and control knob, you change its resistance by varying the voltage at its base, between the values of 0·5V and 0·8V.

The transistor, of course, is not a variable resistor, and many people will frown at the comparison, but the analogy is helpful to understanding the principle. One important difference is that there is not a constant change of effective resistance as the base voltage is changed; in other words the effect is *not* linear. But in many applications, such as described here, this may not be important.

So we need a resistor, R2 in Fig.2.13 (known as a load resistor in this application) in series with the collector of the transistor. The output voltage is taken from the collector. If the transistor is fully off (open circuit) then this voltage will be 12V. If the transistor is fully switched on (saturated) this voltage will be 0V (or nearly 0V).

We now need to set the base voltage so that the transistor is *just about* to switch on. The arrangement is quite cunning, we use resistor R1 connected between the output voltage (collector) and the base. This means that if the output voltage rises towards 12V, the voltage at the base will also rise, causing the transistor to switch on more, which in turn pulls down the output voltage.

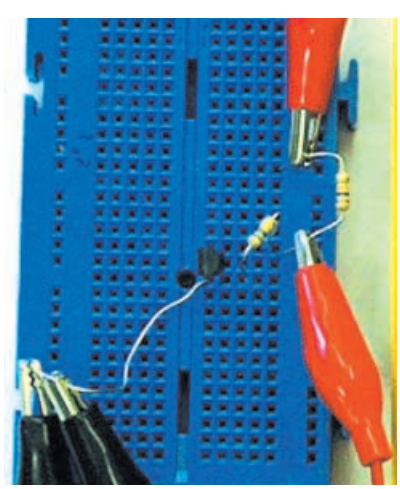


Photo 2.4. Breadboard assembly of the circuit in Fig.2.13.

If the output voltage falls towards 0V, the voltage at the base will fall, so turning off the transistor. Hence the base voltage is self-regulating, and the output voltage sits at a few volts above zero.

A test circuit is shown in Photo 2.4. Any high-gain *npn* transistor may be used, such as a BC549. A supply of around 9V to 15V is ideal for these transistor circuits.

We need only to "wobble" the base voltage up and down a little to cause a much larger wobble at the output. So we connect up a microphone as shown in Fig.2.15.

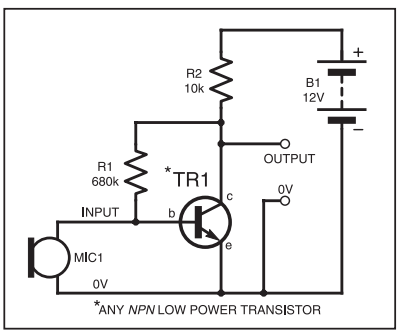


Fig.2.15. Incorrect method of adding a microphone to the circuit of Fig.2.13.

Unfortunately the circuit now fails. The problem is that the microphone allows current to flow to the 0V power line, and so pulls down the d.c. base voltage, well below 0·5V. You will have to shout very loudly to make anything happen!

We need another cunning solution. Note that the d.c. conditions of our transistor circuit were self-stabilizing before the microphone was connected. When we speak into a microphone, an a.c. signal is generated. We need a device which will allow the a.c. signal to pass, but block the d.c. A capacitor fulfils this need, and is shown as C1 in Fig.2.16.

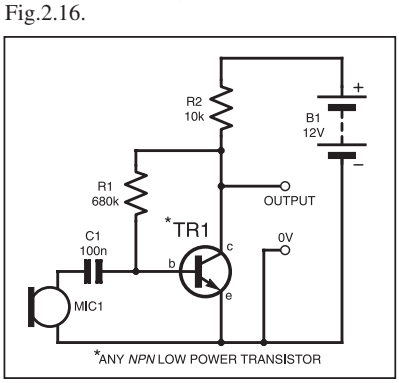


Fig.2.16. Correct method of interfacing a microphone to a transistor amplifier.

Now we find that the output voltage will wobble up and down in step with the microphone. An oscilloscope may show that the output is not a very good copy of the input, and if you want hi-fi results you will need much more carefully designed circuits. But a single transistor is quite effective in this demonstration.

USING AN ELECTRET MICROPHONE

The circuit of Fig.2.17 shows an extra resistor, R3, as needed if an electret microphone insert is used. These microphones are excellent (and cheap),

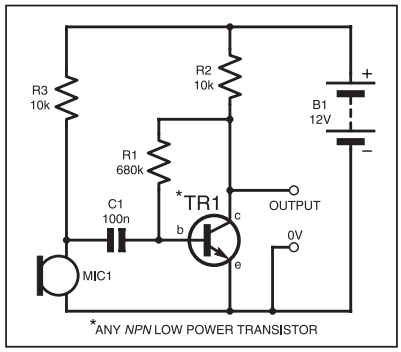


Fig.2.17. Resistor R3 is required if the microphone is an electret type.

but require a d.c. supply to operate. The d.c. is supplied via resistor R3. Again, the capacitor, C1, prevents the d.c. flowing via R3 to upset the delicate d.c. conditions around the transistor.

CASCADING AMPLIFIERS

You can increase the voltage gain still further by connecting two similar circuits as shown in Fig.2.18. This will provide a significant increase in the gain, enabling an electronic switch, for example, to be controlled by quite low sound levels.

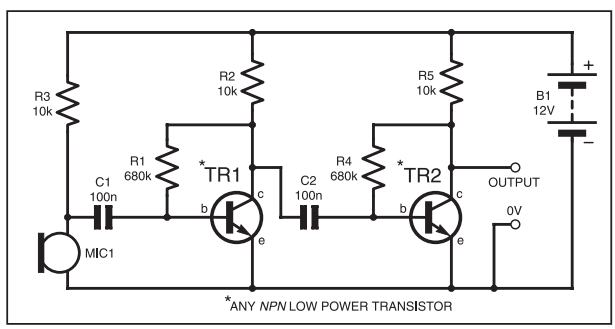


Fig.2.18. Connecting two transistor amplifier circuits in series to further increase voltage gain.

MOSFETS

MOSFET transistors offer a very good alternative to a standard bipolar power transistors. As the price of the MOSFET range falls, and the number available increases, MOSFETs are well worth considering.

The word MOSFET stands for Metal Oxide Silicon Field Effect Transistor. A MOSFET has three connections, gate, drain and source, as shown in Fig.2.19. The layout of its leads conforms to the TO220 style of package, and this applies to all the MOSFETs mentioned in this series. Other MOSFETs may have their leads arranged differently – always check with the supplier.

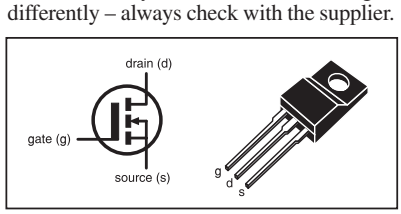


Fig.2.19. N*-channel MOSFET symbol and typical case stye.*

MOSFETS are divided into two groups, *n*-channel and *p*-channel. We will consider *n*-channel types here since these are by far the most popular and therefore readily available.

You can think of a MOSFET in terms of a bipolar transistor, where the gate (g) acts like the base (b), the drain (d) acts like the collector (c), and the source (s) acts like the emitter (e). However, unlike a bipolar transistor, the gate requires almost no current in order to make the MOSFET switch on.

Assuming a 5V supply, a voltage at the gate of about 2V or more creates an electrostatic field, which causes the MOSFET to turn on. Hence current will flow through the MOSFET from drain to source. In other words, it is the 2V *voltage* at the gate that causes the MOSFET to switch on.

Remember that virtually no current is required at the gate, yet the current flowing from drain to source can be several amps. Hence the current gain of the device is very large – much larger than for a Darlington transistor. This makes the MOSFET very useful when used with low output current sources, such as logic gates.

A WORD OF CAUTION

A MOSFET may sound too good to be true; however, there are a few negative points to consider. Firstly the price may be a little higher than a Darlington transistor, and a MOSFET can be damaged by static electricity, so you must touch an earthed item of equipment before handling them to discharge any static electricity from your body.

The names *drain* and *source* can be confusing, as can the direction of the arrow in the symbol. It is also less easy to use the device as an interface between two different voltages. For example, you may want a 5V logic circuit to drive a 12V motor via a transistor. A Darlington would be fine, but in the author's experience a MOSFET (such as the common BUZ11A) may become overheated when a 5V input is controlling a 12V supply load. But help is at hand – an excellent range of "auto-protected MOSFETs" is now available, as we will see later.

The circuit in Fig.2.20 shows how the MOSFET can be employed to switch on a lamp. Note that resistor R1 is needed to minimise the risk of the gate being affected by static electricity. If around 2V to 5V is applied to the input, the MOSFET will switch on, and make the lamp light. A very small current at the input (a microamp or less) is able to control a current of several amps at the output.

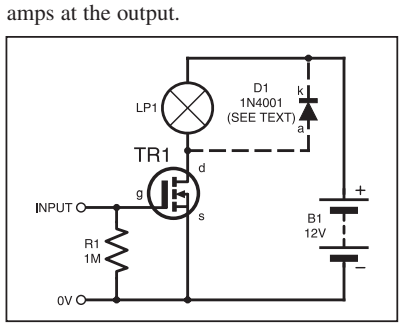


Fig.2.20. Using an N*-channel MOSFET to control an output device.*

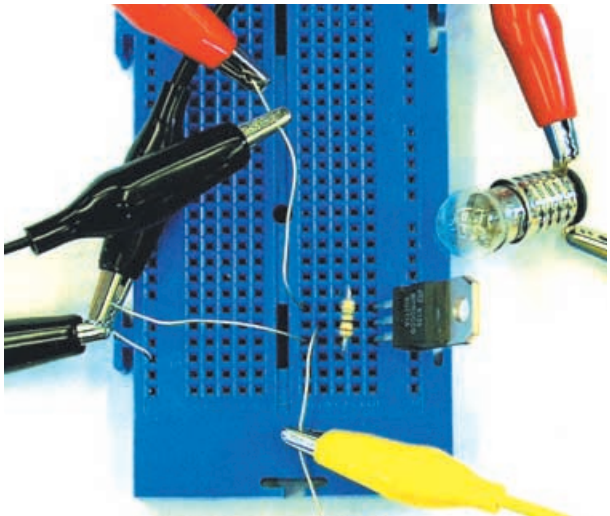


Photo 2.5. Breadboard assembly of the circuit in Fig.2.20.

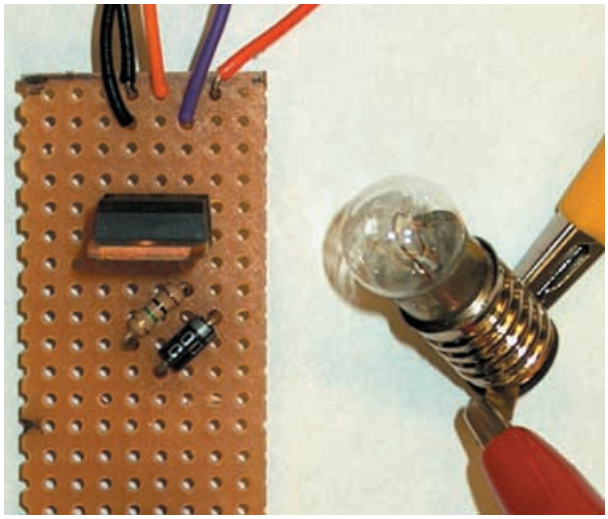


Photo 2.6. Stripboard assembly of the circuit in Fig.2.20, but using an auto-protected MOSFET, type VNP10N06.

Diode D1 would be needed to protect against back-e.m.f. if a relay, solenoid or motor is used instead of a lamp, otherwise it can be omitted. A simple test circuit based on Fig.2.20 is shown in Photo 2.5. MOSFET type BUZ11A has been employed.

CHOOSING A MOSFET

There is a vast choice of MOSFETs available, but not all types work equally well in low voltage circuits. Whilst a traditional choice might be a type BUZ11A, as used in Photo 2.5, the new generation of "auto-protected power MOSFETs" are probably more useful, particularly in low voltage circuits. These work very well with logic level inputs and are virtually indestructible.

Prices have tumbled recently and MOSFET type VNP10N06 or similar is suggested. This device makes an ideal output buffer, but note that in its data sheet the gate is renamed "input", but otherwise the pin layout shown in Fig.2.19 still applies.

A simple interface circuit based on an auto-protected power MOSFET is shown in Photo 2.6. The circuit is based on the arrangement shown in Fig.2.20, but allows a 5V logic circuit to control a 12V power circuit.

NEXT MONTH

In Part 3 next month we examine op.amps.

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BIO-FEEDBACK TENSION MONITOR – RELAXATIVE!

IF you, like so many other people in this day and age, arrive home from work stressed out and with the problems of the day still lingering, this simple little instrument will go a long way to relieving nervous tension.

Of the various types of feedback devices, probably the best approach for the amateur experimenter is the Galvanograph, better known as the Galvanic Skin Response Monitor. The instrument described here relies for its operation on changes in skin resistance in sympathy with changes in emotional state. An increase in tension level reduces skin resistance and, conversely, a decrease in tension is accompanied by an increase in skin resistance.

The correlation between emotional stress and skin resistance is still not fully understood. What is known, though, is that minute changes in the permeability of the skin produce corresponding voltage variations across two electrode pads attached to two fingers on the same hand.

These signal fluctuations are amplified and fed to an oscillator to produce an audible tone. A decrease in pitch therefore signifies a decrease in tension, and vice-versa. A visual indicator in the form of a panel meter also aids the user in monitoring tension levels. The monitor is quite sensitive to fluctuations. During use, a sudden moment of stress, even a deep sigh, will increase the pitch and cause a shift of the meter needle.

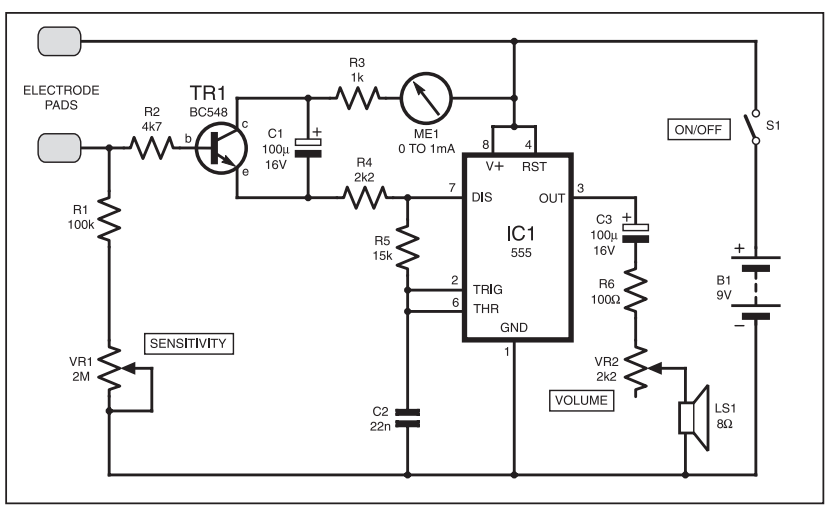

Fig.1. Bio-Feedback Tension Monitor circuit.

Circuit Details

In the circuit diagram of Fig.1, IC1 is configured as an astable multivibrator to drive an 8-ohm miniature speaker LS1 via capacitor C3, resistor R6 and volume control potentiometer VR2. The latter allows users to set a desired level and avoid it becoming a distraction.

Whereas the trigger input of IC1 is normally connected to the positive rail via a resistor in a conventional 555 oscillator, here it is connected via resistor R4 to the emitter of transistor TR1. The base of TR1 is connected between one electrode pad and the voltage divider formed by potentiometer VR1 and resistor R1. It will be seen that with the pads fitted to the fingers, the tone level will be dependent on the setting of VR1 and skin resistance.

Resistor R2 in the transistor base is necessary should the pads be accidentally touched together. A 1mA meter is fitted in the collector line, along with R3, as a visual indicator. Although not essential or intended to measure current levels, it does help to emphasize fluctuations in emotional level.

The design of the pads is not critical. For the prototype, stripboard was used. The tracks were wired together at one end and connected to a 30cm length of twin lighting flex. The pads were then glued to Velcro straps.

When the unit is first switched on, a high-pitched tone should be heard, rapidly diminishing and ceasing. Turn the Sensitivity control VR1 to the minimum setting. Attach the electrodes to the fleshy pads of the first two fingers on the less-dominant hand with the Velcro straps, firmly but not tight. Rest the hand comfortably and keep it reasonably still, allowing half a minute for the pads to "bond".

Normally, at the minimum setting, the oscillator will hardly tick over, unless the user is in a high state of anxiety. Keep in mind that any form of stimulant, and that includes tea, coffee, alcohol and cigarettes, will reduce one's capacity to relax.

Rotate the control until a medium pitched tone is obtained and apply *your* relaxation technique. The monitor does not teach any method of meditation or relaxation; it only monitors the *effectiveness* of the technique applied. The tone should slowly diminish, with fluctuations as unconscious thoughts flit across the mind. When the sound ceases altogether, repeat the above procedure by increasing VR1. Twenty minutes is considered by therapists to be an adequate relaxation session.

Tony Lee,
Old Reynella, Australia

INGENUITY UNLIMITED

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IU is *your* forum where you can offer other readers the benefit of your Ingenuity. Share those ideas, earn some cash and possibly a prize!

L.E.D. BARGRAPH – DISCRETE DISPLAY

THE circuit shown in Fig.2 was devised as a cheap alternative to a moving coil meter when I wanted to monitor the output current of a power supply. Its operation is as follows:

As the output current increases from zero, it flows through l.e.d. D1 and resistors R1 and R2 until the voltage across R2 is about 0·6V. At this point transistor TR1 starts to conduct, shunting current round D1 and through D2/R3. When this current produces 0·6V across R3, TR2 begins to conduct, shunting the extra current via D3/R4. This continues until finally D5 is illuminated, showing "full scale deflection".

The purpose of resistor R1 is to provide sufficient voltage across the circuit to cater for:

- 0·6V across the 33Ω resistor
- The voltage across the l.e.d.
- 0·3V across the transistor in saturation (this is also the voltage across R1)

The minimum voltage required across the circuit is about 3V, and this must be taken into account when considering the power supply voltage, which must be connected before any voltage regulator.

Using the resistor values shown, the maximum current for each l.e.d. is about 17mA, so "full scale deflection" is about 85mA, though the display is not perfectly linear – the second l.e.d. starts to illuminate above about 15mA, and the other l.e.d.s start in approximately 20mA increments.

I tried building a display using 10 l.e.d.s but the circuit was unstable; as soon as the 6th l.e.d. started to illuminate, the circuit oscillated in the Megahertz region, and the l.e.d.s lit before they were supposed to (this situation was worse when I left the decoupling capacitors out), so five l.e.d.s. seems to be the limit.

P. A. Tomlinson, Hull

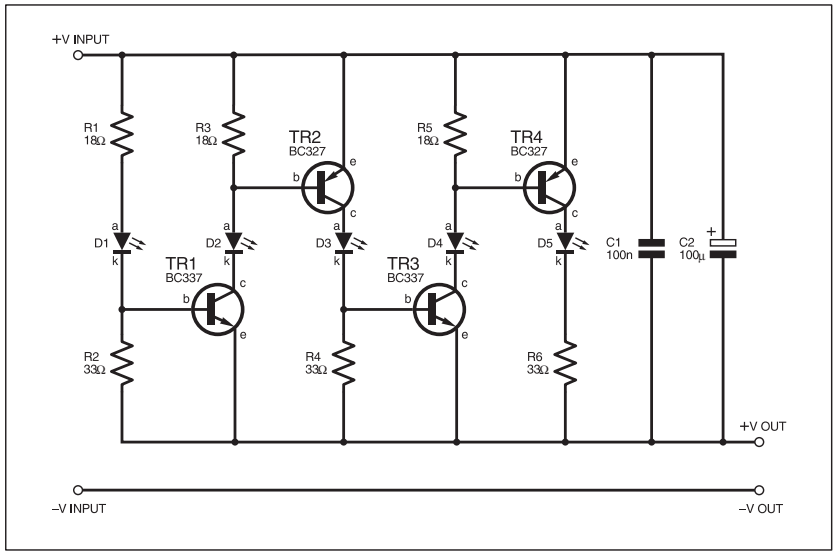

Fig.2. Circuit diagram for an L.E.D. Bargraph simulator.

CRICKET OVERS COUNTER – HOWZAT!

THE circuit diagram in Fig.3 was designed after a request from a local cricket coach for a device that could keep count of the number of balls and overs bowled. The circuit operation is simple – after each ball has been bowled, the scorer presses switch S2, which sends a negative-going pulse to the trigger input, pin 2, of CMOS timer IC1, triggering it for a period determined by the values of components R3 and C2.

The resulting positive output from IC1 pin 3 triggers the inputs of decade counters IC2 and IC3. It also enables all the 7-segment common cathode l.e.d. displays until the timing period is over, thus conserving battery power (i.e. the displays will show the ball and over count for a few seconds after S2 has been pressed, before turning off.

IC2 counts the balls and then resets itself, and IC3, when output Q7 goes high when the sixth ball is reached. The solid-state buzzer WD1 is simultaneously also turned on, via transistor TR1, signalling the end of the over. It remains sounding for the same duration as the display is on.

The balls display is returned to zero and the reset pulse clocks counter IC4, ensuring that the l.e.d. units display advances by one digit. When the tenth over is reached, counter IC5 receives a carry-out pulse from IC4 and therefore the tens display advances by one digit and so forth.

A maximum of 99·5 overs can be counted. An extra display stage could be added for a greater number of overs. No reset switch is included – resetting can be achieved by switching the unit off and then on again, after a brief delay to allow capacitor C4 to discharge completely.

A good quality switch must be used for S2.

C. R. and G. J. Taylor,
Kwa-Zulu Natal, South Africa

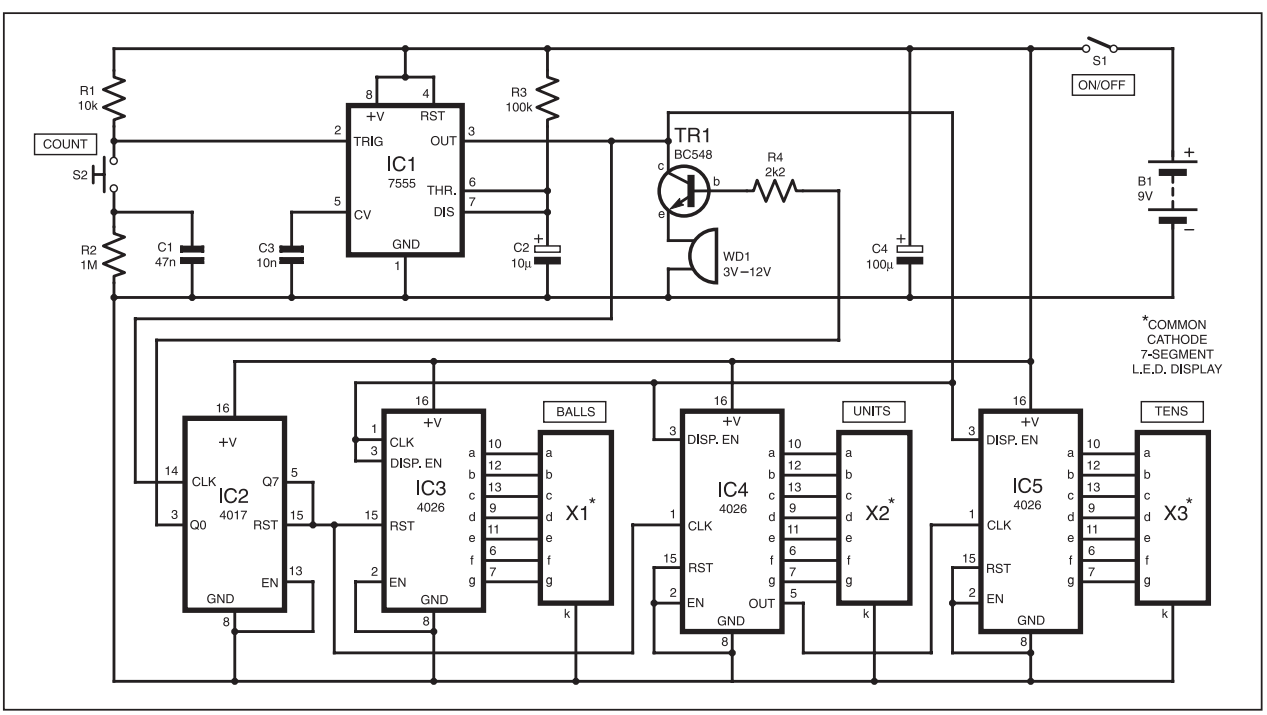

Fig.3. Circuit diagram for a Cricket Overs Counter.

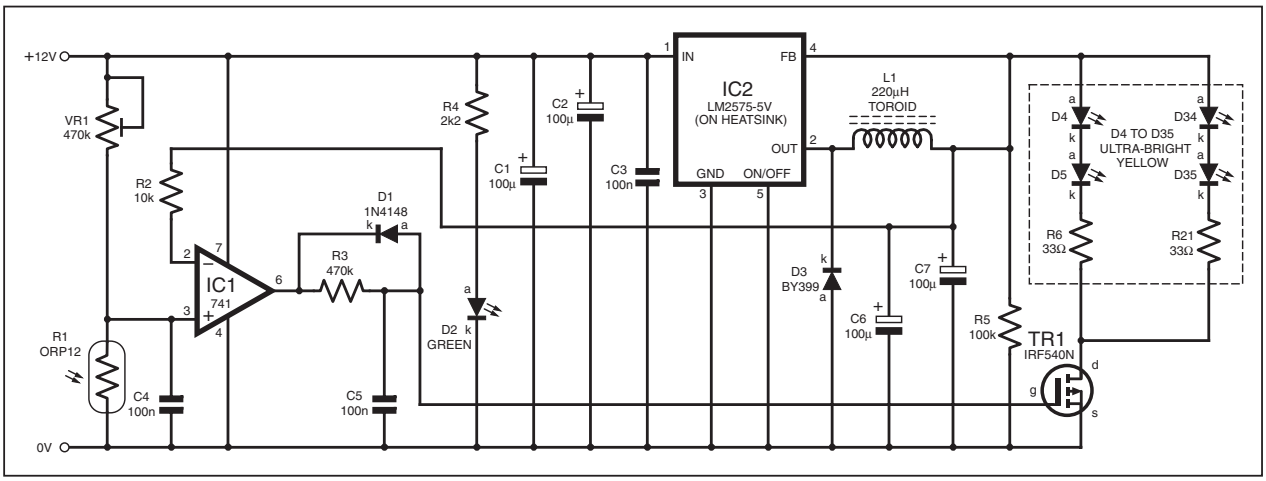

Fig.4. Circuit diagram for the Garden Light Controller.

A FRIEND brought me his garden light which had a broken 60W bulb. He asked me to change it into a low power bulb. Instead of this, I built the low power circuit shown in Fig.4 which uses 32 ultrabright yellow l.e.d.s to replace the original bulb.

Regulation was needed to maintain a constant light and a simple switch-mode device type LM2575 (5V version) was chosen to save power. This device, IC2, uses step-down mode, which has about 10% higher efficiency than step-up mode. Four components, D3, C6, C7 and inductor L1 are needed for IC2 to operate in this mode. The output voltage is regulated at 5V. Resistor R5 allows C6 and C7 to discharge when the 12V power supply is removed.

The circuit around IC2 provides power to illuminate the l.e.d.s (D4 to D35). These are connected in pairs, each pair having a ballast resistor (R6 to R21). The l.e.d.s were arranged in groups of eight assembled on four sub-circuit boards, providing four facets for the garden light.

The l.e.d.s are turned on by a light-sensitive controller, formed around op.amp IC1, configured as a comparator. The ambient light level is detected by a light dependent resistor, R1. Its sensitivity is controlled by preset VR1 and the resulting voltage across it is fed into the non-inverting input (pin 3) of IC1. The inverting input (pin 2) is fed, via resistor R2, by the voltage generated by IC2.

When the outdoor light level has fallen below the preset point, the output of IC1 (pin 6) goes high and turns on *n*-channel power MOSFET TR1 via resistor R3, and so turning on the l.e.d.s. Capacitors C4 and C5 minimise the effect of intermittent triggering when the light level is hovering just at the turn-on point. Diode D1 discharges C5 when the light level changes from low to high. Resistor R3 causes a small delay in the charging of C5.

The circuit is powered at 12V d.c., provided by a small mains adaptor that is safe for outdoor use. Indication that power is connected is provided by l.e.d. D2, buffered by R4. Capacitors C1 to C3 help to smooth the power line. It was found that the circuit efficiency is around 80%. A small heatsink should be used with TR1.

In use, adjust VR1 to set the light level at which you want the l.e.d.s to be turned on. My friend is well satisfied with his modified garden light.

Myo Min, Yangon, Myanmar

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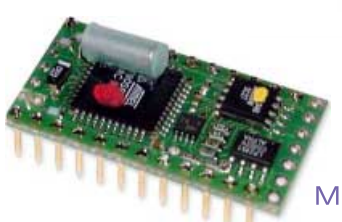

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News . . .

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

PIEZO ZOOMING

Barry Fox has good news for spies and snoopers!

PICTURE phones, PDAs and key-ring cameras should soon be able to zoom and focus with far greater precision. Recently published patents reveal that a small technology research company in Cambridge, 1Limited, has found a way to make a thin sheet of piezoelectric material work as a motor that moves whatever it touches in precision steps. The sheet can be used flat to make a linear motor or rolled into a cylinder to make a mount for a miniature camera lens.

The lenses currently used in small digital cameras and picture phones suffer from being "fixed-focus". They are set to a compromise middle distance focus which blurs close and very distant objects. Small cameras zoom, for telephoto effect, by digitally enlarging a selected area of the picture. This inevitably also enlarges the pixels that make up the picture, which spoils the image with an overlaid mosaic effect.

Physically moving the lens for optical focussing and zooming lets a camera take clear telephoto shots, and focus tightly on close documents, but the motors needed to twist and turn the optical components in the lens take up too much space for a miniature camera.

Piezo Micro-Motors

The Cambridge lab use a roller with fine blades to cut a pattern of parallel slits through a sheet of piezoelectric ceramic lead zirconate titanate, while it is in the "green" soft state. The cut sheet is then pressed against an indented mould to push the lands between the slits out from the surface. This forms many hundreds of little bridges, standing on 2mm legs at an angle of 45 degrees to the surface.

The sheet, which looks like a fine-toothed cheese grater, is then sintered to harden the ceramic, and conductive material printed or plated onto the bridge legs to make electrodes. The tops of the bridges are roughened to give them a friction grip.

When electric current is fed to the electrodes, the legs flex to move the bridges. If the sheet is pressed against a movable object, the roughened bridges work as friction micro-motors and move the object in tiny stick and slip steps of around 0·25 micrometres. Current is fed to the bridges in waves at 65kHz, so that all the little bridges push together to create millions of tiny rapid drive steps.

If the sheet is pressed hard against a moveable object, or laid underneath it, the object creeps in a straight line. If the sheet is rolled up to form a tube mount for a lens, the optical components can be twisted, turned and slid backwards and forwards under electronic control. So a miniature camera can have automatic optical zoom and focus.

1Limited has not yet announced the project but full details have been published in British patent application number GB 2 381 376.

Tony Hooley, President and Chief Scientist at 1Limited, confirms the research project. "The material could be used in printer heads," he says. "But our big push is to get it into cell-phone cameras, for the zoom mechanism".

Piezo Lock

A MAJOR innovation for locks has been announced by Servocell. Their Active Latch module is based on proven smart piezo-material technology which is widely used in circuit breakers for its speed, reliability and durability.

Active Latch offers several advantages over traditional locking approaches. It can be integrated into existing lock designs, and is small enough to fit within the door leaf or lockers and cabinets. All electronics are on-board and the device is controlled via a two-wire system making it compatible with existing access control systems.

Browse **www. servocell.com**.

GLOWSTAR LIGHTING

THE Glowstar Lantern launched by Sollatek Distribution is a solar-powered light that could give millions of people in developing countries an affordable source of light with virtually no running costs, waste or pollution.

The Glowstar can be recharged using a solar panel, a car adaptor or an a.c. mains adaptor. It is supplied with a 5W lamp, the equivalent of a 25W domestic or GLS lamp, although lamps equivalent to 40W and 60W GLS can be used instead.

A long-life, rechargeable 12V sealed battery allows Glowstar to be used in any orientation. Its tough case means that the lamp can cope with the harshest environments.

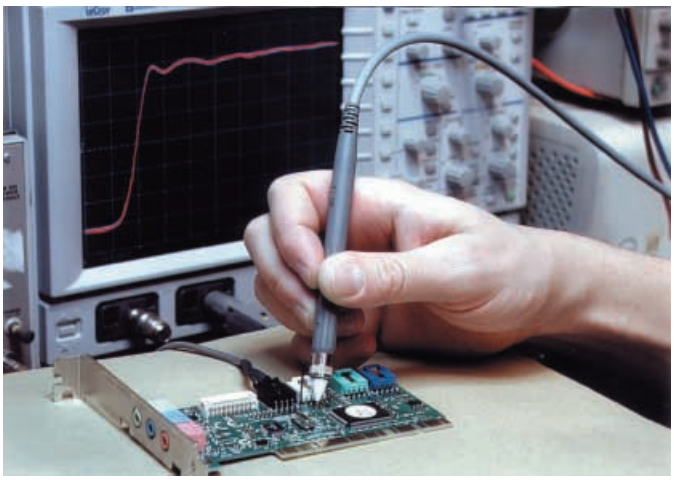
The lantern results from a collaboration between Sollatek and the Intermediate Technology Group, a charitable foundation dedicated to providing low-cost sustainable solutions to third world problems. Their patron is HRH The Prince of Wales.

Glowstar Lantern prices start at £50 and solar panels start at £16.

For more information contact Sollatek Ltd., Dept EPE, 10 Newlands Drive, Poyle, Slough, Berks SL3 0DX. Tel: 01753 688 300. Fax: 01753 685 306.

Email: sdl@ sollatek.com. Web: www.glowstar.net.

AWARDED PROBING



ACTIPROBE, a new range of "active" probe devices, has been introduced by Multi-Contact, world-leading manufacturer of interconnect products and accessories.

Suitable for use with various test instruments, including oscilloscopes, spectrum and network analysers, the Actiprobe incorporates a range of enhanced performance features that make it ideal for measurements requiring the undistorted display of steep signal pulses.

Offering an extremely low input capacitance of <1·2pF and a wide frequency range with bandwidth up to 1·3GHz, there are four different device types designed for 50Ω or high-impedance (>100kΩ) scope inputs and available in a.c. or switchable d.c./a.c. versions. Complementing the Actiprobe is a wide choice of push-on accessories.

For more information contact Multi-Contact (UK) Ltd., Dept EPE, 3 Presley Way, Crownhill, Milton Keynes, Bucks MK8 0ES. Tel: 01908 265544. Fax: 01908 262080.

Email: sales@multi-contact.co.uk. Web: www.multi-contact.co.uk.

Charon Interface

TR Control Solutions have announced the introduction of Charon 1 and its associated range of embedded network devices. Charon 1 is a tiny embedded ethernet interface and device server that enables monitoring and control of a wide variety of devices via a LAN or WAN (including the Net).

It is aimed at designers wishing to add embedded network capacities to their products. Network protocols include TCP/IP, UDP/IP, SNMP. SMPT and HTTP. The module provides a 10BaseT Ethernet interface, RS232 port and eight TTL I/O lines. A development kit is available for evaluation.

For more information browse **www.trcontrolsolutions.com**.

Sherwood Cat

SHERWOOD Electronics 2004 catalogue has been released. It contains a wide variety of full-specification components and equipment with new products and increased ranges of existing stock. It covers all sorts of components that the typical hobbyist constructor frequently requires, from batteries and boxes, through active and passive components (including some reasonably priced assortment packs), to tools and transformers.

The catalogue costs £1, but it also contains two 50p discount vouchers.

Contact Sherwood Electronics, Dept EPE, 7 Williamson Street, Mansfield, Notts NG19 6TD. Tel: 01623 632892.

High-Flying Courses

BROOKLANDS College in Surrey has collaborated with the South East England Development Agency (SEEDA) to provide a flexible, accessible and inexpensive JAR66 programme. This is aimed at those who wish become more knowledgeable about aircraft maintenance in several of its various aspects, one of which is electronics.

The programme is delivered entirely online at the location, time and speed of individual learners, but with the support of a trained and experienced team of specialist on-line tutors. For a limited period, some course modules are *completely free of charge* to EC citizens.

The modules comprise Electronic Fundamentals, Electrical Fundamentals, Digital Techniques, Physics, Mathematics, Human Factors, and Aviation Legislation.

For further information browse **www.jar66now.com**.

Brooklands College's main website is at **www.brooklands.ac.uk**.

Vintage Valve Fair

THE Vintage Valve Technology Fair will be held on Sunday 7 March 2004. The venue is at Haydock Park Racecourse, Newton Le Willows, Merseyside WA12 0HQ – on the A49, five minutes from M6 junction 23. Public entry is from 9.30 to 14.30, at £2.50.

For more information browse **www.myciunka.supanet.com/VVTF2003**, or phone 01274 824816.

Karaoke Partying

GOODMANS have launched their largest ever Karaoke product range, consisting of seven home entertainment Karaoke systems, ideal for Christmas and New Year party fun (we hate to remind you – but that season's not far off again!). UK sales of Karaoke, say Goodmans, have rocketed with the advent of TV programmes like *Pop Idol* and *Popstars*, and now "good old-fashioned sing-alongs" have been brought right up to date with the new fully featured range.

Sophisticated vocal editing features enable you to sing with or without backing singers and background music. With the built-in CD Graphics feature you can now read the song lyrics on your TV screen rather than from a photocopied sheet of paper. On-screen lyrics are highlighted in time to the music so you sing at the right pace.

Goodmans are at the forefront of Karaoke technology and this comprehensive range now offers complete home entertainment systems ideal for teenager's bedrooms, through to a Karaoke microphone that will give you instant applause at the touch of a button (the only applause some of you might deserve!).

Goodmans products are widely available at all good high street audio stores. You can also browse **www.goodmans.co.uk**.

NEW RADIO BOOK

IAN POOLE, author of our regular *New Technology Update*, tells us that he has just had a new book published, *Newnes Guide to Radio and Communications Technology*.

Its contents include: an introduction to radio; radio waves and propagation; modulation; antenna systems; receivers; transmitters; broadcasting; satellites; private mobile radio (PMR); cellular telecommunications; short range wireless data communications.

It is in paperback, 320 pages, published by Newnes, ISBN 0750656123, price £16.99. Newnes website is at **newnespress.com**.

Ian has his own radio-related website at **www.radio-electronics.com**.

Windmilling Young Minds

WINDMILL Workshops tell us that they run workshops for students of 11 years and over where they can build their own computer controlled robot and learn about electronics during a weekend at The Creative Robotics Weekend Workshop.

They are also running a postal course called The Electronic Wizards Apprenticeship where students receive an educational "wonder box" in the post every two weeks with electronic projects and interesting facts. Students start with the basics and rapidly build up until they can create their own inventions!

For more information browse **www.kidstuff.co.uk**.

Wythall Rally

WYTHALL Radio Club is holding its 19th Annual Radio & Computer Rally on Sunday 14 March 2004 at Woodrush Sports Centre, Shawhurst Lane, Hollywood, near Birmingham, on the A435, two miles from M42 junction 3. Doors open 10am to 4pm, admission £1.50. Email: enquiries@wrcrally.co.uk. Web: www.wrcrally.co.uk.

New Technology Update

New techniques for doping diamond could favour its use as a commercially viable semiconductor. Ian Poole reports.

DIAMONDS are a girl's best friend, or so the saying goes. Now they could be more than a girl's best friend as they could become a mainstay of the electronics industry in years to come. It is becoming increasingly difficult to keep pace with the requirements of the IT industry. With ever-growing requirements the physical limits of the current technologies are approaching, and new ideas are needed to enable the needs of the chip industry to be met.

One idea that is appearing in a number of research papers is the use of diamond. In the August '03 *Update* we looked at research indicating that diamonds may be able to support superconduction. However, they are also being used to bring back the sparkle into semiconductor research.

Diamond Advantages

Diamond has a number of advantages over the more traditional semiconductors that are normally employed. It can be run at higher temperatures than those that are used today. This would enable it to use higher voltages than silicon designers are being forced to use because of size constraints, forced on them to gain the speed and levels of integration. This is impacting on factors such as noise – a critical limitation that is proving itself to be a significant problem in many designs.

Temperature is another threat to the development of current semiconductor technologies, diamond is the best conductor of heat available, and this will enable any diamond fabricated i.c.s to generate more heat that their silicon counterparts whilst still being able to run at the same temperature. This could be a major enabler for the future as heat generation is a significant problem for i.c. designers and it is one of the major factors forcing operating voltages down.

Apart from these fundamental advantages, diamond is very inert. This makes it ideal for applications including biosensors. In addition to this its well known optical properties make it ideal for use in light emitting diodes and laser diodes.

Whilst diamond has many advantages, one of the major drawbacks is its cost. However, there is work progressing to investigate methods of making diamond more cheaply.

Developments

Diamond has been used as a semiconductor by researchers for some years. It was as far back as 1982 that the transistor action was first demonstrated. The *n*-type conducting layer was made by implantation damage in a natural IIIb diamond. As the natural IIIb diamond is *p*-type, no further implantation was required to create this area. It then took until 1987 until the first transistor with any gain was produced.

Since then a number of developments have been undertaken. In one a Metal–Insulator–Semiconductor Field Effect Transistor was fabricated and details published in 1991. To fabricate this device a *p*-type conducting layer was formed by implanting boron ions in a semi-insulating sample of type IIa diamond. This created a *p*-type layer 200nm thick.

After implantation the diamond was annealed at a temperature of just over 1260K in nitrogen to remove any implantation damage and to activate the boron. Silicon dioxide was then deposited over the implanted layer to provide the gate insulation. This was achieved using indirect plasma enhanced chemical vapour deposition. The drain and source contacts of gold were then added as well as the gate layer.

Laboratory tests of the diamond f.e.t. were run at room temperature and showed that it exhibited the typical f.e.t. characteristics with the pinch-off effect quite visible.

There have been many other developments in addition to this. One example is a single hole diamond transistor that was developed in Japan where the surface conductivity of the diamond was controlled.

Latest Research

Although many successful laboratory devices have been made, one of the real problems with diamond is the doping. Because of its rigid structure it is difficult to dope and this means that the commercialisation of diamond devices is significantly limited.

However, a further development has been made by Jaques Chevallier of the Centre National de la Recherche Scientifique in France. The process that has been adopted by Chevallier and his team is to dope the diamond grown by chemical vapour deposition with boron. This normally gives a *p*-type doped diamond.

By exposing this diamond to a deuterium plasma the diamond changes its polarity and becomes an *n*-type material. The reason for this is thought to be that boron-deuterium complexes are formed which then donate electrons. The diamond treated in this way also has a greater conductivity than that fabricated by other methods.

The process has been found to be reversible as heat can drive out the deuterium so that the diamond returns to its former *p*-type state. This means that if the process is used in this form, then it would have to be the last heat stage in the process otherwise the introduction of the deuterium could be nullified.

The advantage of this process is that it enables *n*-type material to be manufactured far more easily. In the past, doping diamond to produce *n*-type material has proved to be difficult. This new development will open the way to making both *p* and *n* type materials more easily available.

Low Cost Diamond

One of the major drawbacks with the use of diamond is obviously the cost. Silicon has achieved its place of dominance in the market mainly as a result of its low cost. Other semiconductors such as gallium arsenide have waited in the wings because they are more difficult and hence more expensive to use.

To reduce the cost of diamond there are a number of initiatives under way. For example one company, Apollo Diamond based in Massachusetts, is synthesizing diamond using a process known as Chemical Vapour Deposition. By using this process they are able to produce wafers in sizes between 3mm and 10mm square, with larger sizes expected to be available in the near future. Thicknesses range between 250 microns and 4mm depending upon the application.

As the diamond is produced synthetically it is of a very high grade. Cost is still an issue, but at least this development is a step in the right direction, and no doubt new processes will be developed that will bring the costs more into the realms that are acceptable.

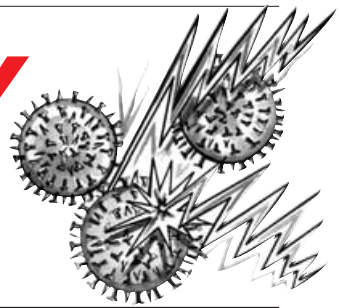
Summary

Whilst diamond is not likely to suddenly displace the more established semiconductor materials, there is still plenty of interest in developing diamond semiconductor devices. The work is starting to show promise, and eventually it may produce some significant returns.

However, in view of its current cost, the industry pundits are not placing any timescales on when it will be introduced into widespread use. Although silicon does not offer the best performance of any semiconductor, its favourable cost has meant that it is the most widely used semiconductor. Those that are more expensive are only used where their performance is crucial. The cost of diamond itself will determine into which category it falls.

Special Feature

ELECTROTHERAPY – A BRIEF HISTORY



STAN HOOD

A personal view of the use of electricity in medicine – from Galvani to Hulda Clark

THIS article was inspired by the appearance in *EPE* March 2002 of the constructional project *PIC Virus Zapper* by Andy Flind. Yours truly, as a builder of a traditional Hulda Clark zapper and similar electrotherapeutic devices, seeks here to provide both a necessarily brief history of electricity in medicine, and more importantly a caution or two for the new enthusiast.

Where the following treatise ventures my humble opinion, my hope is that I steer a middle course past the zealots on one side, who believe that electric machines can cure anything and dismiss expensive drug-based medicine as merely the vested interests of rich greedy drug companies, and on the other side past the caring medical practitioners with perhaps a blinkered traditional view, who look upon the zealots as dangerous because they give sometimes desperately sick people false hope with quack machinery and discourage them from receiving appropriate conventional treatment until all hope of cure or remission is lost.

HEALTH WARNING

I must say all this, in no particular order, to the budding enthusiast in alternative electrotherapy: *always* check with your doctor before using any electrotherapy machine on yourself; do not use it on anyone else, even with their permission, unless you are absolutely sure that their doctor has ok'd it (and you can prove it to a judge later, if need be!).

Never attempt to diagnose a medical condition and never claim that you can cure anything, on pain of the risk of serious criminal charges being brought against you; do not zap if the person being treated is pregnant, has an electronic implant such as a pacemaker, or is not an adult.

LIGHTWEIGHT HISTORY

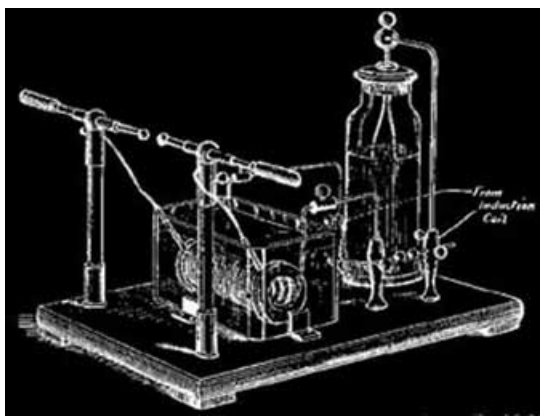
In general the established medical fraternity, at least in the Western world, has ridiculed certain types of electrotherapy for much of the 20th century and to the present day. This was not always so.

The first recorded use of electricity which probably had an effective "dose" of current took place about the year 1800. The nephew of Galvani, the early experimenter with electricity in living tissue, applied electrical currents to the head of a man who was suffering from a psychiatric condition. The nephew, Aldini, claimed that the treatment was successful and that his patient could return to his usual duties.

By 1840 the medical treatment of choice for bone fractures which didn't heal was to apply electric shock treatment to the area. In 1860, Dr Arthur Garrett, a fellow of the Massachusetts Medical Society, published *Electrophysiology and Electrotherapeutics*, a textbook covering the use of electricity to treat a range of conditions. These were the days when the physicians had to make their own batteries and instruments for measuring and applying the electricity.

The dawning of the 20th century saw electricity becoming more available by means of the new generating plants and superior batteries made commercially to standard specifications. In contrast with this improved availability, electrotherapy as a science, with some exceptions, gradually lost favour among the medical fraternity in the first three or four decades of the new century.

It rather depends on one's point of view as to why this was so. Perhaps during this period the new discoveries in drug-based medicine were found to be superior to jolts of electricity; or perhaps there really was a conspiracy by the big drug companies to discredit or suppress all knowledge of what an excellent and virtually free cure-all electrotherapy was.



Early Tesla Apparatus from Paris. Was this the start of electrotherapy? Courtesy **www.electrotherapymuseum.com/Oudin_Resonators_Tesla_Coils.htm**.

TESLA AND ABRAMS

The genius Nikola Tesla, prolific inventor, including inventing the polyphase a.c. electrical system still in use today in the form of the national power grids in many countries, made mention of the therapeutic use of electrical discharges from experimental machines he built and used on himself. Later, he commercially manufactured electrotherapy machines, in the very early 1900s.

During the 1920s, a man by the name of Abrams had some early success, allegedly curing some diseases with electrical frequencies radiated into the body. Who knows what may have come of Abrams' work if the new-fangled radio broadcasting stations springing up everywhere hadn't been creating a rising level of electromagnetic "smog" or interference which, according to Abrams, upset the delicate workings of his equipment.

Indeed, Abrams' last demonstration to the medical profession of the diagnostic capabilities of his electrical machinery, although successful, had to be conducted in a completely electrically shielded building. By the way, that demonstration carried no weight with the establishment medical observers because, as they explained, they didn't understand how Abrams' electrotherapy equipment worked. Therefore they could not and would not endorse it!

This period was the beginning of the end of Abrams' credibility with the medical profession. After his earlier promising start, from this point on his work was mercilessly scorned by establishment medicine and he died prematurely, it is said as a result of the ridicule.

ROYAL RAYMOND RIFE

Royal Raymond Rife was a contemporary of Abrams, and is likely to have heard of the latter's work. Some historians say that this is certainly so, and indeed imply some collaboration between them. It appears that Rife, like Abrams, had some recorded early successes in curing illnesses.

EPE April 2001 carried an excellent 10-page supplement written by

Aubrey Scoon, detailing Rife's life and work. I recommend reading Aubrey's informative article. (It can be downloaded from the Library on the *EPE Online* website at **www.epemag.com**.)

KIRLIAN

In 1939, Semyon Davidovich Kirlian, an electrician, was called in to do some electrical maintenance work in a Russian hospital. While there, he observed a patient being given treatment by some kind of electrotherapy machine which created a visible glow of light (an electrical corona discharge) around the treatment area.

This is what gave Kirlian the idea of building what came to be known as the Kirlian Camera, which photographed the high-voltage electrical "aura" around the fingertips (only fingertips at first – later, Kirlian photographs could be taken almost anywhere on the body).

Kirlian claimed that this aura could show the state of health of the subject, the exact nature of any illnesses, and could also give earlier advance warning of illnesses to come than any other medical technique of the time. His equipment was not therapeutic so much as diagnostic, but it is included here because of its relevance to any discussion of early machinery which applied electricity to people for a medical purpose.

Kirlian's work was unknown in the Western world until 1970, thanks to the old communist "iron curtain". If one were to believe Western Kirlian protagonists, his methods enjoyed a measure of respect among the Russian medical establishment.

In the Western world today, Kirlian photography as a diagnostic tool is employed almost exclusively by alternative health practitioners.

ROBERT O. BECKER

Dr Robert O. Becker (not related to Dr Robert C. Beck, later in this article, or to *EPE*'s Tech Ed!) in the 1960s, was able to show how the proper application of minuscule electrical currents could stimulate limb regeneration in salamanders, and "turn on" bone growth in dogs. Carried to its ultimate conclusion, this would have meant the electrotherapeutic capability to, say, re-grow an arm which had been amputated! His research didn't get that far.

Some of Dr Robert Becker's research showed that currents down in the low d.c. microampere range were effective in this regard. Indeed his research indicated that the applied d.c. currents had to be so very low to prevent the onset of electrolysis in living tissue. (I wonder what we should make of Dr Hulda Clark's pulsed d.c. blood zapper, which is current-limited to milliamperes, a thousand times greater than Dr Becker's suggestions. More on this later).

TENS DEVICES

Transcutaneous Electrical Neural Stimulation (TENS) started off as an alternative palliative pain-relief method by applying pulses of electricity from a special "black box" to a pain site through electrodes taped to the skin. I've seen two completely different explanations as to how a TENS machine lulls pain. Both appear to be accepted with reservations by the medical fraternity until a "real" explanation for the relief is agreed upon.

TENS devices have achieved limited acceptance within mainstream medicine, to the extent that in the UK the machines are available on the National Health, while in parts of Europe TENS machines are not considered a serious medical tool. In New Zealand, my homeland, TENS machines are available for hire through the Public Health system.

KNOTT TECHNIQUE

We should now back up a little, to lay some historical groundwork for some modern developments of electrotherapeutics. In the 1920s, before antibiotics, there was a procedure, acknowledged as risky, used by the medical establishment to attempt to cure diseases which were unable to be banished by the usual methods of the time.

This somewhat dangerous technique was known, I believe (I have only come across one mention of this in my alternative research), as the *Knott Technique*, presumably because it was developed by a Mr Knott! It involved pumping the blood out of the body, irradiating it with ultraviolet (UV) light, and returning it to the body. Apparently, it didn't always work!

These days we know that short wavelength UV damages human skin both short and long term. This same light is sometimes used to maintain sterile atmospheres in industrial situations, that's how deadly it can be to living cells. Perhaps it was a case of pity the poor patient whose body had to cope with both the original disease and blood half-destroyed from UV light!

I have heard anecdotes that this procedure is currently available from a few very alternative "therapists", and that in one case, death followed shortly after treatment (whether due to the original illness or the treatment is not known).

STEVEN KAALI

My own professional electronic training taught me nothing medical, however I personally relate the Knott technique to another, recently patented "blood-cleaning" system which works by running a weak electrical current through the blood while it is similarly outside the body.

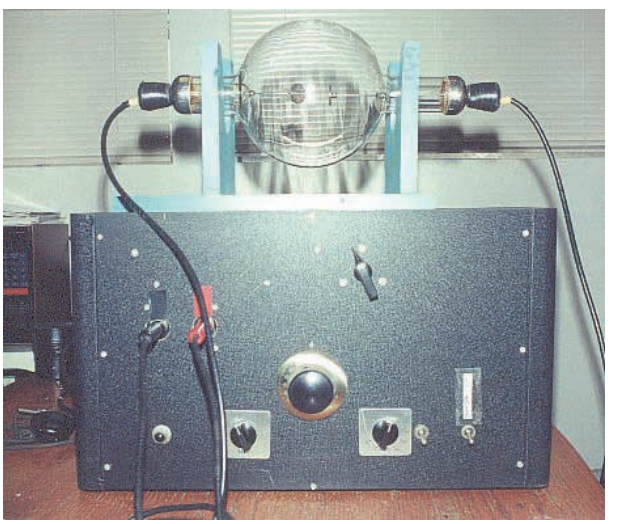
The US patent dated February 23, 1993, granted to Dr Steven Kaali MD, *et al*, is based on the discovery that the weak current can disable most bacteria and viruses up to and including the HIV virus (initial experiments done in a laboratory dish)! Dr Steven Kaali appears to consider that the "bugs" are not killed, merely disabled sufficiently so that the body's immune system can finish them off in their weakened state.

REALITY CHECK

Because this was such a dramatic assertion of Dr Kaali's, I hasten to add my own healthy touch of scepticism here for the benefit of any reader who may be desperately searching for an AIDS "cure". Think about it, if this technique of Dr Kaali's could really disable the HIV virus in a real-world situation rather than just a laboratory dish, don't you think it would have been trumpeted from every roof-top in every country in the world by now, as the first "miracle cure" for the 21st century?

Patents by definition are public knowledge, and this is why we the people know how to do it, and that the power from the tiniest of readily-available torch batteries would be more than enough to effect the "cure". Believers in electrotherapy are sometimes rather fanatical about their pet "conspiracy theory" which usually revolves around the "rich greedy drug companies" and their suppression of amazing and cheap electrical cures for everything!

I prefer to believe simply that there are difficulties in getting an electrical viral and AIDS inhibitor from the laboratory to the person-in-the-street.



An original Rife Machine, 1939, manufactured in San Diego, California, for an unknown doctor. Exactly how this unit operates is at present not known. Courtesy **www.rt66.com/~rifetech/rife.html**.

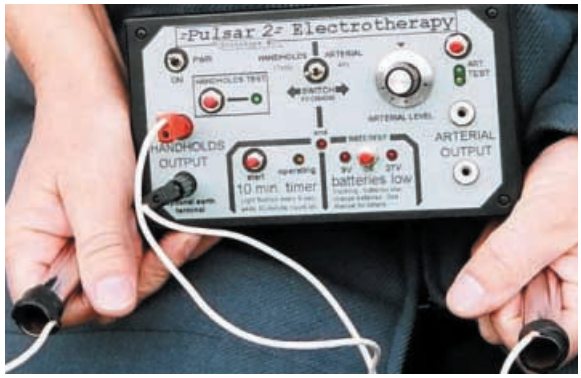
It is about here in my text that I will possibly be starting to annoy the afore-mentioned conspiracy theorist. No problem. All he/she has to do to shut me up completely is to produce for *EPE* the doubtless thousands of people who can swear that they have been cured of AIDS in an underground laboratory by the quick cheap electronic Kaali method in the nine years since the 1993 Kaali patent grant showed the world how to do it!

ROBERT C. BECK

Apparently Dr Robert C. Beck also thought there would be problems with treating viral and bacterial illnesses by physically removing the patient's blood first. Using Kaali's work as a basis, he devised a method of "blood-cleaning" by weak electric currents which leaves the blood safely inside the body.

His system works by applying a low frequency alternating current to electrodes taped to the wrist adjacent to the point where the pulse is felt strongest. The hope is that the current will flow across the artery concerned, thus treating the blood within. At least that is what some of the websites dedicated to Dr Beck's work say. Other websites would have the low frequency applied to a wrist and an ankle on the same side of the body, with the explanation that the electric current takes a long path through various arteries, thus cleaning the blood.

Unlike Rife's machines alluded to earlier, Dr Beck's blood-cleaner doesn't have different frequencies for different illnesses; one frequency (4Hz) does the lot, and Beck himself asserts that the frequency does not have to be exact. The researcher in non-medical-approved electrotherapy will find it worthwhile to look at some of the Beck promotional websites (try using Google to search for Beck and you will probably end up with more sites than you can handle).



The author's homemade electrotherapy machine. Courtesy ***www.postmaster.co.uk/~stanwhood/66554/***.

ELECTROLYSIS – BAD!

Decades ago I did some brief research with very low frequencies and electrolysis of salt solutions, not for medical reasons. As a result I found the discussions on various websites on the merits of Beck's original 4Hz a.c. compared with a 100Hz "Beck" system developed by others, quite enlightening.

I am not making a personal recommendation of any kind now, but from my earlier experience with salt solutions I speculate it might be possible that choosing 100Hz instead of 4Hz could reduce the risk of damaging electrolysis of living human fluids. If any hobbyists were to consider at some time constructing a Beck device, they would be well advised to check websites for the many cautions that Beck advocates for the use of his system, before trying it out.

I have built a Beck 4Hz machine, and I believe I suffered a side-effect from using it, which in the past I would normally have associated with poor circulation in my body. I must also say that this would not stop me using my Beck machine on myself again if medical science were unable to help me and any possible side-effect was judged to be minor compared to what was already wrong with me.

Dr Beck has supporters who can testify that his system makes sick people well, and detractors who say that the Beck system is unproven and therefore "cannot" work – in spite of any *anecdotal* evidence shown to the detractors that it does work!

(Interesting word, *anecdotaI*. To me it means true stories told by honest people. There appear to be some in the scientific fraternity, however, who use this word as a synonym for "lies". This excessive scepticism is a pity in my opinion. I really do try to be open-minded without sliding into gullibility.)

EPE ZAPPER INSPIRATION

Dr Hulda Regehr Clark, Ph.D., has developed what she calls a blood "zapper", which is said to kill or disable any blood-borne viruses or bacteria (*EPE*'s previous and present Virus Zappers are Clark-type zappers). Like Beck's basic blood cleaner, Clark's device uses very simple and cheap electronics to put square-wave current into the body.

Unlike Beck's a.c. device which uses small pads taped to the skin, Dr Clark's pulsed d.c. uses two cylindrical copper handholds. Clark's device runs on a lower voltage and a higher frequency than Beck's. Clark's dosage is three seven-minute sessions spaced twenty minutes apart, while Beck's is either 20 minutes or one hour a day (depending on the chronology of the Beck advice one accesses) for three weeks or more!

Dr Clark says that her system is very safe because of the very low voltage and current and dosage period (but she still gives a caution in bold print with border in the same book, *The Cure For All Diseases*, where she tells us also how safe it all is). Dr Beck for his part lists many cautions for the use of his blood cleaner.

ELECTROLYSIS AGAIN

I must repeat that Dr Clark's system uses d.c., with a possible resultant risk of electrolyzing body fluids. On the other hand, in her defence, I can speculate from experience that there is a possibility that electrolysis may not occur because the d.c. is applied in a high frequency burst with a mark/space ratio of about 1·2/1 if her original circuit is used. I speculate that electrolysis may not have time to start before each fraction of a millisecond burst of current stops.

On the first hand again, I could be wrong because a website which deals responsibly with all manner of electrotherapeutic devices, recommends almost any other system over the Clark one because of a side-effect (stiffening in a finger joint) the website owner developed after a Clark session (see **www.ioa.com/~dragonfly/clarkzapper.html**).

Could electrolysis have precipitated out some solids in those finger joints, wrapped as they were around the Clark copper electrodes? He also reported (bravely for a male, I thought) temporary impotence after the Clark session.

Clark fans may not like hearing this, but I believe I understood correctly from some of Dr Clark's supporters that we should share our experiences with the Clark device. This man has done exactly that, and as a result we can all use our Clark virus zappers in a more informed, responsible way.

UNFAIR COMPARISON?

It may not be fair to compare, as I have done, the Clark and Beck methods of blood cleaning. While the electronics in each case uses a 555 timer at its heart and both people appear to be genuine altruistic researchers, their approach to, their motivation for, and their explanation of their respective works reflect their independent developments.

OPINIONS AND MOTIVATION

So there it is, electro-medicine lightly skipped over, but hopefully useful enough to start the reader off in this interesting field. Enjoy your own research, but remember I for one would be highly suspicious of anyone who tried to tell me that there are no side-effects from poking electricity or indeed magnetism into people.

My introduction to this fascinating field took place in a rather back-to-front way. In the 1960s I worked in a New Zealand government complex of high-powered radio transmitters complete with about 850 acres of aerial farm, mostly giant HF rhombics. While living and working on the base, which always had several transmitters operating 24 hours a day, I suffered irritating and sometimes painful illnesses and mood swings.

I was healthy until I got there, and I have kept good health for the nearly 40 years since I left. It wasn't until the 1980s when publications began to appear about the health problems of long-term power station workers that I realized I was essentially reading a list of my own problems of my time on the radio base. Perhaps after all, my tribulations of all those years ago were not simply a supposed traumatic change from adolescence to adulthood.

So it was in the 1980s I first began to theorize that if electricity could cause symptomatic harm (and that is all it did in my case as a young man), then perhaps a different electrical application to the body might give at least palliative relief for one's minor ailments, if not more. Thus began my journey into electrotherapy, a somewhat frustrating one for me because apart from getting the occasional cold or bout of flu, in my 57th year I am sickeningly healthy (sorry!) with good blood pressure so do not have many opportunities to try my electro-gadgets out on myself.

Electro-human interaction can be a highly engaging interest, but there is some wacky stuff out there along with the good, so watch that gullibility factor and don't ever offer "healing" unless you really are a licensed medical practitioner.

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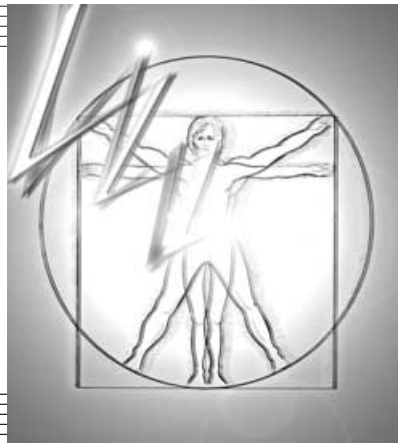
Numerous websites accessed by keying Dr Hulda Clark, Dr Robert Beck, and those name variants into the **www.google.com** search engine. □

Constructional Project

PIC VIRUS ZAPPER MK2



ANDY FLIND

An alternative method that could keep those bugs at bay!

IMAGINE, if you will, a simple battery operated device capable of stopping the common cold and many other afflictions in their tracks. At the onset of a sore throat, say, the user would simply grasp a pair of electrodes, switch on, and soon become perfectly well again.

Sounds like an impossible medical pipedream, doesn't it. Yet this is the claim for the *Clark Virus Zapper*, the invention of Dr Hulda Regehr Clark, versions of which are widely available from internet sources. Many users swear by its effectiveness.

The Zapper works by applying a pulsed voltage, usually from a 9V battery, to a pair of electrodes placed in contact with the user's body, resulting in pulses of current through the body which are claimed to destroy the viruses and bacteria.

The *EPE Virus Zapper* (Mar '02) version proved very popular with readers, although at the time of publication the author was not really convinced that it worked! However, after two bad colds in rapid succession, he felt "run down", with a sore throat which refused to clear up. Eventually the notion of Zapping arose.

By the following morning the sore throat had gone and a steady return to full health ensued. On subsequent occasions the treatment was repeated at the apparent onset of a cold and appeared to stop it in its tracks. It is impossible to know whether the improvements would have occurred anyway, but each time a treatment is followed by positive results the likelihood of some connection is reinforced.

EXPERIMENTAL ZAPPER

For those who wish to experiment, a simple Zapping circuit is shown in Fig.1. The circuit is based on an ICM7556 dual timer, IC1, although it could also be constructed using two ICM7555s. It generates output frequencies of 23kHz and 2·5kHz, selectable with switch S1, but these can easily be changed by altering the values of capacitor C3 and resistors R1 and R2.

Transistor TR1 boosts the weaker pull-up drive provided by the output of timer 2, while the "discharge" pin of timer 1 is used to pull the output towards negative. The final output is a squarewave and is ideal for testing the Zapper principle.

FREQUENCY CONSIDERATIONS

There has always been disagreement concerning the best frequency for zapping. Values from Hulda Clark's original 22kHz, down to 2·5kHz and lower, have their devotees. Supporters of lower frequencies claim they penetrate body tissues to a greater depth for increased effect, and indeed this was the criterion used by the original *EPE* project.

Some users think frequency does not matter and even just tapping a connection against a battery terminal to pulse the current is sufficient. The most recent models use a swept (continually changing) output frequency which is claimed to hit the "resonant frequencies" of the organisms it is supposed to destroy, although this sounds like confusion with the principle of the Rife Generator. (For more about the remarkable Rife device, see *The End to All Disease* by Aubrey Scoon, *EPE* April '01).

However, sweeping the output frequency does neatly sidestep the question of which frequency is best, and as it is the latest development the PIC Virus Zapper Mk2 incorporates it.

The fixed frequency output of the simple circuit of Fig.1 can be made constantly variable if capacitor C3 is fed with a voltage-controlled current, with the timer output switching between charge and discharge. Voltage control makes it relatively simple to generate a swept output frequency range. A block diagram of the method used is shown in Fig.2.

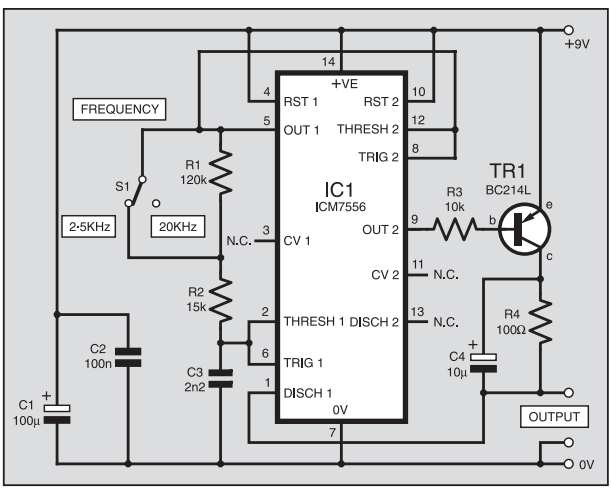


Fig.1. Circuit diagram for a simple zapper.

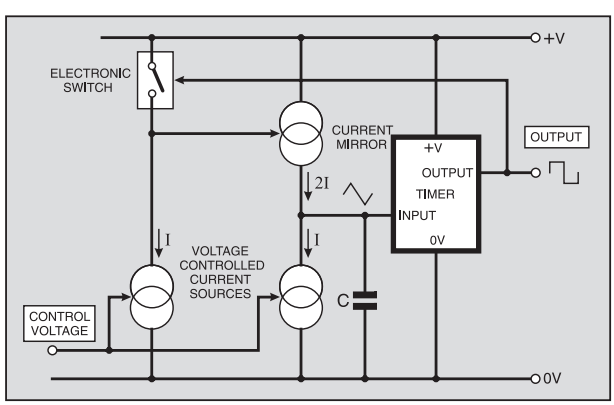


Fig.2. Block diagram of a voltage-controlled oscillator.

Two voltage-controlled current sources both sink current to ground. One of these is directly connected to capacitor C and so tends to discharge it. The other feeds a "current mirror" which "reflects" twice the current back from the positive rail. This is also connected to C so, when both current sources are operating, the net current is positive and charges C.

However, an electronic switch can turn off the current mirror by shorting its input to the positive rail so that C discharges. The capacitor is connected to the timer inputs and the timer controls the switch as they reach threshold voltages of $^1/_3$ and $^2/_3$ of the supply voltage. The advantage of this method is that the current mirror and switch are easily implemented with transistors for a very rapid switching action.

MK2 CIRCUIT

The complete circuit diagram for the PIC Virus Zapper Mk2 is shown in Fig.3.

The frequency generation and output stages of the circuit are all shown in the lower half. CMOS timer IC3 is used as a simple oscillator with a period of about 16 seconds, or eight seconds in each phase direction, as set by capacitor C8 and resistor R9.

Although the waveform across capacitor C8 is actually exponential in shape, it only swings between one-third and two-thirds of the supply voltage, so it is sufficiently close to a triangle wave for this design. It is fed to op.amp IC4a which, in conjunction with *pnp* transistor TR2, forms a current generator in which current is sourced from TR2's collector towards ground (0V).

Resistors R10 to R12 in effect provide an impedance of 7·333kΩ from two-thirds of the supply voltage, nominally 6V, so the current varies from zero when the voltage across C8 is at its maximum, to just over 400μA at minimum. This produces a voltage ramping between 0V and 1·35V across resistor R13. Op.amp IC4b buffers this voltage.

Buffering is not essential but the spare amplifier is available and it makes for easier testing. Op.amps IC4c and IC4d with associated transistors TR4 and TR6 form the two current sinks shown in Fig.2. The collector of TR6 goes directly to timing capacitor C9 and the inputs of timer 1 in CMOS dual-timer IC5.

The collector of TR4 goes to the current mirror formed by TR3 and TR5. TR3 compensates for the temperature-dependent voltage drop across the base-emitter junction of TR5 so that all the voltage developed across resistor R14 reappears across the parallel combination of R16 and R18. The use of two resistors here doubles the output current which goes to C9.

Transistor TR7 when switched on diverts the current from TR4 to the positive supply rail to stop the operation of the current mirror. Following this, the output stage operates in the same manner as the simple circuit of Fig.1. Transistor TR8 allows the output to be stopped in the low state. The output is unlikely to be a perfect squarewave due to component tolerances but it is close enough for the intended purpose.

The outputs of CMOS timers cannot source as much current as they can sink so transistor TR9 boosts sourcing for a rapid rise time. Since all the voltages and currents in this circuit are more or less proportional to the supply voltage, the output frequency range remains almost constant despite variations in supply voltage, removing the necessity for voltage regulation. In fact, it continues to operate to below 6V, ideal for operation from a 9V PP3 type battery.

COMPONENTS

See SHOP TALK page

Resistors

R1, R3	56k (2off)
R2	100k
R4, R19, R21, R22	10k (4 off)
R5	150Ω
R6 to R8	560Ω (3 off)
R9	1M
R10 to R12, R20	22k (4off)
R13 to R18	3k3 (6 off)

All 0·6W 1% metal film.

Potentiometer

VR1	10k min. preset, round

Capacitors

C1, C4, C8, C11	10μ radial elect. 16V (4 off)
C2, C3, C7, C12	100n polyester layer, 5mm pitch (4 off)
C5, C6	22p ceramic disc, 2·5mm pitch (2 off)
C9	2n2 1% polystyrene (see text)
C10	100μ radial elect. 16V

Semiconductors

D1	1N4148 signal diode
D2	red l.e.d., high bright., 3mm (see text)
D3	yellow l.e.d., 3mm, 2mA (see text)
D4	green l.e.d., 3mm, 2mA (see text)
D5	red l.e.d. 3mm, 2mA
TR1 to TR3, TR5, TR7, TR9	BC214L *pnp* transistor (6 off)
TR4, TR6, TR8	BC184L *npn* transistor (3 off)
IC1	LP2950CZ-5 +5V micropower voltage regulator
IC2	PIC16F84 microcontroller, preprogrammed (see text)
IC3, IC6	7555 CMOS timer (2 off)
IC4	LM324 quad op.amp
IC5	7556 CMOS dual-timer

Miscellaneous

PL1	4mm plug, red
PL2	4mm plug, black
S1	s.p.s.t. slide switch
SK1	4mm socket, red
SK2	4mm socket, black
WD1	piezo sounder, 5V d.c., 25mm dia.
X1	4MHz crystal
X2	alphanumeric l.c.d. module, 2 lines x 16 characters (per line) (see text);

Printed circuit board, available from the *EPE PCB Service*, code 425; Plastic case 150mm x 80mm x 50mm; PP3 battery holder and clip; 8-pin d.i.l. socket; 14-pin d.i.l. socket (2 off); 18-pin d.i.l. socket; connecting wire; solder etc.

Approx. Cost Guidance Only

£26
excl. case & batt.

WARNING

Like all bio-electronic devices, this zapper MUST NOT be used by anyone with a heart pacemaker, or by expectant mothers, at least not before taking qualified medical advice concerning safety. If any side effects are experienced, immediately stop using the zapper.

Please read the *Electrotherapy* article in this issue before using this device.

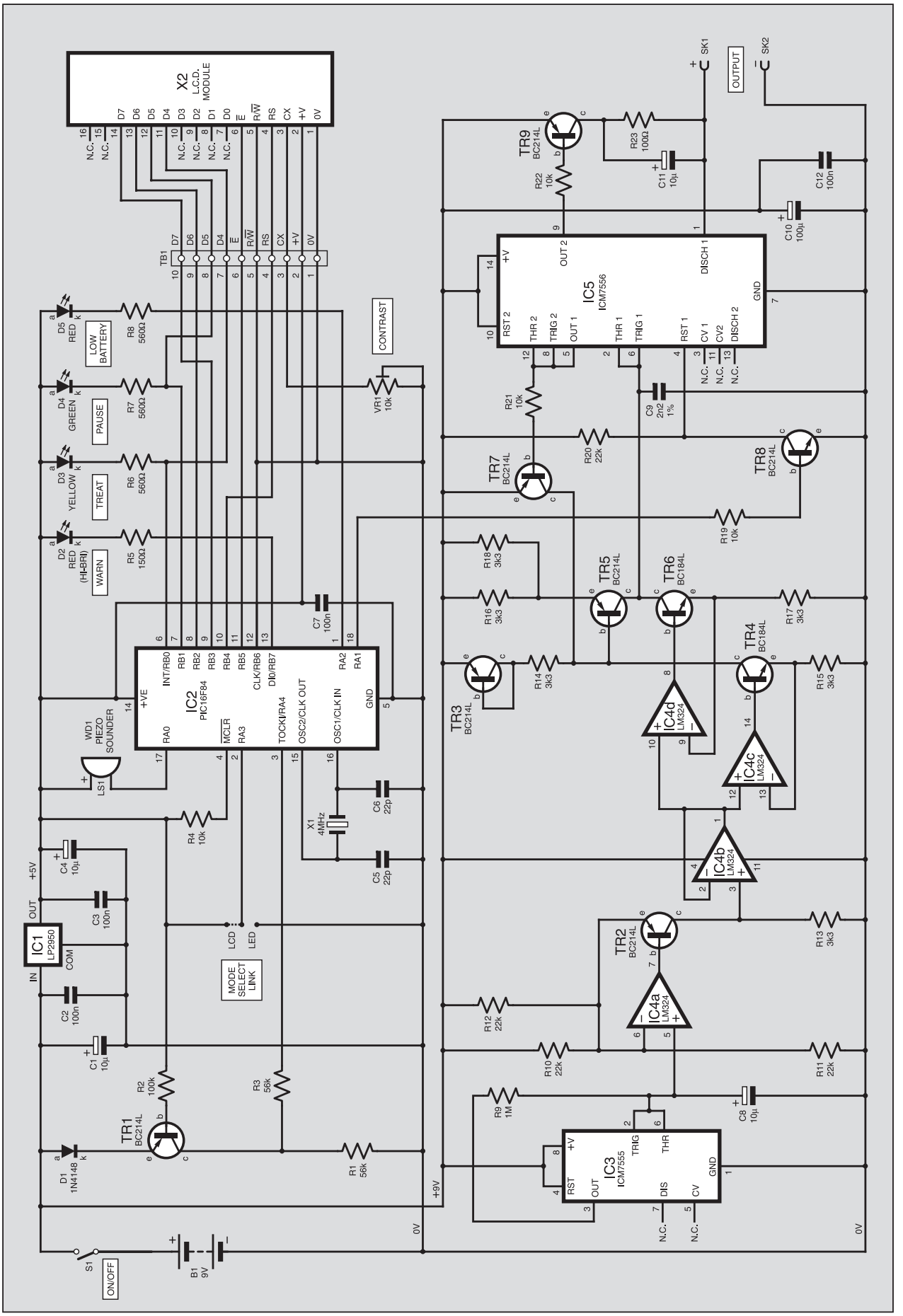


Fig.3. Complete circuit diagram for the PIC Virus Zapper Mk2.

PIC FUNCTION

Unlike the previous Zapper project, PIC microcontroller IC2 in this design is used only for timing and indication. Indeed, it could be omitted if preferred – see later.

A session consists of three seven-minute "treatments" separated by two pauses of 28 minutes. The output stage can be used on its own provided the user is prepared to time it, but the control part of the circuit takes care of all timing, indicates progress, and is simple and inexpensive to add.

Originally, the PIC was programmed for l.e.d. indication, but later it was decided that an l.c.d. display would be better so alternative software was created. However, it seemed a shame to discard the l.e.d. program and it was felt that some constructors might prefer this anyway, so eventually both versions were combined. At switch-on, the PIC checks its pin RA3 to decide which program to run and a simple connection on the p.c.b. controls this.

POWER SUPPLY

A 5V supply is provided for the PIC and l.c.d. by regulator IC1. This is an LP2950CZ-5 which has a lower consumption and input voltage requirement compared to the more familiar 78L05, making it more suitable for battery operation.

Transistor TR1, a *pnp* device, senses low battery voltage. Whilst the supply is more than 1·2V above the regulator output (set by the voltage drop across TR1 base-emitter and diode D1 junctions) TR1 will be "on", so the collector voltage, applied to RA4 of IC2 through resistor R3, is high. When the supply voltage falls below about 6·5V it falls quite sharply. The PIC senses this and activates the low-battery indicator l.e.d. D5.

Piezo sounder WD1 and high-brightness l.e.d. D2 alert the user to the start and finish of various parts of the sequence. Experience with the first design showed that some constructors would prefer not to have an audible indication so WD1 can be omitted or fitted with a switch if desired.

The remaining two l.e.d.s, D3 and D4, indicate the stages of treatment and should be omitted if an l.c.d. display is used. Terminal block TB1 carries connections to the l.c.d. and preset VR1 provides screen contrast adjustment.

CONSTRUCTION

The printed circuit board component layout for the PIC Virus Zapper Mk2 is shown in Fig.4. This board is available from the *EPE PCB Service*, code 425.

Before commencing construction, the desired configuration should be chosen. If PIC control is not required everything on the lower half of the board can be omitted, along with transistor TR8 and resistor R19, to give a frequency-sweeping output stage that can be timed manually by switching the unit on and off.

If automatic timing is to be included, a choice should be made between l.e.d. or l.c.d. indication. There are three small "ovals" in the p.c.b. tracks beneath IC2, see Fig.5. Two of these are already bridged by a thin track to select l.c.d. operation so if this is preferred no change is necessary. If the l.e.d. indication is required it will be necessary to cut this bridging track and make a short insulated wire connection as shown in Fig.5 to connect IC2 pin 2 (RA3) to 0V. It is possible to change the choice later simply by fitting the required output indication and reversing this connection.

The author's usual construction sequence consists of fitting pins for external connections followed by the components, broadly in order of their physical height. Ensure that the semiconductors and electrolytic capacitors are positioned the correct way round.

Sounder WD1 is a d.c. operated type so care should be taken with its connection polarity. Some sounders have flexible leads for connections but the one used in the prototype had two pins projecting from the rear. Holes were drilled in the p.c.b. to

PIC VIRUS ZAPPER Mk2

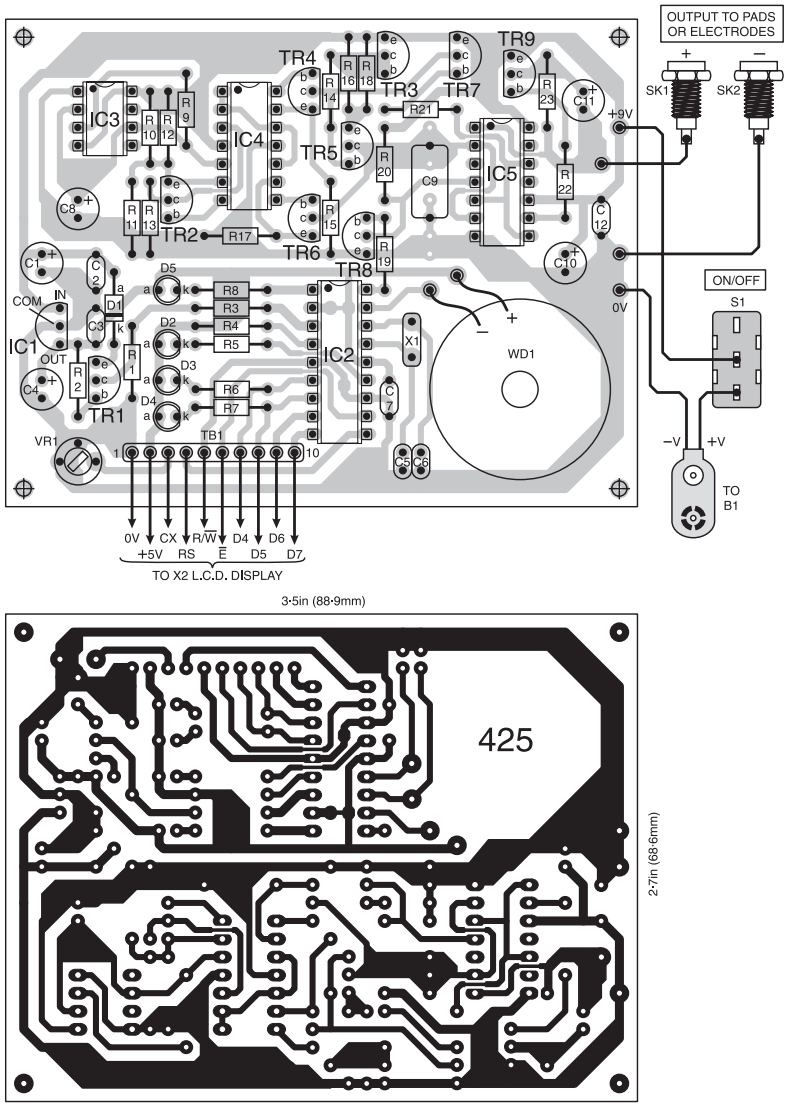


Fig.4. Printed circuit board component layout, full-size copper foil master and wiring details.

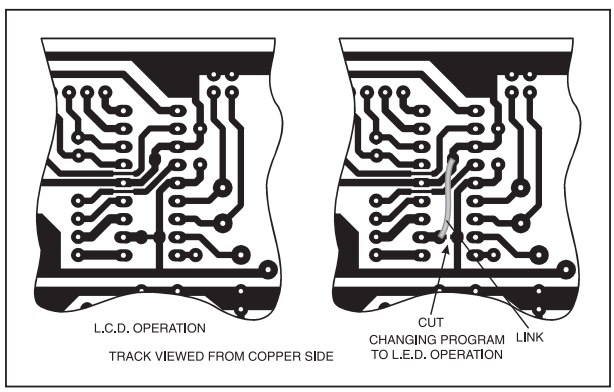
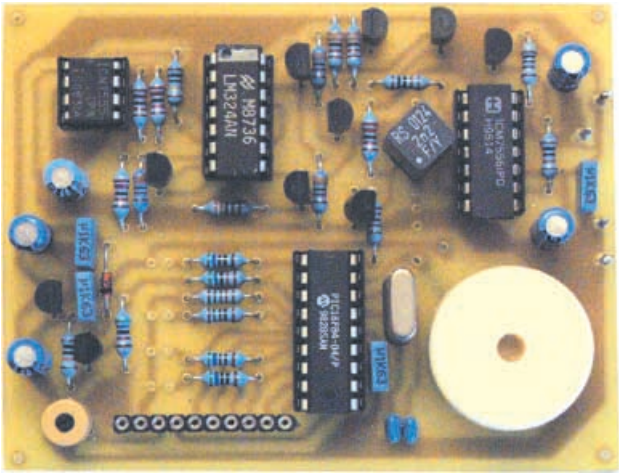


Fig.5. Track modification for l.e.d. operation.



Completed Zapper circuit board.

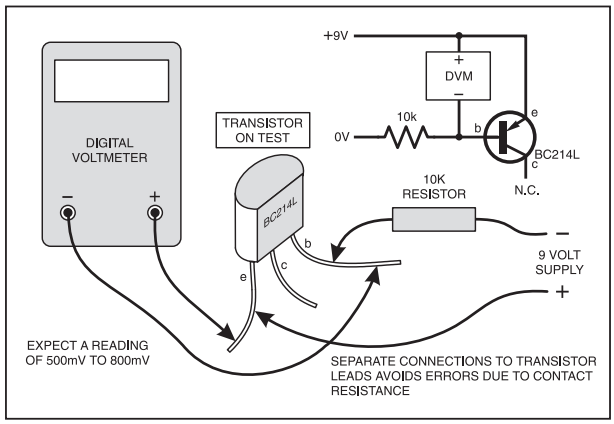


Fig.6. Simple test procedure set-up for matching the base/emitter voltages of two pnp *transistors (TR3, TR5). This improves the output mark-space ratio.*

accommodate these. It was secured with double-sided adhesive foam and the connections were made with short insulated wire links on the track side of the board.

Capacitor C9 should ideally be a 1% tolerance type to keep the output frequency close to the intended range. Sizes of these vary so the p.c.b. has sufficient space and holes to accommodate various types.

The transistors are of the "L" suffix type with a central collector lead. Conveniently, all the BC214L *pnp* types have their flat side to the left of the p.c.b., whilst all the BC184L *npn* types face right.

MATCHING TRANSISTORS

As mentioned earlier, it is unlikely that the output of the oscillator will be a perfect squarewave due to slight mismatches in the currents flowing into C9, caused by component tolerance errors. A likely source of error is a mismatch between the base-emitter voltages of TR3 and TR5 so, although the circuit should work well enough if these are not matched, it is worth finding a pair with similar voltages.

The procedure is actually quite simple and requires only a digital voltmeter and a 10kΩ resistor, as shown in Fig.6. From a dozen transistors tested in this way, the author found three pairs which matched within a couple of millivolts, and fitting a pair in these positions produced a worthwhile improvement in the output mark-space ratio.

FIRST TESTS

It is recommended that IC2 to IC5 should be fitted one at a time as part of a test sequence. The first step is to power the board without any of them inserted. Following a brief surge as the electrolytic capacitors charge, the supply current should then settle at around 0·5mA. The regulated +5V supply from IC1 should be present on pin 2 of connector TB1 and pin 14 of the socket for IC2.

If this checks out IC3 should be inserted, remembering to disconnect the supply first. This i.c. should make very little difference to the supply current but its operation can be confirmed by monitoring output pin 3 with a meter. It should swing between ground and supply voltage level at intervals of about eight seconds. Following this check, op.amp IC4 can be fitted.

The supply current will now vary between about 1·5mA and 2·5mA as IC3 cycles. The voltage at pins 1 and 2 of IC4 should vary slowly between approximately 0V and about 1·35V and these values should also appear on pin 9 and pin 13.

Next, the dual-timer IC5 can be inserted. It should not be necessary to ground the base of control transistor TR8, although this can easily be done with a link between pins 5 and 18 of IC2's socket. The supply current will again vary slowly as IC3 cycles, this time between 2·5mA and 6·5mA. If an oscilloscope is available, the output can be viewed as a squarewave sweeping continuously from below 2kHz to above 22kHz and back.

The mark-space ratio probably will not be perfect but a meter across the output should read reasonably close to half the supply voltage. Component discrepancies have more effect at the low end of the output frequency range so this average reading is likely to vary slightly. As described earlier, matching the base-emitter voltages of transistors TR3 and TR5 can bring about a significant improvement.

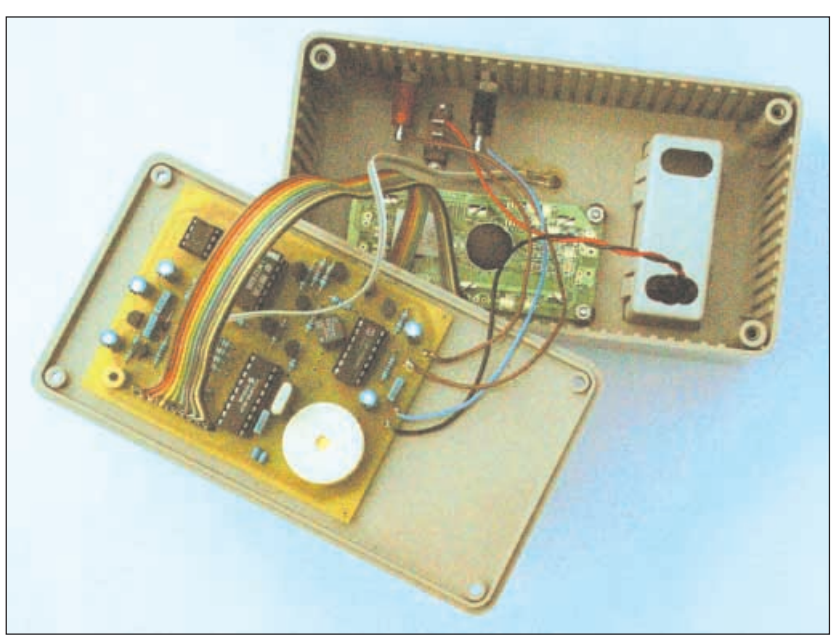
Linking pins 14 and 18 of IC2's socket will turn on transistor TR8, which should cause the output to stop in the low state, with an overall supply current somewhere between 3mA and 4mA.

Low-battery detection can be checked by monitoring pin 3 of IC2's socket whilst gradually lowering the supply voltage. It should be about 0·5V below the supply voltage and fall in step with it down to about 6V, after which further supply voltage reduction should cause a rapid drop to zero.

ENCLOSURE

The prototype is fitted into a 150mm × 80mm × 50mm plastic case. The general layout can be seen in the photographs. It is admittedly a little tight, and was checked carefully with computer graphics before taking drills and files to the case. However, it should not be too difficult to follow this layout from the photos.

The electrode connections are via 4mm sockets, coloured red and black for positive and negative. The l.c.d. display connections are shown in Fig.7. L.E.D.s D2 to D5



Completed unit showing the display module mounted in the base (now the front panel) of the case and the p.c.b. on the lid.

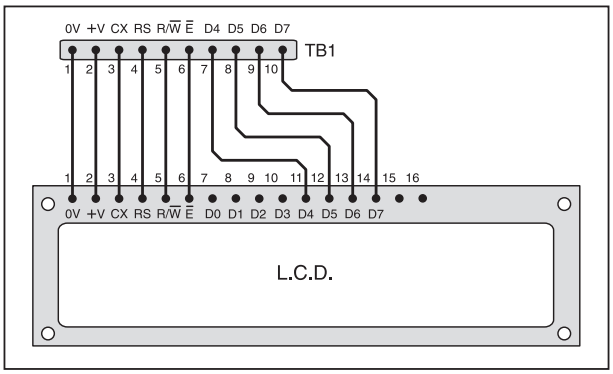
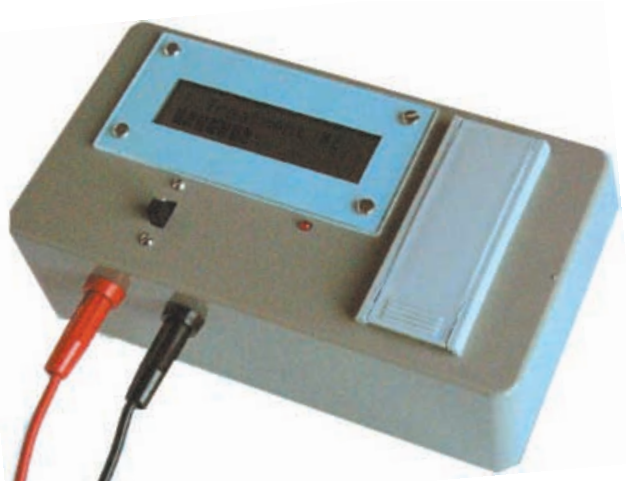


Fig.7. Connection details for the l.c.d.

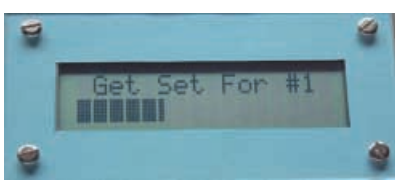


are shown as being fitted to the p.c.b. but in practice will normally be fitted to the case and connected to the board via short leads. If the l.c.d. is fitted, D3 and D4 should be omitted.

The high-brightness l.e.d. D2 is optional. It flashes with the audio signals and, with the l.c.d. program, during a 30-second period to tell the user to connect up for a treatment. It is really an attention grabber for those who prefer not to use audio indication.

FINAL CHECKS

After assembly into the case, it is just a matter of inserting IC2 and carrying out a final operational check. Assuming the l.c.d. is fitted, it will probably be necessary to adjust VR1 for the best contrast.



First switch-on display.

Following switch-on the unit should display a welcome message for five seconds, followed by a beep and the message "Get Set For #1" on the top line with a bargraph taking thirty seconds to fill the lower line. This is primarily intended to allow users who prefer the traditional copper electrodes to moisten these and grasp them firmly.

There should then be another beep and the message "Treatment #1", should appear with a bargraph taking seven minutes to complete. Another beep should then accompany a display of "Intermission 1" with a 28 minute bargraph. This should be followed by two more "Get Set" and "Treatment" sessions separated by a second intermission, all appropriately numbered so that the user can see the point reached by the sequence.

Commence treatment display.

At the end of the session the messages "Session Complete" and "Please Turn Off!" should be shown whilst the unit beeps plaintively to remind the user to switch off.

First "rest period" display.

The l.e.d. sequence is similar, save that the point reached cannot be so clearly displayed. The yellow l.e.d. D3 flashes for thirty seconds as a "Get Set" indication, then stays on for seven minutes for the treatment.

The 28 minute intermissions are indicated by flashing green l.e.d. D4. The yellow l.e.d. D3 gives single flashes for the first "Get Set", groups of two flashes for the second and groups of three for the last, to give some idea of the progress of the session. When the session is complete all three l.e.d.s D3 to D5 flash, with audio beeps from sounder WD1 at intervals of about seven seconds.

RESOURCES

The software for this design is available from the *EPE PCB Service* on 3·5-inch disk, for which a small handling charge applies. It is also available for *free* download via our website home page, accessible via **www.epemag.wimborne.co.uk**. It is in folder path ***PICs/ZapperMk2***.

The software source code was written in a variant of TASM using *Toolkit TK3*, through which it may also be translated to MPASM grammar. The hex file is supplied in MPASM format.

Read this month's *Shoptalk* page for details about purchasing preprogrammed PICs and other components for this project,

ELECTRODES

The electrodes of the original *EPE Zapper* were made from 22mm copper pipe. For readers who would like to use these, the construction is shown in Fig.8. However, the author's experience suggests that self-adhesive gel electrodes work just as well, and commercially available zappers increasingly seem to use these. Suitable types can be obtained from suppliers of TENS pain relief devices. Ones

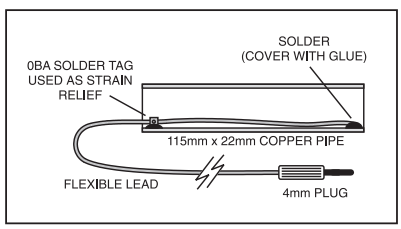


Fig.8. Suggested electrode construction.

having an area of more than a square inch (6·5 sq cms) should be suitable.

Since the original design called for a copper electrode to be held in each hand, the author places adhesive ones on the insides of the wrists where good contact is easily made. Unlike many bio-medical devices, Zappers are claimed to work best with unidirectional pulses, though nobody is saying whether the positive should be applied to the right hand or the left! The output sockets are coloured red and black and constructors should feel free to experiment!

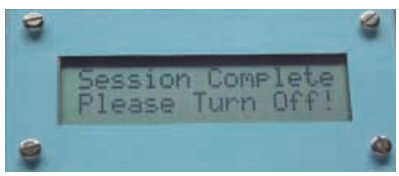
MEDICAL CONSIDERATIONS

Generally it is impossible to feel the pulses generated by this Zapper, which operates at only 9V, unlike TENS units where the user is generally instructed to increase the voltage until a marked tingling sensation is felt.

However, the author is aware of two instances with the previous design where users have experienced a burning sensation. In one instance the user persevered anyway, subsequently reporting that the effect diminished with repeated use and was no longer a problem.

Like all bio-electronic devices, this zapper MUST NOT be used by anyone with a heart pacemaker, or by expectant mothers, at least not before taking qualified medical advice concerning safety. If any side effects are experienced, immediately stop using the zapper. Please read the *Electrotherapy* article in this issue before using this device.

Reports from constructors on the results, or lack of same, achieved through zapping will be most welcome. □



READOUT

Email: john.becker@wimborne.co.uk

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

All letters quoted here have previously been replied to directly.

WIN AN ATLAS LCR ANALYSER WORTH £79

An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd., will be awarded to the author of the *Letter Of The Month* each month.

The Atlas LCR automatically measures inductance from 1μH to 10H, capacitance from 1pF to 10,000μF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%.

★ LETTER OF THE MONTH ★

SOLAR UV DETECTION

Dear EPE,

In the Nov '03 *Readout* you queried a source for UV sensors. I am an analytical chemist rather than an electronics engineer but earlier this year I had occasion to make a portable solar UV meter and bought a sensor and 2-channel amplifier board from SP3 Plus in Tunbridge Wells, Kent (01892 615726 or email **info@sp3plus.co.uk**).

The sensor itself was a UVB4 (225-380nm wavelength), price £12.40 and the amplifier board, based on a Burr Brown OPA128, cost £39.70. Both are in fact manufactured by TWLUX of Berlin (**www.twlux.de**). I found other suppliers on the internet by searching on "UV sensors".

The price of these items is probably more than hobbists would like, but then there is not much call for UV detection in the hobby market other than for measuring sunburn potential.

The device was completed by taking the output from the amp (up to about 1·7V in the midday sun this summer) and displaying on a stripped out multimeter hardwired to the 20V range. Maplin were offering two of these multimeters for £4.99; I couldn't make a cheaper display myself. The range could have been hardwired to 2V had I known, but the amplifier output was specified at 4V max and the sunshine of other countries might provide more UV, so it was not worth the effort to re-solder from 20V.

The only "inelegant" part of the construction was the need to use three PP9 batteries. Two are used back-to-back to provide ±9V for the amp, and one is used for the multimeter. Everything is housed in a plastic case (15cm × 9cm × 5·5cm) and there is an on/off switch to activate the multimeter and amplifier.

The real problem is calibration of the voltage output to a simple usable scale of solar UV levels – because there isn't one. The solar UV index (**www.met-office.gov.uk/weather/uv/uv_uk.html**) has too many variables. It depends on latitude, altitude, cloud cover, whether you are light skinned or dark, have freckles and so on. What you can't do is look at the output and allow yourself say 30 minutes in this level of sunshine, and this will be a problem for anybody incorporating a UV monitor into your *PIC Met Office* (Aug/Sep '03). Eventually I devised the following (very) empirical scale by daily monitoring: 0·0V to 0·3V, very low UV; 0·3V to 0·6V, low; 0·6V to 1·0V, moderate; 1·0V to 1·4V, high; above 1·4V, very high.

However, the UV meter is very usable. I amused many of my friends by demonstrating the effectiveness of their sunglasses, double-glazing and sun lotion (smeared on cellophane).

If anybody is interested in low cost monitoring of solar UV they might also like to look at the following web sites for additional information

www.uvtechnology.com/function.html – offering a credit card sized UV meter powered by sunlight and costing $20 (US).

http://store.sundancesolar.com/enbeaduvsenb.html – showing the chemical alternative to measuring UV using photochromic crystals.

Norman Dyson, via email

Thanks very much Norman – I wish I had known this when I did Met Office!

ER AND THE BOMB!

Dear EPE,

Referring to your *Earth Resistivity Logger* (Apr/May '03), do you think that the probes could be used underwater? I know that they have to be insulated but maybe a new type of probe could be fabricated that would only come in contact with the earth below the bottom where it wouldn't be so wet.

My reason for asking is that there is a lost H-Bomb (for real) in the ocean or shallow marsh at Tybee Island, Georgia, USA. Refer to **www.tybeebomb.com** for particulars. I am presently in contact with the local government to see if they wish to search for this lost bomb and maybe there would be an application for your Logger if it could be used under water.

Dick Gurske, via email

Goodness, Dick, the problems of trying to use my ER in this way are too complex for me to wish to even try to answer! Anyway, in reality, I think that ER is not the best way to detect an H-bomb! A magnetometer or ground-scan radar might provide a better and faster answer. You also need a Geiger counter I reckon (and an up-to-date Will)!

All the best, take care – real good care . . .

BBC BASIC FOR WINDOWS

Dear EPE,

I am an avid reader of the magazine and teach Systems and Control using mainly the Picaxe system of PIC microcontrollers. I have read several of the articles published on the PC serial port and being an owner of VB6 professional I have access to the MSCOMM32 facilities described. Consequently, I needed something the students at school could use without copyright problems or the need for a network version of VB6 (expensive). I found that R.T. Russell's version of BBC BASIC for WINDOWS even in its demo form to be just the ticket, see **www.rtrussell.co.uk**.

It has simple to use routines for reading the serial port and, as all BBC BASIC lovers will know, the language is powerful and logical to use with great help facilities. It is much easier I believe than QBasic and he has enhanced it in line with the Windows environment. Registration is not that expensive either. Couple this with the Picaxe 28X sertxd command, which allows programming and serial data transfer down the same lead, it really becomes simple to plot graphs of sensors such as thermistors or l.d.r.s for lab use and data logging. Well done Mr Russell.

Pete Jensen, Hull, via email

Thanks Pete, that sounds useful.

DIY MICROCOMPUTER

Dear EPE,

Would you be planning any articles/series on constructing a microcomputer using a PIC? I'm building a small net appliance (**www.picoweb.net/download/pwbbsch1.pdf**) and would like to do it with a PIC. Might be fun! The OS and basic programming code software for the **picoweb** server are free, as is the schematic, etc.

It would be great if *EPE* designed some serial-port sensor devices to connect to the microPC. The sensor/human/machine interface is HTML, and thus to access the sensor info is a pretty simple operation. Just about everyone has a book or experience with writing HTML, and it's available around the world.

I was also thinking about a camera connection (also available as an add-on device, via the Net for about US$55 or less) and placing it in a cave to obtain pictures of wildlife; maybe in the yard as an intrusion detector with camera; a vacation camera via the net, etc. Lots of different things and novel ideas occur.

Also, with a microPC available as a backdrop, maybe readers and enthusiasts would open a new field of endeavour and spark interest in combining and/or adapting the regular *EPE* projects to microPC use? I see this as a way to possibly engage a new engineering client in electronics and project building. Maybe even a page devoted to microPC development, based on a PIC, or Atmel AVR, and *EPE* sensor devices?

I also see that with some work, maybe by some magazine enthusiasts, a true programming language can develop and it could be the foundation of a new field of microPC interface/sensor programming. Great possibilities abound, and a new field for *EPE*.

David R Mynatt, Austin, Texas

Interesting concepts Dave, but no we haven't any plans on this and somehow suspect that it might be too complicated for any of us regular PIC addicts to want to undertake. Although the circuit could be simple, it's the software that would be a major undertaking. I'm also not sure that everyone has "experience with writing HTML".

And I can't help but feel that introducing yet another language into this Babel-filled world might just muddy the waters even further. Readers – your thoughts please!

COOL RECEPTION?

Dear EPE,

The trouble with *EPE* is I have to raid the Winter Fuel Allowance time and time again, and this is because of Raymond Haigh's wonderful, immaculate radio constructional projects.

I am one of the fortunate ones with a full set of Denco coils, and at 80 plus a bit I still get as excited when I pick up a signal from the back of beyond on a set I made in the 1970s as I did in 1938 with a crystal set.

It's going to be a long, cold winter, must get out the thermals, and the soldering iron!

Peter McBeath, Morpeth, Northumberland

So we'd better hope for a warm winter in Morpeth, then, Peter! Of course, as you imply, you will have the benefit of the warmth of your soldering iron to huddle round. Glad to know you recognise what the priorities are!

KINDLY FAREWELL

Dear EPE,

It is with some regret that I have decided not to continue my subscription to *EPE*, and am aware that my current subscription ended with the October issue.

This has not been an easy decision to make, but as I haven't actually used the magazine for some time, I cannot really justify the cost. I fully realize that I shall be missing out on my main hobby, but I can always keep in touch by buying the odd copy now and again from my local newsstand. My main interest is still electronics, but I now have much more expensive tastes, and I haven't really constructed anything for a long time. I did buy the boards for the *UFO Detector* (Jan '01), but never constructed the project. Who knows, I still may do this one day (if I can still find the boards)!

I wonder how many other readers can boast of their commitment as I can! I have taken every single copy of *EPE*, since it started as *Everyday Electronics* with the November 1971 issue, priced at just 17·5p! The main feature in this issue was a record player. I didn't build it, but I did build the amplifier, and used it for something else! I also took every copy of *Practical Electronics* which started, I seem to recall around 1964 (*Nov '64 was first cover date, Ed*) until *EE* incorporated it, and hence became *EPE*. Then there was *ETI*, and *Hobby Electronics*, neither of which I took regularly, but nevertheless bought sufficient issues of both magazines. I also took *Practical Wireless* for a time when I started work in 1961.

So now, as I approach 60, I am leaving this all behind, but maintain a wealth of electronic knowledge, that I not only use as my hobby, but is extended to my work, as a cinema technician of over 40 years. I wish to thank you for a really excellent magazine, and hope that you continue to prosper with it. It is sad that I have decided to discontinue my subscription, but as I have said, I shall continue to buy an odd copy or two, from time to time.

I thank you for listening to me, and wish *EPE* every continued success.

Norman Buxton, a very satisfied reader,
Ipswich

What can one say? Farewell and thanks Norman.

ECG TRACES

Dear EPE,

Regarding the *Readout* letter *Biopic Upgrade* in the October issue, the standard ECG trace for one normal heartbeat is described as the PQRST waveform. Broken down into stages, the P-wave is a tiny "blip" above baseline and is all that shows when the top chambers of the heart contract. These are the cisterns that fill with blood between beats and, when full, "flush" (like a loo cistern!) to fill the ventricles. The ventricles thus receive their fill of blood all at once and can then squirt it at adequate pressure into the arteries.

When the ventricle contracts, the ionic charge around the cell membrane depolarises. This action produces a small peak below baseline (Q-wave), a large peak above (R) followed by a small peak below (S). The QRS complex is thus the orderly contraction of the ventricles, after which the trace momentarily returns to baseline. Next, closely following, is the small T-wave, another blip above baseline, where the ventricular muscle membrane repolarises and the muscle relaxes ready for the next beat.

In answer to your question, ST displacement is where the brief gap between the QRS complex and the T-wave does not fall back to baseline, a condition which is related to the adequacy of the blood supply.

Of course I've oversimplified. The exact shape, even the direction of deflection from baseline, depends on the precise placing of the electrodes. For diagnostic purposes, precise, repeatable and standardised surface anatomical landmarks are chosen. Different combinations of electrodes give rise to different shaped traces, almost as if viewing the heart from different angles.

Interesting as the waveforms may be to electronics enthusiasts, though, the message is do NOT attempt to make any deductions about health, or lack of it, using amateur-grade equipment. You are experimenting with the equipment, not the person attached to it!

Dr. Godfrey Manning, BSc, MB, BS

Thank you Godfrey. And yes, d.i.y. projects such as Biopic *I always try to emphasise are not for use in true health diagnostic situations. Many years back I worked for a while with a medical equipment company, repairing their heart defibrilators and monitors etc, and that was a real eyeopener into all sorts of heart related monitoring situations and for which I would never presume to try to emulate through* EPE. *But* Biopic *I felt had a basic interest value.*

PORTABLE PROGRAMMER, PLUS SERVOS

Dear EPE,

I see the portable PIC programmer has been mentioned again, in the August '03 *Readout*. Having built several different PIC programmers myself (including one powered by the USB port so I can use it from my laptop with very little extra hassle), I considered this as a project before I saw it mentioned in *EPE*. I felt that there were some quite simple solutions that could be implemented, possibly even on an 8-pin PIC. I did not, however, pursue the design since I would have very little use for it myself. Is there any interest?

I also note you enquire whether anyone could be encouraged to do an R/C servo project (the one mentioned by Gareth Evans (same *Readout*) seems quite plausible). I am currently working on a project that is based around R/C servos and controlled by PICs. This has several elements that are of a similar nature and therefore would not require much adaptation to follow his design brief. I would be happy to investigate this project further if there is any interest in it.

Tom Bennellick,
via email

Thanks Tom. Regrettably there has been little response and at present I would not feel justified in doing a portable programmer. Regarding R/C servos, as I said to you in private email, why not send Editor Mike an outline of your idea, with a proposed circuit and see what he thinks, he might be interested.

The latter comment applies to anyone with an idea they think might interest us – send Mike a brief outline complete with a rough circuit diagram for his consideration.

FREE SPICE

Dear EPE,

Regarding your *Circuit Surgery* Sep/Oct '03 discussions about SPICE, you seem to be biassed towards commercial products, for which the free versions are limited in functionality. If you follow the news groups **sci.electronics.cad** (a great resource for SPICE users), you will have heard about LTspice, also known as SwitcherCAD III. LTspice is absolutely free from the Linear Technology web site **www.linear.com/software/**.

This is the internal tool used by all Linear Tech staff, and has been free for years – over 100,000 people have downloaded it. A complete re-write of the standard SPICE code, it is reputedly faster and more accurate than any other spice, and is actively maintained (for free) by Linear staff who regularly contribute and answer questions on the news groups. LTspice also runs most if not all the PSpice and other models available. An easy to use Windows program, it also runs under Win on Linux.

Why pay, when in the opinion of many, the best (by far) is free!

Another thing that you might be interested in, if you haven't seen it before, is the Ant logic analyser from **www.rockylogic.com**. I have an Ant8, and it's wonderful (price, size and spec), absolutely perfect for PIC/Atmel/General μP work. I carry mine with my laptop all the time. The company is in Felixstowe, a town known more for its haddock than high tech (groan, did I really just type that . . .).

I have no connection with LT or Rockylogic, other than as a very happy customer.

Nick de Smith,
via email

Useful comments, Nick, thank you, and which I sent on to the co-authors of Circuit Surgery.

But what's wrong with haddock? It's become part of this PIC addict's staple diet since some fish shops no longer stock cod on ecological grounds!

P.C.B. CAD

Dear EPE,

In the April 2003 issue Malc Wiles was telling a tale of woe and asking for a possible review of p.c.b. CAD programs. Well, I have been using a CAD package for quite a while now and have just bought the latest release as it not very expensive and has most of the features that Malc and many other readers would require.

The program is called Sprint Layout from Abacom in Germany, currently in release 4.0. It is very intuitive to use and has some excellent features for laying out p.c.b.s, creating and saving your own symbols is a snip. Ok so it doesn't have schematic capture or a fully featured autorouter but it has a neat feature that if you have a scanner you can scan a p.c.b. image in from a magazine which appears in the background and allows you to overlay lay it with proper tracks and pads.

Printing features allow the tiling of the p.c.b. layout, moving it to any position on the paper etc. The cost is about 39 Euros (£24). The website at **www.abacom-online.de** is in English and German. Demos are available.

In *Net Work* May 2002 issue, Alan Winstanley reviewed Lochmaster 2.0, a stripboard design package and Front Designer 2.0 from the same company. Lochmaster is now at release 3.0, and there are many more electronic software packages available from them.

I have no connection to the above company other than as a satisfied customer, both with the product and with the service.

Richard Lengkeith,
via email

Thanks for the useful comments Richard. Naturally I must remain impartial as excellent p.c.b. CAD packages are available from some of our advertisers. Anyone looking for such packages is recommended to obtain the demo versions and try them all.

WANTED!

Recently found on our Chat Zone:

A reward is offered for information leading to the arrest of Eddy Current, charged with the induction of an 18-year-old coil named Milly Henry, found induced, half choked, and robbed of valuable joules. This unrectified criminal, armed with a ferrite rod, escaped from Western Primary Cell where he had been clapped in ions since last Faraday. With the erg to be free, his escape was carefully planned in three phases.

First he fused the electrolytes, then he climbed through a grid, despite the impedance of the warders whose reactance was slow. Finally he went to earth in a magnetic field. What seems most likely is that he stole an AC motor, this is of low capacity, and he is expected to try and change it for a megacycle, and return by a short circuit to ohm. He may be a potential killer and offer serious resistance.

A.C. Maynes-Humm,
via the Chat Zone

Hmmm . . . seems to me A.C. that there's something unstable in your output which should be probed by a systems analyst with full scope for tracing the source of the base humour you are emitting . . .

BLOWN BULBS

Dear EPE,

Having read the Nov '03 *Circuit Surgery* concerning vehicle blown bulb detection, I can't help feeling it suffers from the sledgehammer to crack a nut syndrome.

There is a simple way to detect blown bulbs: as well as bad earths, contacts and similar faults that cause reduced current through the bulb – who hasn't been behind a caravan or trailer whose brake lamps dim and flash in time with the indicators?

All you need is a glass type reed switch and some enamel covered wire. You wrap a coil of the enamelled wire around the reed switch and pass the bulb current through it. When the lamp is on, the magnetic flux caused by the current passing through the coil will cause the reed switch to close. Any significant reduction in the circuit current flow will allow the switch to open.

The reed switch can be simply connected to a small indicator lamp or l.e.d. circuit to display its status. Because the magnetic flux needed to close the switch is proportional to the current flowing though it multiplied by the number of turns in the coil, the only adjustment is to get the number of turns in the coil surrounding the reed switch correct, so that it just closes reliably for the current required by the wattage of the bulb in question.

To do this all you need to do is to connect the bulb to a suitable 12V supply via the coil (use a fuse!), a multimeter set to a resistance range connected across the reed switch, and a little time to experiment. Wind turns of wire around the reed switch until switching on the current to the lamp just closes the reed switch (meter resistance goes low). Add another few turns, say 5% and you're done.

For other bulb wattages you will need different turns of wire – fewer for a large wattage bulb, more for a small one. You can use the first experiment as a guide. For instance, if your initial experiment used a 20W bulb and needed 10 turns, a 10W one will need about 20 turns and a 40W will need about five.

As mentioned, this device will also detect reduced current through the lamps due to a faulty earth etc. As soon as the current falls to about 70% of the correct value the reed switch will open. This depends to some extent, though, on the particular reed switch used.

A quick safety note: DO use wires of an adequate current rating for the coil – it will carry the full current of the lamp. DON'T wind thick wire directly on the reed switch – it will break – use a suitable former. Do use sensible construction techniques that won't lead to shorts etc.

Sorry, no PICs, op-amps, low- or high-side drivers, etc., here, but then again, no gain calculations, open loop stability, common mode or standby current problems either. Voltage drop across the coil is insignificant. It's simple, cheap (sorry, *low cost*) and it works!

I make no claims for originality – first saw this one in a magazine article umpteen years ago.

David Palmer, Chessington, via email

Thank you David, a seemingly simple alternative surgical approach!

PIC-ING UP TRAFFICMASTER

Dear EPE,

Some years ago, both the RAC and the AA did a small battery powered device that detected the Trafficmaster signals on motorways and major roads, and gave a simple l.e.d. based signal of any hold-ups.

More recently Vodafone produced a unit (I have one and I am pleased with it). It is a bit more sophisticated as it uses a single digit dot matrix l.e.d. display and three discrete l.e.d.s. I was going to buy a unit for my two sons last Christmas, but the units are no longer available.

The only technical information I can find on the Web is at **www.gadgets.demon.co.uk**. This seems to describe the new system that uses 153·2750MHz (FSK). I think the original system was on UHF not VHF. Each beacon transmits a short message indicating the direction of any hold-up and whether it's a short or long delay.

I wonder if *EPE* could publish a d.i.y. version of the original unit?

Ken Horton, via email

It's not something I could take on, Ken, and I don't know if Trafficmaster still outputs such signals. Perhaps your letter might prompt a reader to look into it and offer us one if feasible.

DATA LOGGING

Dear EPE,

I needed to monitor the charge on a lithium battery the other day and could have done with a data logger. I had a look at your excellent 8-channel version (Aug/Sep '99), but thought it was a bit too beefy for the job. You don't have any simpler (and smaller) designs in the pipeline do you? Ideally, what I'd like to see is a portable standalone logger that is programmed via the RS232 then disconnected to do its job. Once the data has been captured, it is then squirted back into the PC via the RS232 again.

If not, looks like I'll have to find the time to lash up a MAX187 ADC, PIC16C84 and a couple of serial EEPROMs!

John Scott Paterson, Newcastle, via email

No John, I've not done anything simpler, but am using variants of that Logger's software in other more sophisticated designs, e.g. Met Office, Earth Resistivity *etc. Ignore the PIC16x84 if you attempt to make your own (the C84 version is obsolete anyway). The PIC16F87x family is far better suited, having its own ADC, plus serial chip interface options.*

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Constructional Project

CHRISTMAS CHEEKS

THOMAS SCARBOROUGH

A Christmas project with a difference. Instead of enhancing your festive decorations, it is designed to enhance . . . you!

WITH recent advances in semiconductor technology, the maximum luminous intensity of red l.e.d.s has increased to several candelas. Now consider that human flesh is translucent to red light. Combine these two facts, and we have the basis for the present project. The average cheek has a thickness between one and two centimetres, and this makes it possible to "backlight" a cheek from the gums with a high intensity l.e.d., causing it to glow in the subdued light of a Christmas party or disco etc.

The slimline circuit featured here is slipped between the gums and cheek, and is activated by the presence of saliva. Afterwards, when it is removed and cleaned-up, its current consumption drops to practically zero. Therefore, the circuit could likely be used for years in a row without battery replacement.

CIRCUIT DESCRIPTION

The full circuit diagram for the Christmas Cheeks is shown in Fig.1. It incorporates two main building blocks – a solid-state switch, and a timer for pulsing l.e.d. D1.

Since it would be difficult to include an on-off switch in any circuit which is exposed to saliva, a solid-state switch in the form of transistor TR1 is employed. This switches on the circuit only when it is placed in the mouth.

About one-third of a milliamp flows across the "switch", and this may be experienced as a slightly metallic taste on the tongue. This flows across the base-emitter junction of TR1, causing TR1 to conduct.

With the choice of a BC107B transistor as the solid-state switch, collector current is limited to roughly 16mA. This limits total power consumption to about 50mW, which suits the maximum output of the astable oscillator IC1, as well as the maximum power dissipation rating of modern high intensity l.e.d.s.

The l.e.d. D1 should have a minimum power dissipation rating of 50mW – alternatively, replace IC1 with the bipolar NE555N i.c., in which case a 30mW rating will be adequate. Note that not all l.e.d.s live up to their luminous intensity ratings, and it may be best to test D1 before employing it.

Capacitor C1 charges through resistors R1 and R2, and discharges through R1 alone. With equal values for R1 and R2, this provides a duty cycle of about one-third for l.e.d. D1, with the rising and falling voltage at the trigger and threshold inputs (pin 2 and pin 6) of IC1 causing

COMPONENTS

See SHOP TALK page

Resistors

R1, R2	47k 0·125W 5% carbon film (2 off)

Capacitors

C1	47μ miniature axial elect. 10V

Semiconductors

D1	High intensity red l.e.d., approx. 1cd and 30° viewing angle
TR1	BC107B *npn* bipolar transistor
IC1	7555 CMOS timer

Miscellaneous

B1	3V CR2032V2A, vertical mounting lithium cell, 20mm dia.

Printed circuit board (double-sided) available from the *EPE PCB Service*, code 427; polyester resin and hardener; tissue paper and thread; solder, etc.

Approx. Cost Guidance Only

£6 *excl. batt. & resin*

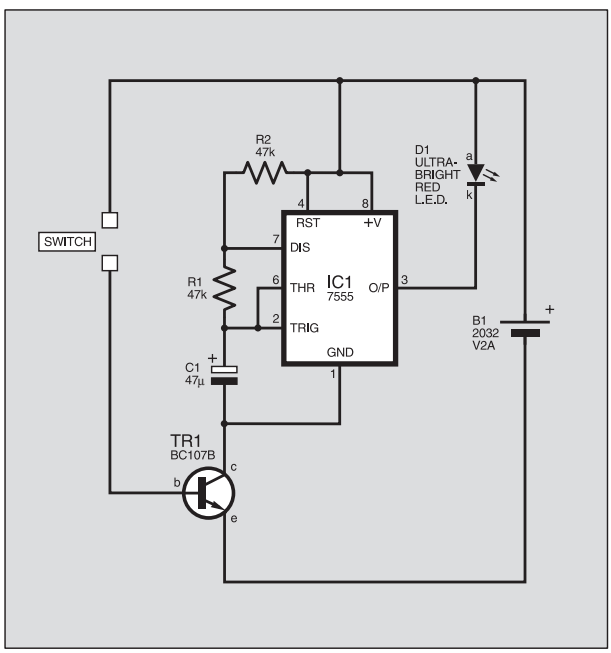


Fig.1. Full circuit diagram of Christmas Cheeks. Note that the l.e.d. should be an ultrabright type.

output pin 3 to switch either "high" or "low". Thus, l.e.d. D1 is "on" for about 1·5 seconds, and "off" for about 3 seconds.

For better control of power through transistor TR1 (to prevent power surges in particular), no supply decoupling capacitor is used. The specified lithium battery is rated 190mAh, which ensures a continuous life of about 12 hours when inserted in the cheek .

CONSTRUCTION

The double-sided printed circuit board (p.c.b.) measures just 23mm × 21mm and is available from the *EPE PCB Service*, code 427. The topside component layout, together with the full-size copper track patterns for the top and underside, are shown in Fig.2.

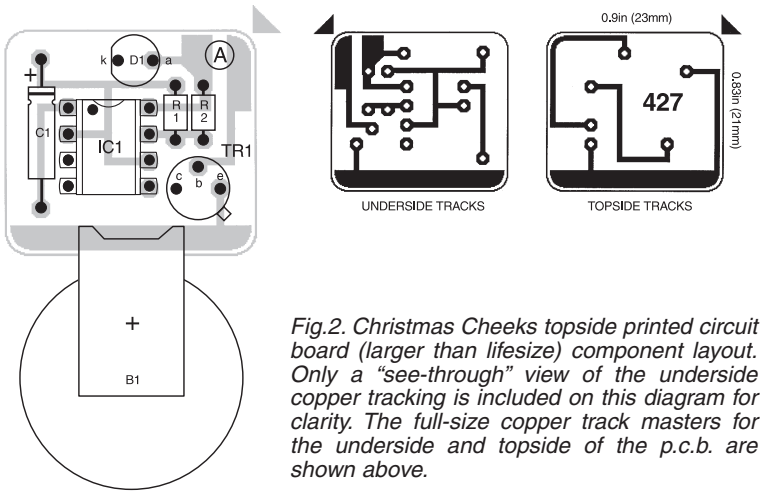


Fig.2. Christmas Cheeks topside printed circuit board (larger than lifesize) component layout. Only a "see-through" view of the underside copper tracking is included on this diagram for clarity. The full-size copper track masters for the underside and topside of the p.c.b. are shown above.

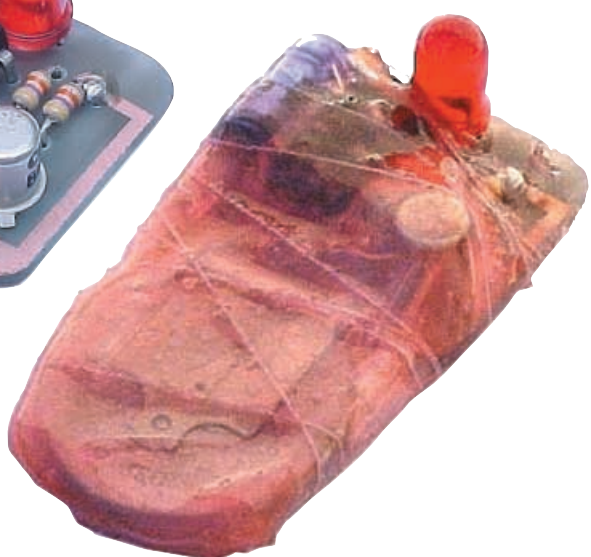
Components mounted on the topside of the completed p.c.b. Note that the junction of IC1 pin 8 and resistor R2 is soldered on both sides of the p.c.b.

A miniature axial electrolytic capacitor is used for C1, so as to keep the p.c.b. flat and easy to insert between gums and cheek. If an axial capacitor should be unavailable, a microminiature radial type may be pressed into service. Miniature 0·125W resitors are employed for R1 and R2. No dual-in-line (d.i.l.) socket is used to mount IC1 on the p.c.b., especially since we intend later to encapsulate the board in polyester resin.

UNCONVENTIONAL

In a break with convention, we need to solder IC1 first, on the topside and underside of the p.c.b., since this is difficult to solder later on. IC1 is a CMOS device, and soldering should be done quickly, to avoid any damage. Also, anti-static precautions should be observed (touch your body to earth before touching the i.c.).

Next, the p.c.b. topside connections of TR1 and D1 may be soldered, observing the correct orientation of D1 (the polarity of high intensity red l.e.d.s may be confusing, therefore orientate D1 only according to the "flat" on the encapsulation, which is the cathode, *k*). The copper track may be soldered as seen in the photographs, and briefly heated to press the components down for a better fit. Then solder the resistors and the remaining leads of D1 and TR1. The junction of IC1 pin 8 and R2 is soldered on both sides of the p.c.b.



(Above) The "mummified" printed circuit board, including the lithium cell battery. (Right) Underside view of the p.c.b. The two large copper areas at the top left-hand corner are the "switch moisture contacts". These pads must not be covered with resin – see text.

Now solder C1, observing the correct orientation, in position. Finally, all leads need to be clipped as short as possible, and even filed flat and smooth after soldering, so as not to aggravate the gums or cheek.

With initial soldering complete, the lithium battery is soldered to the largest and thickest horizontal solder pads on opposite sides of the p.c.b., by means of its vertical mounting pins, keeping its negative terminal flush with the p.c.b. underside. The positive terminal is soldered to the component side of the p.c.b.

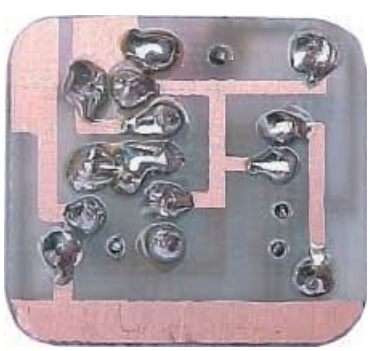
COVER-UP

The completed circuit board, including battery, now needs to be encapsulated in polyester resin. The author dipped the p.c.b. in polyester resin, then wrapped it in tissue paper, tied it with thread, and dipped it a second time in polyester resin, see photograph. Since polyester resin has very low conductivity, this will not draw any significant current from the battery when wet. Check for a conductivity of 1M or greater before using any other sealant.

When dipping the p.c.b. in the resin, hold the board at the corner marked *A* in Fig.2, and submerge all *except* this corner in the resin. This corner may also be covered with sticky tape (Sellotape). Only the two broad copper tracks at point *A* should be left exposed, these being the contact "switch" pads between the positive supply and base connection of TR1, the solid-state switch.

TESTING AND USE

For initial testing, moisten a finger, and hold it across the solid-state switch's contacts (and across the contacts only). Do not short-circuit the contacts, since this could destroy the circuit. After about three seconds, l.e.d. D1 should illuminate, then it should pulse at a slow rate, as indicated earlier.



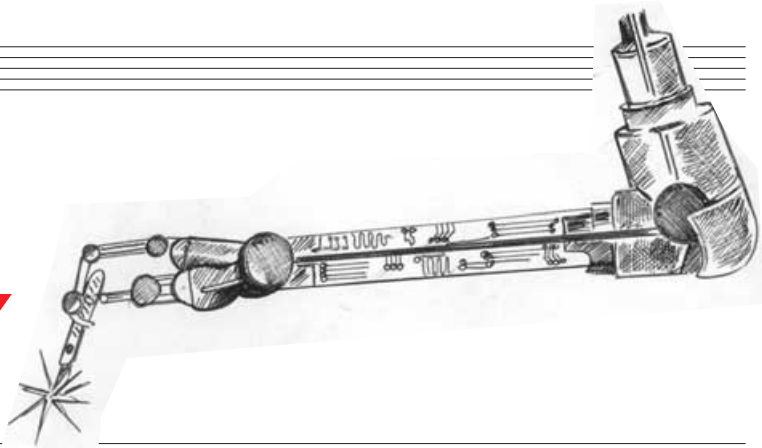
Once the circuit is encased in polyester resin, insert it between gums and cheek, with the battery resting between the bottom gum and cheek. The l.e.d. should rest against the upper gum, facing the cheek.

For added effect, a second unit may be built for the opposite cheek. If desired, a simple brace may be attached to the p.c.b., to make it more stable in the mouth.

The dimensions of Christmas Cheeks are intended for an adult mouth only. Certainly, the circuit is ***NOT*** recommended for youngsters *below 8 years of age*, since this may represent a choking hazard. For a smaller mouth, the circuit may need to be mounted horizontally in the cheek for a comfortable fit. □

Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY and IAN BELL

Continuing our introduction to Spice circuit simulation with a worked example based on a reader's query. We also suggest uses for ultraviolet l.e.d.s.

High-side Current Sensing in Spice

LAST month we started looking at a problem from reader ***R. D. Thompson*** with a circuit that detects failure of a 12V, 2A light bulb, which is required to indicate when the bulb fails to draw any current.

A possible solution uses a small value sense resistor in series with the bulb, in this case choosing 0·1 ohms, which will drop about 200mV (leaving 11·8V for the bulb) and consume only a few milliwatts. The voltage on the sense resistor can be amplified and Mr Thompson tried a circuit for this, which unfortunately did not work as expected.

However, the general approach is valid and is known as *high-side current sensing.* We concluded that one of the problems with the suggested circuit (see Fig.1, page 775 last month) was that the common mode input range of the op.amp used was insufficient for the task. It also used an open-loop op.amp so the gain was far higher than needed. Furthermore, open loop operation makes the op.amp very sensitive to non-idealities such as offsets, which could easily prevent correct operation even with rail-to-rail common mode input.

There was a design error in the circuit schematic given last month, if implemented using an ideal op.amp, the output switches between zero and a large negative voltage. As a real op.amp cannot output voltages that fall outside of its supply voltages, the output would stay at zero. If we swap the op.amp inputs round the circuit would work with an idealised op.amp, but we may not be so lucky using a real device.

LTSpice

To continue with our recent Spice simulation theme, we can illustrate a possible solution to this problem using LTSpice. In this instance we chose LTSpice rather than PSpice because it has a larger number of op.amp models. The PSpice Student Edition download has the μA741, LM324 and LF411, which are not really suited for this application. LTSpice download has over 200 op.amp models though, all of which are, of course, LT devices.

To find the right op.amp we can use the product selector on the LT website (**www.linear.com**). If we specify single supply, 12V operation and rail-to-rail input and output then one device that meets these requirements, that is also available in LTSpice, is the LT1806 (single) or LT1807 (dual) 325MHz, single/dual, rail-to-rail input and output, low distortion, low noise precision op.amp.

Model Approach

As we explained in the Sept. and Oct. '03 *Surgeries* when we introduced Spice, simulating a circuit requires more than just "entering" the schematic. In this month's application we need to include the power supply and we also have to model the bulb in both its normal and broken states.

The power supply is straightforward; we can simply use a 12V voltage source, including an appropriate series resistance (for the supply internal resistance) if we believe that it will significantly impact circuit performance. In this case we will just use a 12V source.

Modelling the bulb is a little trickier. We need to switch the input between the "open circuit" and "bulb on" conditions. When the bulb is on it draws 2A, when there is open circuit zero current is drawn.

We can model this with a pulsed current source, which switches between 2A and 0A. The timing of the pulses is fairly arbitrary; we used a period of 20ms, which is obviously much faster than a real bulb breaking and getting replaced, but is fine for looking at the behaviour of the circuit.

To set this up we add a current source to the schematic, and right click to bring up the setup window, select PULSE and enter the following data. I1=0, I2=2, Tdelay=0·01, Trise=1μ, Tfall=1μ, Ton=0·01, Tperiod=0·02, Ncycles=4.

It is often useful to simulate an idealised version of our circuit. This tells us if our basic concept is correct before progressing to a more realistic simulation. An ideal op.amp can be simulated using a voltage-controlled voltage source, which is an E element in spice.

Ideal Circuit

This is shown in the "ideal" circuit of Fig.1. Note that the E element has been set up entering the text **table=(–1 0, 0 0, 120u 12, 1 12)** in the value field (obtained by right clicking). In general the table is a set of input-output voltage pairs that define the behaviour of the voltage source. Input voltages between the points given in the table produce output voltages linearly extrapolated from the values given.

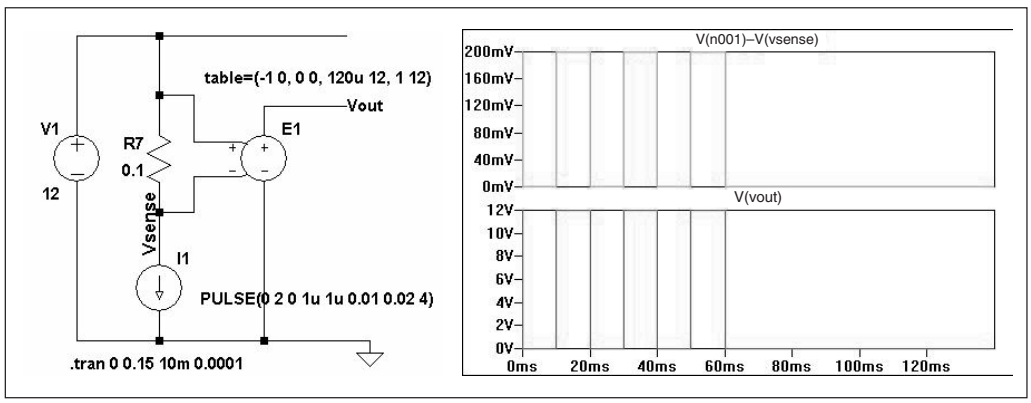


Fig.1. Spice simulation for an "ideal" circuit.

Fig.2. Screen simulation results for the circuit of Fig.1.

The table used here causes the output to saturate at 0V for negative input differences, and for small positive input differences gives the E element a gain of 100,000 until the output saturates at 12V.

The results shown in Fig.2 confirm correct operation of the ideal circuit – it switches its output between 0 and 12V as the current input switches on and off. The input waveform is displayed as the voltage across the sense resistor, obtained by entering the expression V(n001) – V(vsense) in the "Add traces to plot" window.

Note that the supply is named n001 automatically as this particular node was not given a name. You can find the node name by placing the cursor over the wire when editing the schematic.

High-side current monitoring is a fairly demanding task for an op.amp. Non-ideal aspects such as the restricted input range (as we have discussed), and also problems such as offsets, may make it difficult to obtain a satisfactory circuit. There are actually a number of dedicated high-side current monitoring i.c.s which may provide a better solution in some applications.

The reader's circuit implemented with an LT1807 is shown in Fig.3. The results are shown in Fig. 4 and indicate that the circuit does not really function as required.

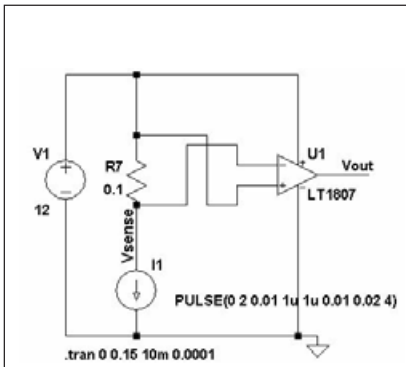


Fig.3. Circuit diagram for reader's circuit using an LT1807 op.amp.

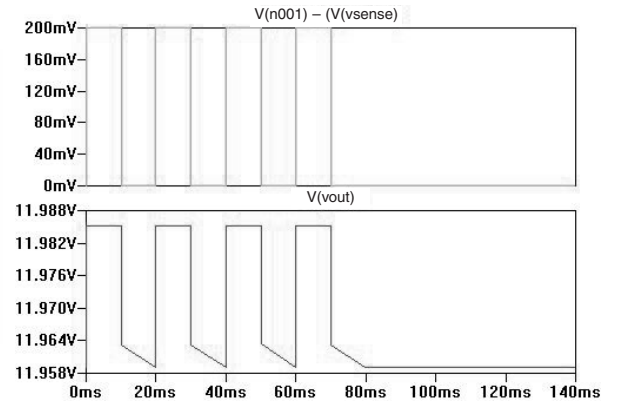


Fig.4. Simulation results from Fig.3. Response not as required.

Difference of Opinion

It seems that we need a different circuit, one in which the op.amp is used as a *closed loop* amplifier. As we mentioned last month our requirement is for a differential amplifier with a gain of about 60. We can achieve this using a standard op.amp differential amplifier configuration.

However, as we are using a single supply we need to create a virtual ground at half the supply voltage. We can do this using a resistor divider with a decoupling capacitor. We have discussed single supply op.amp circuits in more detail in previous columns.

A suggested circuit is shown in Fig.5 and the simulation results in Fig. 6.

The gain of the circuit is 100/3·3, about 30, so a 200mV input just takes the op.amp into positive saturation (6V swing from virtual ground). Thus, the output switches from around 6V (the virtual ground reference point) to 12V as the input switches. In this circuit we could reverse the connections to the sense resistor (via R3 and R4), which would result in an output that switched between 0V and 6V.

If a 0V to 12V output was required we could add a comparator connected to Vout. The comparator threshold would set the low current threshold for open circuit detection. We could also use the same circuit to detect currents above a particular threshold, or use a window comparator to check that the current was within an acceptable range. To change the sensitivity of the circuit we could change the gain or the sense resistor value.

Hopefully readers can now see the benefits of being able to simulate circuits in a package such as PSpice or LTSpice and how it enables circuits to be developed with less of the trial and error of using physical components and building prototypes. *I.M.B.*

Ultraviolet L.E.D.s Stand Out

There was an interesting new arrival in *Circuit Surgery* recently in the shape of ultraviolet light-emitting diodes. They are encapsulated in glass-clear packages and produce visible lilac-coloured light when illuminated. Their wavelength is typically 410 nanometres. However, their UV intensity soon becomes apparent when used in e.g. a darkened room. I found that the UV l.e.d. would –

- make any fluorescent material glow vividly;
- make white objects shine brightly (shades of 1980s discos, white suits and UV lighting!);
- cause luminous paint (e.g. wristwatches) to "excite" very strongly.

These devices might find applications in backlighting, decorative lighting or in instrumentation, as well as in novelty decorations.

A Stabilo Boss Luminator highlighter pen (e.g. from Staples office supplies) contains liquid ink and can be used to draw designs in fluorescent colours. These really do "jump out" when UV-excited! Or consider decorating a child's bedroom ceiling with luminous stars – they can be made to flash or flicker when UV light is shone onto them. (Luminous powder was spotted for sale on Ebay recently, or you can buy luminous paint from some DIY stores.)

The sample UV l.e.d. device has a forward voltage of about 4V but has a quite low forward current of only 10mA maximum. One source is Maplin (**www.maplin.co.uk**) who list a 5mm type, code N74AJ price £2.99. *A.R.W.*

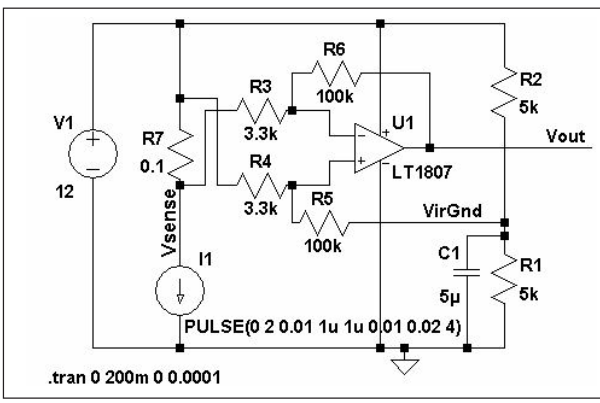


Fig.5. Circuit using a differential amplifier for high-side current sensing.

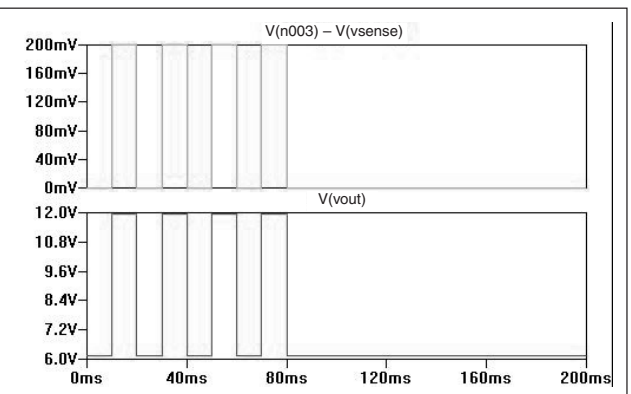


Fig.6. Spice simulation results for the circuit of Fig.5.

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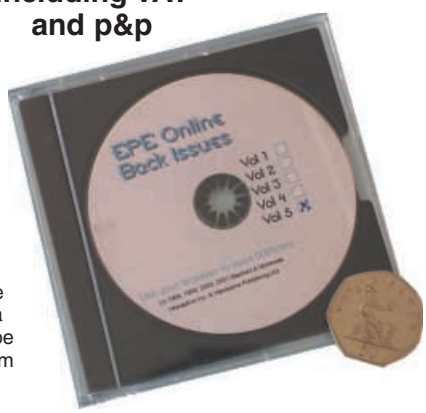

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INTERFACE

Robert Penfold

DIRECT INPOUT32.DLL CONTROL OF THE PC SERIAL PORTS

THE previous *Interface* article covered using the new version of **inpout32.dll** with the PC serial ports. Unlike its predecessor, the new version of this Visual BASIC add-on works just as well with Windows NT/2000/XP as it does with Windows 95/98/ME.

It is not restricted to use with the printer ports, and it enables any port in the I/O map to be directly accessed from Visual BASIC. These days there is little else in the I/O map that can be usefully accessed, but direct control of the serial ports is possible and is sometimes the easiest way of doing things. Direct control of the PC serial ports was covered in a previous *Interface* article, but as this was published several years ago it is worth taking another look at this subject.

Highs and Lows

There are Visual BASIC add-ons specifically for accessing the serial ports, and these have also been covered in previous *Interface* articles and elsewhere in *EPE*. In some circumstances one of these add-ons might be better than using direct access.

To some extent it is a matter of personal preference. If you are happy to work directly with the registers of the UARTs and forgo any high-level support from Visual BASIC, direct control of the serial ports will often be the best approach.

Those having no experience of low-level programming of computer hardware will probably prefer to use MSCOMM and the like. It has to be pointed out though, that high-level support for the serial ports is normally in a form that is less than ideal for use with most do-it-yourself add-ons.

With your own add-ons it is often byte by byte communications that is needed, whereas the serial port support tends to be aimed at file or text transfers. MSCOMM and similar aids can be used with your own add-on gadgets, but as explained in previous *Interface* articles, there are a few unnecessary complications.

In fairness, there are clearly some advantages in the high-level support that these add-ons provide. For example, things like setting the word format and baud rate are much easier.

Taking Control

At its most fundamental level direct control of the serial ports just involves writing transmission data to the appropriate address. The baud rate and word format are handled via the operating system, where the appropriate default values are set. At the other extreme the baud rate and word format are set by writing to the control registers in the serial chip, and the status registers are used to regulate the flow of data into and out of the chip.

The serial chip used in the original PCs was the 8250, but in recent PCs it is more usually a chip from the 16550 family. Actually, in a modern PC the serial interfaces are provided by one of the support chips. However, this will include circuitry that is functionally the same as a device from the 16550 family.

The manual for the PC's motherboard should indicate which chip is being mimicked by the support chips, but it does not really matter which "virtual" chip is used. The main control registers are exactly the same for 8250 and all versions of the 16550. The differences are in some of the more obscure functions, and are usually of no practical consequence.

Serial ports one and two (COM1 and COM2) are normally at base addresses &H3F8 and &H2F8 respectively. These are the addresses that are used when reading and writing data. The seven addresses above each base address are used for reading status information and writing to the control registers.

The following is a full list of the registers:

Address	R/W	Register	DLAB
Base	Read	Received data	0
Base	Write	Data for 0 transmission	
Base	R/W	Clock divider latch (LSB)	1
Base + 1	R/W	Clock divider latch (MSB)	1
Base + 1	Write	Interrupt enable	0
Base + 2	Read	Interrupt identification	
Base + 3	R/W	Line control	
Base + 4	R/W	Modem control	
Base + 5	Read	Line status	
Base + 6	Read	Modem status	
Base + 7	–	Reserved	

Baud Rate

As is so often the case with computer chips, the functions of the registers are something less than completely straightforward. The base address has three functions and the address above this has two different functions. This is made possible by having a control bit that is used to switch these addresses between two modes.

The control bit is at bit seven of the line control register, and it is called the divisor latch access bit (DLAB). With this bit set at 0, which seems to be its default state, the base address is used for reading and writing data, and the one above is the interrupt enable register.

With DLAB set at one, the base address and the one above are used for the clock divider latch. This operates in the standard serial interface fashion. A clock signal is fed to the UART via a divide by "N" circuit. The two bytes in the divider latch are combined to form a 16-bit value, and the clock signal is divided by this amount.

A wide range of baud rates can be set with good accuracy by writing the appropriate value to the clock divider latch. The UART's clock frequency is at 1·8432 MHz, but the UART has a built-in divide-by-16 action. This gives a maximum baud rate of 115200 with a value of one written to the divider latch. It is supposedly possible to obtain a rate of 230400 baud with zero written to the clock divider latch, but with most PCs this does not seem to work.

Any of the standard baud rates can be set by using a suitable division rate, but it is not essential to use standard rates for your own add-ons. Crystals designed for generating standard baud rates are readily available at low prices though, so it is probably best to use a standard rate unless there is good reason to do otherwise.

The correct divisor is obtained by dividing 115200 by the required baud rate. User add-ons often operate at baud rates of 115200, 19200, 9600 or 4800 baud, and these respectively require 1, 6, 12 and 24 to be written to the divisor latch LSB. For all three rates zero should be written to the MSB.

Interrupts

Selecting the sources that will generate interrupts is handled via the interrupt enable register. The easy way of handling the serial port is to simply disable all interrupts. Using interrupts is not compulsory, and is not practical unless you are a reasonably accomplished programmer. Switching off the serial port interrupts should ensure that conflicts between the operating system and your own routines are avoided.

If you should decide to use interrupts, Table 1 shows the function of each bit in the interrupt enable register. Setting the appropriate bit of the interrupt enable register high (1) enables the corresponding interrupt source.

Table 1

Bit	*Interrupt Source*
0	Received data available
1	Transmitter holding register empty
2	Receiver line status
3	Modem status
4	Enables sleep mode (16750 UART only)
5	Enables low-power mode (16750 UART only)
6	Reserved
7	Reserved

Determining whether or not an interrupt has occurred is achieved by reading the three least significant bits of the interrupt identification register. If bit 0 is at 0 an interrupt is pending. The binary code in the other two bits then indicates the source of the interrupt. Table 2 shows the code for each of the four possible sources.

Table 2

Source	Bit 2	Bit 1	Priority
Receiver line status	1	1	1
Receiver data	1	0	2
Transmitter register	0	1	3
Modem status	0	0	4

Word Format

All the standard word formats are available, and the line control register is used to set the one that is required. In common with the majority of UARTs, the format for transmission and reception has to be the same. The functions of the line control register are shown below. With asynchronous serial communication there is always one start bit.

Bit 0	Bit 1	Data bits
0	0	5
0	1	6
1	0	7
1	1	8

Bit 2 at 0	One stop bit
Bit 2 at 1	Two stop bits (1.5 with 5 data bits)
Bit 3 at 0	No parity checking
Bit 3 at 1	Parity checking enabled
Bit 4 at 0	Odd parity (if parity enabled)
Bit 4 at 1	Even parity (if parity enabled)
Bit 5	Stuck parity bit
Bit 6 at 0	Normal operation
Bit 6 at 1	Forces data output terminal to logic 0
Bit 7	Divisor Latch Access Bit (DLAB)

Examples

As a practical example of using the serial port registers, suppose that it is necessary to set up the serial port for operation at 9600 baud, and that the usual word format of eight data bits, one stop bit, and no parity is required. As explained previously, 9600 baud requires a value of 12 to be written to the divisor latch. However, DLAB must first be set to 1 to give access to these latches. DLAB must then be set back to 0 and at the same time the other bits are set-up to give the required word format. This means that bits 0 and 1 must be set high with all the other bits set low, giving a value of three to write to this register. In Visual BASIC (with the **inp** and **out** functions added using **inpout32.dll**) the following instructions will set up serial port 2 correctly:

```
OUT &H2FB,128
OUT &H2F8,12
OUT &H2F9,0
OUT &H2FB,3
```

In order to transmit bytes of data it is then just a matter of writing the appropriate values to the base address, which is &H2F8 for serial port 2. An easy way of testing baud rate control is to write a value of 255 to the MSB of the divider latch at address &H2F9, which will set the baud rate at an extremely low value. In fact it will be low enough for the binary output patterns to be observed via an l.e.d. connected to the output line of the port, see Fig.1.

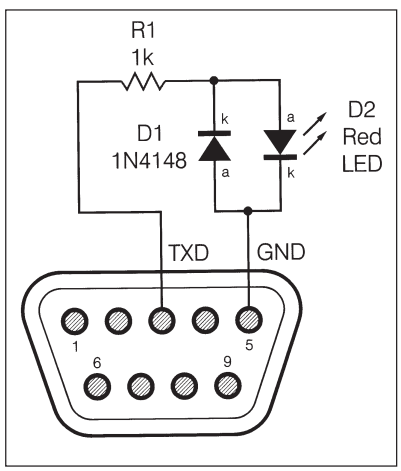

Fig.1. With a very low baud rate an l.e.d. can be used to monitor the port's output.

Hold-Off

When writing data to a serial port it is essential to bear in mind the relative slowness of these ports. The speed of modern computers and programming languages is such that it is easy to write data to the port at an excessive rate. This can result in bytes of data being corrupted or lost completely. Writing two bytes of data to a serial port in rapid succession should not give any problems, since the UART's buffering should store the second byte until it can be transmitted.

There will almost certainly be an error if three or more bytes are written to a serial port in rapid succession. Obviously this will never occur in some applications because only an occasional byte of data will be sent. In some other applications the throughput of data will simply be too great to permit the use of serial interfacing at all. It is applications that involve the sending of short bursts of data that are likely to be problematic.

There are two basic approaches to controlling the flow of data. The time taken for each byte to be sent is easily calculated, and it is ten times the duration of each bit.

At 9600 baud each bit lasts 104μs (1/9600 = 0·000104s). Therefore, the duration of ten bits at 9600 baud is 1·04ms (1040μs). At 9600 baud, using a software-generated delay of more than 1·04ms will therefore ensure that the serial chip does not miss bytes of data.

The alternative is to use a status flag of the UART and a software loop to provide a hold-off until the serial chip indicates that it is ready to receive the next byte of data. This can be achieved using interrupts, but it is easier to simply monitor the appropriate status flag in the Line Status Register. The following is a full list of the bit functions in the Line Status Register.

Bit	Function
0	Received data ready
1	Overrun (unread data overwritten)
2	Parity error
3	Framing error (no stop bit detected)
4	Break interrupt indicator
5	Transmitter buffer register empty
6	Transmitter register empty
7	Unused (reads logic 0)

When a byte of data is written to the chip it is first placed in the transmitter buffer register, but it is immediately transferred to the transmitter register if that register is empty. Otherwise the data is transferred as soon as the transmitter register becomes empty. The data is then shifted out bit-by-bit, with any additional bits such as stop bits being added.

There are two transmitter status flags, and the one at bit 5 is set to 0 when the transmitter buffer register is full. The flag at bit 6 is set at 0 when there is data in either register. A software loop can provide the required hold-off by monitoring either of these flags, and preventing further data being written to the port until the flag has returned to logic 1. This requires a loop along the lines of "repeat until (&H2FD AND 32) = 32".

Handling the reception of data is a bit more difficult than controlling its transmission, and is something we will consider next time.

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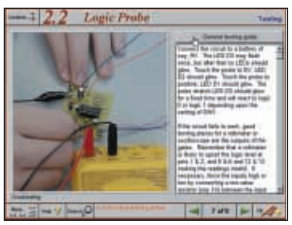

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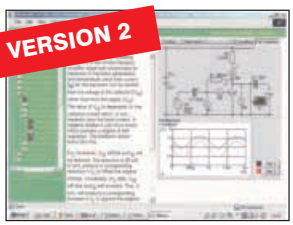

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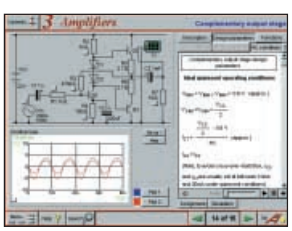

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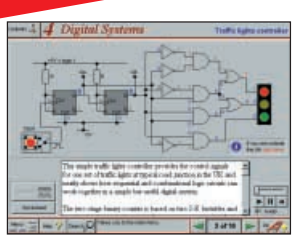
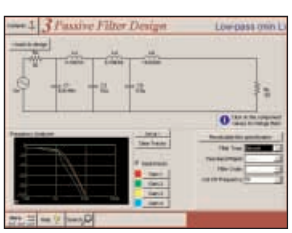


Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

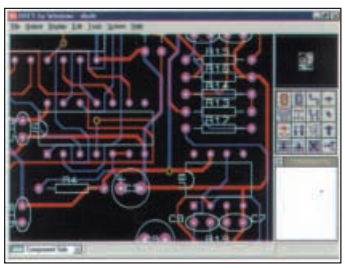
FILTERS



Filter synthesis

Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots. etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

ROBOTICS & MECHATRONICS

Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student .....£45 inc VAT
Institutional (Schools/HE/FE/Industry).....£99 *plus* VAT
Institutional 10 user (Network Licence) .....£199 *plus* VAT
Site Licence.....£499 *plus* VAT

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

PICmicro TUTORIALS AND PROGRAMMING

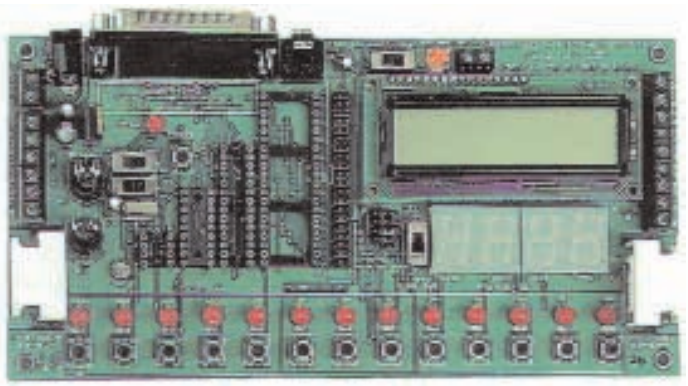
HARDWARE

VERSION 2 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 13 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- All inputs and outputs available on screw terminal connectors for easy connection



£145 including VAT and postage

12V 500mA plug-top PSU (UK plug) £7

25-way 'D' type connecting cable £5

SOFTWARE

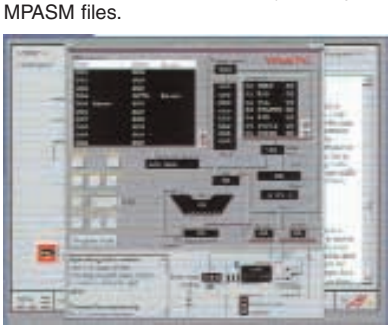
Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V2.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro micro-controller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

● Comprehensive instruction through 39 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



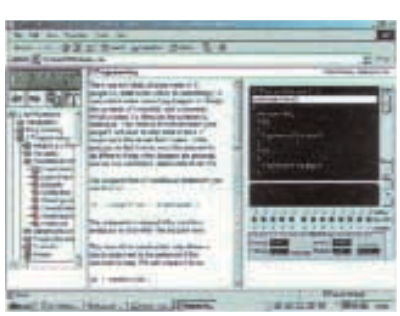
Virtual PICmicro

'C' FOR PICmicro VERSION 2

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

FLOWCODE FOR PICmicro

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex robotics and control systems in a matter of minutes.

Flowcode is a powerful language that uses macros to facilitate the control of complex devices like 7-segment displays, motor controllers and l.c.d. displays. The use of macros allows you to control these electronic devices without getting bogged down in understanding the programming involved.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 2 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols (ISO5807) ● Full on-screen simulation allows debugging and speeds up the development process ● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 8, 18, 28 and 40-pin devices ● Institutional versions include virtual systems (burglar alarms, car parks etc.).

Burglar Alarm Simulation

PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

Hobbyist/Student	**£45 inc VAT**
Institutional (Schools/HE/FE/Industry)	**£99 *plus* VAT**
Flowcode Institutional	**£70 *plus* VAT**
Institutional 10 user (Network Licence)	**£249 *plus* VAT**
Site Licence	**£599 *plus* VAT**

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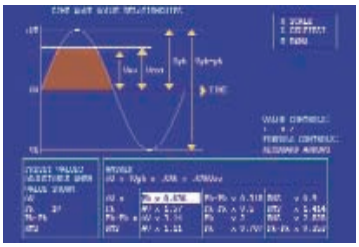
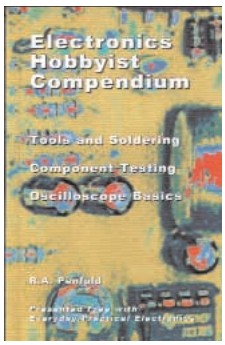
TEACH-IN 2000 – LEARN ELECTRONICS WITH EPE

EPE's own *Teach-In* CD-ROM, contains the full 12-part *Teach-In* series by John Becker in PDF form plus the *Teach-In* interactive software covering all aspects of the series. We have also added Alan Winstanley's highly acclaimed *Basic Soldering Guide* which is fully illustrated and which also includes *Desoldering*. The *Teach-In* series covers: Colour Codes and Resistors, Capacitors, Potentiometers, Sensor Resistors, Ohm's Law, Diodes and L.E.D.s, Waveforms, Frequency and Time, Logic Gates, Binary and Hex Logic, Op.amps, Comparators, Mixers, Audio and Sensor Amplifiers, Transistors, Transformers and Rectifiers, Voltage Regulation, Integration, Differentiation, 7-segment Displays, L.C.D.s, Digital-to-Analogue.



Sine wave relationship values

FREE BOOK WITH TEACH-IN 2000 CD-ROM



Each part has an associated practical section and the series includes a simple PC interface so you can use your PC as a basic oscilloscope with the various circuits.

A hands-on approach to electronics with numerous breadboard circuits to try out.

£12.45 including VAT and postage. Requires Adobe Acrobat (available free from the Internet – **www.adobe.com/acrobat**).

FREE WITH EACH TEACH-IN CD-ROM – *Electronics Hobbyist Compendium* 80-page book by Robert Penfold. Covers Tools For The Job; Component Testing; Oscilloscope Basics.

ELECTRONICS IN CONTROL

Two colourful animated courses for students on one CD-ROM. These cover Key Stage 3 and GCSE syllabuses. **Key Stage 3:** A pictorial look at the Electronics section featuring animations and video clips. Provides an ideal introduction or revision guide, including multi-choice questions with feedback. **GCSE:** Aimed at the Electronics in many Design & Technology courses, it covers many sections of GCSE Electronics. Provides an ideal revision guide with Homework Questions on each chapter. Worked answers with an access code are provided on a special website.

Single User £29 inc. VAT. Multiple User £39 plus VAT

Student copies (available only with a multiple user copy) £6 plus VAT

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VERSION 3

Contains a range of tried and tested analogue and digital circuit modules, together with the knowledge to use and interface them. Thus allowing anyone with a basic understanding of circuit symbols to design and build their own projects. Version 3 includes data and circuit modules for a range of popular PICs; includes PICAXE circuits, the system which enables a PIC to be programmed without a programmer, and without removing it from the circuit. Shows where to obtain free software downloads to enable BASIC programming.

Essential information for anyone undertaking GCSE or "A" level electronics or technology and for hobbyists who want to get to grips with project design. Over seventy different Input, Processor and Output modules are illustrated and fully described, together with detailed information on construction, fault finding and components, including circuit symbols, pinouts, power supplies, decoupling etc.

Single User £19.95 inc. VAT. Multiple User £34 *plus* VAT

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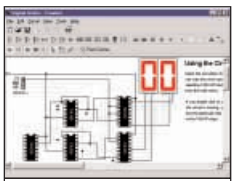
DIGITAL WORKS 3.0



Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability ● Software for simulating digital logic circuits ● Create your own macros – highly scalable ● Create your own circuits, components, and i.c.s ● Easy-to-use digital interface ● Animation brings circuits to life ● Vast library of logic macros and 74 series i.c.s with data sheets ● Powerful tool for designing and learning.

Hobbyist/Student £45 inc. VAT.
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ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 JPG images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Also contains a **FREE** 30-day evaluation of Paint Shop Pro 6 – Paint Shop Pro image editing tips and on-line help included!

Price £19.95 inc. VAT

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98/NT/2000/ME/XP, mouse, sound card, web browser.

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Note: The software on each version is the same, only the licence for use varies.

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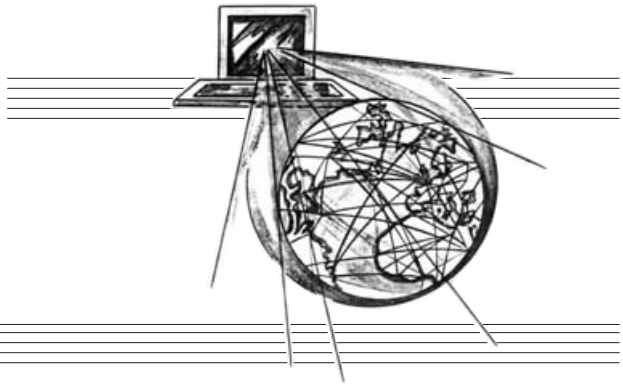
SURFING THE INTERNET

NET WORK

ALAN WINSTANLEY



WELCOME to our monthly column specially written for Internet users. This month's *Net Work* looks at developments in the web browser world, focusing on what has happened to Netscape, once the T. Rex of browsers, but now on the verge of extinction. Or is it?

Children of the Revolution

In my archives I have a copy of the Netscape 1.22 browser: it fits easily onto a 1.44MB floppy disk. During the early 1990's development of the web browser, Microsoft was nowhere to be seen: if you wanted to surf the web, most Internet enthusiasts used the Netscape browser, which itself was born out of a project called Mosaic, developed at the National Center for Supercomputing Applications. *NCSA Mosaic* was for many users, their first introduction to surfing the world-wide web. As it was said at the time, "it (Mosaic) now boasts over 100,000 users worldwide."

In the early evolution of web-based Internet content, students at NCSA, led by Marc Andreessen, created a user-friendly program that enabled ordinary non-technical users to make sense out of the distinctly technical world of web sites and Hypertext Mark-Up Language, or HTML, the code behind web page creation. However, the Mosaic project belonged to NCSA who weren't about to give it up or see it commercialised, so Andreessen together with Jim Clark, founder of Silicon Graphics Inc., and supported by a group of highly talented programmers, formed Mosaic Communications Corporation (later, Netscape) in 1994.

Whilst NCSA ceased work on Mosaic in January 1997 Andreessen's team went from strength to strength, giving us *Netscape Navigator*, the browser that handled 75% of all web traffic at the time. A browser emulator at **http://www.dejavu.org/** will allow you to relive the web as we used to, all those years ago!

No Escape

Netscape became universally popular but the potential goldmine it offered its makers was in danger of slipping away. Commercial product was being downloaded that went unpaid for (hard to believe, but true). In 1995 the UK saw a widely-publicised "Netscape Amnesty" which allowed users to register for £15 and enjoy "guilt-free web surfing", plus the chance to upgrade to the eagerly-awaited new Netscape 2.0, which would add support for Sun Microsystems' Java, and would include an email client as well. Over time, more compatibility with JavaScript and frames was added. Web design would become truly murderous, having to cope with the different ways in which alternative non-compliant browsers rendered the code and did their own thing with the content.

Meantime, Microsoft had performed a handbrake-turn on their strategy and realised that the Internet was looming like a rising Tsunami. Its first attempt to break into the browser market, Microsoft Internet *Explorer 1.0* was mediocre and Netscape still continued to enjoy the lion's share of the market, although it was still failing to capitalise on its market advantage.

Microsoft continued to evolve its browser, which became heavily integrated into its Windows 95 operating system: since every Windows PC would henceforth include a free web browser, why buy one from Netscape? The rest is a long, sad tale of anti-trust lawsuits and protracted legal battles. Not ready to roll over and die just yet, Netscape released further versions, while Microsoft embedded more horrors into its own Windows operating system – MSIE 4 introduced many new features that seriously challenged the sanity of many computer users. It is still considered by the writer to be the most loathsome web browser ever devised.

Dispensing with the need for users to buy a licence, Netscape went open-source and gave its code away, a move intended to be a community-driven crusade designed to stymie the spiralling uptake of Microsoft Internet Explorer. After such a stellar growth, the inevitable happened and Netscape as a standalone enterprise was ultimately doomed: AOL Time Warner purchased the company in 1998, and various bits of AOL internet software (e.g. AIM – AOL Instant Messenger and its "Buddy Lists") were duly integrated.

Cashing in on the Netscape brand, in 1999 AOL Europe rolled out Netscape Online, a short-lived subscription-free consumer Internet service. Since then, Netscape has gradually been re-invented and absorbed into AOL Time Warner as a media brand rather than as a web browser.

At the same time, in mid 2003, AOL also announced it was giving $2 million over two years to the Mozilla Foundation, to support on-going open-source browser development, presumably also to pacify long-term Netscape lovers fearful of seeing their beloved browser being shut down. For the time being at least, it is still possible to download probably the last iteration of Netscape (V7.0) from the portal site **www.netscape.com**.

*Firebird 0.7 browser has some refreshing new features (free from **www.mozilla.org**).*

Rising from the Ashes

In the very early days of Netscape's creation, Andreessen and his team dubbed their browser project *Mozilla*, whose mascot was a friendly green dinosaur, an icon that was instantly recognised by Netscape devotees then as today's users would relate to, say, the Google logo. The Mozilla Museum at **http://home.snafu.de/tilman/mozilla/index.html** contains many archived samples of Mozilla artwork.

Although the Netscape browser may ultimately wither on the vine, its heart beats on in the form of the Mozilla browser (**www.mozilla.org**), an open-source alternative to MSIE. Mozilla Firebird is a small (6MB) but perfectly formed browser. Based on the Gecko layout engine also used in Navigator 7, it uses "tabs" for easier navigation, and also has a pop-up blocker plus various annoyance eliminators. (Mac users can try Camino 0.7). Mozilla Thunderbird is a separate Mail and Usenet client. The open-source rolling beta development means that they are not yet suited to neophyte users accustomed to packaged, commercial (and paid-for) products, but it is worth trying the free downloads.

Firebird is installed simply by unzipping the 6MB file into its own folder, then create a shortcut to the **.exe** file. It has some lovely features (including integrated Google search, and on-the-fly rendering of text when resizing pages) and is a "must" for enthusiasts.

It is rather ironic that the slow demise of Mozilla should leave 95% of web users struggling with another prehistoric creature in the shape of Microsoft Internet Explorer 6, now overdue for radical improvements in its usability. However, what goes around, comes around, and Mozilla may come back to bite a chunk out of Explorer yet. You can email your comments to **alan@epemag.demon.co.uk**.

Constructional Project

PRACTICAL RADIO CIRCUITS

RAYMOND HAIGH

Part 7: The Superhet: Preselectors, mixers and oscillators

Circuits for the set builder and experimenter

THIS month we begin to consider a simple to operate receiving system capable of the highest levels of selectivity and sensitivity. Known as the supersonic heterodyne, or **superhet** for short, it has been the dominant receiver technology for seventy years. Its application is now universal, from the simplest domestic portable to state of the art equipment used in government listening stations.

HOW IT WORKS

With the superhet system, all incoming signals, whatever their wavelength, are changed to a fixed frequency at which almost all of the amplification takes place.

Frequency changing is achieved by "beating" or "heterodyning" a locally generated oscillation with the incoming signal. The frequency difference between signal and oscillation is kept constant, and the resulting beat frequency is, therefore, also fixed and constant.

By converting all signals to a fixed frequency, known as the *intermediate frequency* (i.f.), the problems of instability and inconsistent performance that can afflict multi-stage tuned radio frequency (t.r.f.) receivers are avoided. The main cause of this instability is feedback via the ganged tuning capacitor and wavechange switch wiring. The inconsistent performance arises from the change in the *Q*-factor and impedance as the tuning capacitor is rotated.

In the superhet, ganged variable capacitors and coil switching are eliminated from the fixed frequency i.f. stages, and very high levels of gain can be achieved without instability. Moreover, performance is not affected by changes in tuning capacitor values.

Fixed frequency amplification makes possible the introduction of crystal, mechanical or ceramic filters capable of tailoring selectivity to suit all types of signal and reception conditions (more about this later). It is also easier to provide effective automatic gain control (a.g.c.) systems.

The inclusion of frequency changing circuitry makes the superhet different from all other types of receiver. Unfortunately, it brings with it some unique problems, and the evolution of the circuit has been largely shaped by attempts to overcome them.

Germanium diodes are still widely used for the detection or demodulation of the signal (see Part One). In addition to recovering the audio modulation, the diode produces a d.c. voltage which varies relative to signal strength. This is used to change the base bias on the transistors in the i.f amplifier and reduce their gain when strong signals are being received. This facility is known as automatic gain control, or a.g.c. for short.

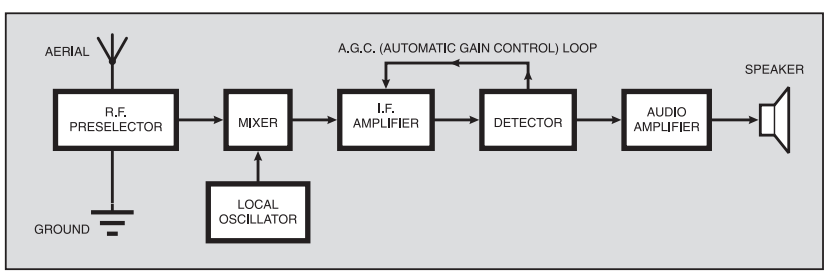


Fig.7.1. Block schematic diagram of a basic superhet receiver.

BASIC CIRCUIT

A block diagram for a basic superhet receiver is given in Fig.7.1. The receiver is tuned to the desired station by a Preselector stage comprising one or more tuned circuits.

The Local Oscillator operates at a higher frequency than the incoming signal, the difference between the two being equal to the intermediate frequency (i.f.). This difference has to be maintained over the swing of the tuning capacitor. How this is done is described later.

The input signal and local oscillation are combined in the Mixer stage. This results in the production of a number of frequencies, and a tuned circuit in the mixer's output selects oscillator frequency minus signal frequency; i.e., the desired intermediate frequency.

Signals, at this new and fixed frequency, are amplified in the I.F. Amplifier. In basic receivers, intermediate frequency amplifiers usually comprise two transistors coupled by radio frequency transformers (known as i.f. transformers) tuned to the i.f. Higher performance receivers incorporate a ceramic, mechanical or crystal filter to improve selectivity.

Audio amplifier stages are similar to those discussed earlier in the series (see Part Two).

WHISTLES

Superhet receivers are prone to spurious responses. At their simplest, they take the form of a whistle that changes in pitch as the set is tuned through a station. The principle cause is second channel or "image" interference.

Second channel interference arises because the mixing process can produce an output, at the intermediate frequency, from two, different, incoming signals. These are at the oscillator frequency *minus* the intermediate frequency, and at the oscillator frequency *plus* the intermediate frequency (the "second channel"). The image signal is, therefore, spaced from the wanted signal by twice the intermediate frequency.

Whistles are caused when the interfering signal is not quite twice the i.f. distance from the wanted station, say one or two kilohertz out, the resulting beat producing the whistle as the receiver is tuned through the station.

Strong signals spaced twice the i.f. above the frequency reading on a silent part of the dial can be heard and mistaken

for transmitters operating at the actual dial reading. These "phantom" stations become more intrusive as the receiver is tuned up through the shortwave bands.

This is because simple preselector stages become less and less able to reject signals spaced by only 910kHz (i.e twice a standard i.f. of 455kHz) from the wanted station as the reception frequency rises above 5MHz or so. It is for this reason that inexpensive receivers sometimes appear so "lively" on the shortwave bands.

Reception of signals in close proximity to the receiver's i.f. can also be a cause of whistles. More difficult to trace are whistles caused by harmonics produced by the non-linear action of the receiver's own detector.

INTERFERENCE

The problem of second channel interference can be greatly reduced by either increasing the selectivity of the preselector stage, or raising the intermediate frequency, or both.

High performance receivers of the valve era with i.f.s of 460kHz had three tuned circuits in the preselector stage. When the i.f. was increased to 1600kHz, two tuned circuits were considered adequate. Domestic valve receivers often adopted a bandpass arrangement to improve preselector action on medium and shortwaves. A typical circuit diagram, featuring modern coils, is given in Fig.7.2.

The lower the intermediate frequency, the greater the selectivity of the receiver (more about this later). This imposes limitations on raising the i.f. to reduce second channel interference, and designers began to include two or more frequency changers. This permitted the use of a *high* first i.f. to minimize image interference followed by a *low* second to ensure adequate selectivity.

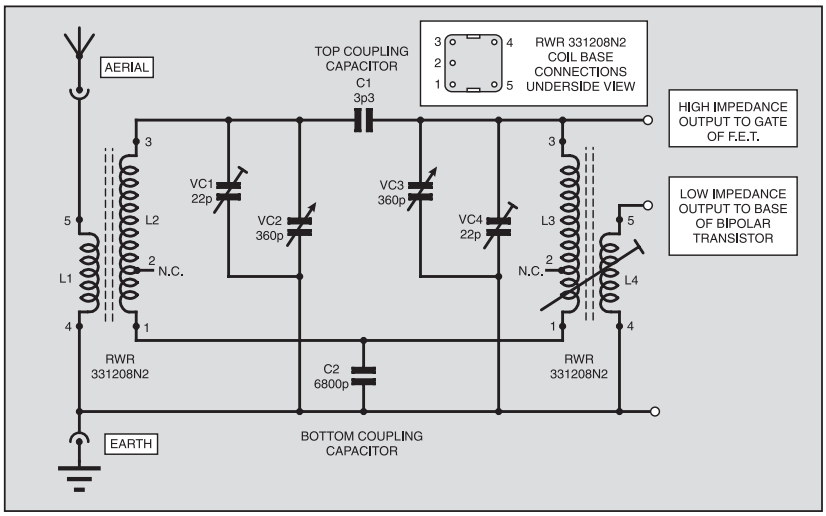


Fig.7.2. Circuit diagram for a bandpass tuned circuit for improving the selectivity of the r.f. preselector stage. The coil type shown is for medium wave reception.

Modern, high performance communications receivers often have a first i.f. of 45MHz, followed by a transitional stage of 10·7MHz and a final of 455kHz. Each of the three frequency changers tends to cause spurious responses, and these receivers have to be designed with the utmost care or the attempted cure only aggravates the problem.

Whistles caused by the reception of signals close to the intermediate frequency can usually be cured by the insertion of a wave trap, tuned to the intermediate frequency, at the aerial input. Wave traps were discussed in Part Two.

Problems caused by the radiation of harmonics produced by the detector can be avoided by adequate post-detector filtering, sensible receiver layout, and screening.

FREQUENCY CHANGERS

The term frequency changer was coined early in the development of the superhet. It is something of a misnomer. Combiner, mixer, or even modulator would better describe the process which takes place when the local oscillation heterodynes or beats with the incoming signal to produce the intermediate frequency.

Mixer is currently the most favoured term, but audio engineers and radio engineers have a completely different understanding of the word. Audio engineers demand a high degree of linearity in a mixing stage to ensure that the signals being merged onto the same path remain unchanged. They must not interact with one another to produce new frequencies.

BRIEF HISTORY

The Superhet had its origins during the earliest years of radio. Indeed, seminal patents predate the valve.

In 1901, Dr. R. A. Fessenden patented a system whereby two unmodulated signals, radiated by a transmitter, were combined at the receiver. The signals differed in frequency by about 1kHz and the resulting beat note produced an audible tone from a diaphragm activated directly by the fine iron wire core of the receiver's tuning coil. Fessenden's receiver could have been described as a sonic heterodyne.

He later improved the arrangement by substituting a locally generated oscillation for one of the transmitted signals. In this way the frequency difference and, hence, the tone of the beat, were brought under the control of the operator.

These experiments predated the valve, and high frequency alternators were used to generate oscillations in the 50kHz to 100kHz range at the transmitting and receiving stations.

American Navy researchers increased the sensitivity of Fessenden's system in 1913, when they used a rectifier to mix the signals and produce an audible beat note in conventional earphones.

Lee de Forrest patented his triode valve in 1903 and, by 1913, researchers in Europe and America had discovered its usefulness as an oscillator. During that same year, Captain H. J. Round used a single valve as oscillator and mixer. He called his circuit the Autodyne.

The 1914-18 war gave an enormous impetus to the development of the superhet. There was a need to operate at frequencies between 500kHz and 3000kHz which, at the time, were considered very high. The triode was still the only amplifying device available to designers.

Unfortunately, because of the capacitance between its grid and anode (input and output pins), it became unstable at frequencies much above 100kHz. By adopting the superhet principle and converting all incoming signals to a frequency below 100kHz, these primitive valves could be made to provide the necessary amplification.

Captain H. J. Round, M. Latour and Major E. H. Armstrong for the Allies, and W. Schottky for the Germans, researched the problem. Schottky filed a patent application in June 1918, but he was unable to develop his circuit. Armstrong's patent was filed in December, six months later. Like Schottky's, it made reference to all of the essential features of the superheterodyne.

Unlike Schottky's, it was based on the construction of a working receiver. Credit for the invention of the circuit is, therefore, usually ceded to Armstrong.

In 1918, L. A. Hazeltine patented a feedback circuit known as the Neutrodyne, which neutralized the triode's grid-anode capacitance and made stable amplification at higher radio frequencies possible. This, together with the development of the screen-grid valve (which greatly reduced the capacitance between the input and output), prolonged the life of the t.r.f. receiver through the 1920s in America and well into the 30s in Europe. The superhet then began to dominate the domestic receiver market.

Subsequent developments have been directed towards eliminating spurious responses, increasing selectivity, and overcoming the effects of oscillator drift. The weight and mechanical complexity of some of the best receivers of the valve era have been replaced by electronic sophistication in the high performance sets manufactured today.

In terms of the crucial ability to resolve the weakest signals under difficult reception conditions, there have been few, if any, significant improvements since the end of the valve era.

Conversely, radio mixers (other than mixers that function purely as modulators) must posses a degree of non-linearity to ensure that the local oscillation combines or heterodynes with the signal to produce the intermediate frequency at the output.

Diodes, which display the most extreme form of non-linearity, were used as mixers in primitive superhets (they still are in some communications receivers and receivers operating at frequencies approaching 1GHz). This is why mixers were referred to as the first detector in the early days of radio. Mixers which function by passing two signals through a non-linear device are known as additive mixers.

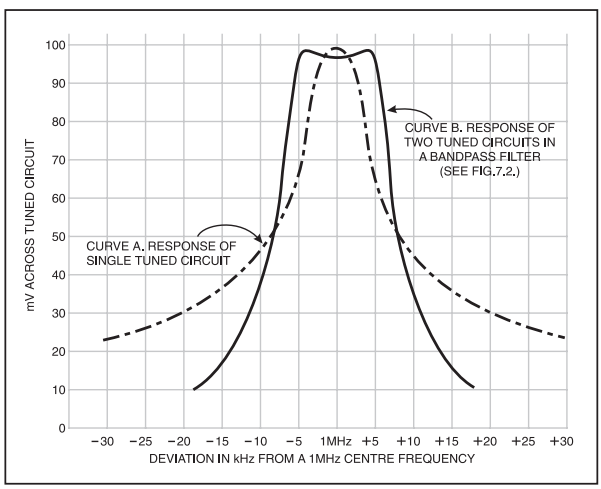


Fig.7.3. Comparing the selectivity of a single tuned circuit with two tuned circuits in a bandpass filter.

The development of multi-grid valves in the late 1920s and special frequency changer valves in the 30s permitted a different mode of mixing. Known as multiplicative mixing, the locally generated oscillation was applied to a subsidiary grid placed in the electron stream so that it modulated the incoming signal frequency. The valve operated in a linear fashion, and the intermediate frequency was selected at its output (anode), by a tuned circuit, in the usual way.

This form of mixing was the norm until the end of the valve era. The introduction of the transistor in the 1960s brought about a return to non-linear, additive mixers.

TRACKING

As we have seen, the oscillator must operate at signal frequency plus intermediate frequency over the full swing of the tuning capacitor. Maintaining this constant difference is known as *tracking*.

Taking the medium waveband as an example, the signal or preselector circuits will tune from 550kHz to 1650kHz. Assuming an i.f. of 450kHz, the oscillator will have to run from 550 + 450 = 1000kHz to 1650 + 450 = 2100kHz.

The difference in coverage is achieved by using a lower inductance tuning coil in the oscillator circuit. Its inductance is calculated so that the frequency of oscillation is 2100kHz when the tuning capacitor is set to its minimum value.

This measure, by itself, is not sufficient to ensure accurate tracking. The maximum value of the tuning capacitor must also be reduced to ensure that the frequency of oscillation is 1000kHz when its vanes are fully meshed. Sometimes a lower value oscillator section is ganged with the signal tuning capacitor. More commonly, both sections of the ganged capacitor are identical and a fixed capacitor is placed in series with the oscillator tuner to reduce its maximum value. This fixed capacitor is known as a *padder*.

With the correct choice of inductor and padder values, tracking is perfect at three points on the dial: close to either end and around the centre point. At all other points the error is minimal.

UNDER AND OVER

The oscillator in some of the first general coverage, solid state receivers ran below the signal frequency on the highest shortwave range (12MHz to 30MHz) because of the limited performance of early transistors.

Operating the oscillator above signal frequency is, however, standard procedure. Indeed, simple arithmetic will reveal that, with workable tuning swings, it becomes difficult and then impossible, as frequency is lowered, to run the oscillator below signal frequency.

It's now time for us to take a look at some circuits.

PRESELECTING

Increasing the efficiency of the preselector circuits will do much to overcome the inherent defects of the superhet system. In Fig.7.2, two tuned circuits L2/VC2 and L3/VC3, have been coupled to increase selectivity. Known as a bandpass filter, its performance is compared with a single tuned circuit in the graph of Fig.7.3.

Correctly set up, this arrangement passes a narrow band of frequencies beyond which the response falls off comparatively steeply. In this way, good selectivity is achieved without attenuating the higher audio frequencies on the boundaries of the modulation envelope (see Part One). For this reason, two tuned circuits, coupled inductively, formed the basis of all intermediate frequency transformers (i.f.t.s) during the valve era. (The miniature i.f.t.s used in most transistor radios are now singly tuned.)

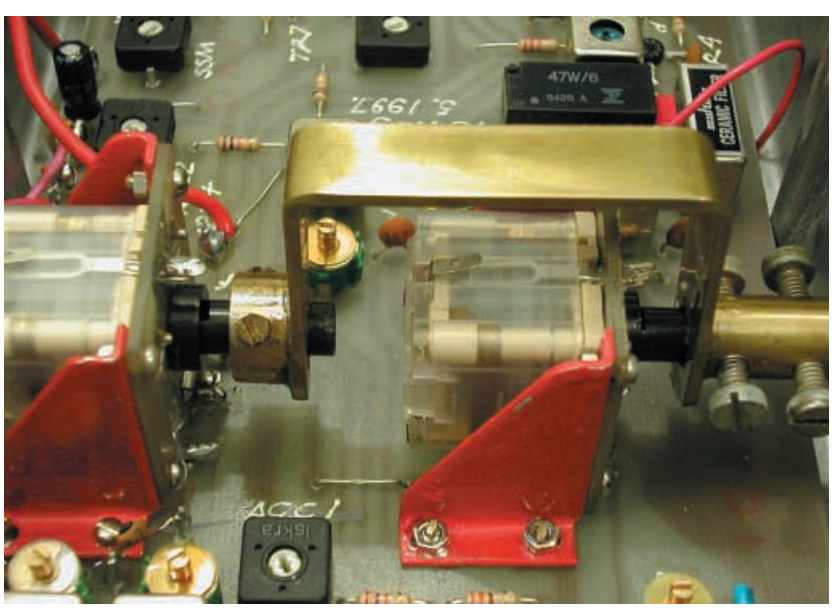
Returning to Fig.7.2, signal transfer is effected by C1 and C2, known as the series and shunt (or top and bottom) capacitors respectively. As frequency increases, coupling increases via C1 and reduces via C2. With falling frequency the reverse is the case. This ensures that the response of the filter is reasonably constant over the swing of ganged tuning capacitors, VC2 and VC3.

Coupling windings, L1 and L4, match the high impedance tuned circuits to the aerial and base of a bipolar transistor mixer. The high impedance gate of a field-effect transistor can be connected directly to winding L3. Preset trimmer capacitors, VC1 and VC4, and adjustable inductor cores, permit the two circuits to be exactly matched to one another in a process known as *alignment*.

The values quoted for capacitors C1 and C2 will produce a passband, on medium waves, around 10kHz wide. Reducing C1 and increasing C2 will narrow the response, ultimately to a single peak.

GANGING-UP

When the preselector has two tuned circuits the receiver requires a three-gang tuning capacitor. Three-gang air-spaced variables are still manufactured but are expensive. An alternative is to link two, polythene dielectric tuning capacitors to produce a four-gang arrangement at modest cost. Details of this solution are given in the mechanical diagram Fig.7.4.



Author's method of providing a metal brace between two solid dielectric tuning capacitors to form a four-gang unit.

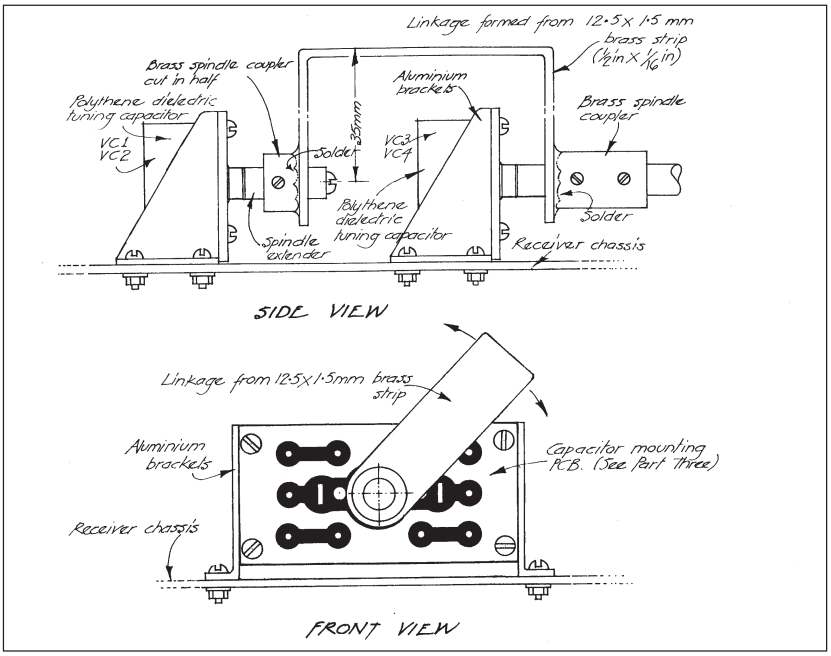


Fig.7.4. Mechanical details for linking solid dielectric tuning capacitors to produce a four-gang unit.

Contact faces on the linkage strip and brass spindle couplers should be tinned and the parts assembled on a length of 6mm (1/4in.) spindle before being "sweated" together. This ensures perfect alignment.

Lack of screening precludes the insertion of a signal frequency amplifying stage between VC1 and VC2. These capacitors can, therefore, only be used for the bandpass circuit already described. Such a stage could, however, be provided between VC2 and VC3 if adequate screening is installed. Instability does not normally arise through interaction between signal and oscillator circuits because they operate at different frequencies. Receiver component layout should, however, separate them as much as possible.

SELF-OSCILLATING MIXER

The self-oscillating mixer circuit used in almost all of the transistor portable receivers manufactured since the 1960s is shown in Fig.7.5.

The tuned circuit formed by tuning capacitor VC1 and the ferrite loop aerial, L1, selects the station. To minimize damping, signal transfer to the low impedance base of transistor TR1 is via coupling winding L2.

This transistor version of Alexander Meissner's oscillator is tuned by L5 and VC4, with capacitor C5 acting as the swing-reducing padder. Feedback from TR1 collector (c) to emitter (e) is via coils L3 and L4, the latter winding providing oscillator injection at the emitter. Oscillation amplitude is sufficient to drive the device into the non-linear region of its characteristic curve and this produces the desired mixing action. (This is an additive mixer).

Base bias for TR1 is fixed by resistors R1 and R2, and capacitor C1 is a d.c. blocking capacitor. Emitter bias is provided by resistor R3 which is bypassed by C3. Transformer IFT1, with its tuned primary, selects the 455kHz intermediate frequency (i.f.).

Supply rail decoupling is achieved by R4 and C4. Trimmer capacitors VC2 and VC3, together with the adjustable cores in L1, L5, and IFT1, facilitate the accurate setting up of the circuit.

Anyone who has used a correctly aligned transistor portable (can there be anyone who hasn't?) will know that this simple and economical circuit works surprisingly well on medium and long waves. This is due, in no small measure, to the high *Q* (and hence selectivity) of the ferrite rod aerial and its modest signal pick-up. Injecting stronger signals via a long wire aerial results in spurious responses, cross modulation problems and oscillator "pulling" (the oscillator tends to lock onto strong signals).

Performance of the simple mixer/oscillator deteriorates on the shortwave bands. Again, the modest signal pick-up of the set's whip aerial does much to hide the defects of the circuit, but spurious responses increase as frequency rises.

Moreover, a reluctance to oscillate becomes evident, above 10MHz or so, if the amount of tuning capacitance in circuit is much above 200pF. Emitter bias resistor R3 may have to be selected to ensure reliable operation at higher frequencies.

As far as the author is aware, three winding oscillator coils are not available, to home constructors, for the long and shortwave bands. On these ranges, TR1 emitter (e) should be connected, via resistor R3 and its bypass capacitor C3, to a tap close to the "earthy" end of coil L5.

BETTER PERFORMANCE

Separating the mixer and oscillator stages and the use of field-effect transistors improves performance. Field-effect transistors have a square law relationship between their drain current and gate/source voltage, and overloading produces only the second harmonic.

Bipolar transistors, on the other hand, exhibit an exponential base/collector current relationship, and overloading produces a range of odd and even harmonics.

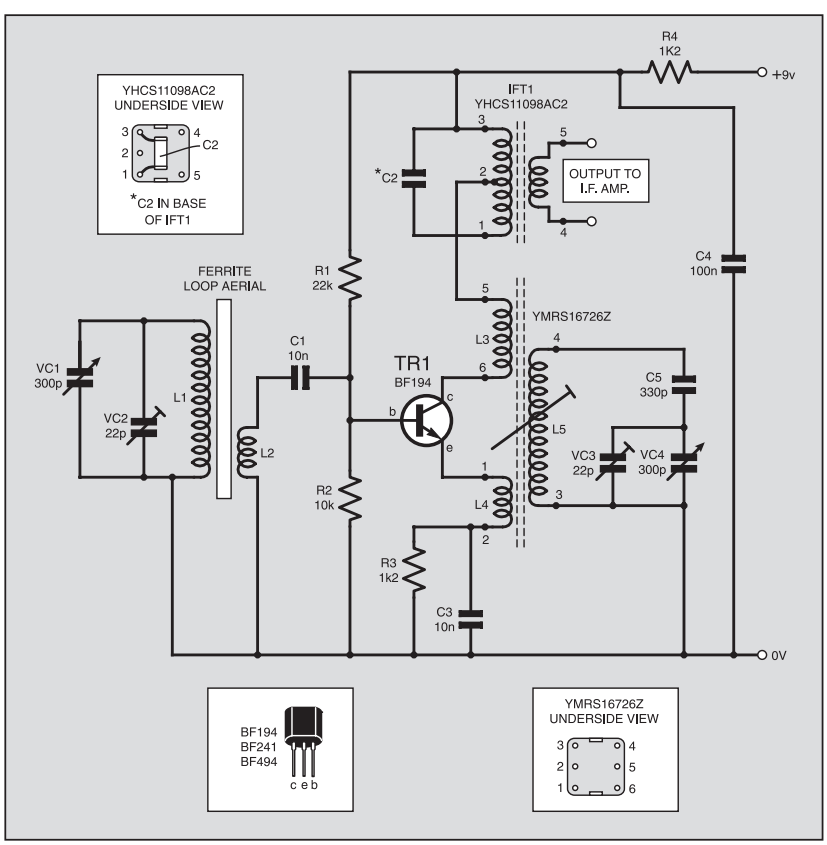


Fig.7.5. Circuit diagram for a bipolar transistor mixer/oscillator stage used in most domestic portable receivers. Oscillator coil (L3 to L5) and "padder" capacitor C5 are for medium wave reception.

5-BAND DUAL-GATE MOSFET TUNER/MIXER

A sensitive, 5-band superhet receiver front-end

DUAL-GATE MOSFET TUNER/MIXER

A circuit, popular since the 1960s, for simple general coverage communications receivers, is given in Fig.7.6.

Dual-gate MOSFET TR1 acts as the mixer and TR2, a junction f.e.t., is used as the maintaining device in an Armstrong oscillator. The high impedance gates of TR1 minimize damping on the signal frequency tuned circuits and permit a direct link to the oscillator. Gate two (g2) of TR1 is held at about 1V by connecting it, via signal isolating resistor R3, to the source (most dual-gate MOSFETs work well as mixers with this arrangement).

This modern version of Armstrong's oscillator performs reliably up to about 30MHz. It is, however, prone to squegging (going in and out of oscillation at a supersonic frequency) and stopper resistor R5 and the decoupling resistor, R4, prevent this. Source bias on TR2 is optimized by preset VR2 to ensure reliable oscillation, on the highest shortwave range, when the tuning capacitor is set at maximum.

The MOSFET mixer requires an oscillator injection of between 1Vr.m.s. and 2Vr.m.s. A higher voltage is developed across coil L4 and low value coupling capacitor C4 reduces it to within this range. This is a multiplicative mixer. The oscillator voltage modulates the signal. It does not drive the MOSFET into non-linearity.

Padder capacitor C5 can be connected in series with oscillator coil L4 in order to simplify wavechange switching. Oscillator output is, however, more constant when C5 is connected directly in series with variable capacitor VC4.

Power supply to the oscillator should be well smoothed and regulated to minimize drift.

ATTENUATION

Any receiver intended for serious listening must have some means of attenuating strong signals at the aerial input (see Part Three). Rotary potentiometer VR1 is adequate, but the switched resistor arrangement shown in Fig.7.7 is more reliable and less noisy at high frequencies.

The levels quoted take no account of aerial impedance and are approximate.

PADDERS AND COILS

Padder values and Toko coil numbers for a five-band general coverage receiver are given in Table 7.1. The circuit diagram of Fig.7.6 is more sensitive, less vulnerable to cross modulation, less noisy than the mixer/oscillator arrangement depicted in Fig.7.5, and more immune to oscillator pulling. With its 455kHz i.f. it is still affected by spurious responses, and at least one more tuned circuit is needed ahead of the mixer to make its performance acceptable in this respect, even at medium frequencies.

Table 7.1: Toko Coil Numbers and Padder Capacitor Values for a Superhet Receiver with a 455kHz I.F.

Band	Preselector (L1/L2)	Oscillator (L3/L4)	Padder (C5 pF)	Coverage (MHz)
LW	CAN1A350EK	RWR331208N2	150	0·14 to 0·3
MW	RWR331208N2	YMRS80046N	330	0·53 to 1·6
SW1	154FN8A6438EK	154AN7A6440EK	680	1·5 to 4
SW2	154FN8A6439EK	154AN7A6441EK	1500	3·5 to 12
SW3	KXNK3767EK	KXNK3766EK	2000	10 to 30

Notes:
(1) See Fig.7.6 for circuit diagram.
(2) The quoted tuning ranges are approximate. The tuning capacitors, VC2/VC4, should have a minimum value of not much more than 10pF and a maximum of at least 300pF.
(3) Alignment on LW will be easier, and tracking improved, if a fixed capacitor of 56pF is connected across L2 and 150pF is connected across L4.

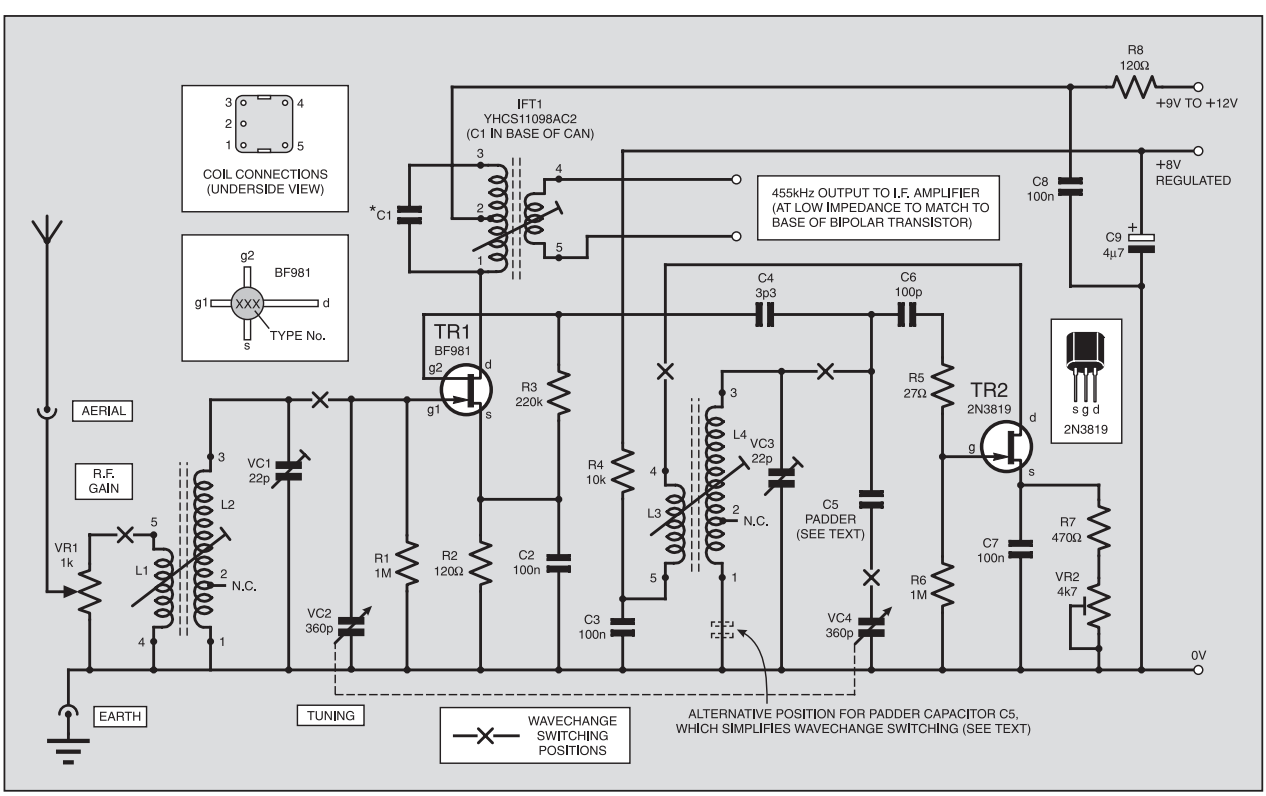


FIg.7.6. Circuit diagram for a 5-Band Tuner/Mixer using a dual-gate mixer with an f.e.t. Armstrong oscillator (455kHz i.f.). See Table 7.1 for coil and padder capacitor details. (No constructional details are given for this circuit.)

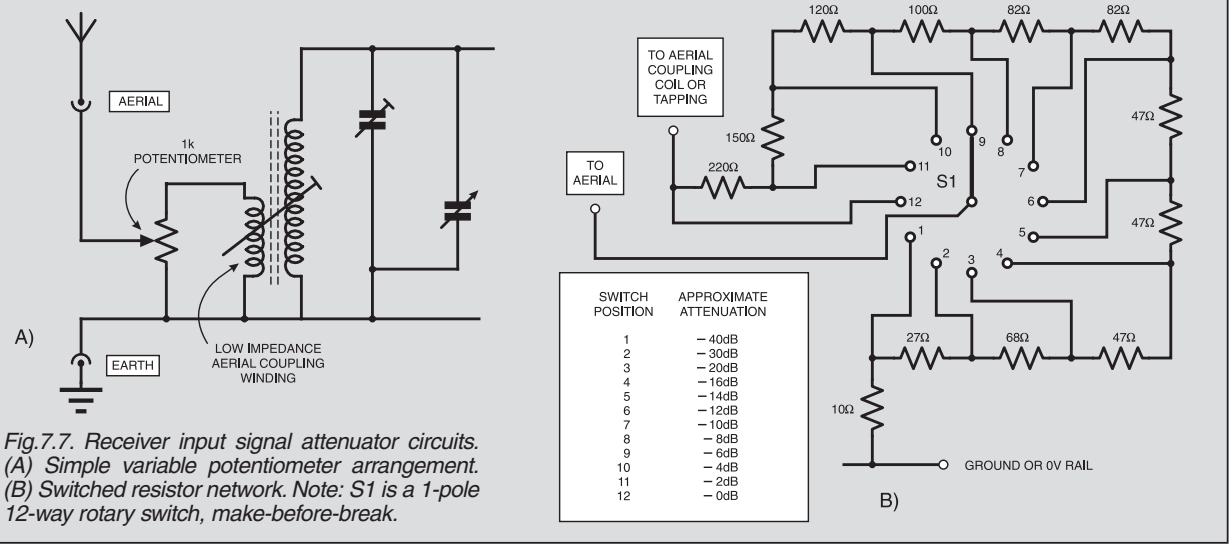
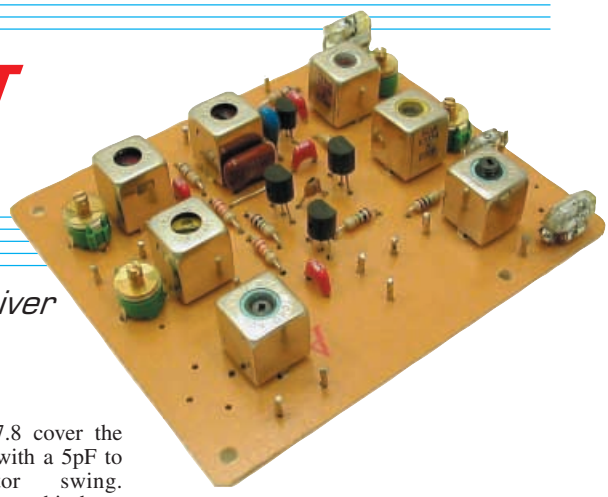


Fig.7.7. Receiver input signal attenuator circuits. (A) Simple variable potentiometer arrangement. (B) Switched resistor network. Note: S1 is a 1-pole 12-way rotary switch, make-before-break.

3-BAND SW SUPERHET TUNER/MIXER



A three-band (1·7MHz to 30MHz) SW receiver front-end, with a 1·6MHz i.f.

SHORTWAVE SUPERHET

Providing additional signal frequency tuned circuits involves considerable complication, especially with multiband receivers. Another way of reducing spurious responses is to increase the intermediate frequency, and this solution is adopted in the circuit diagram for a 3-Band Shortwave Superhet Tuner/Mixer depicted in Fig.7.8.

Some readers have reported difficulties in obtaining dual-gate MOSFETs, so two junction f.e.t.s, TR1 and TR2, have been cascaded (or cascoded!) to form the mixer. Oscillator injection is via the gate of TR1, which is biased at half the supply voltage by resistors R3 and R4. The signal path is isolated by R2 and C5 bypasses the bias supply at radio frequencies.

Field-effect transistor TR3 is the maintaining device for the Hartley oscillator, feedback from its source being applied to a tapping on tuning coil L2b, via resistor R8 and wavechange switch S1c. Padder capacitor C6b is placed in series with coil L2b in order to simplify wavechange switching, and capacitor C8 couples the oscillator to the mixer stage.

Hartley's oscillator may be marginally more drift free than Armstrong's at higher frequencies, but it was chosen because the simple tapped coil permits the series connection of commercial windings to produce the inductance values needed for the 1·6MHz i.f. Voltage regulator IC1 stabilizes the supply to the oscillator to reduce drift.

TUNING COILS

The coils shown in Fig.7.8 cover the 4·5MHz to 11·8MHz range with a 5pF to 130pF tuning capacitor swing. Experimenters are urged to try this busy range first.

Details of the coils and padders for two other ranges, affording continuous coverage from 1·7MHz to 30MHz, are given in Fig.7.9. The differing connections to the Toko coil windings should be noted.

Intermediate frequency transformers for 1·6MHz are no longer retailed, and IFT1 comprises a standard Toko coil tuned by capacitor C2.

CONSTRUCTION

The mixer/oscillator stage and its six tuning coils are assembled on a single printed circuit board. The component side and wiring to the 3-way 4-pole rotary wavechange switch are illustrated in Fig.7.10, together with a full-size copper track master. This board is available from the *EPE PCB Service*, code 426.

Table 7.2: Toko Coil Numbers and Padder Capacitor Values for a Shortwave Superhet Receiver with a 1·6MHz I.F.

Range	Preselector (L1a to L1c)	Core Depth (mm)	Oscillator (L2a to L2c)	Core Depth (mm)	Padder (pF)	Coverage (MHz)
SW1	154FN8A6438EK	2·5	TKANS32696	2·5	147	1·7 to 4·7
SW2	154FN8A6439EK	1·5	BKANK3334	2·5	330	4·5 to 11·8
SW3	BKXNK3766	2	BKXNK3766	1·5*	1500	10 to 30

Notes:

(1) See Fig.7.8 for circuit diagram.

(2) The specified coverage is obtained with a 5pF to 130pF tuning capacitor.

(3) Core depths are measured down from the top of the can.

(4) *The measurement quoted for Range 3 oscillator coil (L2c) is the *height* of the core *above* the top of the can.

(5) The core of intermediate frequency transformer IFT1 is set 2mm down from the top of the can.

COMPONENTS

3-BAND SW SUPERHET TUNER/MIXER

Approx. Cost Guidance Only **£25** *excl. reduction drive, case & batt.*

See SHOP TALK page

Resistors

R1, R2, R6	1M (3 off)
R3, R4	22k (2 off)
R5, R9	180Ω (2 off)
R7	47Ω
R8	220Ω

All 0·25W 5% carbon film

Potentiometer

VR1	1k rotary carbon, linear

Capacitors

C1, C3	1n ceramic (2 off)
C2	220p polythene or ceramic "low k"
C4, C5, C9, C11,	100n ceramic (4 off)
C6a (Range 1)	147p polythene (100p + 47p, 2 caps.)
C6b (Range 2)	330p polythene
C6c (Range 3)	1500p polythene
C7	27p polythene or ceramic "low k"
C8	3p3 ceramic "low k"
C10	4μ7 tantalum bead, 16V
VC1a to VC1c, VC3a to VC3c	2p to 22p min. film dielectric trimmer capacitor (6 off: see text for reducing this to 4 by using integral trimmers in VC2/VC4)
VC2, VC4	5p to 130p polythene dielectric variable capacitor (with two a.m. tuning gangs, plus trimmers – see text)

Inductors

L1a, IFT1	154FN8A6438 Toko screened (metal can) coil (2 off)
L1b	154FN8A6439 Toko screened (metal can) coil
L1c, L2c	BKXNK3766 Toko screened coil (2 off)
L2a	TKANS32696 Toko screened coil
L2b	BKANK3334 Toko screened coil

Semiconductors

TR1, TR2, TR3	2N3819 n-channel field effect transistor (3 off)
IC1	LM78L05ACZ +5V voltage regulator

Miscellaneous

S1	4-pole 3-way rotary switch, make-before-break
S2	s.p.d.t. toggle switch

Printed circuit boards available from the *EPE PCB Service*, code 426 (SW Mix/Osc) and 406 (T/Cap – optional); aerial and earth screw terminals; coaxial output socket; epicyclic reduction drive; one large and one small plastic control knob; single-core audio type screened cable; multistrand connecting wire; battery holder and connectors; nuts, bolts, washers and p.c.b. stand-offs; solder pins; solder etc.

Note: Case is the Regenerative Radio from Part 3.

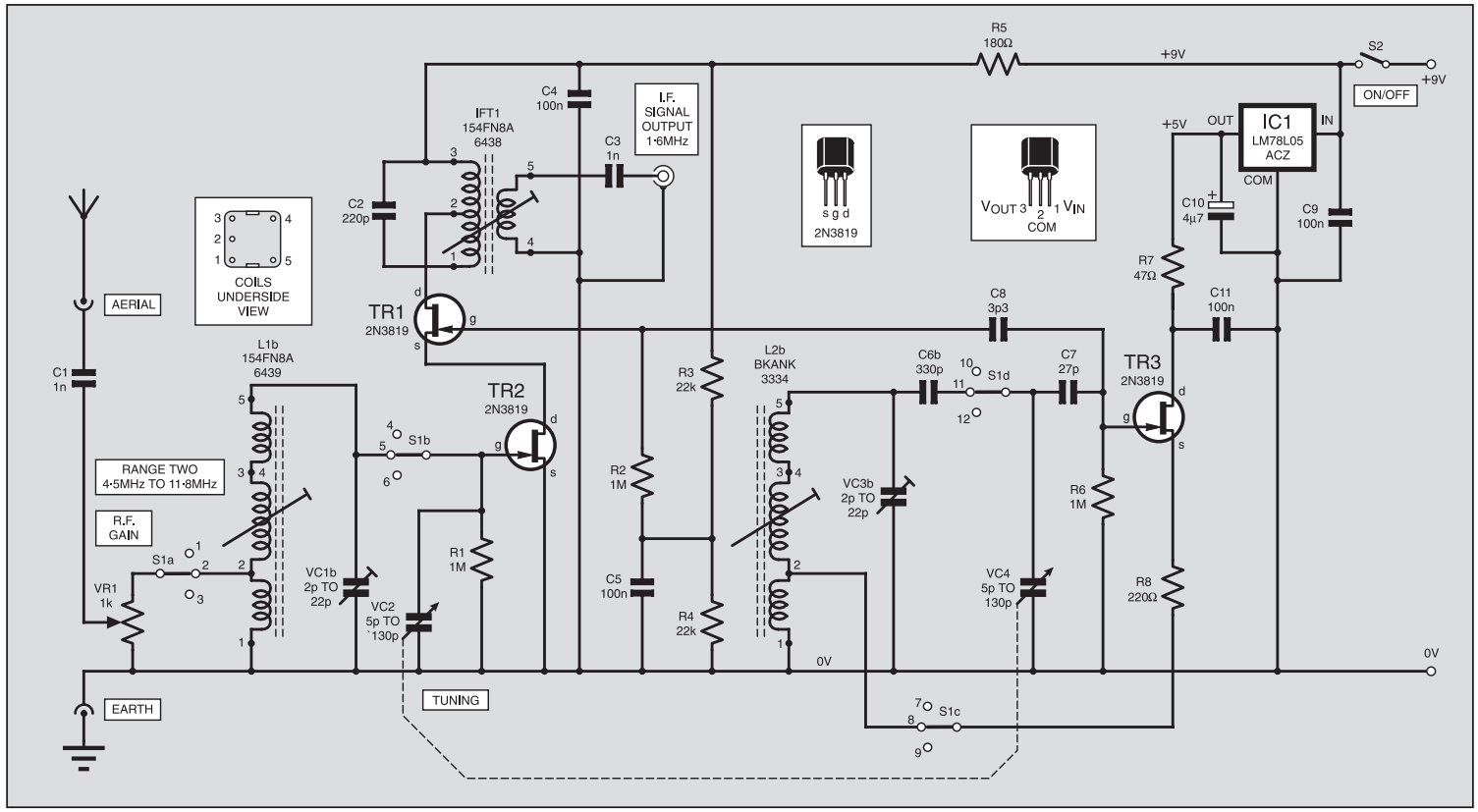


Fig.7.8. Circuit diagram for the mixer and oscillator stages for the 3-Band SW Superhet Tuner/Mixer. Coils for Range Two (4·5MHz to 11·8MHz) are shown. For ranges One and Three, see Fig.7.9.

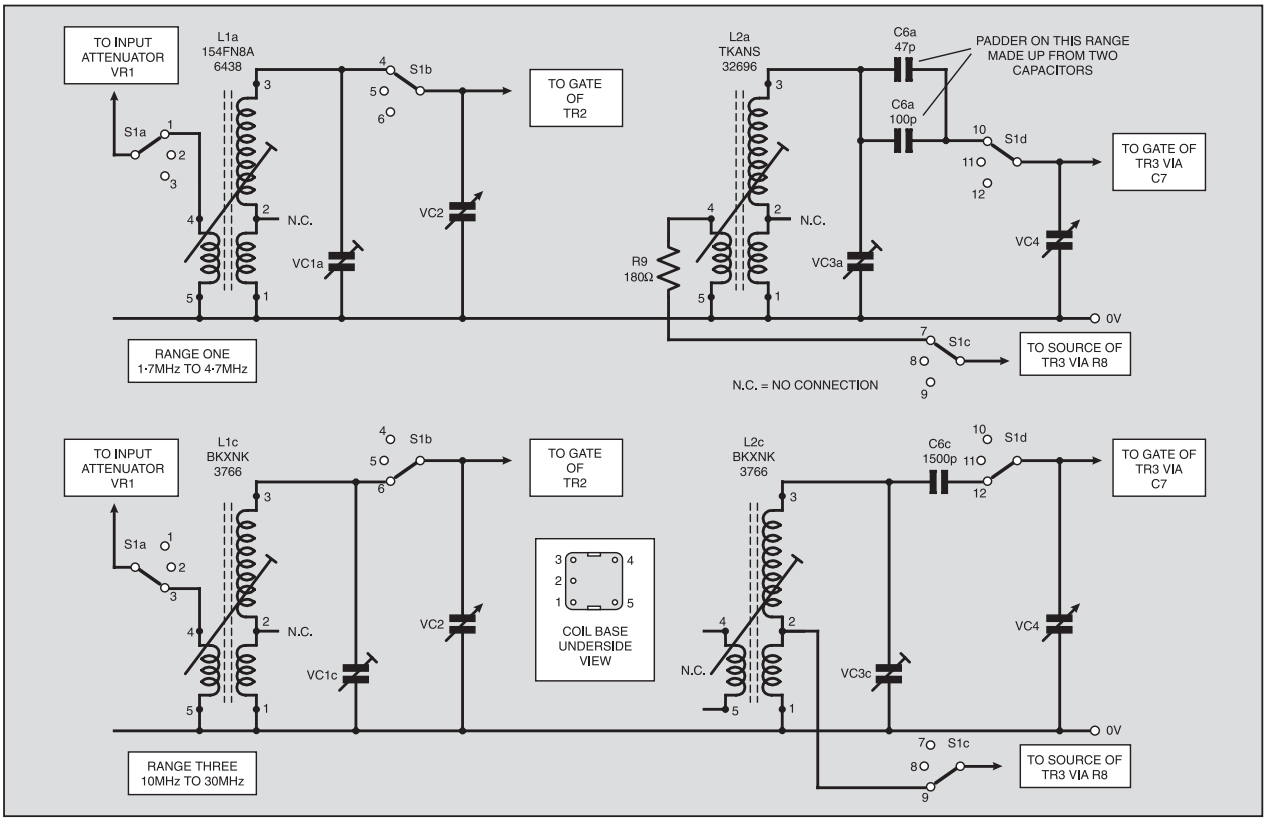


Fig.7.9. Circuit diagrams for the mixer/oscillator coil switching and padder arrangements for Shortwave Range One (1·7MHz to 4·7MHz) and Range Three (10MHz to 30MHz). VC2 and VC4 are ganged tuning capacitors and VC1 and VC3 are 2p to 22p trimming capacitors. See Fig.7.8 for Range Two details and full circuit.

Solder pins at the lead-out points simplify off-board wiring. They should be inserted first, followed by the Toko coils. Type numbers on the coil cans are easily removed by the smallest amount of handling: if they are to be retained they should be protected by clear sticky tape.

Follow the coils with the resistors, then the capacitors. Mount the transistors and the i.c. last. It is a good idea to use a miniature crocodile clip as a heatshunt when soldering the field effect transistors in position.

WAVECHANGE SWITCH

The coils have been arranged on the board so that the highest frequency inductors are closest to the wavechange switch. This minimizes lead-lengths where stray inductance would have the greatest impact. The wavechange switch and tuning capacitor must, however, be located as close as possible to the printed circuit board, and the photographs show the prototype arrangement.

Source resistor R8 and blocking capacitor C7 affect the willingness of TR3 to oscillate. Reducing the value of R8 and increasing C7 makes oscillation more vigorous. These components are used to link the p.c.b. to the wavechange switch S1. This makes them accessible to readers who wish to experiment, or who need to compensate for a low gain transistor.

Coil winding ratios make more source resistance necessary on Range One, and this takes the form of resistor R9 on the printed circuit board. See also Fig.7.9.

Provision is made on the board for a pair of trimmers, VC1/VC3, for each wave range. This will be necessary if an air-spaced tuning capacitor, without integral trimmers, is fitted. The suggested polyvaricon has its own trimmers, which will serve for a single range version, or for range three in a multirange receiver.

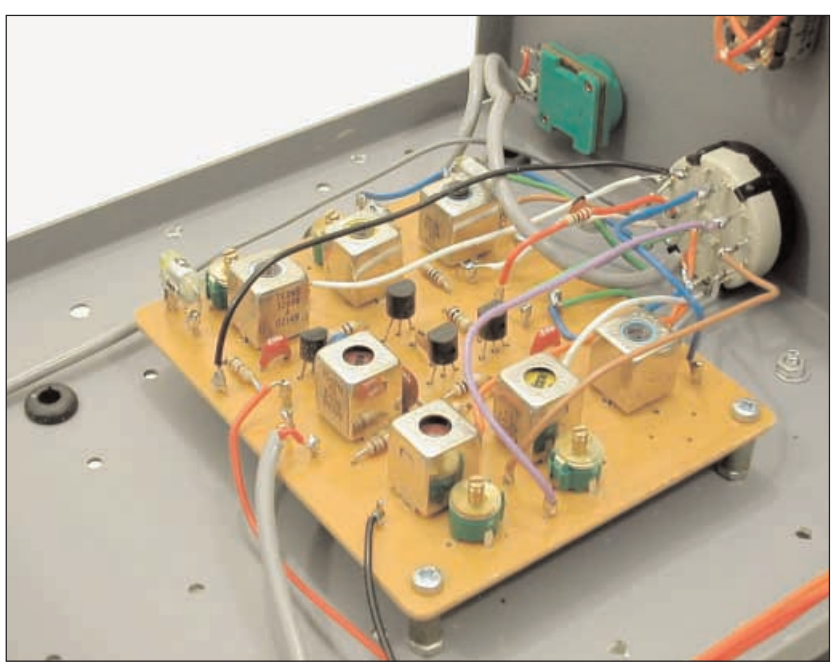
COMMISSIONING

Check the board for poor soldered joints and bridged tracks. Check the orientation of IC1, the semiconductors and tantalum capacitor C10. Check the wiring to the wavechange switch S1.

If all is in order, connect a fresh 9V battery. Current consumption should be in the region of 10mA and the voltage at the output of IC1 should be precisely 5V.

I.F. STRIP

Almost any medium wave receiver will act as the second mixer, i.f. strip, detector



Printed circuit board mounted on chassis (underside) and wired-up to the rotary wavechange switch.

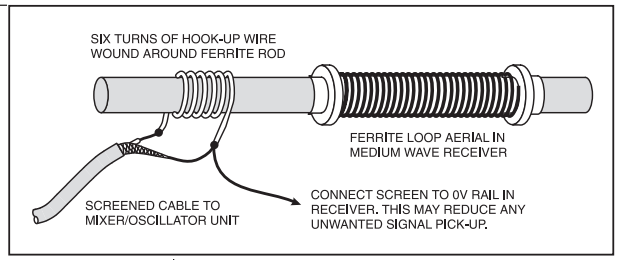


Fig.7.11. Linking the Mixer/Osc. to a portable radio. The radio provides the second mixer, i.f. amplifier, detector and audio amplifier functions.

and audio amplifier. A car radio, which has effective screening, is particularly suitable.

The Regenerative Radio described in Part 3 and Part 4 works well as an i.f. strip (the *Q*-multiplier control can be used to resolve single-side-band signals). Combinations of this kind are known as *supergainers*.

Connect the mixer/oscillator to the receiver via not more than 600mm (2ft) of *screened* cable. If a transistor portable is being used, wind about six turns of hook-up wire around the ferrite rod aerial and connect the cable to this, as shown in Fig.7.11.

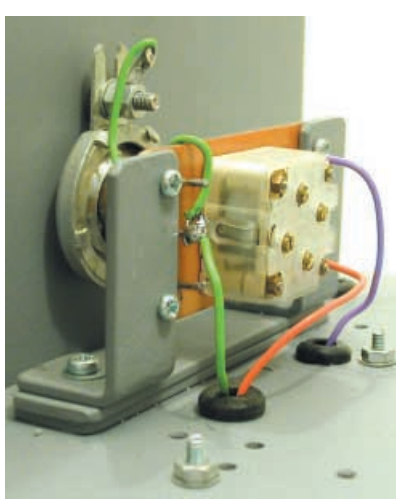
SETTING UP

The i.f. strip in the receiver is already aligned, and the simple procedure described below should enable readers who do not have access to a signal generator to get the shortwave mixer/oscillator tuner working.

Tuning the I.F.

Commence the tuning of the i.f. by setting all trimmers, including the tuning capacitor's integral trimmers, to minimum capacitance and set the coil and IFT1 cores to the depths quoted in Table 7.2.

Connect the tuner board to a medium wave receiver. Now switch on the receiver and tune it to a silent part of the dial at the



Above: Chassis view of tuning capacitor mounting, which is mounted directly above the p.c.b.

Fig.7.10. The 3-Band SW Superhet Tuner/Mixer printed circuit board component layout, interwiring and full-size copper foil master. VR1, S1 and VC2/VC4 all viewed from the rear.

extreme high frequency end of the medium wave band. Mark the dial setting on the receiver (the tuning of the shortwave mixer/oscillator unit will be altered if the setting is changed).

Aligning Range Two

Connect a battery and an aerial to the shortwave mixer/oscillator unit, switch it to Range 2 and rotate the tuning capacitor. Signals should be picked up around the dial.

Tune in a station with the tuning capacitor (VC2/VC4) set close to *maximum* and adjust the core of L1b to peak the output. Now tune in a station with VC2/VC4 set close to *minimum* and adjust trimmer capacitors, VC1b/VC3b, to peak the output.

Repeat these adjustments until no further improvement can be obtained.

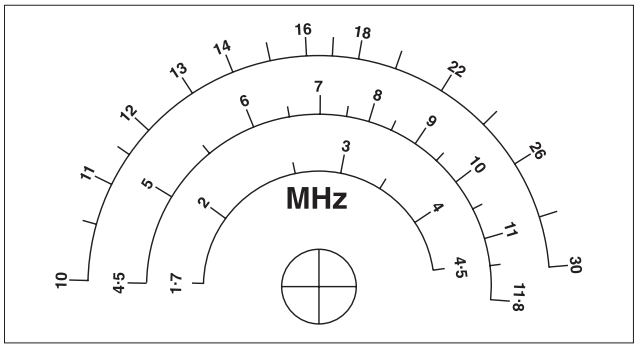


Fig.7.12. Calibrated tuning dial (half-size approx.) for the 3-Band SW Superhet Tuner.

Ranges One and Three

Switch to Range 3 and carry out the same procedure. The difficulty here will be finding a station at the high frequency end of the dial: try listening in the early afternoon. If integral trimmers are being used for the alignment of this range, set them to the lowest possible value, then switch back to Range Two and refine the adjustment of VC1b/VC3b to allow for the additional standing capacitance.

Switch to Range 1 and repeat the process. As frequency lowers the settings of cores and trimmers becomes more critical and no signals will be heard if the unit is significantly out of alignment. Setting the cores to the stated depths and a little patience should ensure success.

The calibrated dial of the prototype receiver is reproduced, half-size, in Fig.7.12. Oscillator coil core and trimmer settings have a very significant effect on coverage, and it is only useful as a general guide.

The setting of the core of IFT1 is not critical. After carrying out the above procedure it should be adjusted to peak the output from the unit.

PERFORMANCE

The precise frequency limits of each range cannot be set or defined without an accurately calibrated signal generator. It is, however, possible to align the unit well enough for it to give a very acceptable level of performance.

The use of field effect transistors brings all of the advantages mentioned earlier. Adopting a 1·6MHz i.f. greatly reduces the problem of spurious responses.

Tuning rate, with a single epicyclic reduction drive, is much too fast. Ways of making tuning less critical were discussed in Part Four, and next month a constant rate fine tuning system will be described.

SHOP TALK with David Barrington

PIC Virus Zapper

Most of our components advertisers should be able to suggest a suitable display module for the *PIC Virus Zapper*, but it would be advisable to check out the pin-out arrangement of the one being offered before purchasing; you can, if you wish, hardwire it to the p.c.b. The alphanumeric display module used in the prototype was one that originally came from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***).

For those readers unable to program their own PICs, a ready-programmed PIC microcontroller can be purchased direct from the author for the sum of £5 (add £1 for overseas). He will be supplying either the PIC16F84 or the PIC16F627, both devices are pin-for-pin compatible. Orders (*mail only*) should be sent to **Andy Flind, 22 Holway Hill, Taunton, Somerset, TA1 2HB**. Payments should be made out to *A. Flind*.

The software is available on a 3·5in. PC-compatible disk (Disk 6) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 891). It is also available *Free* via the Downloads click-link option on the home page when you enter our main web site at **www.epemag.wimborne.co.uk**, then enter the PIC Microcontroller source codes folder and select **PIC Virus Zapper**.

Christmas Cheeks

After browsing through a few components catalogues, it would appear that finding an l.e.d. with an identical specification to the one used in the *Christmas Cheeks* prototype is likely to cause some problems. Most of the red ultrabright and superbright l.e.d.s that we looked at seem to have "viewing angles" ranging from 50° to 60° and not the 30° listed by the author.

The types that appear to meet the author's specification or better are ones with "water clear" packages. You can, of course, use the standard ultrabright or superbright and accept a more diffused light intensity.

Practical Radio Circuits–7

As with previous *Practical Radio Circuits* projects, the inductors are really the only "specials" in this series. The author quotes two sources but has informed us that there may be a small delay as some coils have had to be re-ordered from Japan. However, by the time you read this issue they should have arrived.

All the Toko coils are available from **JAB Electronic Components** (☎ ***0121 682 7045*** or ***www.jabdog.com***), mail order only, or from **Sycom, Dept EPE, PO Box 148, Leatherhead, Surrey, KT33 9YW** (☎ ***01372 372587*** or **www.sycomcomp.co.uk**). You will need to order by quoting their type numbers as listed in the parts box and on the circuit diagrams.

The polyvaricon (polythene dielectric) variable capacitor will normally be found listed as a "transistor radio" type and consist of an antenna and oscillator section, plus trimmers. They are currently stocked by **ESR Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code 896-110 and **Sherwood Electronics** (see page 896), code CT9. The one in the prototype was obtained from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code AB11M.

PIC Nim Machine

We do not expect any buying problems to be encountered when gathering together parts for the *PIC Nim Machine* project.

A pre-programmed PIC16F877-20 (20MHz) microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £10 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (Disk 6) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 891). It is also available *Free* via the Downloads click-link option on the home page when you enter our main web site at **www.epemag.wimborne.co.uk**, then enter the PIC Microcontroller source codes folder and select **PIC Nim**.

Teach-In 2004 Part 2

No problems to report on this month's instalment of our new *Teach-In '04* series. All the various transistor types mentioned should be readily available from our components advertisers, particularly **Cricklewood Electronics** (☎ ***0208 452 0161***).

Good News! We have just been informed that **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) have produced two Teach-In components kits, one for the main components, including a plug-in breadboard, and the other containing most of the additional parts listed under "miscellaneous" in Part 1. See their ad. on pages 816/817.

Details of all the prices and ordering information for this month's printed circuit boards can be found on page 891.

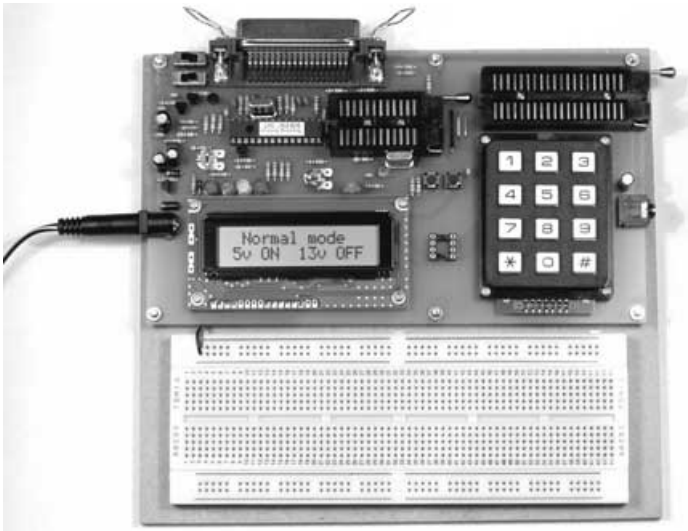
PLEASE TAKE NOTE

Cardboard Clock *(Nov '03)*

Use normal thin card for the clock wheels as thick (art supplies) card may be too heavy and stop it. Use a rectangular file to make the grooves that support the wheels axles. Depth is correct when a screw laid in the groove is half buried. Point "D" is the 15mm horizontal section of suspension hook W2. Cement end B of the pendulum post (A1) to the backboard.

For the pendulum rod start with a 1 metre length of 24s.w.g. wire, and draw it slightly, to straighten it. Before bending it, mark the bend points with a pencil. The letter p shows on which side to position the pliers, when making bends Q and R. When readjusting the coil table rely on the rubber band, and not on the bolt through hole E.

Learn About Microcontrollers



PIC Training & Development System

The best place to start learning about microcontrollers is the PIC16F84. This is easy to understand and very popular with construction projects. Then continue on using the more sophisticated PIC16F877 family.

The heart of our system is a real book which lies open on your desk while you use your computer to type in the programme and control the hardware. Start with four very simple programmes. Run the simulator to see how they work. Test them with real hardware. Follow on with a little theory.....

Our complete PIC training and development system consists of our universal mid range PIC programmer, a 306 page book covering the PIC16F84, a 262 page book introducing the PIC16F877 family, and a suite of programmes to run on a PC. The module is an advanced design using a 28 pin PIC16F872 to handle the timing, programming and voltage switching requirements. The module has two ZIF sockets and an 8 pin socket which between them allow most mid range 8, 18, 28 and 40 pin PICs to be programmed. The plugboard is wired with a 5 volt supply. The software is an integrated system comprising a text editor, assembler disassembler, simulator and programming software. The programming is performed at normal 5 volts and then verified with plus and minus 10% applied to ensure that the device is programmed with a good margin and not poised on the edge of failure. DC version (shown) for UK, battery version for overseas. UK orders include a plugtop power supply.

Universal mid range PIC programmer module
+ Book Experimenting with PIC Microcontrollers
+ Book Experimenting with the PIC16F877 (2nd edition)
+ Universal mid range PIC software suite
+ PIC16F84 and PIC16F872 test PICs. £139.00
(Postage & insurance UK £9, Europe £14, Rest of world £24)

Experimenting with PIC Microcontrollers

This book introduces the PIC16F84 and PIC16C711, and is the easy way to get started for anyone who is new to PIC programming. We begin with four simple experiments, the first of which is explained over ten and half a pages assuming no starting knowledge except the ability to operate a PC. Then having gained some practical experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music, including a rendition of Beethoven's *Für Elise*. Finally there are two projects to work through, using the PIC16F84 to create a sinewave generator and investigating the power taken by domestic appliances. In the space of 24 experiments, two projects and 56 exercises the book works through from absolute beginner to experienced engineer level.

Hardware & Ordering Information

Our PIC software is supplied as a self installing programme which will operate on any modern PC whichever operating system is used. For full information click onto 'Using PIC Software' on our web site.

Telephone with Visa, Mastercard or Switch, or send cheque/PO for immediate despatch. All prices include VAT if applicable.

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Experimenting with PC Computers with its kit is the easiest way ever to learn assembly language programming. If you have enough intelligence to understand the English language and you can operate a PC computer then you have all the necessary background knowledge. Flashing LEDs, digital to analogue converters, simple oscilloscope, charging curves, temperature graphs and audio digitising.

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Book + top up kit 2t + software £37.98
(PP UK £4, Europe £10, Rest of world £14)

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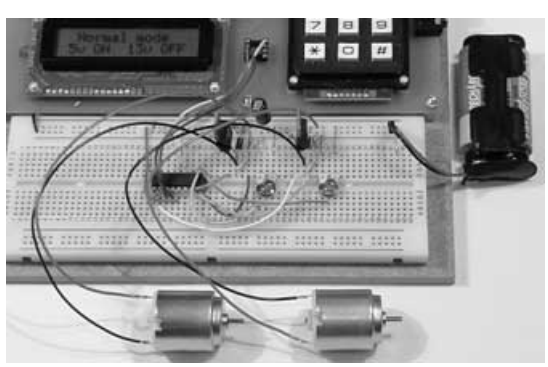
The assembler and C & C++ kits contain the prototyping board, lead assemblies, components and programming software to do all the experiments. The 'made up' kits are supplied ready to start. The 'top up' kit is for readers who have already purchased kit 1a or 1u.

Assembler and C & C++

Click on 'Special Offers' on our website for details of how to save by buying a combined kit for assembler and C & C++.



Experimenting with the PIC16F877

The second PIC book starts with the simplest of experiments to give us a basic understanding of the PIC16F877 family. Then we look at the 16 bit timer, efficient storage and display of text messages, simple frequency counter, use a keypad for numbers, letters and security codes, and examine the 10 bit A/D converter.

The 2nd edition has two new chapters. The PIC16F627 is introduced as a low cost PIC16F84. We use the PIC16F627 as a step up switching regulator, and to control the speed of a DC motor with maximum torque still available. Then we study how to use a PIC to switch mains power using an optoisolated triac driving a high current triac.

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The whole of the 12-part *Teach-In 2000* series by John Becker (published in *EPE* Nov '99 to Oct 2000) is now available on CD-ROM. Plus the *Teach-In 2000* interactive software covering all aspects of the series and Alan Winstanley's *Basic Soldering Guide* (including illustrations and Desoldering).

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The series gives a hands-on approach to electronics with numerous breadboard circuits to try out, plus a simple computer interface which allows a PC to be used as a basic oscilloscope.

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Also included are techniques for connecting a PC to a remote control system, the use of a microcontroller in remote control, as exemplified by the BASIC Stamp, and the application of ready-made type-approved 418MHz radio transmitter and receiver modules to remote control systems.

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Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

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Computing & Robotics

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The book was written with the non-expert, busy person in mind. It explains what hardware requirements you need in order to run Windows XP successfully, and gives an overview of the Windows XP environment.
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After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages **Order code NE31** **£18.99**

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

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Testing, Theory and Reference

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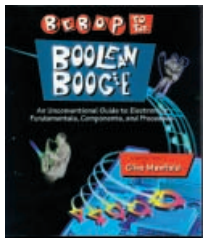
Clive (call me Max) Maxfield
An Unconventional Guide to Electronics Fundamentals, Components and Processes



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

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The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

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None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

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R. A. Penfold
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There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

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HIGH-SPEED DECIMAL TO BINARY FOR PICS

PETER HEMSLEY

Speed up your PIC's decimal data conversion and compression

MATHS is all about playing with numbers, so let's play and create a super-fast decimal to 16-bit binary routine for PIC microcontrollers. It is based on expressing powers of ten in terms of powers of two.

Here are the first five powers of ten:

```
1      = 1
10     = 8 + 2
100    = 64 + 32 + 4
1000   = 512 + 256 + 128 + 64 + 32 + 8
10000  = 8192 + 1024 + 512 + 256 + 16
```

If X represents any decimal digit between 0 and 9 then:

```
X      = (X × 1)
X0     = (X × 8) + (X × 2)
X00    = (X × 64) + (X × 32) + (X × 4)
X000   = (X × 512) + (X × 256) + (X × 128) + (X × 64) + (X × 32) + (X × 8)
X0000  = (X × 8192) + (X × 1024) + (X × 512) + (X × 256) + (X × 16)
```

These five expressions are the basis on which we can write a routine to convert a string of decimal digits into binary. The routine is to be written in assembler so any expression must be conducive to available processor instructions, namely NIBBLE SWAP, SHIFT LEFT and ADD.

Conducive numbers to work with are:

2 (SHIFT LEFT to multiply by 2)
16 (NIBBLE SWAP to multiply by 16)
256 (The result goes into the high byte of the binary)

If your mind is somewhat blank at this point let's try a simple example to get the grey matter working.

The number 300 can be written as:

$(3 \times 64) + (3 \times 32) + (3 \times 4)$

Re-writing it in terms of conducive numbers we get:

$3 \times 16 \times 2 \times 2 + 3 \times 16 \times 2 + 3 \times 2 \times 2$

Now reduce and re-arrange the expression to:

$((3 \times 16 + 3) \times 2 + 3 \times 16) \times 2 = 300$

Check it with your calculator.

This expression can be calculated easily using NIBBLE SWAP, SHIFT LEFT and ADD.

LISTING 1

```
; 5 digit decimal to 16 (17) bit binary. By Peter Hemsley, March 2003.
; Input decimal digits in D0 (LSD) to D4 (MSD)
; Output 16 bit binary in NUMHI and NUMLO
; No temporary variables required
; Code size: 33 instructions
; Execution time: 33 cycles (excluding Call and Return)
; Returns carry set if > 65535 (and NUMHI-LO MOD 65536)
dec2bin16
        movf    D1,W            ; (D1 + D3) × 2
        addwf   D3,W
        movwf   NUMLO
        rlf     NUMLO,F

        swapf   D2,W            ; + D2 × 16 + D2
        addwf   D2,W
        addwf   NUMLO,F

        rlf     D4,W            ; + (D4 × 2 + D3) × 256
        addwf   D3,W
        movwf   NUMHI

        rlf     NUMLO,F         ; × 2
        rlf     NUMHI,F

        swapf   D3,W            ; – D3 × 16
        subwf   NUMLO,F
        skpc
        decf    NUMHI,F

        swapf   D2,W            ; + D2 × 16 + D1
        addwf   D1,W
        addwf   NUMLO,F
        skpnc
        incf    NUMHI,F

        swapf   D4,W            ; + D4 × 16 + D0
        addwf   D0,W

        rlf     NUMLO,F         ; × 2
        rlf     NUMHI,F

        addwf   NUMLO,F
        skpnc
        incf    NUMHI,F

        movf    D4,W            ; – D4 × 256
        subwf   NUMHI,F

        swapf   D4,W            ; + D4 × 16 × 256 × 2
        addwf   NUMHI,F
        addwf   NUMHI,F
        return                  ; Q.E.D.
```

FEWER TERMS

Ok that was easy enough, so now for the tricky part.

The 1000's and 10000's expressions contain six and five terms respectively. If we also use SUBTRACT, the number of terms can be reduced to three and four:

X = (X × 1)
X0 = (X × 8) + (X × 2)
X00 = (X × 64) + (X × 32) + (X × 4)
X000 = (X × 1024) – (X × 32) + (X × 8)
X0000 = (X × 8192) + (X × 2048) – (X × 256) + (X × 16)

These five expressions can now be written in terms of conducive numbers and combined to give:

N = (((D1 + D3 + D4 × 256) × 2 + D2 × 16 + D2 + D3 × 256) × 2 – D3 × 16 + D2 × 16 + D1 + D4 × 16 × 256) × 2 + D4 × 16 + D0 – D4 × 256

Where D0 = ones, D1 = tens, D2 = hundreds, D3 = thousands, D4 = ten thousands

To save this author a lot of typing, and you a big headache, the details of how this expression was arrived at have been omitted. It is simple enough though a little lengthy.

There is a problem however, it is the –D4 × 256 at the end of the expression. If the input is greater than 63231 the running total will exceed the allotted 16 bits. So, again, re-arrange the expression:

N = (((D1 + D3 + D4 × 256) × 2 + D2 × 16 + D2 + D3 × 256) × 2 – D3 × 16 + D2 × 16 + D1) × 2 + D4 × 16 + D0 – D4 × 256 + D4 × 16 × 256 × 2

Now there is an addition of a large number at the end of the expression, therefore overflow will not occur.

PIC ROUTINE

The PIC routine in Listing 1 is an almost literal translation of this expression into assembler, with just a few tweaks to make the code more efficient. The variables may be allocated (equated) to any registers of your choice.

The routine will work with numbers up to 99999, the 17th bit (or bit 16) being returned in the Carry.

Finally, if your numerical value is expressed in ASCII text characters, each character may be converted to a BCD (binary-coded-decimal) format by subtracting 48, which makes it easy to then check if it is a valid decimal digit.

RESOURCE

This software routine is available from the *EPE PCB Service* on 3·5in disk (Disk 6, *PIC Tricks* folder), for which a nominal handling charge applies. It is also available for free download from the *EPE* Downloads page, accessible via the home page at **www.epemag.wimborne.co.uk**. It is in the *PIC Tricks* folder, as file **Dec2Bin16.txt**.

The *PIC Tricks* folder holds other excellent PIC maths routines written by Peter and which are well worth examining and using.

We shall soon be publishing another set of Peter's routines which are 32-bit based and as such can handle *really* large numbers.

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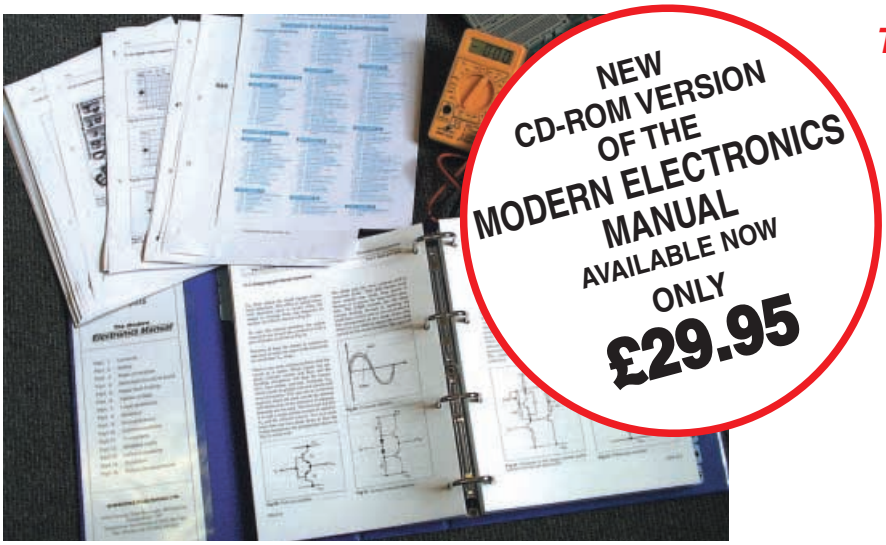

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