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EVERYDAY

Vol.33 No.1

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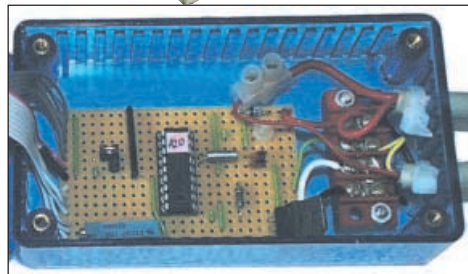
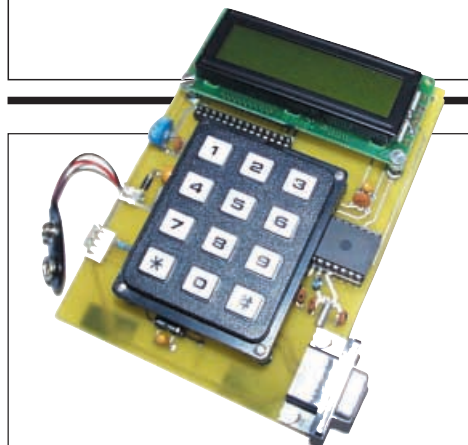
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Our February 2004 issue will be published on Thursday, 8 January 2004. See page 3 for details

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NEXT MONTH

PIC LCF METER

This simple PIC-based unit was designed to measure and display the values of inductors and capacitors. As a by-product of the technique used, it can also display the frequency of an external 0V/+5V signal source.

The ranges are approximately:

Capacitance: 1pF to 6500 μ F
Inductance: 1 μ H to 10H
Frequency: 0.05Hz to 5MHz

The design is based upon the concept that oscillators can be constructed from CMOS NAND gates or inverters, and that their oscillation frequency depends on the values of inductance, capacitance and resistance in their feedback paths. A PIC16F628 microcontroller monitors the frequencies, performs quite complex mathematical calculations on them and displays the results on an alphanumeric l.c.d. screen. The unit is inexpensive, and straightforward to build.



JAZZY NECKLACE

A chic appearance and a striking piece of jewellery can emphasise the beauty of the wearer, as well as adding a sense of lightness to life.

An item of jewellery that lends itself particularly well to electronic enhancement is a traditional African style necklace which comprises an array of vertical rods, artistically arranged, suspended from a string around the neck.

This project unveils a 21st-Century version of the necklace which, instead of using rods of wood or other customary materials, employs sixteen sparkling clear acrylic rods. These are accompanied by a compact circuit which darts various colours of light down the length of the rods, at random. The result is a truly amazing piece of "jewellery".



PLUS TEACH-IN 2004 – PART 4 LOGIC GATES

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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

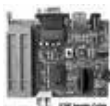


NEW! USB & Serial Port PIC Programmer

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

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.



ABC Mini Starter Pack

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



NEW! DTMF Telephone Relay Switcher

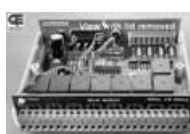
Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12VDC.

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 appropriate 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

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

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.

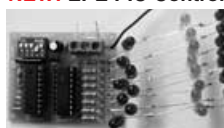
Supply: 9-12V DC (Order Code PSU203).

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 supplied). 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.

Order Code: 1031M – £124.95



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Order Code EPL200 – £47.95

30, 130-300 and 500-in-1 project labs also available – see website for details.



Number 1 for Kits!

With over 300 projects in our range we are the UK's number 1 electronic kit specialist. Here are a few other kits from our range.

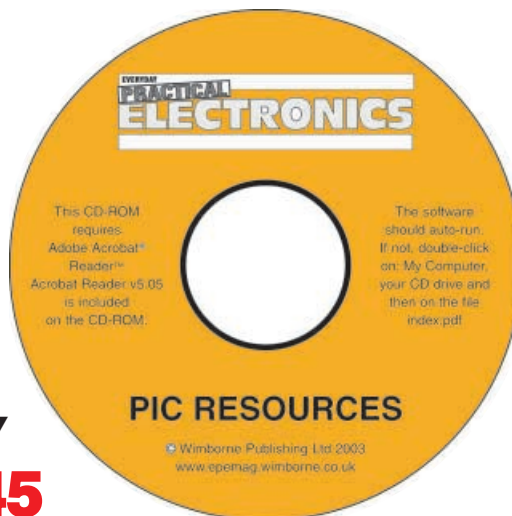
- 1046KT – 25W Stereo Car Booster £26.95
- 3087KT – 1W Stereo Amplifier £4.95
- 3105KT – 18W BTL mono Amplifier £9.95
- 3106KT – 50W Mono Hi-fi Amplifier £19.95
- 3143KT – 10W Stereo Amplifier £9.95
- 1011KT – Motorbike Alarm £11.95
- 1019KT – Car Alarm System £10.95
- 1048KT – Electronic Thermostat £9.95
- 1080KT – Liquid Level Sensor £5.95
- 3005KT – LED Dice with Box £7.95
- 3006KT – LED Roulette Wheel £8.95
- 3074KT – 8-Ch PC Relay Board £29.95
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- 3126KT – Sound-Activated Relay £7.95
- 3063KT – One Chip AM Radio £10.95
- 3102KT – 4-Ch Servo Motor Driver £15.95
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- SWEPT FREQUENCY

An affordable circuit which sweeps the incoming water supply with variable frequency electromagnetic signals. May reduce scale formation, dissolve existing scale and improve lathering ability by altering the way salts in the water behave. Kit includes case, P.C.B., coupling coil and all components. High coil current ensures maximum effect. L.E.D. monitor.



KIT 868 £22.95 POWER UNIT.....£3.99

MICRO PEST SCARER

Our latest design - The ultimate scarer for the garden. Uses special microchip to give random delay and pulse time. Easy to build reliable circuit. Keeps pets/pests away from newly sown areas, play areas, etc. uses power source from 9 to 24 volts.

- RANDOM PULSES
- HIGH POWER
- DUAL OPTION



Plug-in power supply £4.99

KIT 867.....£19.99

KIT + SLAVE UNIT.....£32.50

WINDICATOR

A novel wind speed indicator with LED readout. Kit comes complete with sensor cups, and weatherproof sensing head. Mains power unit £5.99 extra.

KIT 856.....£28.00

★ TENS UNIT ★

DUAL OUTPUT TENS UNIT

As featured in March '97 issue.

Magenta have prepared a FULL KIT for this excellent new project. All components, PCB, hardware and electrodes are included. Designed for simple assembly and testing and providing high level dual output drive.

KIT 866. . Full kit including four electrodes £32.90

Set of 4 spare electrodes £6.50

1000V & 500V INSULATION TESTER



Superb new design. Regulated output, efficient circuit. Dual-scale meter, compact case. Reads up to 200 Megohms.

Kit includes wound coil, cut-out case, meter scale, PCB & ALL components.

KIT 848.....£32.95

EPE TEACH-IN 2000

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.

TEACH-IN 2000 -

KIT 879 £44.95

MULTIMETER £14.45

SPACEWRITER

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.

KIT 849£16.99

Now with PC program for downloading messages to kit. Includes PC program & software disk.

12V EPROM ERASER

A safe low cost eraser for up to 4 EPROMs at a time in less than 20 minutes. Operates from a 12V supply (400mA). Used extensively for mobile work - updating equipment in the field etc. Also in educational situations where mains supplies are not allowed. Safety interlock prevents contact with UV.

KIT 790£29.90

SUPER BAT DETECTOR

1 WATT O/P, BUILT IN SPEAKER, COMPACT CASE 20kHz-140kHz NEW DESIGN WITH 40kHz MIC.

A new circuit using a 'full-bridge' audio amplifier i.c., internal speaker, and headphone/tape socket. The latest sensitive transducer, and 'double balanced mixer' give a stable, high performance superheterodyne design.

KIT 861£27.99

ALSO AVAILABLE Built & Tested. . . £42.99



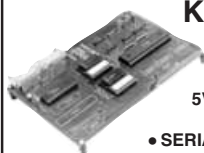
68000 DEVELOPMENT TRAINING KIT

- NEW PCB DESIGN
- 8MHz 68000 16-BIT BUS
- MANUAL AND SOFTWARE
- 2 SERIAL PORTS
- PIT AND I/O PORT OPTIONS
- 12C PORT OPTIONS

KIT 621

£99.95

- ON BOARD 5V REGULATOR
- PSU £6.99
- SERIAL LEAD £3.99



Stepping Motors

MD100...Std 100 step...£9.99

MD200...200 step...£12.99

MD24...Large 200 step...£22.95



MOSFET MkII VARIABLE BENCH POWER SUPPLY 0-25V 2.5A

Based on our Mk1 design and preserving all the features, but now with switching pre-regulator for much higher efficiency. Panel meters indicate Volts and Amps. Fully variable down to zero. Toroidal mains transformer. Kit includes punched and printed case and all parts. As featured in April 1994 EPE. An essential piece of equipment.



Kit No. 845£64.95

ULTRASONIC PEST SCARER

Keep pets/pests away from newly sown areas, fruit, vegetable and flower beds, children's play areas, patios etc. This project produces intense pulses of ultrasound which deter visiting animals.

- KIT INCLUDES ALL COMPONENTS, PCB & CASE
- EFFICIENT 100V TRANSDUCER OUTPUT
- COMPLETELY INAUDIBLE TO HUMANS



- UP TO 4 METRES RANGE
- LOW CURRENT DRAIN

KIT 812.....£15.00

SIMPLE PIC PROGRAMMER

KIT 857... £12.99

Includes PIC16F84 chip disk, lead, plug, p.c.b., all components and instructions

Extra 16F84 chips £3.84 Power Supply £3.99

MAGENTA BRAINBOT I & II

- Full kit with ALL hardware and electronics
- As featured in *EPE* Feb '03 – KIT 910
- Seeks light, beeps, avoids obstacles
- Spins and reverses when 'cornered'
- Uses 8-pin PIC
- ALSO KIT 911 – As 910 PLUS programmable from PC serial port – leads and software CD provided

NEW



KIT 910 £16.99 KIT 911 £24.99

PIC 16F84 MAINS POWER 4-CHANNEL CONTROLLER & LIGHT CHASER

- ZERO VOLT SWITCHING
- OPTO ISOLATED 5 Amp
- 12 KEYPAD CONTROL
- HARD-FIRED TRIACS WITH SOURCE CODE
- SPEED & DIMMING POT.
- EASILY PROGRAMMED

Kit 855 £39.95

PIC 16F84 LCD DISPLAY DRIVER

INCLUDES 1-PIC16F84 WITH DEMO PROGRAM SOFTWARE DISK, PCB, INSTRUCTIONS AND 16-CHARACTER 2-LINE LCD DISPLAY

Kit 860 £19.99

Power Supply £3.99

FULL PROGRAM SOURCE CODE SUPPLIED – DEVELOP YOUR OWN APPLICATION!

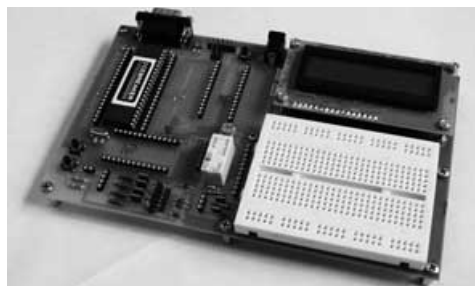
Another super PIC project from Magenta. Supplied with PCB, industry standard 2-LINE x 16-character display, data, all components, and software to include in your own programs. Ideal development base for meters, terminals, calculators, counters, timers – Just waiting for your application!

8-CHANNEL DATA LOGGER

As featured in Aug./Sept. '99 *EPE*. Full kit with Magenta redesigned PCB – LCD fits directly on board. Use as Data Logger or as a test bed for many other 16F877 projects. Kit includes programmed chip, 8 EEPROMs, PCB, case and all components.

KIT 877 £49.95 inc. 8 x 256K EEPROMS

ICEBREAKER
□□□□□□□□□□



PIC Real Time In-Circuit Emulator

- Icebreaker uses PIC16F877 in circuit debugger
- Links to Standard PC Serial Port (lead supplied)
- Windows™ (95+) Software included
- Works with MPASM and MPLAB Microchip software
- 16 x 2 L.C.D., Breadboard, Relay, I/O devices and patch leads supplied

As featured in March '00 *EPE*. Ideal for beginners AND advanced users. Programs can be written, assembled, downloaded into the microcontroller and run at full speed (up to 20MHz), or one step at a time. Full emulation means that all I/O ports respond exactly and immediately, reading and driving external hardware.

Features include: Reset; Halt on external pulse; Set Breakpoint; Examine and Change registers, EEPROM and program memory; Load program, Single Step with display of Status, W register, Program counter, and user selected 'Watch Window' registers.

KIT 900 ... £34.99

POWER SUPPLY £3.99 STEPPING MOTOR 100 STEP £9.99

EPE TEACH-IN 2004

THE LATEST SERIES – STARTED NOV '03

ALL PARTS INCLUDING PROTOTYPE BREADBOARD AND WIRE – AS LISTED ON p752 NOV. ISSUE (EXCL MISC.)
"A BRILLIANT NEW ELECTRONICS COURSE"

KIT 920 ... £29.99

ADDITIONAL PARTS – AS LISTED UNDER MISCELLANEOUS – BUT LESS RADIO MODULES, SOLENOID LOCK AND MOTOR/ GEARBOX.

KIT 921 ... £12.99

EPE PIC Tutorial V2

EPE APR/MAY/JUNE '03 and PIC RESOURCES CD

FOLLOW THIS SERIES WITH EPE PIC TOOLKIT 3

- THE LATEST TOOLKIT BOARD – 8, 18, 28 AND 40-PIN CHIPS
- MAGENTA DESIGNED P.C.B. WITH COMPONENT LAYOUT AND EXTRAS
- L.C.D. BREADBOARD AND PIC CHIP INCLUDED
- ALL TOP QUALITY COMPONENTS AND SOFTWARE SUPPLIED

KIT 880 ... £34.99 WITH 16F84

PIC TUTOR 1 MARCH - APRIL - MAY '98 EPE SERIES 16F84

PIC TUTOR BOARD KIT

Includes: PIC16F84 Chip, TOP Quality PCB printed with Component Layout and all components* (*not ZIF Socket or Displays). Included with the Magenta Kit is a disk with Test and Demonstration routines.

KIT 870 £27.95, Built & Tested £42.95

Optional: Power Supply – £3.99, ZIF Socket – £9.99

LCD Display £7.99 LED Display £6.99

Reprints Mar/Apr/May 98 – £3.00 set 3

SUPER PIC PROGRAMMER

- READS, PROGRAMS, AND VERIFIES
- WINDOWS™ SOFTWARE
- PIC16C AND 16F – 6X, 7X, AND 8X
- USES ANY PC PARALLEL PORT
- USES STANDARD MICROCHIP • HEX FILES
- DISASSEMBLER SOFTWARE
- PCB, LEAD, ALL COMPONENTS, TURNED-PIN SOCKETS FOR 18, 28, AND 40 PIN ICs

- SEND FOR DETAILED INFORMATION – A SUPERB PRODUCT AT AN UNBEATABLE LOW PRICE.

Kit 862 £29.99

Power Supply £3.99

PIC STEPPING MOTOR DRIVER

INCLUDES PCB, PIC16F84 WITH DEMO PROGRAM, SOFTWARE DISC, INSTRUCTIONS AND MOTOR.

Kit 863 £18.99

FULL SOURCE CODE SUPPLIED ALSO USE FOR DRIVING OTHER POWER DEVICES e.g. SOLENOIDS

Another Magenta PIC project. Drives any 4-phase unipolar motor – up to 24V and 1A. Kit includes all components and 48 step motor. Chip is pre-programmed with demo software, then write your own, and re-program the same chip! Circuit accepts inputs from switches etc and drives motor in response. Also runs standard demo sequence from memory.

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See Next / Last Months Ad. for
COMPONENT ACCESSORIES

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4002B	0.19	74HC73	0.40	74LS113
4007UB	0.19	74HC74	0.31	74LS114
4008B	0.23	74HC76	0.20	74LS122
4009UB	0.23	74HC85	0.24	74LS123
4010B	0.23	74HC86	0.22	74LS126
4011B	0.16	74HC107	0.40	74LS132
4012B	0.16	74HC123	0.33	74LS134
4013B	0.17	74HC125	0.26	74LS136
4014B	0.30	74HC126	0.46	74LS138
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4018B	0.26	74HC138	0.29	74LS151
4019B	0.25	74HC139	0.33	74LS152
4021B	0.26	74HC151	0.33	74LS156
4022B	0.32	74HC153	0.30	74LS158
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4024B	0.22	74HC158	0.23	74LS161
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4029B	0.17	74HC164	0.23	74LS174
4030B	0.31	74HC165	0.38	74LS175
4040B	0.24	74HC173	0.27	74LS190
4041B	0.31	74HC175	0.35	74LS192
4042B	0.22	74HC192	0.72	74LS193
4043B	0.35	74HC193	0.40	74LS195
4044B	0.35	74HC195	0.32	74LS196
4046B	0.32	74HC240	0.32	74LS221
4047B	0.34	74HC241	0.32	74LS240
4048B	0.29	74HC244	0.42	74LS241
4049B	0.29	74HC245	0.42	74LS242
4050B	0.24	74HC251	0.38	74LS244
4051B	0.21	74HC253	0.25	74LS245
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4053B	0.22	74HC259	0.57	74LS251
4054B	0.56	74HC273	0.52	74LS257
4055B	0.34	74HC299	0.37	74LS258
4056B	0.22	74HC365	0.38	74LS259
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4520B	0.34	74LS02	0.22	AD812AN
4521B	0.62	74LS03	0.29	AD817AN
4526B	0.40	74LS04	0.22	AD820AN
4527B	0.40	74LS05	0.14	AD822AN
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4558B	0.40	74LS26	0.17	AD8739AN
4559B	0.47	74LS27	0.25	AD8741AN
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EVERYDAY
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THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 33 No. 1 JANUARY 2004

ALL SHAPES AND SIZES . . .

There are not many magazines that have such a wide range of readership as *EPE*. We have readers from as young as 12 or 13 through to those in their eighties. Readers with little or no experience of electronics through to professional engineers and university lecturers; they all avidly follow *EPE*. Our *Ingenuity Unlimited* (IU) feature carries items from readers right across this age and ability spectrum and we are pleased to encourage our younger readers by publishing their innovative circuits from time to time. Not that we always know how old contributors are, but sometimes the handwriting and signatures give us a good clue.

Of course, we also have readers right around the world and regular contributors from every continent. Myo Min, who is a regular IU contributor, writes from Myanmar, perhaps better known to us as Burma; the Rev. Thomas Scarborough in South Africa, many contributors in Australia, New Zealand and America and a few from places like India, Pakistan, Malaysia and most European countries.

I guess the World Wide Web has helped spread the word about *EPE*; our *EPE Online* edition (which is controlled from Alabama, USA) is regularly downloaded by thousands of readers dotted all over the globe, and over 10,000 printed copies are now sent to distributors abroad each month.

. . . EXCEPT ONE

Our hobby is truly international and age and ability seem to be no barrier. The one area where we are not "universal" is in gender. Our research shows that less than three per cent of our readers are female. With the more enlightened UK educational system now offering what were traditionally male subjects to everyone we wonder why there are still so few females interested in electronics. Maybe there are some barriers that still need to be broken down? If you are one of our female readers we would like to hear from you – is electronics still considered to be an unusual subject for girls and, if so, why?

It seems to us that many schools still find it difficult to embrace electronics – even within Design and Technology – as part of the regular curriculum, whilst a few, like Radley College (where our *Teach-In 2004* author, Max Horsey, is Head of Electronics), positively shine at the subject. We guess it is simply down to the background, enthusiasm and ability of individual teachers; again your views on this would be of interest.

2004

Whilst I'm writing this in mid-November, it will be rapidly approaching Christmas and the New Year by the time you read it. So may we wish you all the season's greetings and thank you for your support and enthusiasm over the last year. We hope you have a peaceful, interesting and rewarding 2004.

Mike Kenward

AVAILABILITY

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CAR COMPUTER

MIKE HIBBETT



An aid for motorists who don't live with a mechanic!

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.

Years ago a friend of the author taught him a great technique for monitoring a car's performance. Using a small log book, she recorded each time the fuel tank was filled and by recording the mileage and amount of fuel added, she was able to track the m.p.g. (miles-per-gallon). A gradual reduction in the m.p.g. or a sudden change indicated the onset of a problem that could be rectified before it became serious.

COMPUTER LOG

This Car Computer replaces and improves on the log book method by automatically calculating the m.p.g. (or miles per litre or kilometres per litre) and allowing the user to review its trend on a display. Of course, the lovely thing about software is that there is plenty of scope for "extra features" – which have been added!

It is a handheld unit powered from four AA cells. Through the use of low power design techniques, in both hardware and software, the batteries should last for several months before needing to be changed. A PC link allows information to be conveniently downloaded to it. However, this is not a requirement and the device can be operated without the use of a PC.

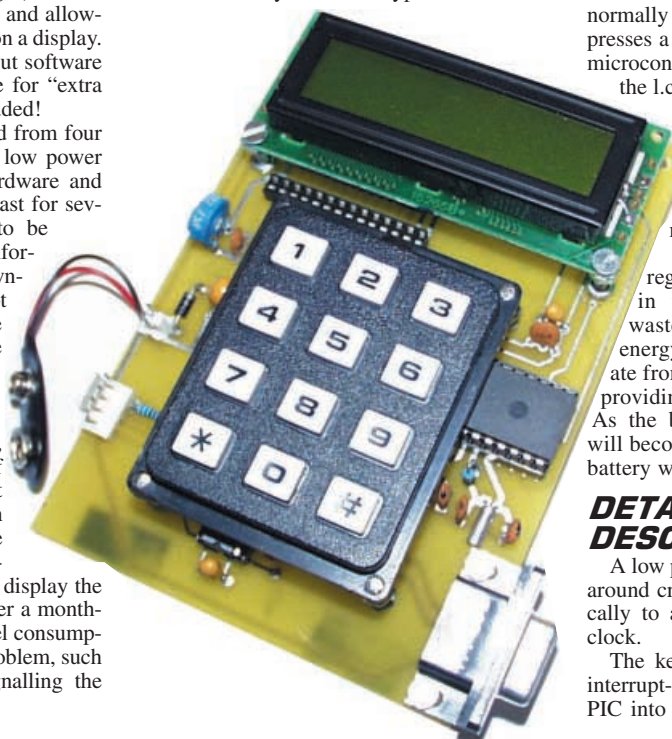
WHAT IT DOES

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, the Car Computer calculates fuel consumption and can display the change in fuel consumption 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.

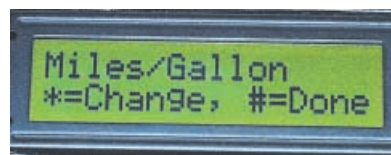
The owner may also enter "service points", which are reminders to take some kind of action such as changing a timing belt or to have an in-warranty checkup. These events are typically time and/or distance based, and the Car Computer can be configured to track elapsed time and distance and prompt the owner at the appropriate moment. These service points may be entered directly or conveniently downloaded from a PC.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Car Computer is shown in Fig.1. The heart of the design is a PIC16F877 microcontroller, IC1. A standard liquid crystal display (l.c.d.) module provides the information display in a two line by sixteen characters per line format. Preset VR1 is used to set the screen contrast. User input is via a 12-key numeric keypad.



A small EEPROM serial memory device, IC2, holds the "service point" information and the historical fuel consumption data from which the fuel consumption trends are calculated. An RS232 level converter, IC3, provides the signal level changes required to connect the microcontroller to the COM port on a PC.



LOW POWER FEATURES

A number of hardware design features have been implemented to enable the Car Computer to run for several months from a single set of batteries. You may have noticed that there is no Off switch!

To conserve power, the microcontroller is normally held in the Sleep operational mode where it consumes negligible power, normally only waking up when the user presses a button. While in Sleep mode the microcontroller removes the power from the l.c.d. and RS232 device IC3 to significantly reduce the circuit power consumption, down to less than 300µA. In this state the circuit can operate for many months before the batteries need to be replaced.

The use of a 9V battery and regulator has been avoided because in this type of application this wastes a huge amount of battery energy. All the components can operate from a 6V supply, so four AA cells, providing 1.5V each, fit the bill nicely. As the battery voltage drops the l.c.d. will become dimmer, giving a simple low battery warning!

DETAILED DESCRIPTION

A low power, low speed oscillator based around crystal X2 wakes the PIC periodically to allow it to update the real-time clock.

The keypad is connected to the PIC's interrupt-on-change port, which wakes the PIC into high-speed mode when a key is

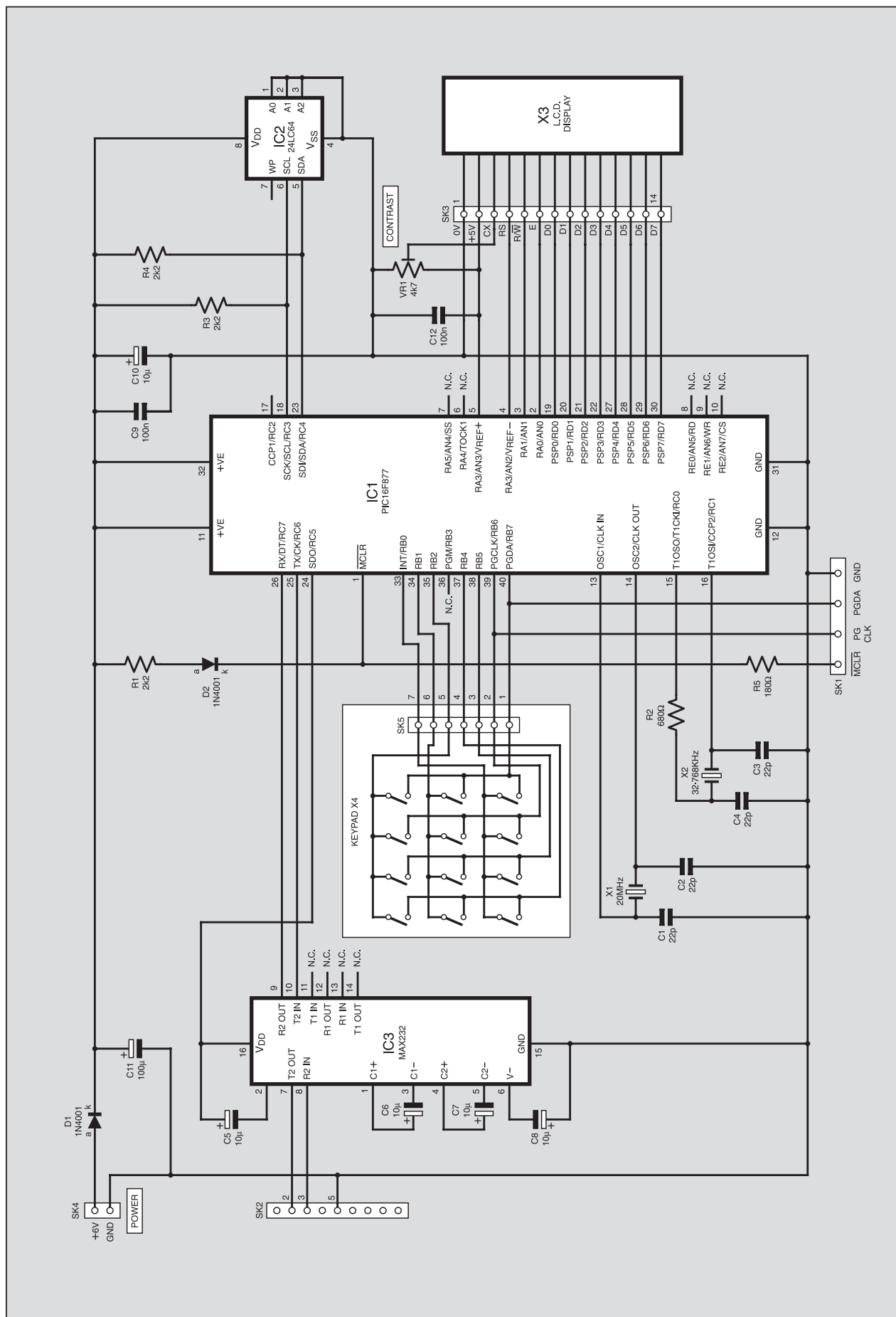


Fig.1. Complete circuit diagram for the PIC-driven Car Computer.

pressed. Once woken the PIC then enables the I.c.d. and displays options to the user. After 60 seconds of inactivity the PIC automatically turns off the I.c.d. and returns to the low power Sleep mode.

CRYSTAL CONTROL

The real-time clock is maintained using an external oscillator connected to the PIC's Timer 1 pins. Most of the oscillator components are within the PIC itself, and only four external passive components are required, crystal X2, which is a standard 32.768kHz "watch" type, plus resistor R2 and capacitors C3 and C4.

The crystal is an AT cut part which requires current limiting, and this is provided by R2. AT cut crystals resemble tiny piano tuning forks and can vibrate to destruction if overdriven. The benefit of this type of crystal is that they operate in a different mode to normal microcontroller crystals, which allows them to maintain a small size when operating at low frequencies.

Crystal X1 provides the main operational clock to the PIC, operating at 20MHz. This clock is switched off during Sleep mode to further conserve power.

Resistor R1 and diode D2 provide a pull-up to the PIC's Reset input (MCLR) and provide protection to the rest of the circuit when programming voltages are applied to the circuit.

The programming connector, SK1, allows in-circuit programming, very useful during development and debugging. Resistor R5 improves noise immunity during programming, which might otherwise lockup the microcontroller.

Battery power is fed in via socket SK4, with diode D1 providing reverse polarity protection to the circuit. It also limits the battery voltage, which can be as high as 6.5V with four new AA cells.

Power for the RS232 interface (IC3) and the I.c.d. are provided by PIC pins RC5 and RA3. The maximum current consumption of the two devices (3mA for the I.c.d. and 15mA for IC3) is well within the 25mA driving capability of the PIC.

CONSTRUCTION

Details of the component and track layouts for the double-sided printed circuit board (p.c.b.) for the Car Computer are shown in Fig.2. This board is available from the *EPE PCB Service*, code 431.

Although the p.c.b. is not particularly complex or densely populated, it is advised that you should fit the components in the following order: i.c. sockets; resistors, diodes, crystals, unpolarised capacitors, polarised capacitors, connectors.

Links between the copper tracks on both sides of the double-sided board can be made using resistor off-cut wires, these should be inserted and soldered first.

Once assembly is completed, but before fitting the I.c.d. or the i.c.s, temporarily connect the batteries and check that power is reaching the correct pins on the i.c. and I.c.d. sockets. If not, check the polarity of diode D1 and look for shorts on the tracks.

If you find a short between i.c. socket pins apply a soldering iron to the pins on the component side of the board and try to "wipe" the solder clear. If this does not solve the problem, try using solder wick.

COMPONENTS

Approx. Cost
Guidance Only

£24

excl. batts & case

Resistors R1, R3, R4 2k2 (3 off) R2 680Ω R5 180Ω All 0.25W 5% carbon film		See SHOP TALK page		IC2	24LC64 64K-bit serial EEPROM
				IC3	MAX232, RS232 interface
				Miscellaneous	
				SK1	5-way BERG header
Potentiometer VR1 4k7 preset, vertical mounting				SK2	DB9 9-way D-type female connector, p.c.b. mounting
				SK3	14-way s.i.l. header
Capacitors C1 to C4 22p ceramic disc, 5mm pitch (4 off) C5 to C8, C10 10μ tantalum, 16V (5 off) C9, C12 100n ceramic disc, 5mm pitch (2 off) C11 100μ tantalum 16V				X1	20MHz crystal
				X2	32.768kHz AT cut watch crystal
				X3	alphanumeric liquid crystal display, 2 lines x 16 characters per line
				X4	12-key data entry matrix keypad
Semiconductors D1, D2 1N4001 rectifier diode (2 off) IC1 PIC16F877-20 microcontroller, preprogrammed (see text)					

Printed circuit board, available from the *EPE PCB Service*, code 431 (double-sided); plastic case, size 102mm x 142mm x 48mm approx. AA-size cells (4 off) and battery clip; connecting wire; solder, etc.

This might damage plastic sockets but the damage is usually only cosmetic.

If use of the PIC programming interface is intended, connect the programming interface to the board and check that 5V appears on the supply pins of the PIC socket, and the programming voltage (12V to 14V, depending on your programmer) is applied to the MCLR pin. If you find the programming voltage is on the PIC supply pins, check the polarity of diode D2.

If all is well insert the i.c.s into their sockets and plug in the I.c.d. and keypad.

Apply power and adjust VR1 for acceptable I.c.d. screen contrast. As the display will become dimmer as the battery level decreases, it is better to have the display set quite dark with fresh batteries.

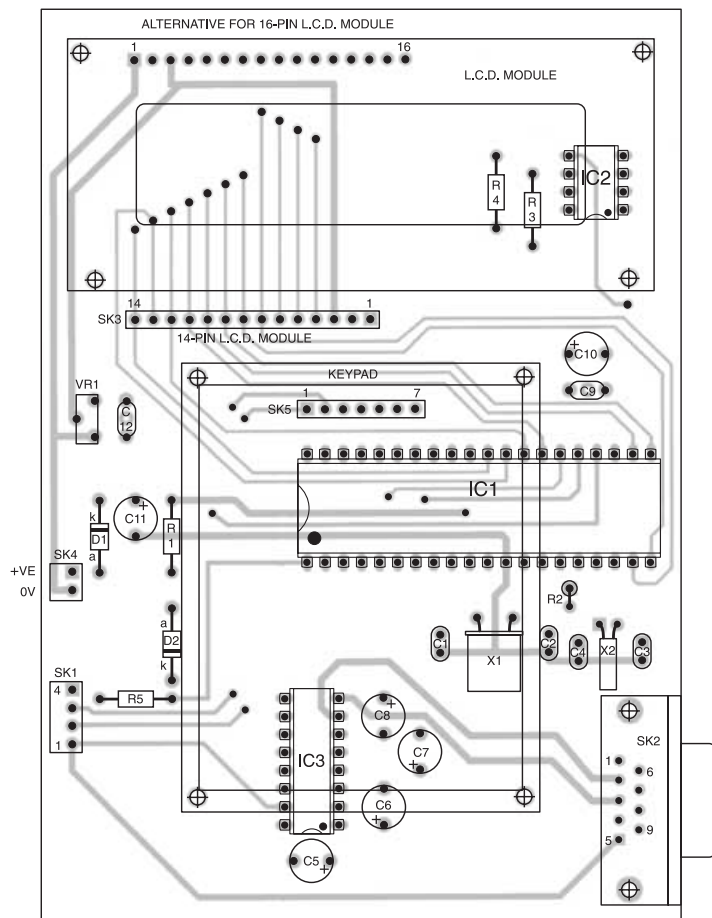
ENCLOSURE

A home-constructed plywood case measuring 102mm x 142mm x 48mm approx. was used for the prototype. A plastic case of similar size may be used instead. Suitable cut-outs should be made to accept the keypad and the I.c.d. Their positions need to be quite accurate. A template for the holes can be made by measuring the dimensions from the p.c.b. artwork. Use a needle file to mark all the corner points on the case and drill small pilot holes, then use a round bladed file to cut out the plastic.

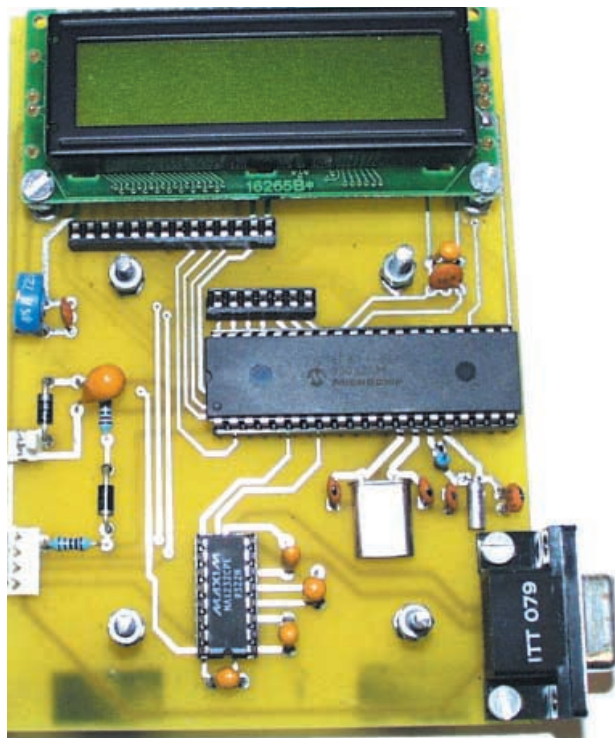
Do not use a soldering iron to melt the plastic away, as the fumes can be highly toxic and the profile uneven. The mounting holes should be countersunk so a label can be placed flush over the case, giving an attractive finish.



The author's home-made wooden case. It is suggested that readers use a plastic case.

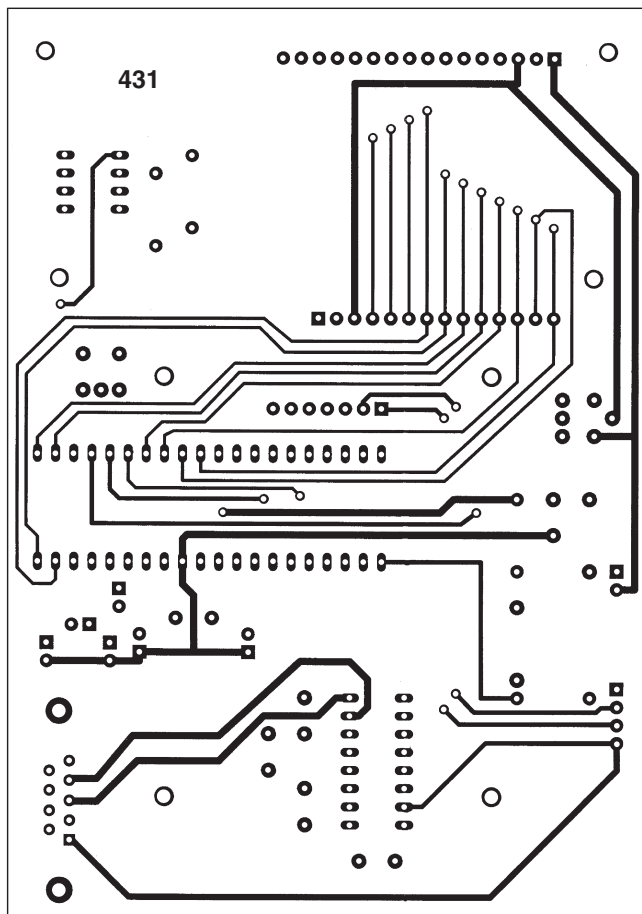
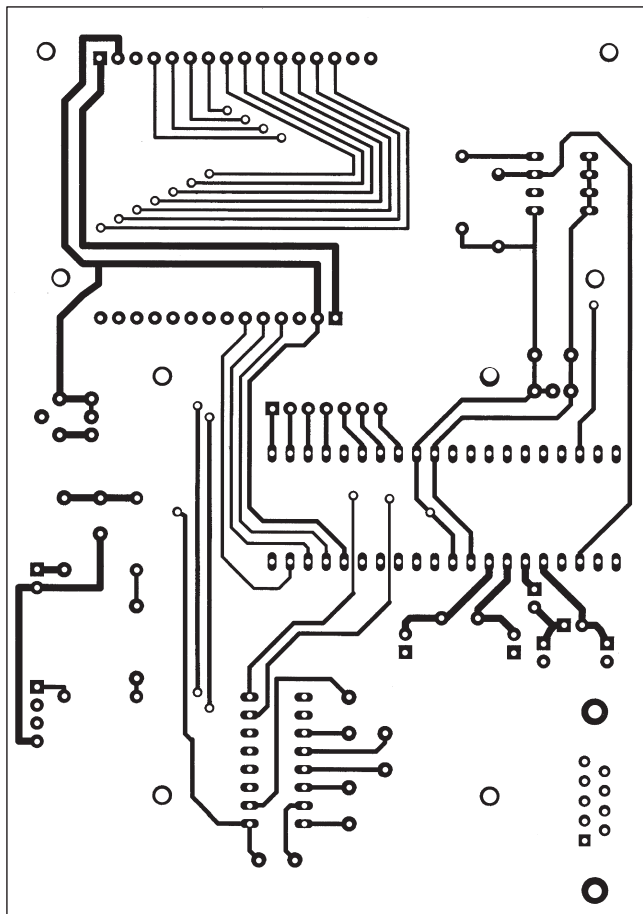


3.5in. (90mm) x 5in. (128mm)



The completed Car Computer circuit board with the keypad removed to show the topside components.

Fig.2 (top left). Car Computer printed circuit board component layout. Only a "see-through" underside copper tracking is shown for clarity. The links between the copper tracks on both sides of the p.c.b. should be inserted and soldered first. The full-size copper track masters for the topside (below left) and underside (below right) are also shown.



CAR COMPUTER SCREEN DISPLAYS

28/02/04
*=Next, #=Done

KM/Litre
*=Change, #=Done

→Enter Fuel
Report by Month

Type: Dist/Date
*=Change, #=Done

35 Miles/Gallon
*=Next, #=Done

→Set Units
Set Clock

→Add Reminder
Delete Reminder

→Erase memory
Connect to PC

SOFTWARE

The PIC and PC software for the Car Computer is available *free* via the *EPE* Downloads page, accessible through the home page at www.epemag.wimborne.co.uk. It is also available on 3.5 inch disk (for which a nominal handling charge applies) from the Editorial Office. Preprogrammed PICs are also available. For further details of these, and advice on component buying, read this month's *ShopTalk* page.

The PIC source code was written and assembled using the GPUTILS assembler, whose toolset is freely available on the internet at <http://sourceforge.net/projects/gputils>.

In-circuit reprogramming of the PIC is possible through connector SK1. The author used David Tait's excellent FPP Programmer for Windows, also freely available on the internet at <http://www.people.man.ac.uk/~mbhstdj/piclinks.html>. Just make sure your programming hardware matches up with SK1 correctly.

PROGRAM OPERATION

The Car Computer provides a number of options that are displayed on the l.c.d. through a menu. When the l.c.d. screen is blank, any keypress will wake the device up and display the menu. Use the "8" and

"2" keys to navigate through the list, and press the "#" key to select. The options are:

Enter Fuel: This option is used each time you add petrol. Always fill up to the same point, such as when the pump clicks off, so the fuel you have added equals the fuel used since last refuelling.

When this option is selected, the previous distance is displayed. Enter the new distance and press "*" when done. Then enter the amount of fuel added. The device will calculate and then briefly display the fuel consumption for this refuelling.

Report by Month: This option can be used to display the monthly fuel consumption trend. It first displays the current month, and as the "*" key is pressed it will display previous months. Press "#" to finish.

View Reminders: Displays upcoming reminders. It first displays the settings – distance and/or date – then the text that will be displayed. Press "*" to see more reminders, or "#" to finish.

Add Reminder: Allows the user to add a new reminder. First choose between the type of reminder – Distance, Date or both. If you select both, the reminder will be displayed when the first event occurs. Once you have entered the distance or date, a flashing cursor is displayed and you may enter the text to be displayed as a reminder.

Use the "4" and "6" keys to move along the line, and "2" and "8" keys to scroll through the ASCII character set. This can be quite slow to enter, so if you have a PC available, use the "Connect to PC" option and the *vc.exe* PC program instead.

Delete Reminder: Allows the user to remove a reminder. Use the "*" key to find the reminder to remove, then press the "0" key to delete it.

Set Units: This option should be used to select the units you wish to enter; Gallons/Litres or Miles/Kilometres. This option should be used before entering any fuel data. If you intend to change the units, you must use the "Erase memory" option first to remove all previously stored data.

Erase Memory: This option removes all historic fuel data, setting the device back to defaults. This would normally only be used when the device is being used for the first time, or you want to start recording information on a new car.

Connect to PC: This option can be used to link the device to a PC to manage the "Reminders". It's a lot quicker to setup the reminders on a PC than type them in by hand. See "PC Interface" below for more information.

Blank Display: Turns the display off, putting the device into low power mode. The device will do this automatically if no key is pressed for 60 seconds.

PC INTERFACE

The PC interface uses a standard 9-pin D-type connector to link to a PC. The *vc.exe* program, provides an easy method of setting the reminders in the device.

To use the interface, simply link the Car Computer with the PC using a standard modem serial cable. Select the "Connect to PC" option on the Car Computer, then run *vc.exe* and click on the PC's display "Read Data" button. To change an entry, click on its index number. Click on "Write Data" to update the memory in the Car Computer. Figure 3 shows an example program in use.

Don't forget to shut down the link on the Car Computer when you have finished as the RS232 interface draws several milliamperes.

Press any key
to close PC link

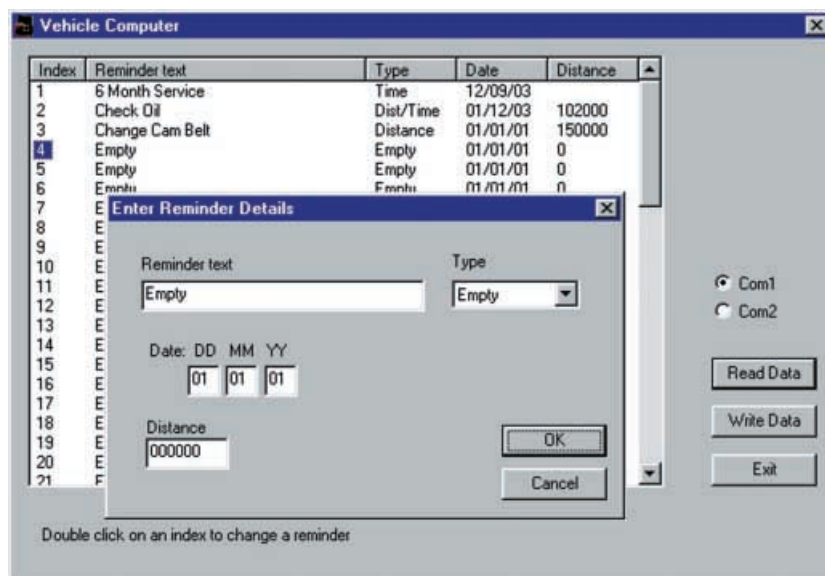


Fig.3. Car computer PC interface program in action.

BEDSIDE NIGHTLIGHT

OWEN BISHOP



This short collection of projects, some useful, some instructive and some amusing, can be made for around the ten pounds mark. The estimated cost does not include an enclosure or batteries.

A two-in-one circuit that will bring comfort and joy to your youngster's room

THIS design is intended as a battery-powered nightlight suitable for a child's bedside. Its power requirements are low and it should run nightly for several months from a lantern-type 6V battery, such as the 908S. It will run for a similar length of time on four D-type cells in a battery holder.

The key to this economical circuit is that it does not stay on all night. It relies on the fact that a typical child drops off to sleep within 10 minutes or so of being "settled down". The nightlight has two filament lamps, such as 6V torch lamps running at 100mA each. These both come on when a pushbutton switch is pressed.

From then on, the lamps are under the control of timer circuits. One of the lamps (LP2) stays on for about six minutes, which is usually long enough for the child to fall asleep. However, the other lamp (LP1) stays on for about 13 minutes. At that time it dims down gradually, to avoid plunging the child into total darkness.

SOUND TRIGGER

The lamp-switching circuit is on a separate circuit board and can be controlled with a pushbutton switch as described above. However, the project also includes a second circuit board, which is optional. This is a sound-sensitive trigger.

When its microphone detects a sound such as a hand-clap, a cry or a shout, or someone hits the bedside table, the circuit generates a low-going output pulse. This triggers the switching circuits to put on the lamps for another 6/13 minutes sequence. Alternatively, the lamps can be switched on by pressing the pushbutton switch, which is located close to an always-on pilot l.e.d.

VISUAL APPEAL

The circuit can be used with a pair of torch-bulbs, suitably enclosed for the safety of the glass, projecting from the top of its enclosure, but there is fun in making the nightlight more attractive to the child. For the prototype a snowman theme was used, but there are many other possibilities. Much depends on the current interests of the child.

An ambitious suggestion is a model steam locomotive, with a blue lamp on the front of the boiler, and a red lamp on the footplate. A biplane is another favourite topic. Or model a mermaid sitting on a rock, or a pixie on a toadstool.

Mr Snowman "keeping watch" on a bedside table.



If you lack modelling skills, there are plenty of ways in which a cheap toy or ornament can be effectively fitted with a pair of lamps.

SOUND-ACTIVATED TRIGGER

Referring to the circuit diagram in Fig.1, the microphone (MIC1) in the sound-activated trigger circuit is an electret type with a built-in f.e.t. preamplifier. It is provided with power via resistor R1. Variations in its output voltage pass across capacitor C1 to the inverting input (pin 2) of comparator op.amp IC1. The potential divider formed by resistors R2 and R3 set the bias voltage for this pin.

The voltage at the op.amp's non-inverting input (pin 3) is adjusted by preset potentiometer VR1. It is set close to the voltage at the inverting input when there is no sound, that is, to approximately 3V.

In the absence of a signal input from the microphone, the output of the op.amp at pin 6 is at a stable level, either high or low, depending on whether the voltage set on VR1 is above or below that on R2/R3. When the microphone detects sound and the alternating signal amplitude at IC1 pin 2 is sufficiently high to repeatedly cross the bias level set by VR1, the output of IC1 swings between the two power line levels, 6V and 0V.

The output waveform from IC1 is a.c. coupled via C2 to the diode pump formed by components D1, D2 and C3, turning on transistor TR1. The low-going transition at the collector (c) of TR1 is a.c. coupled by C4 and triggers timers IC2a and IC2b at their inputs pin 6 and pin 8. These pins are biased normally high by resistor R5.

Sounds such as clicks, claps and whistles, with predominantly high-frequency content are the most effective at triggering the circuit.

The timers may also be triggered by pressing pushbutton switch S1.

TIMING CIRCUITS

When switch S1 is pressed, or the input from the trigger circuit goes briefly low, both timers (IC2a, IC2b) are triggered into action. Their outputs (pins 5 and 9) go high, supplying base current to transistors TR2 and TR3, so turning them on. Current then passes through the lamps, LP1 and LP2. The high output from IC2a also charges capacitor C6.

The length of the high output pulses of the monostables is determined by the values of the timing resistors (R6, R8) and capacitors (C5, C7). The formula is $t = 1.1RC$, where t is in seconds, R is in ohms, and C is in farads. With the values given in Fig.1, the times are approximately 13 minutes for TR2/LP1 and six minutes for TR3/LP2. You could obtain longer times by substituting capacitors of higher values, but remember that this reduces the life of the battery.

Lamp LP2 is switched off after six minutes, when the output at pin 9 of IC2 falls to 0V. After 13 minutes the output at pin 5 falls too, but the fall is slightly delayed while the charge leaks away from capacitor C6. This capacitor is optional and can be omitted. With the value shown, the lamp goes out fairly quickly. For a longer delay, increase C6 to 4700µF or possibly more.

The circuit also has a constantly-on light, provided by l.e.d. D3, which is buffered by resistor R10.

As an alternative to the 6V battery supply mentioned earlier, the project can be powered from a cheap mains adaptor that provides an unregulated 6V d.c. supply at up to 300mA. But remember, if the mains is used, a mains power blackout will leave the child in the dark.

COMPONENTS

Approx. Cost
Guidance Only

£8 (each)
excl. case & batts.

SOUND TRIGGER

Resistors

R1 2k2
R2, R3, R5 1M (3 off)
R4 22k
All 0.25W 5% carbon film or better.

Potentiometer

VR1 100k min. preset, horizontal

Capacitors

C1 1µ tantalum bead, 10V
C2 220n metallised polyester film
C3 470n metallised polyester film
C4 22n, metallised polyester film

Semiconductors

D1, D2 1N4148 signal diode (2 off)
TR1 BC548 npn small signal transistor
IC1 CA3140 op.amp comparator

Miscellaneous

MIC1 electret microphone insert

See
SHOP
TALK
page

TIMING CIRCUIT

Resistors

R6, R8 3M3 (2 off)
R7, R9 2k2 (2 off)
R10 220Ω
Rx (see text)
All 0.25W 5% carbon film or better.

Capacitors

C5 220µ axial elect. 10V
C6 2200µ axial elect. 10V (see text)
C7 100µ axial elect. 10V

Semiconductors

TR2, TR3 BC337 npn low-power transistor (2 off)
D3 red l.e.d., or colour as preferred
IC2 7556 CMOS dual timer

Miscellaneous

LP1, LP2 MES filament lamps, 6V 100mA plus holders (2 off) (see text)
S1 push-to-make switch
B1 6V lantern-type (908S) battery or D-type cells (4 off)

Printed circuit board available from the EPE PCB Service, code 417; 8-pin d.i.l. socket; 1mm terminal pins (5 off); stranded connecting wire; solder, etc.

Printed circuit board available from the EPE PCB Service, code 418; ABS plastic case; 14-pin d.i.l. socket; 1mm terminal pins (7 off); connecting wire; solder, etc.



CONSTRUCTION

The component positioning and track layout details for both printed circuit boards are shown in Fig.2 (Sound Trigger)

and Fig.3 (Timing). These boards are available from the EPE PCB Service, codes 417 and 418 respectively.

Assemble the circuit boards in order of component size, correctly observing the

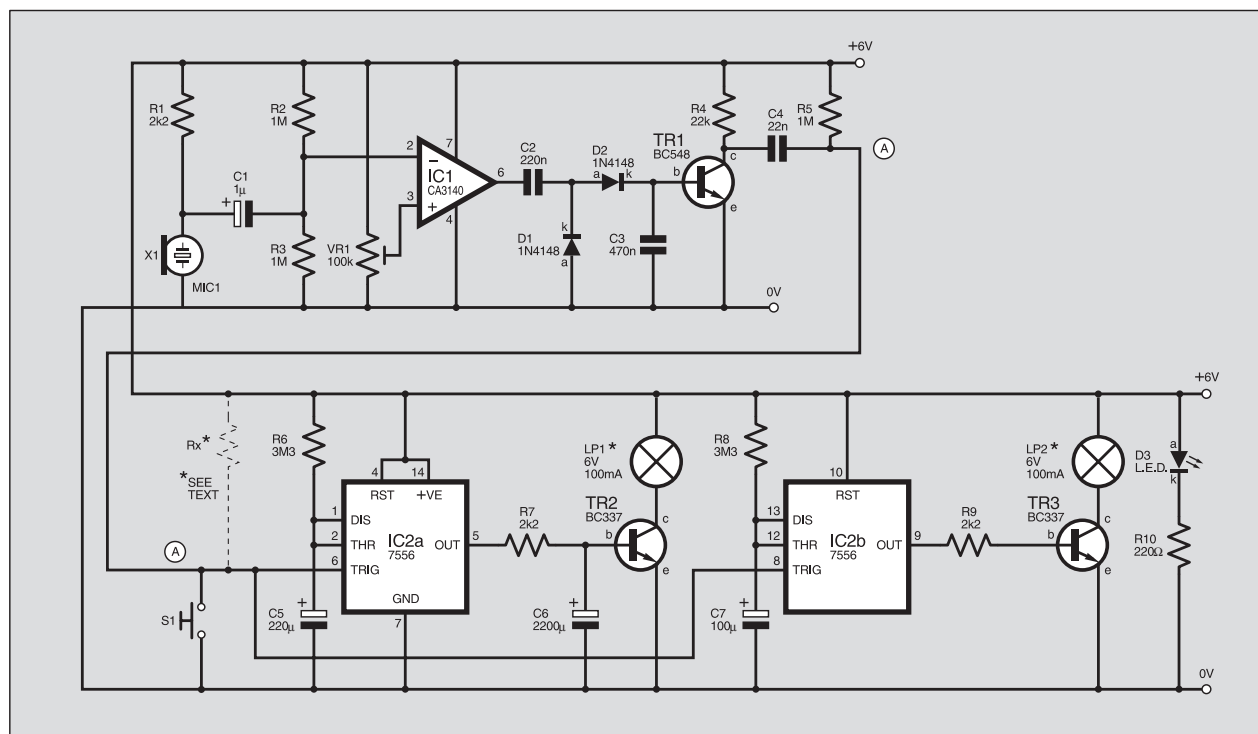


Fig.1. Circuit diagram of the two sections that make up the Bedside Nightlight. The top half is the optional sound-sensitive trigger with the lamp-switching circuit making up the bottom half. These two circuits are built on separate circuit boards.

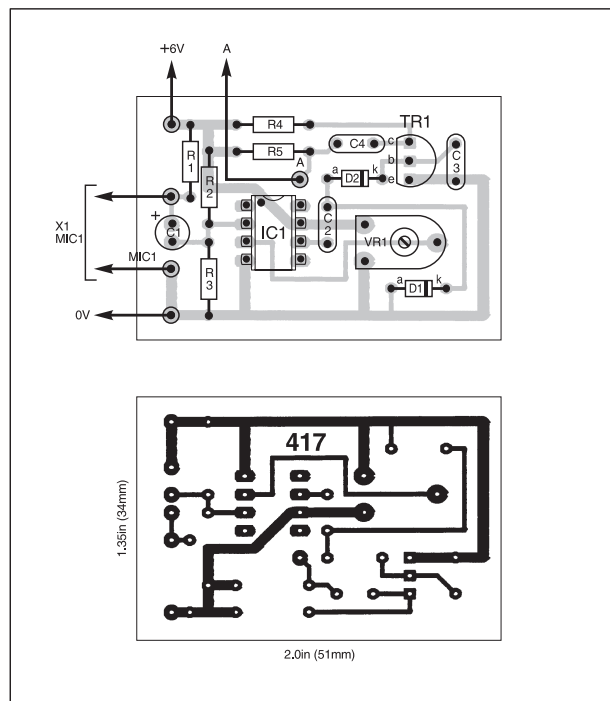
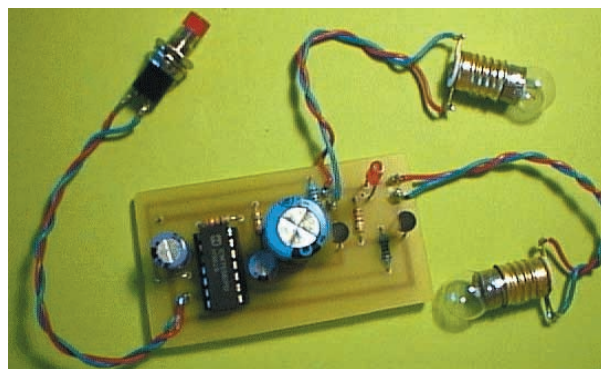
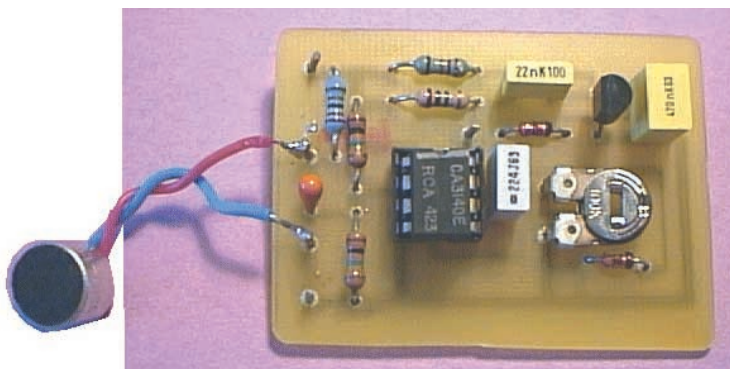


Fig.2. Component layout and full-size copper foil master for the Sound-Trigger printed circuit board. The completed p.c.b. is shown above.

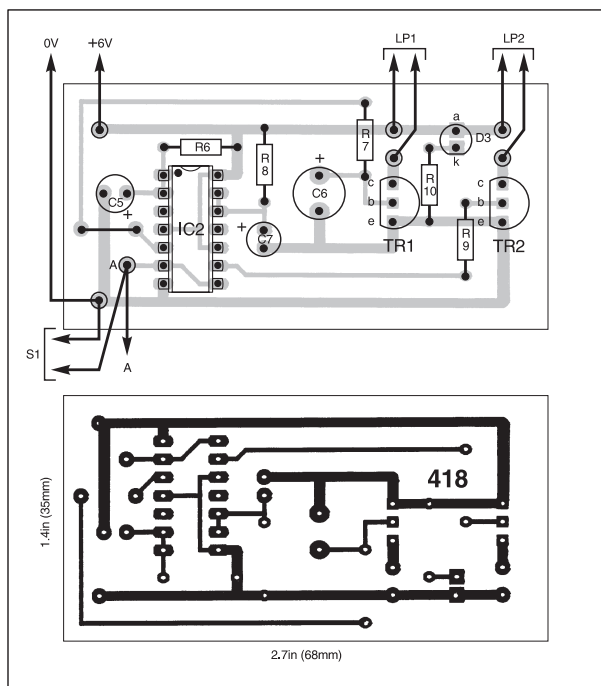


Fig.3. Timing and Lamp-Switching printed circuit board component layout and full-size copper foil master. The finished circuit board is shown above.

orientation of the electrolytic capacitors and semiconductors. Do not insert the i.c.s into their sockets until you have thoroughly checked your assembly and soldering.

Initially check out the timing board on its own. Run paired leads from the allocated points on the p.c.b. to the lamp sockets and insert the filament lamps. You can use lamps of lower power (such as 6V 60mA) if preferred. You could also use high-brightness l.e.d.s in place of the lamps. In this case wire a resistor in series with each l.e.d. to limit the current. A 160Ω or 180Ω resistor limits current to about 25mA.

When power is switched on, the timers are automatically triggered and the lamps come on for the stated six and 12 minute periods.

It makes it more convenient to test the operation of the circuit if these periods are shortened by temporarily connecting additional resistors in parallel with R6 and R8. Using values of 100k each, the delay periods become 11 and 24 seconds.

To check the sound-activated trigger circuit, first measure the voltage at IC1 pin 2, which should be 3V ±0.5V. Then adjust preset VR1 until the voltage at IC1 pin 3 is fractionally less than that at pin 2.

The pulses are so transitory that it is difficult to check the operation of the

trigger circuit without an oscilloscope. However, the practical test is to see if it triggers the switching circuit. Connect both boards to the same supply lines. Link the "A" pins on both boards. Turn on the power and wait for the lamps to go out. The lamps should come on when you clap your hands a metre or so from the microphone. Adjustment to VR1 varies sensitivity.

ENCLOSURE

Once the tests have been successfully carried out, the style of the enclosure can be decided. In the prototype the circuit boards were mounted in a plastic case that also held the battery. The case formed the plinth on which a model snowman was constructed, see photograph.

The technique used for the snowman may be adapted to many other simple models. The basic material used is sheet polystyrene, obtainable from model stores. It is white and translucent and easily cut with a craft knife. Use polystyrene adhesive to assemble the parts.

The snowman was cut from a sheet 1mm thick, and thin coloured cardboard was stuck on to make the hat and hatband, eyes, mouth and buttons. The nose was a scrap of matchstick coloured orange to represent a

carrot. The broomstick was a long (10cm) barbecue match. A "fringe" cut from thin brown paper was wrapped and then glued around one end of the broomstick to make the bristles.

The snowman is supported in a small metal clip (originally intended for vertical support of circuit boards). This is mounted in the centre of the plinth (enclosure) with the pushbutton switch S1 and l.e.d. D3 in front of it. Lamps LP1 and LP2 are mounted on the plinth side-by-side, close behind the snowman's feet. The light from the lamps is diffused by the translucent plastic so that the snowman glows gently in the dark – a soothing sight, inducing sleep!

OTHER APPLICATIONS

The switching circuit could also be used as a corridor light and porch light. It can be triggered by other devices that produce a brief low pulse, including pressure mats, tilt switches and microswitches.

The timing circuit could be used on its own without the sound-activated trigger. However, input pin 6 of IC2a must be biased high by a resistor (Rx) of between about 10kΩ and 1MΩ, soldering it on the track side of the board between this pin and the 6V power rail. □

SPAM WARS

Publicising ways to get round spam filters may, perversely, help prevent spam filters being circumnavigated. Barry Fox reports.

THE Internet has been buzzing with garbled reports of a new patent granted to AT&T in the USA. On the face of things AT&T is helping spammers make our lives a misery. But perhaps AT&T is playing a more clever game. Some of the reports stumble close to the true story. But none get it straight.

Spammers flood the Internet with junk adverts by bulk-emailing the message to many different addresses, often trawled from newsgroups or guessed or predicted from known addresses. Over one third of the email addressed to office systems is now spam.

Anti-spam filters look for duplicate emails that hit an office system in bulk, or reach a private email several times over. Detected duplicates are automatically deleted and added to a blacklist or quarantined for humans to check manually.

Anti-filtering Patent

The US Patent Office recently granted AT&T in New York a patent for a "system and method for counteracting message filtering" (US 6 643 686). The patent describes spam as a "nuisance", describes in detail how anti-spam filter systems work and then reveals a clever way to "foil . . . spam countermeasures based upon duplicate detection schemes".

The defeat trick, reveals AT&T's patent, is to partition the spam address list into sub-lists, change the header and message text slightly for the message sent from each list and randomly juggle the lists in a mathematical pattern so that addresses which are similar (fred1@xyc.com and fred1@xyc.com) get different content.

Internet Patent News Service, the respected patent industry newsletter, branded the patent "a shining example of corporate R&D irresponsibility", "a complete waste of corporate monies (and) a waste of PTO examiner time". Internet news groups are echoing the criticism.

"Don't tell me that AT&T is going to use the patent to fight spammers by suing them", challenges the newsletter.

Initially AT&T wanted to play the move close to its chest. But spokesman Michael Dickman now confirms the object of the exercise.

"We don't want to say too much and compromise law suits", he says. "But contrary to what's being said, this is a legal tool intended as an anti-spam measure. The spammers come at you in every imaginable way. We filed the patent to try and stop them coming this way".

Legal Protection

What the garbled reports have missed is that US company Macrovision has for many years successfully used the same legal tool to fight companies that sell devices intended to defeat video copy protection on VHS and DVD movie releases.

Macrovision was founded in 1983 and now has over a thousand US and international patents. Many cover the company's core system of distorting the train of pulses that TV sets and VCRs use to keep the pictures steady on screen. A TV set can cope with the distorted "pseudo-pulses" and display steady pictures, but a VCR is thrown into confusion and makes a recording which is too bad to watch.

Founder and inventor John Ryan first tried a different tactic in 1986 when he filed US patent 4 695 901, for a method of removing pseudo-sync pulses and so defeating his own technology. The patent gave pirates clear instructions on how to filter out the distorted pulses and so let another video recorder make a perfect copy of a Macrovision-protected tape. But it also lets Macrovision sue them.

Usually a threat of action is enough to curtail sale. Recently Macrovision went to court in Germany and won an injunction against Media Markt TV-Hifi-Elektro GmbH prohibiting the sale of the Macro 2000 copy protection circumvention device.

Says Macrovision's CEO William Kreppick: "We recognized early on that we would be the target of hackers and circumvention devices (and) developed a dual track patenting approach – offensive and defensive. The defensive track was unconventional, since it involved patenting as many ways as we could conceive to defeat our own technology. So we can sue the illicit black boxes and circumvention technologies such as "Macrobusters" and "Macroterminators" or the most recent German Media Markt "Macro 2000" device. There are cases where a 1-2 punch using both patent infringement and copyright infringement will bring circumvention scofflaws to their knees."

So AT&T, like Macrovision, is taking the calculated risk of telling the world how to do something bad, in return for a legal patent monopoly on the bad deed. So the goodies can sue the baddies for patent infringement.

Gibberish Rules OK?

Unfortunately the spammers may already be one jump ahead of AT&T's

ploy. The latest junk email buries a sales pitch in a puzzling welter of gibberish text.

Some offer drugs like Viagra for sale by mail order. Another promises a "Bachelor, Master or Ph.D." in 30 days and the price of a few dinners out, and then signs off with some paragraphs unashamedly labelled "random data".

The random gibberish is there to defeat the filters which work by looking for a high percentage of telltale phrases like "free", "make money", or "Viagra".

It is hard not to have a sneaking admiration for the spammers who keep thinking one step ahead of the filter designers. It seems a pity they could not do something more useful with their talent.

Do not fall into the trap of "clicking here" to reply with congratulations, sarcasm or abuse. The one thing the spammers want more than anything in the world is a reply which proves that a guessed address is "active" and owned by a real live human.

NANOMOTORS REALISED

BROWSING the BBC's website recently, the news was found that one of the ambitions of nanotechnology, building motors on a molecular scale, had been realised by scientists at Berkeley, at the University of California.

The researchers created the world's smallest electrical device earlier this year, a hundred million of which could fit on the end of a pin. Nanotechnology promises to revolutionise medicine, chemistry and electronics. It is said that it could allow the creation of computers the size of a grain of sand, smart fabrics that sense toxic chemicals, and even nanoscale filters to clean the environment.

Alex Zetti and Adam Fennimore of Berkeley built the motors using an atom-fine point of a nano-probe, inserting the circuits onto a silicon chip four millimetres square. The motor's shaft is a mere half a tenth of a thousandth of a millimetre thick.

Dr Fennimore comments that the motor is so small that it is not yet known exactly how it behaves.

For more information browse <http://news.bbc.co.uk/1/hi/technology/3224329.htm>. There is also an animated series of electron microscope images of the motor at www.berkeley.edu/news/media/releases/2003/07/23_motor.shtml.

For more information browse www.lascarelectronics.com or www.3wdata.com.

The complete catalogue and detailed product data can be downloaded in PDF format from Pomona's website at **www.pomonaelectronics.com**.

For more information on this and other Greenweld stock items, call 01277 811042 or browse www.bargains@greenweld.co.uk.

Everyday Practical Electronics, January 2004

TEACH-IN 2004

Part Three – Experimenting with Op.amps

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

DESIGNING a quality transistor amplifier is a skilled business! Each section is dependent on the conditions in previous sections, and the gain of transistors can vary widely from one to another. Clever circuit design can overcome many problems, but when temperature changes occur unequally throughout the system, the circuit can behave unpredictably.

A modern op.amp (operational amplifier) houses the entire circuit on a small chip of silicon and so any change of temperature will occur equally throughout the circuit, hence reducing the problem. Like all integrated circuits (i.c.s) the size and cost are much reduced and reliability increased. The best of all worlds!

OP.AMP TYPE 741

Probably the best-known op.amp is the type 741. This op.amp makes an ideal experimental device since it is electrically robust and can be freely handled without

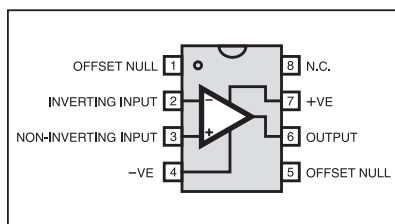


Fig.3.1. Pinout for a type 741 op.amp.



Photo 3.1. A type 741 op.amp.

fear of electrostatic damage. It operates on a wide range of voltages, and is “frequency compensated”. This ensures that it cannot oscillate unpredictably and uncontrollably – a problem often associated with high-gain amplifiers.

This op.amp is housed in an 8-pin d.i.l. package. The package and its pinout symbol are shown in Photo 3.1 and Fig.3.1 respectively. So how does it work?

A clearer view of the op.amp symbol associated with the 741 (and many other types of op.amp) is shown in Fig.3.2. Note that the power supply connections are via pin 7 (positive) and pin 4 (negative). The output is from pin 6. There are two input pins, labelled – and +.

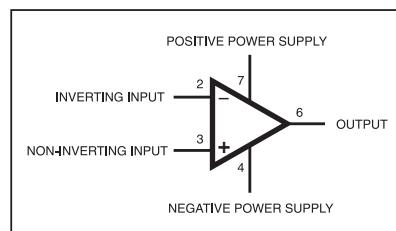


Fig.3.2. Symbol and pin functions for a type 741 op.amp.

The minus symbol indicates the “inverting input” and the plus symbol indicates the “non-inverting input”.

The job of the op.amp is to amplify the difference in voltage between these two inputs, and apply the result to the output. This may sound complicated, but in practice one or other input is generally connected to a fixed voltage and the signal you wish to amplify is applied to the other input.

There are three unused pins, shown in Fig.3.1, but not in Fig.3.2. Two of them (pins 1 and 5) are for special functions such as “fine-tuning” when the op.amp is required to amplify d.c. signals. You will rarely, if ever, need these two pins and they should remain unconnected in your circuits. Pin 8 has no function.

It is worth noting, though, that other single op.amp types may have different functions for pins 1, 5 and 8.

DUAL-RAIL POWER SUPPLY

Before continuing, we need to examine the type of power supply (PSU) often used with op.amps – a dual-rail power supply. This can be understood if you see how it is created from batteries. We will assume two 9V batteries are employed as shown in Fig.3.3.

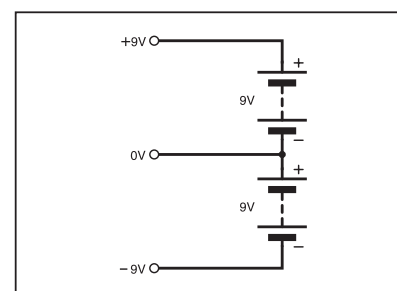


Fig.3.3. Example of a dual-rail power supply.

The two batteries are connected in series, and the point at which they join is called 0V. Note that calling this point 0V is for mathematical convenience – it is not necessarily connected to “ground” or “earth”.

We can now refer to the positive side as +9V and the negative side as –9V. Mains driven dual-rail supplies are also available.

Connecting an op.amp to a dual-rail supply allows it, in many instances, to amplify a.c. signals (e.g. audio signals) without using bulky and expensive d.c. blocking capacitors. We will examine the use of capacitors later when we look at circuits designed to run on a single-rail supply.

OP.AMP EXPERIMENT

The circuit shown in Fig.3.4 can be assembled on a plug-in breadboard and used to illustrate how an op.amp works.

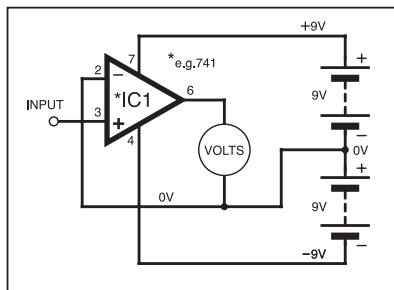


Fig.3.4. The circuit diagram for the first op.amp experiment.

Note that the inverting input, pin 2, is connected to 0V, and the non-inverting input, pin 3, is used as the input. The output is measured on a meter. Most digital meters will display the result numerically, although some may also show it graphically as a bargraph.

When power is applied, and with the non-inverting input unconnected, the output is likely to be at nearly +9V or nearly -9V (but see later). The system is rather like a seesaw which rests one way or the other when nobody is using it.

You can tilt the system the way you want it to swing, by applying a voltage at the non-inverting input. This can be achieved with a potentiometer (pot) connected as shown in Fig.3.5. Another voltmeter has been added to monitor the voltage applied to the non-inverting input (but you can just swap your meter between the monitoring points if you only have one). The assembly used by the author is shown in Photo 3.2.

Now you can make the output swing up or down. Notice that the smallest voltage above and below 0V will cause the output to swing almost fully to +9V or -9V.

In practice the 741 op.amp cannot supply an output equal to the supply rails – it

misses by a volt or so. This is not normally a problem in many circuits, but it is when describing the action! Rather than saying “nearly +9V” and “nearly -9V”, we shall from now on refer to the highest possible output voltage as “high” and the lowest possible output voltage as “low”.

OPEN-LOOP GAIN

Try to adjust the potentiometer very carefully to achieve an output of 0V. It is like balancing a well-lubricated seesaw – very difficult! The reason is that the gain of the op.amp is very high – at least 100,000 and so it only takes a very tiny voltage shift from 0V to tip the output one way or the other.

This gain is often referred to as the *open-loop* gain, i.e. the amount the op.amp will amplify with no feedback circuit. (We will discuss feedback later.)

So what happens if we set the potentiometer to apply 1V at the input? Will the output swing up to 100,000V? Fortunately it will not! Even with an “ideal” op.amp the output can never swing higher or lower than the supply voltage extremes. The supply voltage sets the limits – like the seesaw coming to rest against the ground.

op.amp’s output switches from low to high. Careful setting of VR1 will make the system very responsive to small changes in light level.

So far, we have applied a voltage to the non-inverting input. You can just as easily apply the voltage to the inverting input, and connect the non-inverting input to 0V. The output will now do the opposite of what it did before – i.e. *inverting* the output voltage.

COMPARATOR

The system shown in Fig.3.6 is known as a *comparator*, i.e. a circuit that compares the voltage at the inputs. We generally connect one of the inputs to a fixed voltage (0V in this case) and apply the variable voltage source to the other.

We use a dual-rail supply because this is useful when dealing with a.c. signals, but when dealing with sensor circuits, it is often more convenient to use a single-rail supply and modify the circuit a little, as shown in Fig.3.7, for example.

Note that the negative end of the battery is still referred to as 0V, again for mathematical convenience. The non-inverting input is connected to a “mid-way” voltage created by placing two equal-value resistors in series across the two power supply lines.

Resistors connected in this way are known as a *potential divider*.

RULE OF TEN

To provide a mid-way voltage, you know that the resistors must be equal, but how do you know what value each must be? The answer is to use the *rule of ten*. Find out (using the op.amp manufactur-

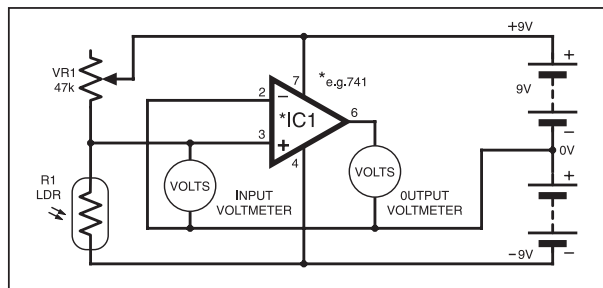


Fig.3.6. Monitoring the effects of an l.d.r. on the non-inverting input when using a dual-rail supply.

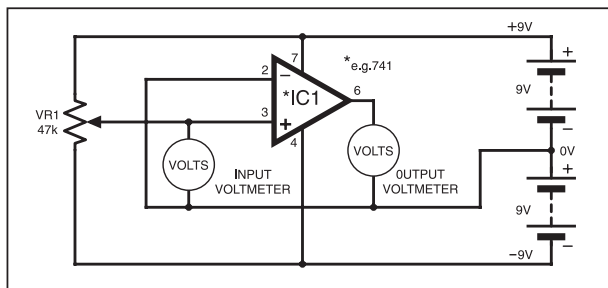


Fig.3.5. Monitoring the effect of varying the voltage level applied to the non-inverting input of an op.amp.

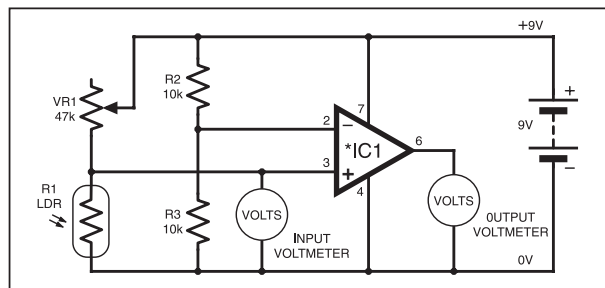


Fig.3.7. As for Fig.3.6, but now using a single-rail supply.

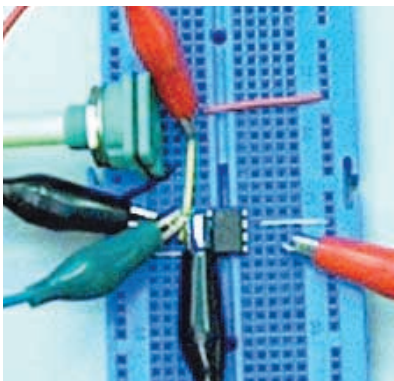


Photo 3.2. Author's breadboard assembly for the circuit in Fig.3.4.

DOING SOMETHING USEFUL

Try assembling the circuit shown in Fig.3.6. Here we are using potentiometer VR1 as a variable resistor, and employing a light dependent resistor (l.d.r.), R1, as a light sensor. Be careful not to set VR1 to zero resistance, or excessive current may flow through the l.d.r., particularly in bright light. In a practical circuit a resistor (say 1kΩ) would be connected in series with the l.d.r. to prevent this problem.

Set VR1 carefully so that the op.amp's output is low. Shade the l.d.r. The output should change to a positive reading. Shading the l.d.r. makes its resistance rise, and so the voltage at the input rises. As this voltage crosses the 0V threshold, the

er's data sheets) the current that will flow via an op.amp input when used in your circuit. You must set your resistor values so that ten times this current flows through the resistors. In many instances, though, you can just stick to values of 10kΩ or so!

Returning to Fig.3.7, resistors R2 and R3 create a mid-way voltage of $9V / 2 = 4.5V$, which is applied to the inverting input. The variable resistor VR1 and the l.d.r. also act as a potential divider and you should adjust VR1 so that the voltage at the op.amp's non-inverting input (pin 3) is just below 4.5V. The output will now swing to fully low (somewhere near to 1.5V with a single-rail 9V supply when using a 741).

Now shade the l.d.r. The voltage at the non-inverting input will rise, and as it

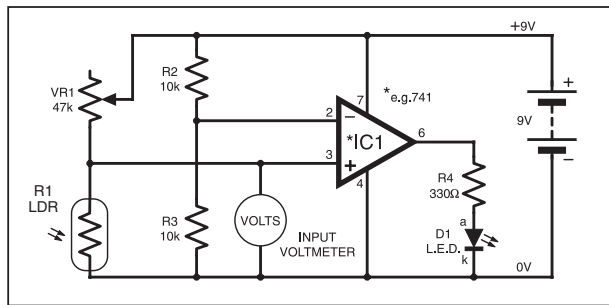


Fig.3.8. Using the circuit of Fig.3.7 to control an l.e.d.

crosses the 4.5V threshold, the output will swing to fully high (somewhere near to 7.5V with a 741 and a 9V supply).

You can extend the circuit to make an automatic light controller as shown in Fig.3.8. An l.e.d., D1, is connected to the op.amp output in series with resistor R4. The l.e.d. should light whenever the l.d.r. is shaded.

In this single-rail circuit you will probably find that the l.e.d. glows dimly rather than turning off properly. This is because the 741 op.amp is likely to output a minimum "low" voltage of around 1V to 1.5V when powered by a 9V single-rail supply.

The solution is to either use an op.amp which can output 0V on a single-rail supply, or place a diode such as a type 1N4001 in series with the l.e.d. The voltage drop across the diode will be about 0.7V, allowing the l.e.d. to switch off properly.

WARNING: Do not use an l.e.d. connected between the output and the 0V rail in a dual-rail circuit, since the l.e.d. may be damaged when the output goes negative, due to the reverse-voltage limitations of the l.e.d. (as discussed in Part 2).

COMBINING CIRCUITS

Most op.amps can only supply a few milliamps from their outputs, and so to switch on an output device, such as a lamp or a relay, a transistor interface may be employed. The simplest transistor circuit shown in Part 2 (Fig.2.2) may be added to

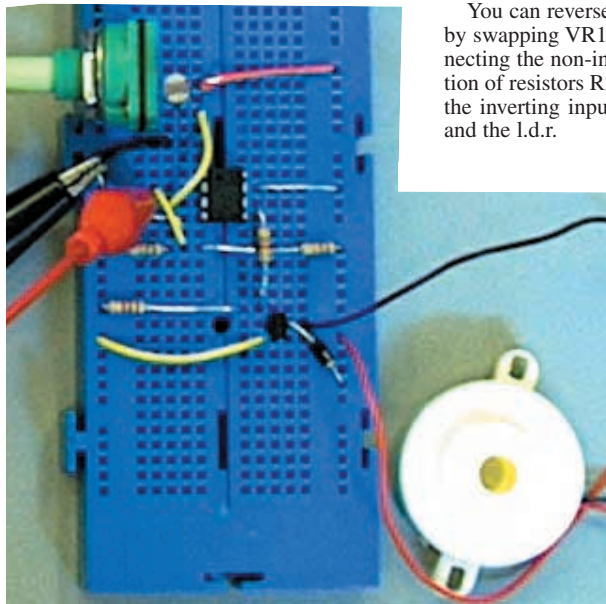


Photo 3.3. Prototype assembly of the circuit in Fig.3.9.

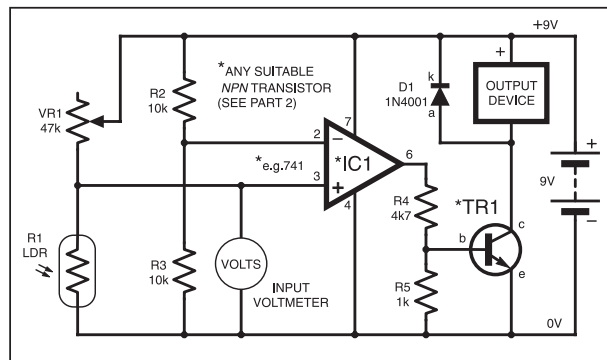


Fig.3.9. Improving the circuit of Fig.3.8 to power a higher-current output device.

the comparator, making the circuit shown in Fig.3.9 and Photo 3.3.

The protective (back-e.m.f.) diode D1 is only required if the output device is inductive, e.g. buzzer, relay coil, solenoid, motor, etc. If the output drives a lamp or *solid-state* buzzer, then D1 may be omitted. If in doubt, leave it in.

Note the inclusion of resistor R5. This is only needed if the output from an op.amp, such as a 741, cannot fall to near zero, as discussed earlier. In this case, the op.amp will never be able to turn off the transistor since a transistor's turn-on voltage is around 0.7V. You could use a Darlington pair (turn-on at about 1.4V) instead of the single transistor, or you could use an op.amp capable of providing a near 0V output (known as a "rail-to-rail" op.amp, e.g. MAX473).

But the simplest solution is to add a resistor as shown. This reduces the minimum voltage output from the 741 to a level below TR1's turn-on threshold.

ALTERNATIVES

You can swap the l.d.r. with a thermistor (or any other environment-sensitive resistance device) to make the system react to temperature changes (or other changes). For VR1, use a variable resistor whose maximum resistance is roughly twice the resistance of the thermistor at room temperature.

You can reverse the action of the system by swapping VR1 and the l.d.r., or by connecting the non-inverting input to the junction of resistors R2 and R3, and connecting the inverting input to the junction of VR1 and the l.d.r.

SCHMITT TRIGGER

You may sometimes want a system to only respond to *larger* signal changes. For example, consider a circuit that causes a lamp to light up automatically at dusk. A sensitive circuit would respond to the falling level of light at dusk, but on a cloudy night, if the clouds suddenly cleared, the lamp may switch off again. This might not be a problem, but if, for example, your circuit triggered an automatic pet feeder at dusk, the pet might receive several days' food in one evening!

A small amount of positive feedback can be employed to eliminate the problem. The circuit shown in Fig.3.10 uses two additional resistors, R6 and R7, to apply a proportion of the output voltage back to the non-inverting input. The ratio of the resistors sets the amount of feedback.

Try the values shown. You will find that the l.d.r. has to be shaded fully before the circuit responds. Once it has responded, the l.d.r. must be fully unshaded for the output to become low again.

In practice you may need to adjust one or other resistor value to achieve the desired effect; for instance, increasing the value of R7 will reduce the effect. This type of arrangement is known as a *Schmitt trigger* circuit.

NEGATIVE FEEDBACK

Whereas positive feedback makes the Schmitt trigger system less sensitive to small changes, negative feedback can be used to make it more controllable by small changes at the input. Try changing the circuit of Fig.3.10 into the one shown in

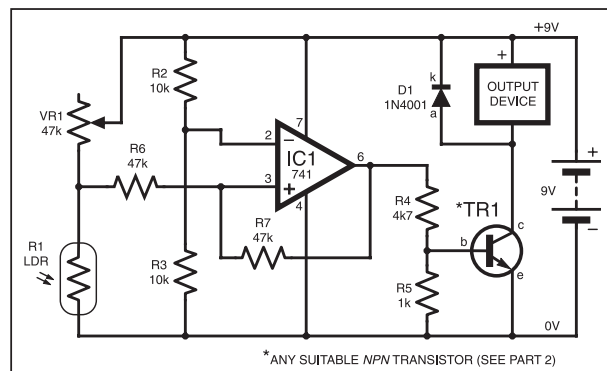


Fig.3.10. The circuit of Fig.3.9 with positive feedback to provide a Schmitt trigger effect and reduce the sensitivity to minor changes at the input.

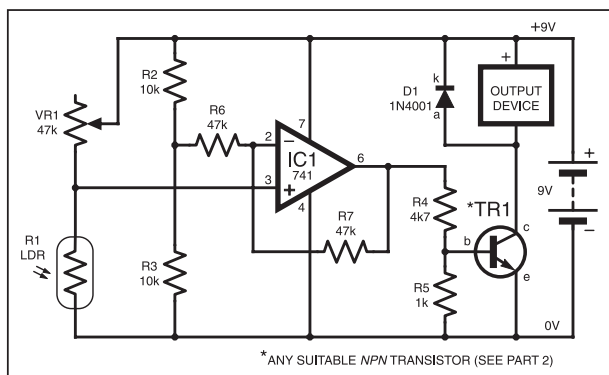


Fig.3.11. Applying a proportion of negative feedback improves controllability to smaller signal changes.

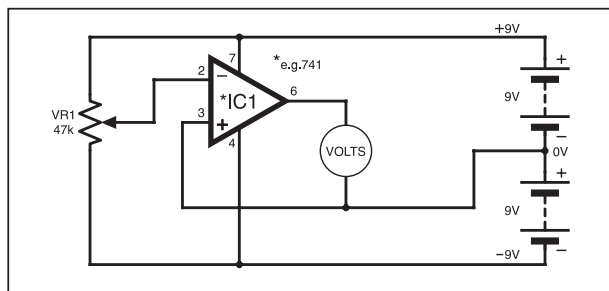


Fig.3.12. The "inverted" equivalent of Fig.3.5.

Fig.3.11. You will find that it is now possible to set VR1 so that the output of IC1 is at half the supply voltage.

Very slight changes in the level of light will make the output move up and down easily and controllably. Our op.amp with its massive open-loop gain has now been tamed and this opens up many other applications.

INVERTING AMPLIFIER

As we will almost certainly want to amplify a.c. signals at some stage, it makes sense to return to a dual-rail system. We will see later how to force an a.c. amplifier to work on a single-rail supply.

Begin by setting up the circuit shown in Fig.3.12. It is similar to Fig.3.5, except that the non-inverting input has been tied to 0V. The variable voltage (the *signal*) from potentiometer VR1 is applied to the inverting input.

You will remember that adjusting the potentiometer causes the op.amp output to switch between high and low. Now apply a small a.c. signal (say 1V peak-to-peak) to the input as shown in Fig.3.13a.

You can obtain an a.c. signal from a signal generator (set to sine wave), or simply use a cassette or CD player and use the "line" output or earphone output. The screen or ground of the link should be connected to 0V in Fig.3.13 (labelled ground/screen). Rotating the wiper of VR1 in Fig.3.12 back and forth a bit will also achieve a similar effect.

The waveforms shown in Fig.3.13b indicate the idealised signals as displayed on an oscilloscope, the smaller trace being the input signal and the larger trace showing the output signal.

A good amplifier will increase the amplitude (size) of the signal, but retain the original shape. Our amplifier, though, has introduced severe distortion, "squaring-off" the peaks of the waveform. You could try listening to it through high-impedance

headphones (of a few hundred ohms or greater) connected to the output.

(Be aware that 8Ω headphones will draw too much current from the output, although they could be used if you add a resistor, say 470Ω, in series with them.)

Note that in Fig.3.13a, the op.amp output is shown connected to a voltmeter. If you wish to listen to the output of this and subsequent circuits, then the signal is taken from the output of the op.amp, and a ground link must be made between the headphones and the 0V line of the circuit.

CLIPPING

The type of distortion illustrated in Fig.3.13b is known as *clipping* distortion. It

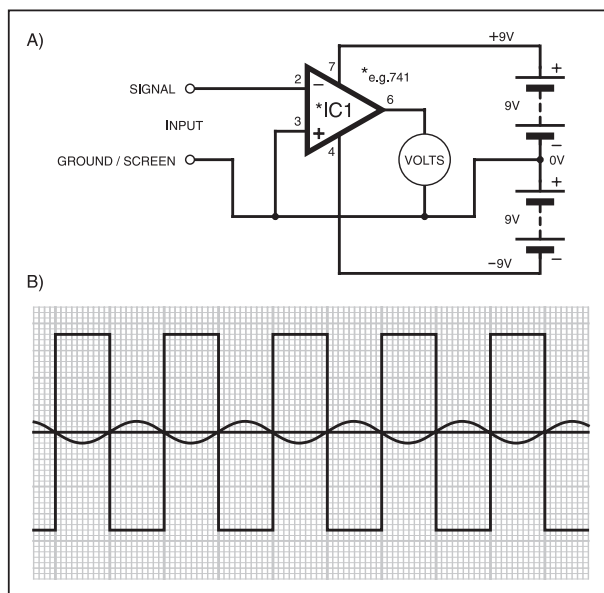


Fig.3.13. Test circuit for use with a.c. signals, plus example waveforms.

is the result of the output trying to swing beyond the op.amp's output voltage limits, and being clipped as a result.

Increasing the supply voltage will not prevent this full-range swing and resultant clipping, so we must reduce the gain of the op.amp, by means of negative feedback again.

CLOSED-LOOP GAIN

As explained previously, the effect of negative feedback is to reduce the gain of the op.amp from its open-loop gain of $\times 100,000$ or more, to a more suitable gain which does not cause clipping, to about $\times 5$ in the case of the input waveform shown in Fig.3.13b.

When negative feedback is used to achieve this, we talk about the *closed-loop* gain of the system. The circuit in Fig.3.14a illustrates how this is done.

Note the addition of the resistors R1 and R2. These apply negative feedback. The

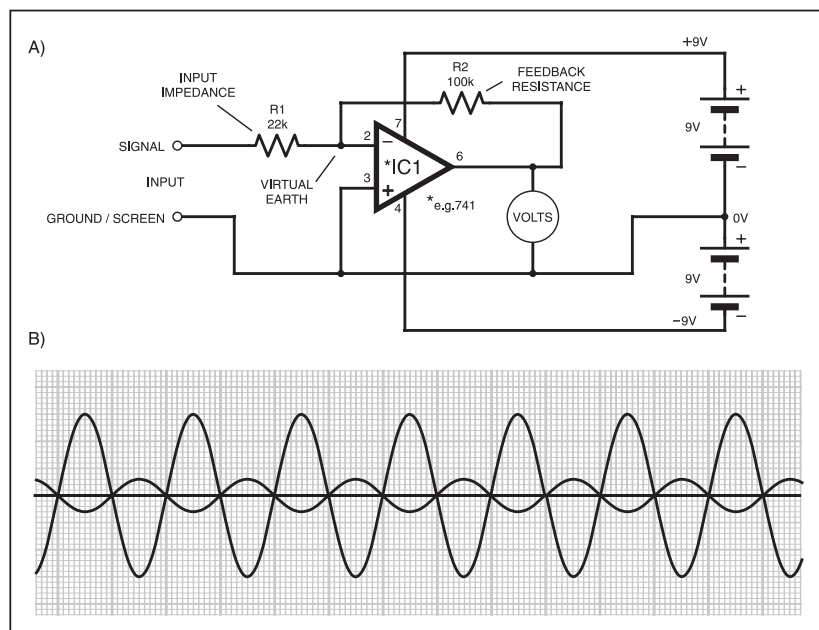


Fig.3.14. Using feedback to prevent output clipping.

waveforms in Fig.3.14b show that the output is now an exact copy of the input, except that it is magnified by about five times. It retains the shape of the input signal, but is inverted in respect to it. In other words, when the input signal moves up, the output moves down. Hence the name of this circuit: *inverting amplifier*.

Resistors R1 and R2 set the gain of the system. You will notice that the ratio of their values is about five. In other words, the gain of the system is given by:

$$-R2 / R1$$

The minus sign indicates that the output is inverted, i.e. negative when the input is positive. You may wonder if the actual gain of the op.amp enters the equation. In fact, the formula above is a slight fudge, based on the assumption that the op.amp open-loop gain is very high.

If your cassette or CD player produces an output greater than about 1V then the output wave may still be clipped a little.

You can connect headphones to the output, but don't expect hi-fi sound! The output from the 741 op.amp is not intended to drive speakers or headphones, and a power amplifier is needed if this is the aim.

A GUIDING LAW

We have shown that the ratio of the resistors labelled R2 and R1 in Fig.3.14 sets the gain of the system. Resistor R2 is generally called the *feedback resistor* (R_f), and R1 the input resistor (R_i). Hence the gain formula is normally written:

$$\text{Gain} = -R_f / R_i$$

But how do you choose the actual values of the resistors? We need to delve a little more into the system.

There is a very useful fact, which applies to all op.amp circuits where negative feedback is used and the circuit is not "saturated" (in other words the output has not been driven to either supply rail). The law states that:

The voltage at the inverting input (pin 2 in this case) will equal the voltage at the non-inverting input (pin 3 in this case).

This means that you can set the voltage at the non-inverting input, and the inverting input will copy this. So, if we connect the non-inverting input to 0V, then the inverting input pin will be at 0V as well. This is very useful, and makes calculations much easier, since there is always a known voltage in the system, regardless of your input and output voltages.

This makes it possible to design audio mixers (for example) with ease, as we will see later, but for now there are some other terms to explain. We will start with *impedance* – what it means, and why it is important.

INPUT IMPEDANCE

The term *resistance* means the opposition to the flow of electricity. So a resistor of 20Ω will offer twice as much opposition than a resistor of 10Ω. A simple resistor will oppose a.c. and d.c. equally.

But a coil of wire has both resistance and an inductive (magnetic) effect, plus a capacitance effect. Its resistance will affect a.c. and d.c. equally, but its inductance and capacitance will affect a.c. more than d.c. Hence if you measure the resistance of a

loudspeaker using a normal multimeter, you will obtain an answer lower than you might expect. You are simply measuring the resistance of the coil.

Loudspeakers are designed to work with a.c. signals (audio signals) and so the value (say 8Ω) stated on the speaker refers to the total opposition to a.c. – allowing for the resistance of the coil, its inductive effect and its capacitance effect. This total opposition to a.c. is called *impedance*.

Returning to the op.amp circuit shown in Fig.3.14, since the voltage at pin 3 (non-inverting input) is held at 0V, so the voltage at pin 2 (inverting input) will copy this, and will become a *virtual earth*. Hence the input signal will simply pass through a resistance equal to R_i (R1 in this case) on its way to zero or *ground*.

Although the signal is alternating, the single resistor will oppose it as if it were d.c., and so we can say that the input impedance of our amplifier is equal to the value of R_i , 22kΩ in this case.

MATCHING IMPEDANCES

Why does input impedance matter? Anyone who has lived in a bed-sitter in an old building will know the problem; the person on the ground floor runs the bath, and the water pressure throughout the building falls to a dribble. You could say that the impedance of the bath tap was so low that it disrupted the pressure throughout the system.

Similarly, if an amplifier circuit allows too much input signal current to flow, the signal voltage will collapse, hence destroying the signal you are trying to amplify.

Still referring to Fig.3.14, the signal has to pass through R1 to reach the virtual earth, into which it "disappears". If R1 has a high resistance then the flow of current will be small, but if R1 has a low resistance, then a large current will be "sucked" in from your cassette recorder etc., and this may cause a problem.

The output impedance of, say, a CD player provides an indication of the current available from the output and, as a general rule, if the input impedance of your op.amp circuit is at least ten times greater than the output impedance of the CD player feeding it, then all will be well. The two systems will be matched.

This is very different from loudspeaker/amplifier matching where, for maximum power via your speakers, the output impedance of the amplifier should be *equal* to the impedance of the speaker.

CHOOSING RESISTOR VALUES

We have shown that the value of the input resistor (R1 in this case) should be as high as possible to reduce the current required from the CD player etc. But there are other constraints. In order to amplify, the feedback resistor must be higher still in value.

If, for example, you require a gain of ten, then the feedback resistor must be ten

times higher than the input resistor. If the value of the feedback resistor is too high, the amplifier may become unstable. In practice, avoid values greater than 100kΩ, although in some cases higher values may be acceptable depending upon other factors in your circuit. If in doubt, experiment.

The output impedance of many items of equipment such as CD players, video recorders etc., is typically around 1kΩ. So if we make the input resistor (R1 in our case) 10kΩ, then all should be well. We then set the feedback resistor to provide the gain we want, within the constraints mentioned earlier.

AUDIO MIXERS

Audio mixers are found in recording studios, theatres and often in video editing systems. The inverting op.amp configuration is the ideal circuit to form the basis of an audio mixer. The reason is illustrated in Fig.3.15.

The virtual earth ensures that no signal from one source can affect another source. You can have as many inputs as you like, and if each of the input resistors have the same value then each signal "sees" the same input impedance and is amplified by the same amount.

Notice in Fig.3.15 that the values of the resistors have been changed a little from those in Fig.3.14. An audio mixer is generally not required to amplify, so we can afford to raise the values of the input resistors, and reduce the value of the feedback resistor, all to 47kΩ. This will provide a gain of unity (one), i.e. the output will equal the input, not forgetting it will be inverted.

However, it may be more convenient if your mixer *did* amplify a little, in which case the feedback resistor could be increased to 100kΩ again, raising the gain to about two.

The fact that the output is inverted compared with the input is not a problem since we cannot (normally) hear phase differences (i.e. signals out of step), although you should avoid inverting one half of a stereo signal without inverting the other half. In other words your left and right speakers should be in step with each other.

A PRACTICAL MIXER

An audio mixer is generally required to allow the input sources to be varied, and so the circuit shown in Fig.3.16 could be employed. Each source is connected to one end of a potentiometer. If the potentiometer has a maximum resistance of 10kΩ, then the input impedance will be a little under

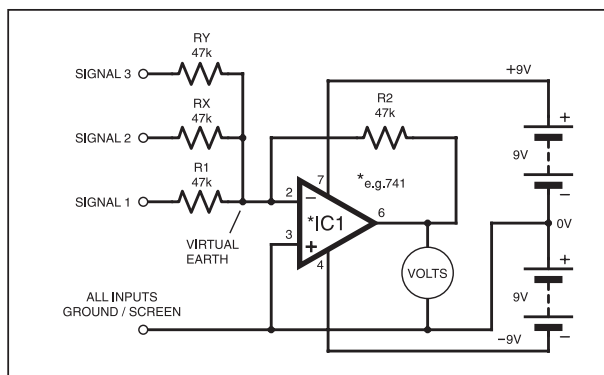


Fig.3.15. Using an op.amp as a signal mixer.

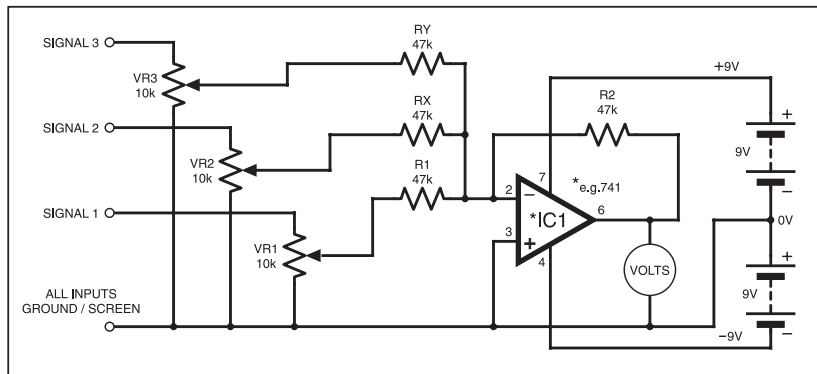


Fig.3.16. A practical dual-rail op.amp mixer with input level controls.

10kΩ altogether, but still acceptable in most applications.

Note that a logarithmic type of potentiometer should be used (not a linear type), since a log type will appear to produce a more even change of sound level as the slider (wiper) is adjusted (this is due to the way in which the human ear responds).

The circuit shown in Fig.3.16 is a simple mono audio mixer with three inputs. You can add more inputs as needed. If you require a stereo mixer, then you will need another identical circuit for the other half of the system.

Whilst the 741 is an ideal op.amp for experimentation, better i.c.s are available which offer lower noise (background hiss) and consume less power. You can also obtain i.c.s with two or more op.amps in one package. Such an i.c. is the NE5532N, as shown in Fig 3.17. This offers low noise and low current consumption.

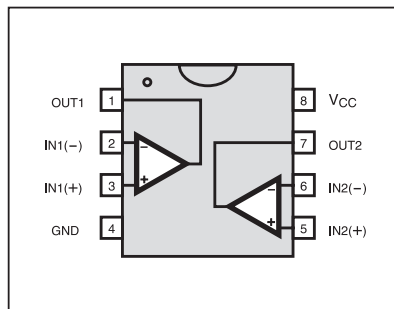


Fig.3.17. Pinouts for a typical dual op.amp.

SINGLE-RAIL SUPPLY

The circuits so far have required a rather cumbersome dual-rail power supply. While this is fine if the power is being derived from a specially made power unit, if you wish to use a battery, or a simple PSU which plugs into the mains and provides a standard 9V or 12V d.c. output supply, then it is very inconvenient.

We will now show how an inverting amplifier can be made to function on a single rail supply, where 0V is the lowest voltage in the circuit. First, though, let's explain a problem, referring to Fig.3.18.

In Fig.3.18a an incoming sinusoidal a.c. signal is amplified by an op.amp running on a dual-rail supply. The result is a uniformly shaped waveform, as you would expect. In Fig.3.18b the signal is amplified by an op.amp running on a single-rail supply. The lower half of the output is missing

since the negative-going aspect of the signal cannot be processed. This would result in severe distortion.

The trick is to raise the average value of the a.c. signal, so that instead of swinging positive and negative (i.e. above and below 0V) the signal swings above and below a mean point, such as 4.5V for a 9V supply. The signal can then be amplified, before being lowered back down to a mean of 0V for outputting.

An example circuit is shown in Fig.3.19a. Notice that the op.amp is connected to +9V and 0V. We use two 10kΩ resistors (R3 and R4) as a potential divider to create a 4.5V supply which is connected to the non-inverting input at pin 3.

Earlier we showed how an op.amp with negative feedback will copy the voltage at pin 3 to pin 2, so in Fig.3.19a pin 2 assumes 4.5V. So now the op.amp sees 4.5V as its mid-point. However, the 50Hz a.c. input signal swings equally above and below 0V, with an average d.c. bias of 0V, and so a capacitor, C1, is used to block the d.c. bias, but allow the a.c. signal to pass.

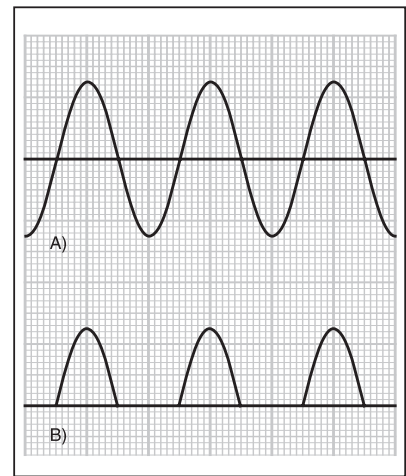


Fig.3.18. An a.c. signal loses its negative-going waveform if incorrectly processed by a single-rail power supply.

You saw in Part 1 how capacitors appear to conduct changes in voltages, even though the two sides are insulated from each other. So the capacitor in Fig.3.19a neatly allows the d.c. bias level to shift from 0V to 4.5V, as shown by the waveforms in Fig.3.19b, representing the signals at points A and B in Fig.3.19a.

If you examined the amplified signals at points C and D, you would see that waveform C is an amplified copy of B, and D is the same signal as C but shifted back down to an average of 0V. So the second capacitor, C2, holds back the 4.5V d.c. level, but allows the a.c. signal to pass.

The signal at point D may be viewed on an oscilloscope, or sent to another circuit – a power amplifier for example, but note the 100kΩ resistor, R5. This is necessary to

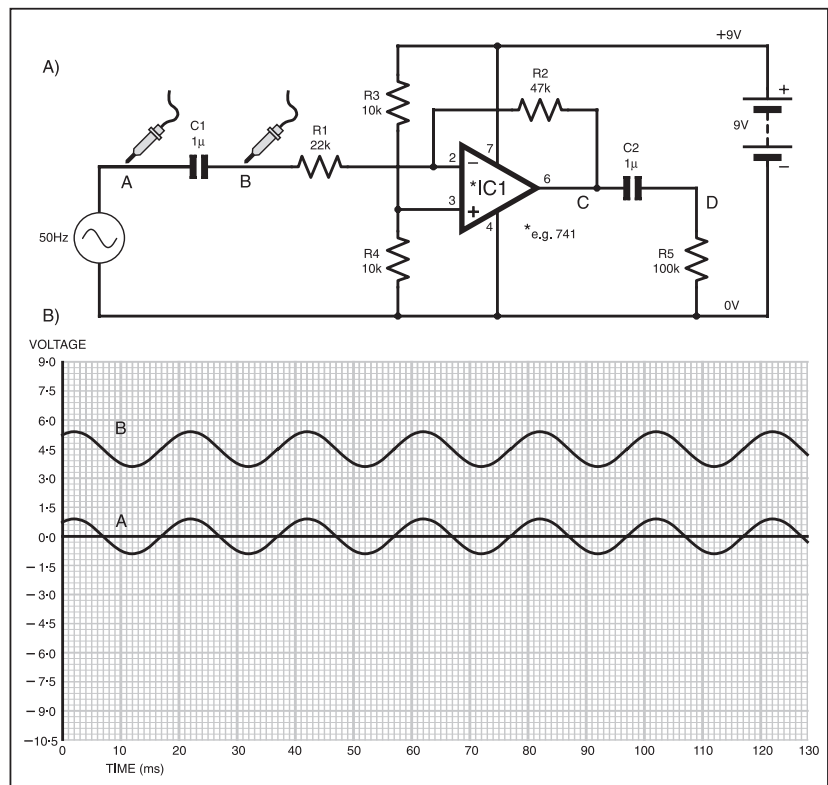


Fig.3.19. Using capacitors to shift the d.c. level of a.c. signals.

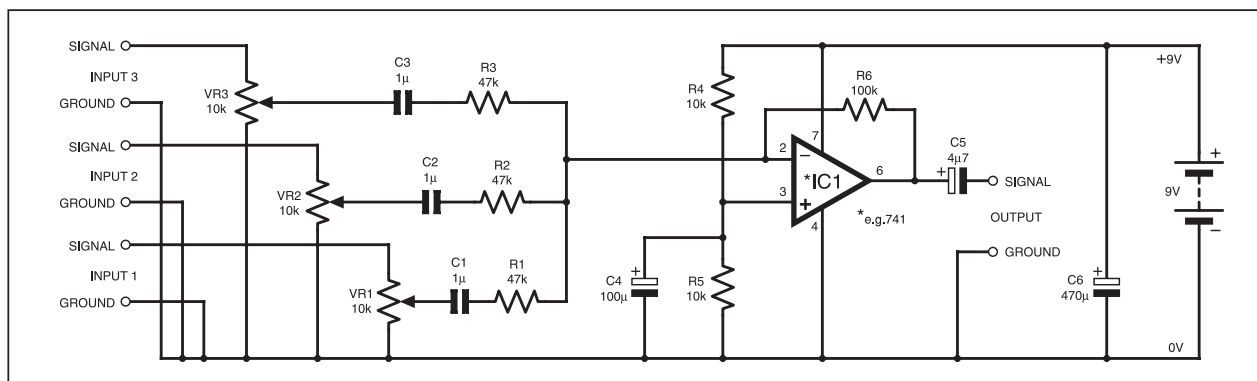


Fig.3.20. Example of a circuit suitable for mixing a.c. signals.

provide a load for the output. If you connect the output to another circuit, then that circuit will provide a load and R5 can be omitted.

CAPACITOR VALUES

Calculating the values of the capacitors (C1 and C2) required in Fig.3.19a can take us into some fairly heavy mathematics, and so a "rule of thumb" is offered.

If the capacitor value is too small, then lower frequencies will be attenuated (reduced). So we need a capacitor which is large enough to cope with all required frequencies, but not so large as to be bulky and expensive. A value of 1µF at the input side (C1) will normally be more than sufficient; in fact you could probably use a 100nF (0.1µF) and not hear any difference.

Use a non-electrolytic if possible – polyester film and polyester layer capacitors (which are non-polarised) of at least 1µF are readily available, and these should be fine. The output capacitor may need to be a little larger, particularly if you have amplified the signal, but use at least 1µF.

If employing electrolytic capacitors, ensure their positive side is towards the i.c. i.e. connected to B on the input side, and to point C on the output side. Non-electrolytic capacitors may be connected either way round.

Be aware that electrolytic capacitors tend to be noisier than non-electrolytic types and, as a general rule, this is another reason why non-electrolytic types are preferable in this type of application, especially if you are dealing with small signals.

CLIPPING

We mentioned clipping earlier when discussing the need for a dual-rail supply. We have avoided clipping the negative half of our signal by shifting its average value up by 4.5V. However, with many op.amp types there is still a danger of clipping if we allow the peak-to-peak signal amplitude to be greater than about 2V when using a 9V supply.

In other words we should avoid allowing it to rise above 6.5V or fall below 2.5V, otherwise the peaks of the waveform may be distorted. So keep the peak-to-peak signal amplitude low (below 2V), or use a higher power supply of say 12V or 15V.

PRACTICAL SINGLE-RAIL MIXER

A practical single-rail mixer is shown in Fig.3.20. The op.amp may be a type 741, but you may prefer one of the modern low

noise types, including the dual op.amp (for stereo use) type NE5532N. The power supply is shown as 9V d.c., but if using a mains power supply adaptor, 12V d.c. would be better to avoid clipping as mentioned previously.

The input capacitors (C1 to C3) are shown as non-electrolytic 1µF types, though 0.47µF (470nF) will normally be just as good. The output capacitor C5 is shown as electrolytic, and it is essential to connect its positive side as shown.

No load resistor has been included at the output, as it is assumed that the output will be connected to another circuit. But remember that you will get strange results on an oscilloscope if you test the circuit without a load (although you may get round this by directly monitoring the output of the op.amp, at pin 6).

Resistors R4 and R5 split the supply voltage in half to bias the non-inverting input. Note the additional capacitors C4 and C6. Both are used to help smooth the supply and remove any ripples present. The value of feedback resistor R6 has been chosen to provide a gain of two (actually -2, since the output is inverted).

LIMITATIONS

A mixer circuit of the type shown in Fig.3.20 is designed for "line-level" signals. This term is explained fully later in the series, but in this context it means the signals used between a CD player, video recorder, cassette recorder etc., and a power amplifier. These signals peak at around 1V. The mixer is not designed to mix high-level signals, such as signals fed directly to speakers, or to mix low-level signals e.g. from microphones, or record decks with magnetic cartridges.

Whilst it may be tempting to connect several microphones to the mixer, the signals are so low that considerable amplification is necessary. If you amplify the signal after the mixer, noise induced by the potentiometers and electrolytic capacitors will swamp your signal. It is essential, therefore, to amplify the microphone signal *before* applying it to the mixer. Commercial mixing desks often have microphone amplifiers built into some of the inputs. Read on for a suitable microphone amplifier.

NON-INVERTING D.C. AMPLIFIER

As you might expect, it is possible to apply a signal to the non-inverting input of an op.amp and tie the inverting input as shown in Fig.3.21. Note that we still have negative feedback in the form of R1. The ratio of resistors R1 and R2 provide the gain according to the equation:

$$\text{Gain} = (R1 / R2) + 1$$

Hence in Fig.3.21, the gain is given by:

$$\text{Gain} = (47k / 10k) + 1 = 5.7$$

Notice that the positive answer shows that the output is in phase with the input, in other words, it is not inverted.

The input impedance of the circuit is equal to the input impedance of the op.amp input itself, and this is likely to be very high. In fact some op.amps with f.e.t. or CMOS inputs have input impedances well in excess of 1MΩ. This very high input impedance is a great advantage in circuit design, and it is easy to reduce if not required.

EXTREMES

If resistor R2 is reduced to zero (e.g. replaced with a wire link) then the gain of the system will rise towards infinity since the inverting input will be fixed at 0V and the circuit will behave like a comparator. The formula shows this:

$$\text{Gain} = (47k / 0) + 1 = \text{infinity (since any number divided by zero is infinity)}$$

In fact, the gain will be equal to the open-loop gain of the op.amp.

If resistor R2 is increased to infinity, i.e. removed altogether, then the formula shows:

$$\text{Gain} = (47k / \text{infinity}) + 1 = 1$$

Hence we see that the output will copy the input – we have a voltage follower.

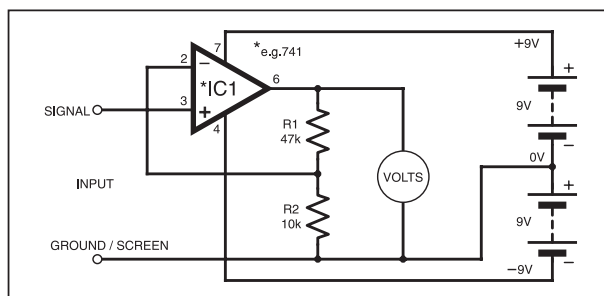


Fig.3.21. Non-inverting d.c. amplifier with dual-rail supply.

VOLTAGE FOLLOWER

As said, any number divided by infinity is zero, so the value of R1 in this instance is irrelevant. It may as well be a piece of wire. (Mathematicians may be worried about the consequence of 0/0 in our formula, but fortunately even a piece of wire has some resistance, so the problem doesn't arise!)

The resulting circuit is shown in Fig.3.22. The output voltage will copy the input voltage. This may not sound very useful, but remember that the input impedance is very high, and the output impedance is much lower – in other words, a minute amount of current at the input can cause a significant current from the output. The circuit is thus useful as a signal buffer.

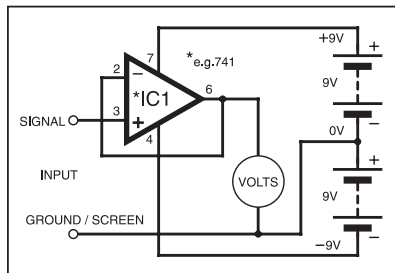


Fig.3.22. Unity gain voltage follower (buffer).

For example, you may have an elderly analogue voltmeter at the back of a cupboard. It is a fairly cheap meter, and its internal resistance is quite low. Hence when you try to take a voltage reading in a sensitive circuit, the meter sucks so much current out of your circuit, that the reading is much lower than expected.

This is a common problem – meters which affect the circuit you are trying to measure. The solution is to construct a voltage follower. The input of your voltage follower requires almost no current (it has a very high input impedance) but it can supply more than enough current to operate your cheap meter. It copies the voltage you are measuring with great accuracy, and outputs this voltage to your meter.

MICROPHONE AMPLIFIER

The high input impedance of the non-inverting amplifier makes it ideal as a microphone amplifier. The arrangement for

a single-rail supply is shown in Fig.3.23. The circuit may be used with a dynamic microphone, i.e. the type which generates a signal without the need for a separate power supply, or you can use an electret microphone providing it is the type which has a battery fitted inside the housing. Cheap electret microphones often employ this method, expensive ones generally require "phantom power", i.e. a 48V d.c. supply which must be fed down the microphone cable from the amplifier.

The signal is a.c. coupled by capacitor C1. Resistors R1 and R2 hold the non-inverting input to a mid-voltage, 4.5V in this case. When an audio signal is delivered by the microphone it is amplified according to the non-inverting formula:

$$\text{Gain} = (100k / 10k) + 1 = 11$$

So if the microphone produces a signal of around 50mV we should obtain an output of around $50 \times 11 = 550\text{mV}$.

Capacitors C1 and C2 perform a similar operation to the input and output capacitors in the inverting circuit (Fig.3.19).

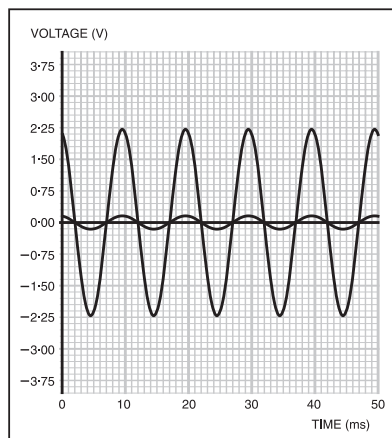


Fig.3.24. Example waveforms for the circuit in Fig.3.23.

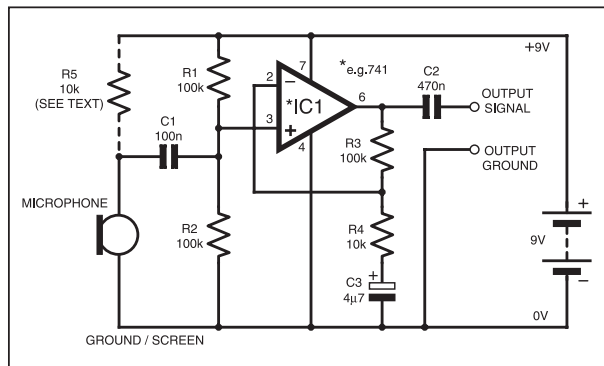


Fig.3.23. Microphone preamplifier circuit, single-rail.

The operation of capacitor C3 is more subtle. It is large enough to offer no resistance to the audio (a.c.) signals, and so as far as a.c. is concerned it is like joining R4 directly to 0V, and the gain equation is intact. But d.c. is blocked, and so as far as the d.c. conditions are concerned, we are effectively joining the output directly to the inverting input. The gain equation is therefore:

$$\text{Gain} = (100k / \text{infinity}) + 1 = 1$$

So applying the op.amp "law" whereby, if negative feedback is applied, the voltage at the inverting input copies the voltage at the non-inverting input, the magic figure of 4.5V (or half the supply voltage) is copied to the non-inverting input, pin 3, and hence to output pin 6. So the whole system sits at 4.5V, and the a.c. signal is amplified as shown in Fig.3.24. The small waveform represents the input signal from the microphone, and the larger one shows the "in-phase" signal from the output.

Note that resistor R5 is only required if an electret microphone insert is used (these were discussed in Part 2). These microphones are inexpensive and provide a good signal, and so are ideal in "low quality" applications, e.g. if you are trying to detect sound, rather than record it. If you use a dynamic microphone (any type) or an electret microphone with a built-in battery, then omit R5.

NEXT MONTH

In Part 4 next month we start to examine logic gates and digital electronics.

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Blurred Vision For Telly

The future of television is definitely digital but will picture quality actually improve? Andy Emerson looks at the options.

IN many people's living memory the only choice with television was whether you watched BBC or ITV. Cable TV was an option in few areas only and in any case, the most it offered by way of "extras" was an out-of-area regional ITV programme plus a selection of radio programmes you could listen to on the TV set's loudspeaker.

Colour pictures and video recorders were dreams for the future, whilst the only television satellite was *Early Bird*, used for transatlantic programme exchanges on special occasions only. Not much choice but no worries either.

PICK-AND-MIX

These days broadcasters are seriously concerned. The cosy world of broadcasting that they controlled exclusively is disintegrating into an unrestrained array of narrowcasting options. With broadband an affordable reality for the majority of the British population, the future of television may well be a pick-and-mix affair where you choose what you watch and when you view.

Forget Sky Channel's feeble offer of "your own private television station"; it's far too expensive and your actual choice is quite limited. The reality is that very soon you will be able to take your pick of the world's television programming at little or no cost, along with a vast selection of pay-per-view offerings of specialist interest (not just XXX material!).

For a realistic price you'll be able to catch up on programmes you missed (as you already can on the BBC radio website) or raid the BBC archives for classic programmes of the past. Once this takes off, you can expect many other providers offering films, music videos and other material for download.

An example of this "niche programming" is TVBrick, an Internet-based system designed to help Japanese nationals overseas keep up with the favourite TV shows from home. It was launched in July by French open-source software company Nexedi and although some critics claim it represents copyright infringement on a massive scale, the scheme sounds perfectly defensible.

It works like this. At home, in Japan, subscribers (yes, it's a paid-for service) connect their TVBrick to the Internet via a broadband link (the box is also connected to a television aerial or cable TV outlet). At their overseas location users watch the digitised programmes either on a standard PC, connected by broadband, or on television using a standalone play-back adapter called the TVBrick Player.

Picture quality is apparently not brilliant but will doubtless improve as technology advances.

MISSING THE POINT

Broadband was just made for applications of this kind and people who see broadband as merely souped-up Internet access are missing the point. That's certainly the viewpoint of Brian Levy, Group Technology Officer for Services and Solutions at British Telecom. "Fast Internet is only one narrow facet of broadband," he declares. "Broadband opens up a vast repertoire of video on demand offerings, online gaming, two-way multimedia hookups and provides the network gateway for all manner of tetherless voice and data devices such as high-speed wireless data networks in the home."

For many people this explosion in choice will not have come a moment too soon, but what worries them is the trade-off in picture quality. When video technologists have spent the last forty years adding colour to television, improving the definition from 405 to 625 lines, then bringing us 100Hz refresh rate screens and DVD discs with undreamed-of clarity, why do we now look like jettisoning this state of near perfection in favour of jerky, smeary images?

Bandwidth is the problem according to some, although the latency or unpredictable delivery speed of packet-based networks like the Internet is another. But what really infuriates "serious" viewers is the "digital vandalism" that the programmers themselves are inflicting on viewers.

CARE AND ATTENTION

Television historian Andrew Henderson takes issue with the BBC over the way that widescreen vandalism is slowly creeping over all broadcasts of older programmes. He cites the Corporation's long overdue repeat of the 1964 series *The Great War* as an example.

He states: "The complete series has had the original picture pointlessly cropped to a new bogus "widescreen" version. Effectively the top and bottom of the image have been selectively trimmed off, to suit the new "improved" 16:9 picture ratio. By doing this, roughly a third of the original picture is removed and the definition and picture quality deteriorates to a point far worse than the original broadcasts."

Why was this thought necessary? This revisionism berates the memory and achievements of the cameramen who risked their lives to provide priceless footage. It also insults the hard work of the

film archivists at the Imperial War Museum who try to preserve footage as originally seen."

This is not to deny the fact that television sets are now mostly made with a 16:9 ratio picture tube, he continues. It's understandable that having bought one of these sets, many viewers will be keen to get as much widescreen as possible (regardless of the corruption of the image). And to be fair, this is a personal preference (much in the same way that some people like deeply saturated colour whilst others prefer subtle, more natural hues).

But remembering the great deal of care the BBC invested in getting PAL colour television "right", you might be forgiven for thinking that widescreen broadcasts would be handled with the same degree of attention. Far from it! Programme schedules regularly feature an often confusing mixture of 4:3 and specially shot 16:9 material, leaving viewers to decide how to watch the individual programmes.

OBNOXIOUS CROPPING

Another example was a classic Wednesday Play, *On the Eve of Publication* by David Mercer. It was made in 1968 using the standard 4:3 ratio but was cropped to 16:9 ratio when re-screened in 2003, creating a complete loss of artistic composition. Says Andrew, "This is the same sort of butchery which was inflicted on many early cinema classics that were re-issued in the 1950s and 60s in "widescreen" versions."

The film cropping practice has mostly stopped, but its use in television is a menace to be discouraged. To add insult to injury, there is a function on some digital receivers that crops 16:9 to 4:3 by chopping off the sides. A viewer watching the Mercer play in this manner would probably have lost 50% of the original image, effectively watching a small area in the centre of the original image."

Why the BBC feels it essential to re-work these old programmes into 16:9 format is beyond Andrew, since only a small minority will want to watch something as obscure as an old 1960s play. These of all people are the ones for whom authenticity is most crucial, making the BBC's action both wasteful and obnoxious.

He concludes, "If you are equally angry about the current conditions, please complain to the BBC. The complaints might be in a minority, but the issues involved will eventually affect the majority. The situation may possibly even change for the better, but let's pray it doesn't get worse."

READOUT

WIN AN ATLAS LCR ANALYSER WORTH £79

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.

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 1 μ H to 10H, capacitance from 1pF to 10,000 μ F and resistance from 1 Ω to 2M Ω with a basic accuracy of 1%.



★ LETTER OF THE MONTH ★

SERVOES AND PICS

Dear EPE,

There have been several queries recently in *Readout* regarding PICs and R/C servos. Last year I built my first PIC project. It used a 20MHz PIC16F877 to simultaneously control eight R/C servos as well as sensing four push-button switches. It is probably worth sharing the knowledge that I obtained in doing this project, and the assembler code routines that drive the servos.

The key points to understand when driving servos are as follows:

Each servo needs to be refreshed with a pulse about 50 times a second, so the main loop in the program must not take longer than 20 milliseconds. The pulse has to be of a precise length between 1ms and 2ms that defines the servo position (typically 1ms gives one end of the servo movement range and 2ms the other end). A simple delay loop can be used to time the pulse duration between switching the pulse on and switching it off (by setting the relevant Port bit on and then off after the delay).

If you send at worst case a 2ms pulse to each of eight servos one after each other this takes 16ms, so you have 4ms (or 20,000 machine instructions) left to do anything else you want, such as, in my case, sensing the switches. If you send a shorter pulse than 2ms, you should wait for the remainder of the time so that the overall loop speed stays constant.

If you want to move the servos in a defined sequence you need a list of positions for each servo, so I had eight tables with up to 20 items in each. In my code there is a routine that converts the one byte servo position field into the relevant length pulse. With a one byte field we get 256 possible servo positions, or better than one degree of positioning accuracy.

To adjust the speed of movement of the servos you need to control how many times you use a value before you move onto the next one from the relevant table (with each time taking one fiftieth of a second). In my case this is variable using the speed-up and slow-down switches. This, however, can give a somewhat jerky movement on the servos as it jumps from one position in the tables to the next. If you want smooth movement you need to interpolate between the values in the table, which is what the interpolate routine in the program does.

The servo lists were set up dynamically, rather than as initial constants, and this allows them to be changed at will while the program is

running in response to the switch inputs, i.e. to switch to a different servo sequence.

On a wiring-up note, servos have three wires, positive, ground and a control signal feed. I used a separate supply (four rechargeable batteries) for the power feed to the servo for the positive and ground connections, and another for the PIC supply (a PP9 battery with a 5V regulator), so that the heavy load and any electrical spikes from the servos did not affect the PIC. The control signal only needs a small current and can be driven directly from the PIC output ports, the eight Port B outputs in my case.

Finally, if you are sensing pushswitches you need to debounce them. A good way is to check on two consecutive times round the main loop that the value is still the same as it was last time.

In my case the servos controlled the hip and knee joints on a 4-legged walking robot that made it to the heats of *Techno Games*, but there will be lots of other applications where sequencing or animatronics need a similar bit of functionality.

The code was developed using the FED PIC assembler and was run initially on a FED development board, but should be easily made to work with other development tools. I don't claim the code to be optimised or perfect, after all it was my first PIC project, but it works just fine, and might just save readers a few months working out how to drive those servos.

I am happy for you to put the code on your web site. It is supplied as assembler file `robotleg1_MPL.asm`.

David Hannaford, Henley-in-Arden, via email

That looks very useful, David. I'll put your code in the PIC Tricks folder on our Downloads page. Many thanks for sharing it with us.

And congratulations on attempting something so sophisticated for your first PIC project. I have long maintained that one of the best ways to learn something is to get stuck into an idea that you want to achieve, and solve each step along that route as a separate item, experimenting with various options until you find a workable solution.

At the end of the day, it doesn't matter whether your code is "optimised" or not. If it does the job you want, then it's a satisfactory method!

consider *craft* the right word, as opposed to, say, *work* or *science*, as most electronic projects are designed to meet a specific human need and therefore require a bit of human design strategy to be widely accepted. A project created by a craftsman is the combination of art and science with a mix of love thrown in for spice.

EPE is a magazine for craftsmen by craftsmen.

Dave Mynatt, Manchaca, Texas USA

You are so kind Dave! I design because I love the challenge, and that seems to be the case with most of our contributors these days.

PEAK ENJOYMENT

Dear EPE,

I do like your magazine. Would you believe just over a year ago, if someone asked me what is the difference between a resistor and a transistor, I would not have known what they were talking about. Only because I was confined to bed for a time and your mag was just something to read, I now find I can build little things from your pages that work. OK, I only copy and do as it says in the article and send off for the parts and circuit board and put them together, but others think I am clever.

I do like your *Teach-In 2004* as well. Now I am beginning to understand what all those little things I put together do. Thanks to Max Horsey, who puts it in nice clear English. Capacitors got me for a while as I kept sending them back because they had the wrong letters on them, until I saw in your mag how to read them.

I've also bought a Peak Atlas Transistor Tester from an advert in *EPE*, and it's a lovely little thing, so simple and now I don't have to search around to find out what sort of transistor or diode I have. I will get the Atlas LCR Meter next.

Meanwhile I have been searching the web and came across *The Educational Encyclopaedia* at <http://pandora.be/educypedia/electronics/motorstep.htm>, which might be of help to your readers as a source for more information.

Peter Mars, via email

Great to read such words of enthusiasm from you, Peter! Yes, electronics is fascinating. Thanks too for the address. All the very best for your continued enjoyment!

UV SENSING

Dear EPE,

Referring to the Cloud Cover letter in *Readout* Nov '03, some years ago, there was an article in the "amateur scientist" column of *Scientific American* regarding atmospheric haze. The sensor used was a green I.e.d. instead of a photo-cell plus filter combination (an idea attributed to Forrest Mims).

Since it is now possible to get violet plus near-UV I.e.d.s (I got mine from Oatley Electronics, who're a little bit like Proops Bros - <http://oatleyelectronics.com/>) perhaps a sensor for UV would not be too far-fetched (it might need two I.e.d.s with one hiding behind a photographer's "UV-0" filter - easier than cutting a piece of Wood's Glass as found on the "blacklight" fluoro tubes at the local disco).

I liked your *Met Office* (Aug/Sep '03), but I didn't see a way of dealing with real rain (I've seen 0-5metre/hour rate when visiting the "out-laws" in Queensland. Forget the raincoat! Where's the soap?). It didn't look like the ultrasonics were protected from golf-ball hail either... much fiddling for retirement methinks, but a great concept nonetheless.

Brian Conner, Australia, via email

Ah, Brian, I remember Proops in London - a real Alladin's cave in my youth! Your rain and hail situations amuse me (am I cruel?!). No I didn't allow for extremes, though I suppose the water barrel level sensor might do for the deluge (I experienced such in Malaya as a child).

Thanks for the kind comments.

WONDERFUL WEATHER!

Dear EPE,

A wonderful project! Again. The multipurpose weather station, *PIC Met Office* Aug/Sep '03, is a challenge any craftsman would be glad to tackle. The use of transducers as opposed to mechanical vanes is a great addition to a weather station, and should make current condition reporting on the ham radio network less cumbersome.

I must say, after being a reader for such a short time, that your projects and special discussions are quality work adding greatly to the knowledge base and enthusiasm for the craft. I

FIXING CANUTE

Some time ago reader **Ken Horton** wrote to say that he had built Canute Tide Predictor (June '00) and that it was:

... in continual use on an ocean-going boat in Portugal. I understand that every so often, the clock goes wrong displaying 25:00 hours before locking-up. Unfortunately, I am unable to give you the precise details of the error as I have not had chance to witness the symptoms first hand.

I replied that I knew Canute was in successful use as other readers had told me so, but that I fully accepted that his unit had this problem. Without details of the circumstances under which the problem occurred, though, I was unable to offer advice.

Recently, however, Ken emailed me to say that the unit had been brought back from Portugal for him to look at, and he had made a few code changes, which he quoted. The code is too lengthy to repeat here, but it has been placed on our Downloads page, within the Canute folder. Many thanks Ken!

UV DETECTION

Dear EPE,

I read with interest the letter entitled Cloud Cover in *Readout* Nov '03. It may be possible to construct a cheap sensor for UV light by using a conventional l.d.r. with a bandpass plastic filter to attenuate non-UV band light. Maybe a photo-voltaic cell would work? UV photons are higher energy than visible light and it would seem foolish for the manufacturers of such cells to cover them in such a way so as to remove this potential source of energy. Presumably the output voltage/current of such a cell is a function of light intensity.

A Cambridge based company selling UV filters is at www.optical-filters.com/uvfilters.html.

Gareth Howard,
via email

That's interesting Colin, and as a first response I felt it might be possible with an l.d.r. Then I realised that many transparent materials, like glass for example, cut out UV (or so I understand). I wondered too if the ORP12's l.d.r. surface would do the same, and so could not be used? If it did let through UV then I can see that your filtering would work. I don't know about PV cells, other than that the one I have also has a glass cover.

Taking to heart your comments, and those from Brian Conner, I sense a round of experimenting coming up!

TILECUTTING P.C.B.S

Dear EPE,

It is now forty years since I first started buying electronic mags. In this time I have built many projects around the home. The latest is a simple network using four PIC16F877s, one in each zone. I know this is a bit of an overkill but I've enjoyed the challenge.

Also, I have found that a motorised tilecutter is ideal for cutting fibreglass p.c.b. Would you like to pass this on to your readers. I am looking forward to my next EPE.

Brian Milner,
via email.

Duly passed on, Brian, thanks! Carry on PICing...

PUNCHED TAPE

Dear EPE,

Do you remember punched paper tape? Seems useless now. It took one-tenth of a square inch just to hold a single byte. Think how much memory is crammed into the same surface area on a silicon chip!

But there is a possible use. The holes fall on the 0.1 inch grid of common components and stripboard. Would any reader like a small sample

to experiment with, to see if it has any use in practical circuit layout? Just send me a pre-paid self-addressed reply envelope and I will forward a length of ready-punched tape. Please note that the quantity that I have is necessarily limited, but I'll do my best.

My tape equipment is the Friden (Singer) Flexowriter. This is a typebar/moving platen electric typewriter with added punch, reader and external interface for computers. I'd like to know if anyone else still has this equipment, or am I the owner of the last remaining machine in Britain? I also have some technical manuals and a (limited) supply of spares, if this should be of help to anyone.

Also, if any reader has a genuine need to prepare or copy eight-track tape, I will try to assist. Note that this is computer and not Telex tape - the sprocket hole spacing is different.

Godfrey Manning G4GLM,
63 The Drive, Edgware, Middx HA8 8SP

Thank you Godfrey, those are interesting offers. And, readers, is Godfrey alone in owning a Flexowriter? I also wonder if I'm alone in owning a Varsity, a typesetting machine with interchangeable fonts and powered by a clock-work mechanism which itself was powered from a mains driven motor.

MORE PIC MATHS

Dear EPE,

After writing my *High Speed Decimal to Binary for PICs* routine (Nov '03 issue), I did attempt "the same trick in reverse", i.e. fast binary to decimal. It is nowhere near as easy and good friend Paul Turner (an EPE online reader) agrees. I was making good progress when he sent me this link:

www.korlanda.com/reggie/snippets.asp?ID=62

I have studied John Payson's code at this site and I was going down exactly the same road as he, but he beat me to the end. Ah well, can't win 'em all!

Peter Hemsley,
via email

Thanks Peter, if you say it's good I know it is! Readers - I can't put this code in PIC Tricks, but you can download it from the address Peter gives.

PLUGGING PORTS

Dear EPE,

Thank you! Robert Penfold's *Interface* of Oct '03 about accessing PC parallel ports using Logix4u's new INOUT32.DLL was very welcome.

Your readers might like to know that I give more information on using the PC's parallel port for hobbyist electronics at www.arunet.co.uk/tkboyd/ele1pp.htm. I've also published a "how to do it in Delphi" tutorial at http://ourworld.compuserve.com/homepages/TK_Boyd/Dt3k.htm.

Tom Boyd,
via email

Thanks Tom, nice to hear from you again - I've browsed your informative site many times. Robert has done more on the new DLL in the December issue as well. This new DLL is an excellent find.

PIC CAR ALARM?

Dear EPE,

My latest EPE, as ever, is a joy to read, and more often far better than television too! Could I put a suggestion forward for some later projects which may have other uses outside the regular ideas in EPE.

I was wondering if using PICs it may be possible to make a two-part car alarm that transmits to a receiver several metres away (e.g. inside a house) to let you know if someone is stealing your car, triggered from the ignition switch perhaps?

Another idea is to make a PIC send a pre-programmed IR transmission to a video recorder to automatically start up and record from a CCTV camera in a garden or house. The trigger would ideally come from a discrete PIR sensor covering a path or other area. It could even just output to a relay as another option, or it could go direct to the SCART plug connection to start it up.

How about an electronic dog's voice (for a van or house), to be triggered when a PIR (again) senses someone walking up a drive or around the back of a house. It could work alongside timed lights for when the occupants are away.

These are only thoughts rambling in my mind after seeing people suffer at the hands of villains.

I look forward to next month's projects, and seeing if I can adapt them or their ideas for other jobs.

Paul Badger,
via email

Thanks for the interesting suggestions, Paul. They might inspire other readers to offer us something on these lines. And, yes, we expect readers to adapt our published ideas for their own purposes. It's not plagiarism, but common-sense use of building blocks!

PAINTING WITH VB6

Recently, while writing a VB6 program, I wanted to "paint" in different colours several areas within irregular outlines. With QuickBasic, and indeed QBasic, it was simple to do this by quoting the coordinates at which the colouring was to commence, the colour of the border at which the colouring was to end, and the colour to be used to fill the area, all done by one command, Paint. After much experimentation, I decided that VB6 would not allow this function.

So I asked reader and contributor Joe Farr about it (regular readers will recall Joe's excellent I.C. Tester of Oct '02, and his recent highly-useful Serial Interface for PICs and VB6, Oct '03). Joe uses VB professionally and I felt he would know a solution - which he does. He replied:

I've attached some VB code that will allow you to flood-fill irregular shapes that have been drawn on a Picture control. Click the button at the bottom of the form to draw a couple of odd shapes and then click anywhere on the picture control to watch it flood fill.

You should be able to adapt this code to your requirements. I have not tried this code on all platforms, but I'm guessing that it should be fine. It works OK on Win2K. You can use it/publish/print it anywhere you think it would be useful. It's just a collection of standard Windows API calls.

Note that there is a "DeleteObject mBrush" in the form_unload event. You must always make sure that this is there, otherwise your PC will run out of resources and all sorts of bad things will start to happen.

It's brilliant - exactly what I needed! So, as I'm sure many VB-using readers will benefit from it, I have put Joe's example code into the Interface folder on our Downloads site. Thank you very much indeed, Joe.

EDDYFYING!

Dear EPE,

In response to the Wanted! posting in *Readout* Dec '03 - any electrical engineer could tell you that Eddy Current is a dissipated field.

Guy Selby-Lowndes,
via email

Nice one, Guy! I've no idea who originated the posting, but we do have a few "jokers" on our Chat Zone...

(Which is accessible via the click-link on our home page at www.epemag.wimborne.co.uk).

New Technology Update

IntelliFET devices improve power supply protection, and nanoporous structures improve fuel cell efficiency. Ian Poole reports.

GENERATING power for electronic circuits and protecting them from surges and failures that may cause greater problems are two challenges facing designers of electronics circuits today. Whilst they may not appear to hit the headlines in the same way as other semiconductor developments, they are equally important.

Sources of failure

One of the major causes of failures in electronic circuits is high voltages reaching them. Even what might be thought of as relatively low over-voltages can cause damage.

One possible cause of failure may be a spike passing through the supply regulator. In the worst instance this might be a failure of the regulator and, although rare, the consequences of a failure of this nature are catastrophic, resulting in most of the chips being supplied by that voltage line being destroyed.

It is also possible for smaller spikes to appear on the supply rails. They may result from spikes on the a.c. power line input that bypass the regulator, or they may arise from static being discharged onto some part of the circuitry and getting through onto the rails or other parts of the circuit.

Short circuits may occur. If left without any protection a short circuit will not only prevent the correct operation of the circuit, but in many cases it will cause further damage as the short could cause an overload elsewhere in the circuit.

IntelliFETs

Naturally there are many integrated circuits on the market these days that very effectively perform the basic protection functions. One of the problems with "off the shelf" solutions is that it is very difficult to gain a balance between over-current and over-voltage situations. Although they considerably improve the survivability in most transient situations, they cannot protect against all the situations that may arise. In addition to this, most of the devices that are available are aimed at the automotive market and they are not optimised for other situations.

To overcome this problem, Zetex have introduced a range of devices they call their IntelliFET range. The chips in the product range are semi-custom devices, programmed in the final mask stage of the production process, and in this way they can be set to suit the application for which they are intended.

The chip is able to protect against the standard over-voltage and over-current

situations that may be encountered. In addition to this it incorporates temperature sensing elements as well as human body model ESD (Electro-Static Discharge) clamps, see Fig. 1. As static is a major cause of failure this is particularly important.

All the elements of the protection circuitry auto-restart once the failure condition has been removed. However, the other feature that needs to be considered in any protection device is the in-rush current that is present on any circuitry that contains capacitors as these need to charge up. Motors also have a high start-up current and this can also be accommodated.

With small over-voltage or over-current situations potentially leading to damage, circuits like this one are part of the drive to improve reliability, especially in the higher voltage applications between 30 and 100 volts. Accordingly, this area of the market is likely to see a large increase in demand.

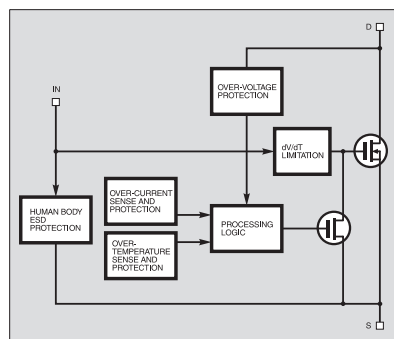


Fig.1. Internal circuit blocks for the Zetex IntelliFET protection device

New fuel cell developments

Battery technology has come a long way in recent years, but a more efficient way of generating electric power can be by using what is called a fuel cell. As the name implies these cells convert their fuel into electrical energy. As the fuel may be very cheap, and the cells can be re-fuelled this can be a very attractive way of powering electric circuits. In fact these cells can be re-filled just like refillable cigarette lighters.

In recent years fuel cells have created a large amount of interest because they promise to provide a convenient source of cheap clean portable energy.

The fuel cell uses oxygen that can be obtained from the air around us and a fuel containing hydrogen, often in the form of a hydrocarbon and this may be anything from methanol to natural gas, or even petrol.

The cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other to generate electricity, heat and water. Catalysts such as platinum are used to increase the rate of the reaction, and therefore the output that can be obtained from each cell.

The problem with fuel cells is that they are generally quite large for the level of power they are able to generate when compared to most batteries. A typical mobile phone for example requires about 3.6 volts at around 300mA when a call is being made and the space available in a phone for the power source is much less than 12 cubic centimetres. Even this figure is falling as phones become even smaller.

However, the output of a fuel cell is proportional to the surface area that is available for the reactions to take place within it. To produce a current of 300mA would require a surface area in excess of 60 square centimetres, and this would mean that the cell would be much larger than the space available in the phone.

To overcome this problem a team of researchers at ST Microelectronics has developed a new structure that enables a much higher surface area to be contained within a much smaller volume.

This has been achieved by implementing a three dimensional structure containing many thousands of buried microchannels that maximise the surface contact area for the gases, the catalysts, and the electrodes.

The research team also succeeded in fabricating a special "nanoporous" layer of silicon that contained millions of pores each measuring a few nanometres in diameter. The combination of the very small pore size with the vast number of pores enables very much greater surface areas to be achieved, and this is the key to increasing the output from the cells. Additionally the research team is working with the University of Naples to develop innovative low cost membranes that exhibit very high levels of conductivity.

Although it was stated that there is still further work to be undertaken to bring these ideas to a state where they can be used in a commercial product, the team are very excited about their potential. It is likely that in years to come, products could use this technology to provide cheap and convenient sources of electricity without any undue impact on the environment.

Further information about new technology, and radio and electronics technology in general can be found at www.radio-electronics.com.

PIC WATERING TIMER

LES CLARKE

*Keep your plants in pristine condition
before you PIC them!*



THIS timer module is designed around a PIC16F84A to control a motorised water valve providing an automatic low pressure watering system for a greenhouse or garden. With little modification it can be used to control other devices.

One of the author's first ever electronic projects was an l.e.d. clock (which he admits was badly soldered onto strip-board!). It used a mains frequency counter type i.c. driving four seven-segment displays, and probably consuming a couple of amps.

Consequently, one of the design constraints for this PIC Watering Timer module was for it to 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.

GARDENERS' WORLD

It is stressed that this timer and its control valve are not intended for use on household mains water. It is designed to control the water feed from a low pressure rainwater butt and should only be battery powered.

Having dabbled with a d.i.y. "automatic" watering system for a small greenhouse, the author found that he regularly had to override the moisture sensor circuit. For some reason it was very difficult to adjust, then just as he thought he had got it right he discovered that the copper soil probes had decomposed!

This timer module now waters his greenhouse tomatoes at regular intervals regardless of the gardener's presence. The only adjustment needed to the circuit is to lengthen the "wet" time bit by bit as the

summer gets warmer (and the "perfect" tomatoes get bigger!) and, of course, make sure that the water is on tap. Good drainage too is essential to allow for any over-watering. The compost's moisture should be checked occasionally.

CIRCUIT DESCRIPTION

The complete diagram for the PIC Watering Timer is shown in Fig.1. The PIC16F84A microcontroller, IC1, is clocked by a standard 32768Hz watch crystal, X1, which is used in conjunction with capacitors C1 and C2.

The module operates as a 24-hour clock, set with programmable timer options entered by a combination of the four push-to-make switches, S1 to S4. These are monitored via PIC pins RA0 to RA3.

Water valve (X3) open and shut testing is provided by temporarily connecting pin RA4 to the 0V line via test points TP1 and TP2.

PIC pin MCLR and the five Port A pins are normally biased high via the s.i.l. resistor module R2 to R7.

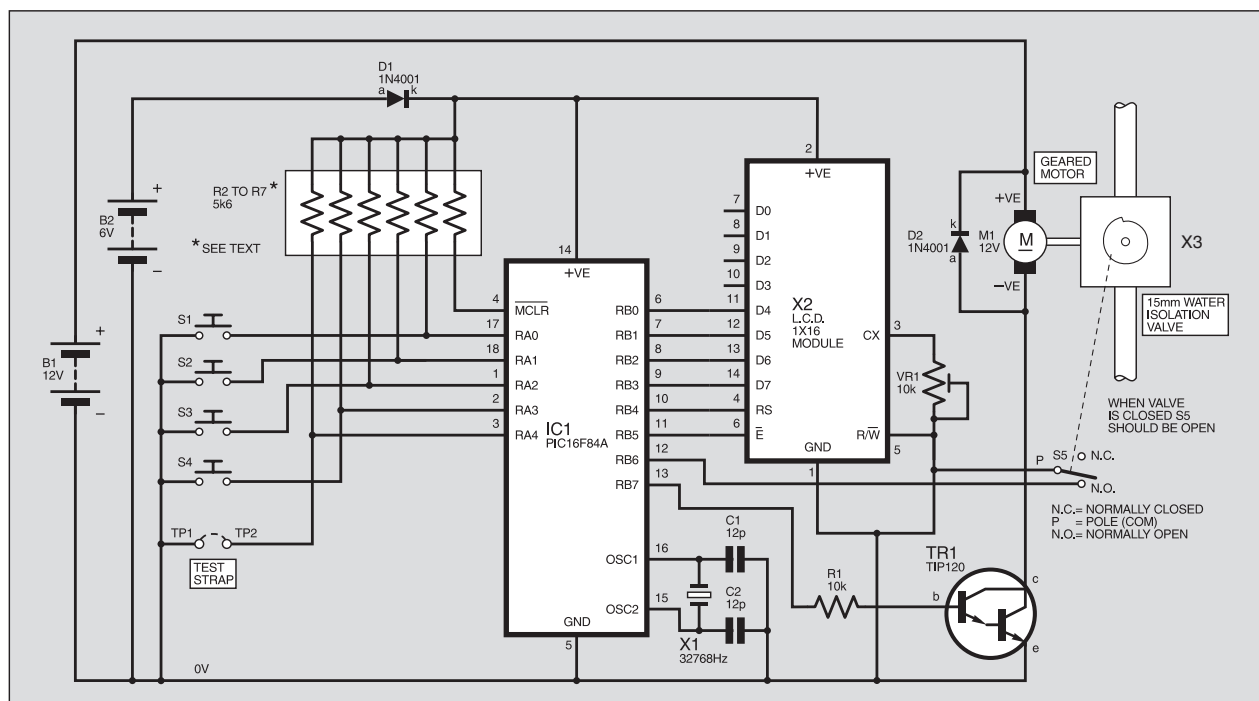


Fig.1. Complete circuit diagram for the PIC Watering Timer.

The liquid crystal display (X2) module used in the prototype is a 16-character single-line device, type Hitachi LM020L. A standard 16-character 2-line l.c.d. may be used instead. It is operated in normal 4-bit mode controlled by Port B, as with the majority of *EPE* l.c.d.-based designs.

PIC pin RB7 controls Darlington transistor TR1 via current-limiting resistor R1. In turn, TR1 controls the water valve drive motor, M1.

Microswitch S5 is connected to PIC pin RB6. The PIC looks for a change in the contact status of this switch to stop the geared motor at the extremes of the valve's open and shut travel. This design requires no drive power to hold the valve in either position, thus saving power.

The prototype control module takes its power from a 6V 1.3Ah rechargeable battery. This keeps it running for about a month. A 6V 10Ah battery would extend the duration to about eight months.

Diode D1 prevents the circuit being damaged by an incorrectly connected battery. It also keeps the supply voltage to the PIC and l.c.d. below the nominal 6V supply from the battery and within their maximum supply limits.

The valve motor is powered from a separate 12V battery, whose capacity depends on the motor's requirements (1.3Ah would be the minimum).

CONSTRUCTION

The circuit is constructed on a small piece of stripboard, 15 strips by 25 holes, as shown in Fig.2.

Assemble in ascending order of component size, using a socket for IC1. Ensure that diode D1 and transistor TR1 are positioned correctly.



Completed PIC Watering Timer controller together with "plumbed-in", motor driven, water valve.

Note that the 7-resistor module (R2-R7) has only the common and six resistor pins used, the seventh resistor's pin should be cut off (the one adjacent to IC1 pin 5).

A multiturn trimpot was used for VR1 as it fitted along a track and bridged the cut – to do this the middle connection was bent back to line up. Alternatively, a small circular or skeleton preset could be used (but would require the stripboard width to be one track wider to accommodate it).

The l.c.d. can be connected to the board using ribbon cable.

The completed assembly was fitted into a small transparent box, measuring 112mm × 62mm × 31mm. In the prototype, the external wires were brought out to a small terminal block to simplify connection to the batteries and motor.

Do not insert the PIC until you have checked the accuracy of your assembly and soldering.

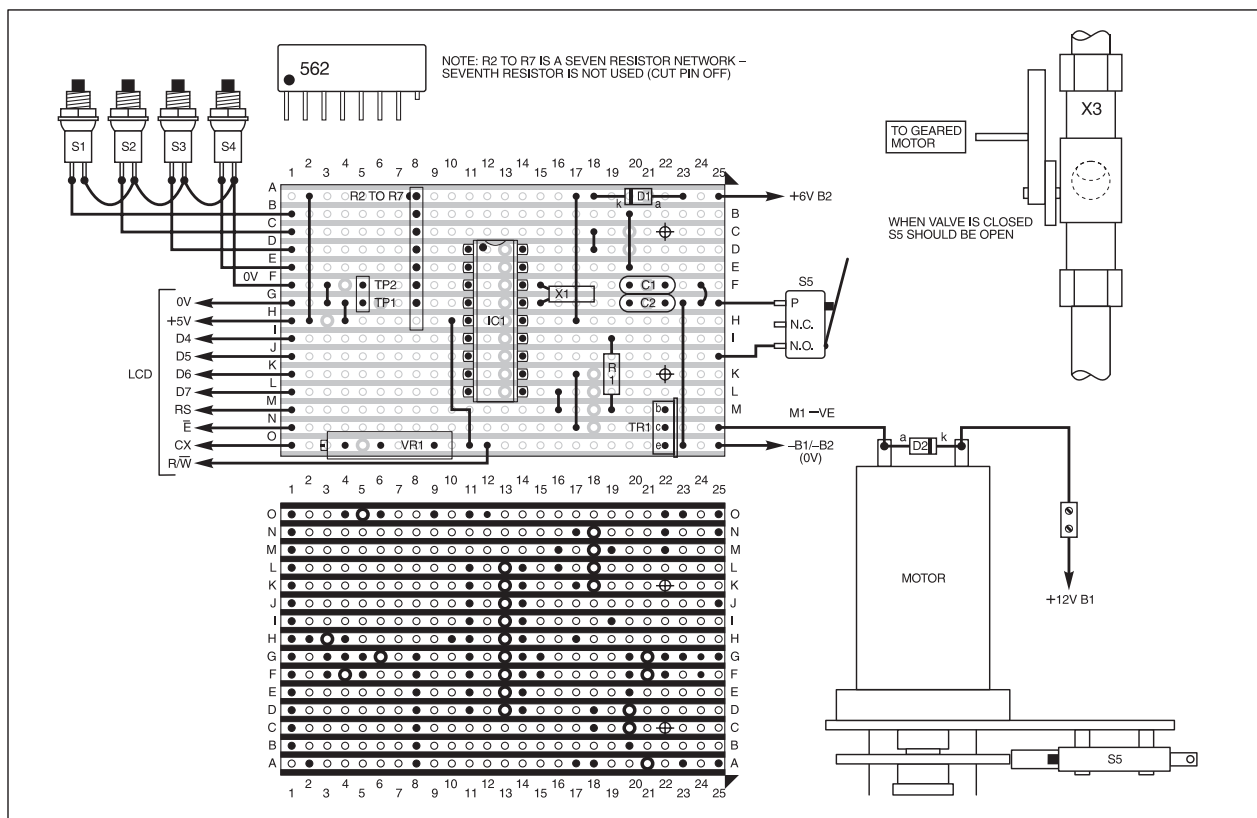


Fig.2. Stripboard component layout, underside copper track breaks and wiring details to off-board components.

MOTOR AND VALVE

With the prototype, the motor used was a small 12V geared type, having a shaft speed of about 100 r.p.m. The size of motor required, though, depends on the torque needed to turn the valve used. As the author's rain water butt fed to 15mm copper pipe, he used a standard metallic isolation valve from the plumbing section of the local d.i.y. store. This type has a screwdriver slot for changing the valve position and, importantly, has a 360 degree rotation.

The motor was fitted to a flat metal plate with the output shaft (typically 0.25in. or 6.25mm diameter) protruding. The cam was made from an old potentiometer knob and some thick flat plastic (see Fig.3). This was drilled to fit the boss, precisely shaped and then glued on the knob base. The switch needs to be "made" for a maximum of 90 degrees rotation (maybe just a bit less to allow for over-travel).

The valve position switch is mounted alongside the cam. Slightly larger holes here will allow for small adjustments to be

made. Using a long switch blade also helps. (A switch with a roller could work just as well.) The plate was fitted with a right-angled metal strip to assist final mounting to a greenhouse platform.

Prior to assembly the motor drive shaft was filed to a flat screwdriver-like blade to fit snugly into the valve slot. This motor/cam/ switch assembly was then fixed precisely above the valve with the

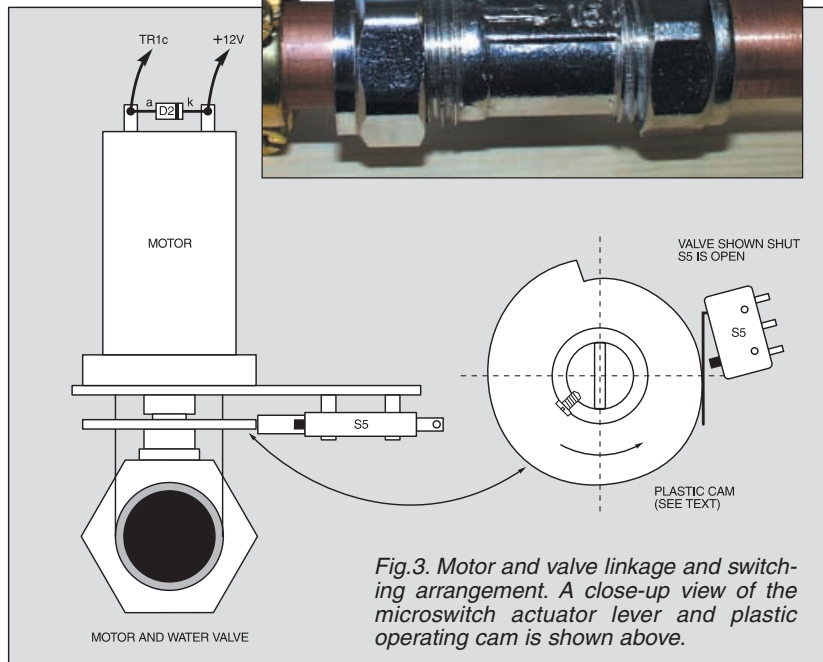
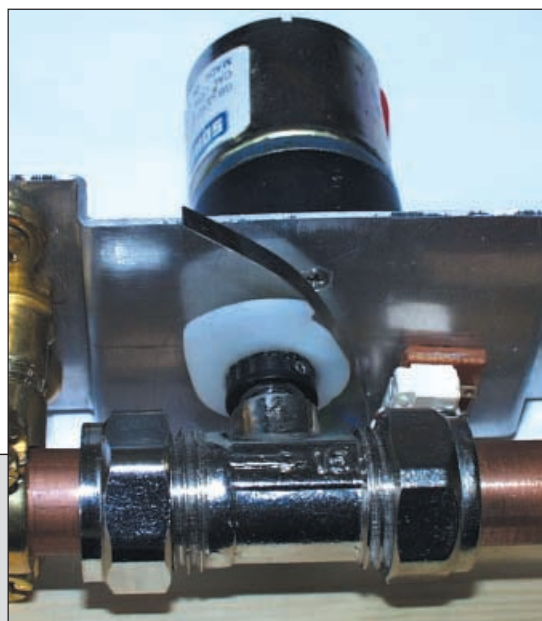


Fig.3. Motor and valve linkage and switching arrangement. A close-up view of the microswitch actuator lever and plastic operating cam is shown above.

Resistors

- R1 10k 0.25W
5% carbon film
R2 to R7 7 x 5k6 s.i.l.
resistor module (see text)

See
SHOP
TALK
page

Potentiometer

- VR1 10k 15-turn trimpot or min. round preset (see text)

Capacitors

- C1, C2 12p ceramic disc, 5mm pitch (2 off)

Semiconductors

- D1, D2 1N4001 rectifier diode (2 off)
TR1 TIP120 npn Darlington transistor
IC1 PIC16F84A-04 microcontroller, pre-programmed (see text)

Miscellaneous

- S1 to S4 min. push-to-make switch (4 off) (1 red, 3 black buttons)
S5 min. microswitch
X1 32768Hz watch crystal
X2 1-line 16-character l.c.d. module (see text)
X3 Water isolation valve (see text)
M1 small 12V geared motor (see text)

Stripboard, 15 strips by 25 holes; plastic case, transparent lid, 112mm x 62mm x 31mm; 4-way terminal block; 6V battery (see text); 12V battery (see text); materials for cam, valve and motor mounting (see text); connecting wires; solder, etc.

Approx. Cost
Guidance Only

£16

excl. motor, valve & batt.

motor drive shaft engaged in the slot and secured.

You may find a plastic isolation valve requires less force to move but sometimes they have a different tap arrangement and may be difficult to mount. A second manual valve or tap used prior to the motorised valve is also useful.

The isolation valve has two Off (vertical) and two On (horizontal) positions for each rotation. To simplify construction, only one closed and one open position are used and the others are ignored. The motor should only stop at either of the two required positions.

Note that diode D2 must be connected across the motor's power terminals, cathode (k) on the positive side.

PROGRAM OPERATION

The PIC's timing operation is under control of Timer 0 (TMR0). In conjunction with its prescaler, an interrupt is generated at a rate of 1Hz. At each interrupt, counters are incremented as appropriate for the seconds, minutes and hours, on a 24-hour clock basis.

At each hourly increment, the software checks whether watering should be turned on at that time. The watering period (from hereon referred to as the "Window") is previously set by the user via switches S1 to S4, as described presently.

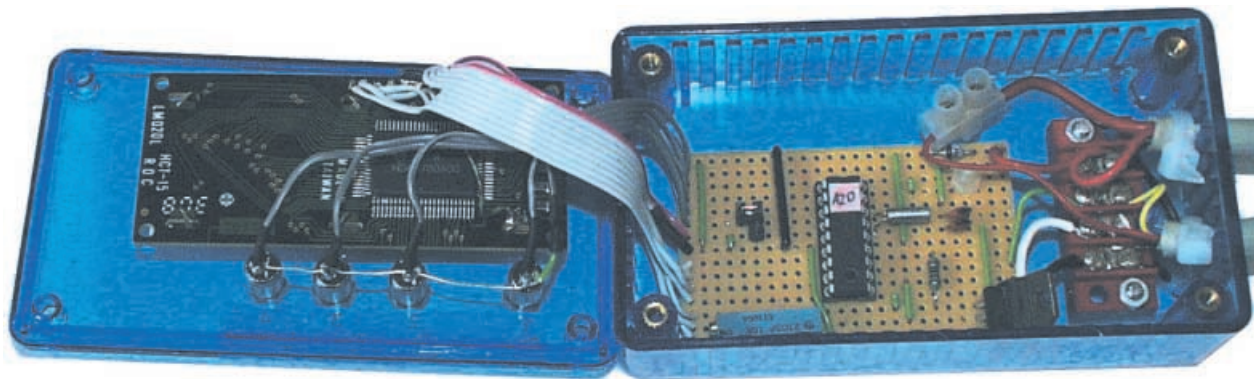
The timer allows the water valve to open only during the active Window, its minimum setting is one hour. The duration of the valve's open period is variable between one and 30 minutes. The valve opening frequency can be once every hour to a maximum of once every eight hours.

These options give a maximum range for the valve's open time of 30 minutes every hour (possibly a little wet) and a minimum of one minute once a day. Default settings are stored in the PIC's non-volatile data memory.

On power-up, the settings are recalled, the valve is shut off, the Window made inactive and the current time set to 12:00. Simultaneously, the l.c.d. is configured and the other registers are initialised. The screen display then cycles for eight seconds, showing the various settings.

The sequence is as shown in Table 1, in which "X" indicates that time setting is required, and "S" indicates that the valve is shut.

On each interrupt, the time is updated and displayed, the colon blinking synchronously. Checks are made of the switches and the Window settings, and action taken accordingly. Note, though, that when power is being applied to the motor, under control of PIC pin RB7, the display is only updated after the motor has stopped.



Layout of components inside the finished control box.

SETTING UP

Pressing switch S1 will start the eight-second display sequence, as shown in Table 1. Then pressing one of the four switches, S1 to S4, gains access to a setting mode, as shown in Table 2. Referring also to Table 1, set the Duration and Frequency first.

The display will revert to Status and Time after the ?-SET Prompt (item 4 in Table 1). When leaving set-up after altering the watering or time settings, the Window status will be initialised, but not for new Duration or Frequency data settings. This allows changing within the active Window. Duration and Frequency changes are applied after the current cycle.

If the Window is active after setting, then Frequency is set to one hour. If inactive, Window timings are displayed. During the active Window, the Duration and Frequency countdowns are displayed. To the left of the time display the condition of the Window is indicated by "A" (active) or "I" (inactive). The valve position is also shown, as "O" (open) and "S" (shut). Pressing switch S1 alone allows the settings to be viewed without making changes.

Below are two example screen displays. The first shows the display following set-up, but prior to the Window start time, with "I" standing for inactive Window, and "S" for shut valve.

W - - 09>18 IS 08:45

The second screen shows a typical display following set-up, but after the Window start time. It shows the current Duration and Frequency, with "A" for active Window, "S" for shut valve. The "C" symbol indicates that the valve will activate at the next hour change.

C - - 05@1h AS*11.45

During normal active Window operation, the Duration and Frequency countdowns are prefixed by "C" (current status). At the beginning of each hour the Frequency is decremented. At zero, a Duration timer is started, the motor is started, the valve opened and the screen updated to show an active Window status.

When microswitch S5 is activated by the motor's rotation, the software turns off transistor TR1, and so stops the motor drive at the correct open spot. The motor is re-energised to shut the valve after the programmed period.

TESTING

With a link connected temporarily between test points TP1 and TP2, and

Table 1. Example screen displays at power-on and when switch S1 is pressed.

		Time	Settings
PROG	XS	12:00	Mode indication
W-00> 24	XS	12:00	Window (continuous)
P-05@2h	XS	12:00	Duration and Frequency (5 mins every 2 hours)
?-SET	XS	12:00	Set-up prompt

Table 2. Setting modes

Setting	Switch S1	Switch S2	Switch S3	Switch S4
Time *	Display/Exit	Enter Time Setting	Fast Advance	Slow Advance
Window *	Display/Exit	Set Window Open Time	Enter Window Setting	Set Window Close Time
Duration/Frequency	Display/Exit	Set Duration	Set Frequency	Enter Duration/Frequency

* The Window settings are updated after these settings

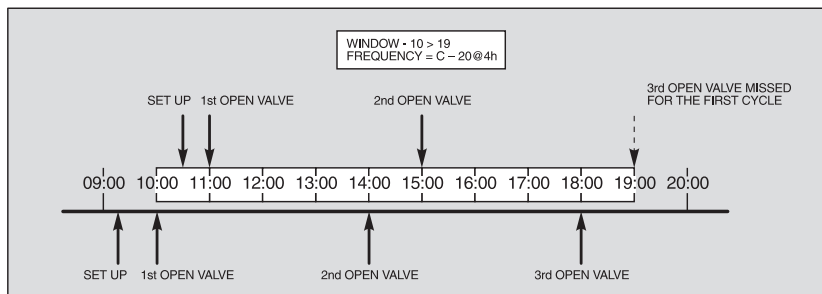


Fig.4. Typical setting up sequence.

power applied, the valve can be opened and shut via switches S1 and S2, respectively.

At this time, the position switch S5 can be adjusted so the valve is left in the correct position when the motor stops.

Powering down is the only exit from Test mode.

IN USE

After testing and adjusting valve and switch operation, the unit can be put to work. Judge what active Window, Duration and Frequency will suit your needs/environment. Start with short wet times and build up.

Setting up is best done outside the active Window, then the first day's Frequency will be correct. If setting up is done after the active starting hour, the Frequency will start with the valve opening on the next hour, see Fig.4.

Bear in mind that when an active Window is started the Frequency count is also started, over-riding any unused setting, i.e. setting a 9-hour active Window

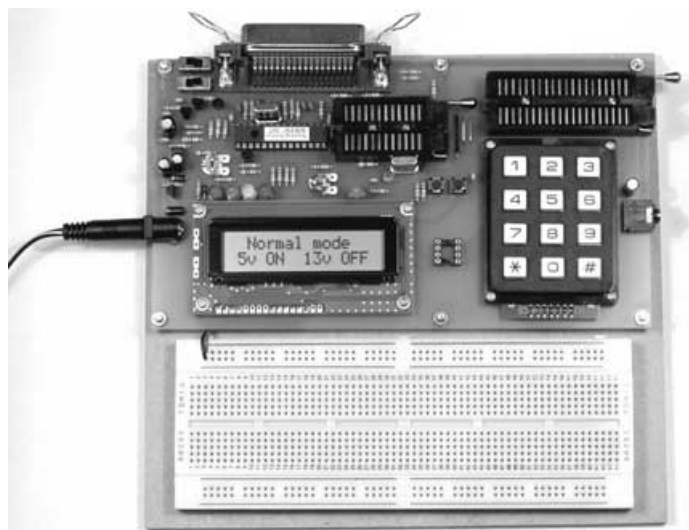
and a 4-hour Frequency will give three openings, with one hour remaining when the Window becomes inactive. The next Window will start the Frequency over again.

Also note that if a valve opening coincides at the end of an active Window, the Window is made inactive first so the expected valve opening will not occur. Setting the active Window to end at 24:00 hours allows continuous operation as the hour's register never reaches this number. Interestingly, setting the active Window to start and end at the same hour makes the timer Window activate every other day!

RESOURCES

The PIC software for the PIC Watering Timer is available from the EPE Editorial office on 3.5in disk, for which a nominal handling charge applies – see the PCB Service page. It is also available for free download via the EPE homepage at www.epemag.wimborne.co.uk; select the Downloads path, and then enter the PICs folder. □

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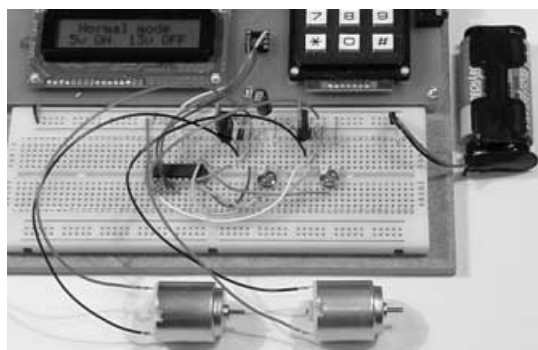
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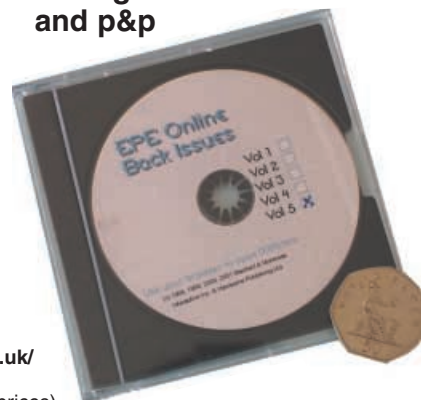
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PRACTICAL RADIO CIRCUITS

RAYMOND HAIGH



Part 8: A double-conversion superhet receiver for the SW bands

Circuits for the set builder and experimenter

LAST month's article covered the advantages and drawbacks of the superheterodyne (or superhet for short) receiver. A design for a mixer/oscillator unit with a 1.6MHz intermediate frequency (i.f.) output was described. Raising the i.f. to 1.6MHz, instead of the more usual 455kHz, reduces susceptibility to second channel interference, the major defect of the superhet.

This final part deals with the intermediate frequency amplifier, which provides most of the selectivity and gain. Teamed with last month's 3-Band SW Superhet Tuner/Mixer, it forms a high performance receiver for the shortwave listener.

SELECTIVITY

Selectivity increases as the intermediate frequency is lowered.

Let us assume a receiver with the low i.f. of 100kHz tuned to a station on 900kHz with an adjacent transmitter operating on 910kHz. Signal spacing is 10kHz (910kHz minus 900kHz), and the adjacent station is, therefore, off tune from the wanted one by a mere 1.1 percent. Normal preselector, or signal frequency, tuned circuits will be unable to prevent the unwanted station reaching the mixer.

After mixing, the wanted signal will emerge at the i.f. frequency (1000kHz local oscillation minus 900kHz signal, equals 100kHz i.f.). The adjacent station will, therefore, emerge at a frequency of 90kHz (1000kHz minus 910kHz). Heterodyning has increased the difference between the signals to 10 percent, and the tuned circuits in the i.f. amplifier are better able to remove the unwanted station.

Performing this calculation with an i.f. of 455kHz reveals a difference, after heterodyning, of around two percent. The improvement with the higher i.f. is, therefore, very much less.

EARLY DEVELOPMENTS

The first superhets had i.f.s below 100kHz in order to ensure stable operation with triode valves. Despite the introduction, during the 1920s, of neutralizing and

the screened-grid valve, measures that permitted amplification at high frequencies, i.f.s of around 100kHz persisted for another decade.

Second channel interference problems (see Part 7) intensify as the i.f. is lowered and/or reception frequency is raised, and manufacturers began to adopt the now standard i.f. of between 450kHz and 470kHz. The growing demand for domestic sets with shortwave coverage no doubt contributed to this development.

Despite the higher i.f., valve superhets with two, double-tuned i.f. transformers were selective enough for domestic listening. High performance communications receivers either incorporated a crystal filter (see below) or had a second mixer/oscillator stage that produced a final i.f. between 50kHz and 100kHz.

Current practice with simple transistor receivers is to provide three, single-tuned,

455kHz i.f. transformers. When greater selectivity is required, a crystal, ceramic or mechanical filter is built into the i.f. amplifier. Low frequency final i.f.s have fallen out of use.

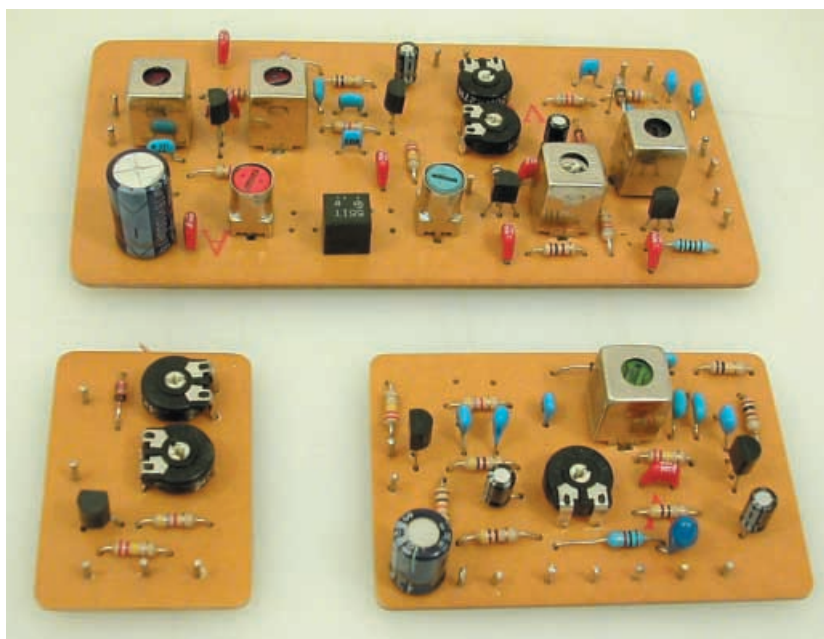
FILTERS

Crystal

The first filters relied upon the piezoelectric nature of quartz, and the way slices of this crystalline material can be made to resonate, very sharply, at radio frequencies.

Professor W. G. Cady exploited this phenomenon, for the first time, in 1921, when he used a slice of quartz to control the frequency of an oscillator.

During the 1930s, circuits incorporating one or two crystals (Robinson's crystal gate and the Simmonds-Robinson two crystal filter) were forming part of high performance receivers. Passbands as narrow as 300Hz (for Morse reception) can easily be achieved with this technique.



Group photograph of this month's printed circuit boards: Second Mixer/Oscillator I.F. Amplifier (top); Signal-Strength Meter (left) and B.F.O./Product Detector (right).

Mechanical

The Collins Radio Corporation of America subsequently developed mechanical filters in which the resonant elements are vibrating metallic discs linked by a rod. Filters of this kind can produce passbands less than 400Hz wide.

They are expensive but capable of very high performance. The signal is transferred to, and extracted from, the disc resonators by a coil wound on the link rod and mounted in the field of a permanent magnet.

Miniature mechanical filters are currently manufactured by Toko, see Table 8.1. Signal transfer involves the piezoelectric effect and the resonant mechanical element is a phosphor bronze strip. Performance is inferior to the Collins filters, but they are very inexpensive and widely used for less demanding applications. Passbands can be as narrow as 3kHz.

Ceramic

Development of the ceramic filter by Murata and Vernitron coincided with the introduction of transistors and the resulting drive towards miniaturization. Ceramic filters also exploit the piezoelectric effect. In this respect they are similar to crystal filters, but they have a lower Q -factor (i.e., they resonate less sharply) and insertion losses are greater.

Manufactured from lead zirconate titanate and other compounds, they are smaller and usually cheaper. They are widely used in radio equipment, from domestic portables to high performance communications receivers.

Details of a number of low and medium priced ceramic filters, together with details of Toko's mechanical unit, are given in Table 8.1. Bandwidths (passbands) are quoted at the 6dB down (i.e., half-voltage) points. The figures represent the full passband, not the deviation from centre frequency.

The i.f. amplifier printed circuit board used here will accommodate any of the filters listed.

PERFECTION

The perfect filter would cause zero attenuation, have a flat response within the passband, sharp cut-off at the passband boundaries, and completely attenuate all other frequencies. In practice, filters have an uneven response (ripple) within the passband, spurious responses beyond, and an insertion loss ranging from around three to ten decibels (dB).

Ceramic filters are prone to spurious responses, which are much reduced when they are combined with tuned matching and i.f. transformers.

MATCHING

The specified filter performance will only be realized if its input and output impedances are correctly matched to the amplifying devices in the i.f. strip. This is not easy to achieve with bipolar transistors (automatic-gain-control alters bias levels and changes input impedance).

Serious mismatching causes an asymmetrical passband, increased insertion

losses and ripple. In practice, the filters detailed here will perform well despite slight imperfections in matching. They are a very convenient way of achieving high selectivity with an intermediate frequency of 455kHz.

GAIN

During the valve era, gain within the i.f. amplifier was invariably provided by a single variable μ valve. Variable μ valves display a large change in amplification when the bias voltage is shifted by the a.g.c. circuitry. To achieve the same level of gain, transistor superhets require two i.f. amplifier stages.

Increasing use is being made, in domestic portables, of integrated circuits that contain all but the audio stages on a single chip. When these devices are employed, a miniature filter and its matching transformers provide selectivity.

Modern communications receivers usually have two, specialized, integrated circuit "gain blocks" in the final i.f. amplifier. Excellent a.g.c. performance, predictable impedances (for filter matching) and high levels of gain are achievable with these devices.

Unfortunately, they are not widely available to home constructors and, continuing the practice adopted throughout the series, the i.f. amplifier "strip" described here uses easy-to-obtain, non-critical semiconductors.



DUAL-CONVERSION SW RECEIVER

An add-on i.f. amplifier board for last month's SW Superhet Tuner/Mixer

SECOND MIXER/OSCILLATOR

To secure acceptable selectivity, the 1.6MHz output from our first mixer (Part 7) must be lowered to 455kHz. Constructors seeking higher selectivity will then be able to use one of the 455kHz filters already described. The i.f. amplifier must, therefore, be preceded by a second mixer/oscillator.

The full circuit diagram for the Second Mixer/Oscillator is given in Fig.8.1. Here IFT1 is tuned to the 1.6MHz incoming frequency, by capacitor C2, its low impedance coupling winding ensuring a correct match to the first mixer (See Part 7).

Signals developed across IFT1 are applied to TR1 gate (g), the second mixer, the local oscillation being injected at its source (s). Biasing of this stage is by resistor R2, which is bypassed by capacitor C4.

Tuned transformer IFT2 selects the 455kHz heterodyne and acts as TR1's drain (d) load. The stage is decoupled by R1 and C1.

The second oscillator must operate at 2055kHz (1600kHz plus 455kHz). Tuned circuit L2/C6 determines the frequency of oscillation and the maintaining device is TR2, an n -channel field effect transistor. Low impedance mixer coupling winding L1 minimizes damping on the tuned circuit.

Feedback for this Hartley oscillator is taken from the source of TR2 and applied to a tapping on L2 via bias resistor R5 and bypass capacitor C9. Supply line decoupling is by R4 and C10.

BANDSPREAD

The second oscillator frequency can be altered, over narrow limits, by potentiometer VR1 which varies the reverse bias on varicap diode D1. This tunes the second

i.f. amplifier across the broad passband of the first, in effect shifting the first i.f. This results in a bandspeed or fine tuning system that has a constant rate, irrespective of reception frequency.

The fine-tuning rate is preset by VR2. Potentiometer "noise" is eliminated by capacitor C11 and resistor R6 isolates the signal circuits from the bias network. Blocking capacitor C7 prevents the shorting of the bias through coil L2.

FILTER

Intermediate frequency transformers, IFT2 and IFT3, ensure an acceptable match to any of the Toko or Murata filters listed in Table 8.1. A filter, X1, with a **total bandwidth** of 4kHz is recommended for general listening on the shortwave bands. Wider filters can be used to avoid side-band cutting, but selectivity will be excessively compromised if the passband is greater than 6kHz.

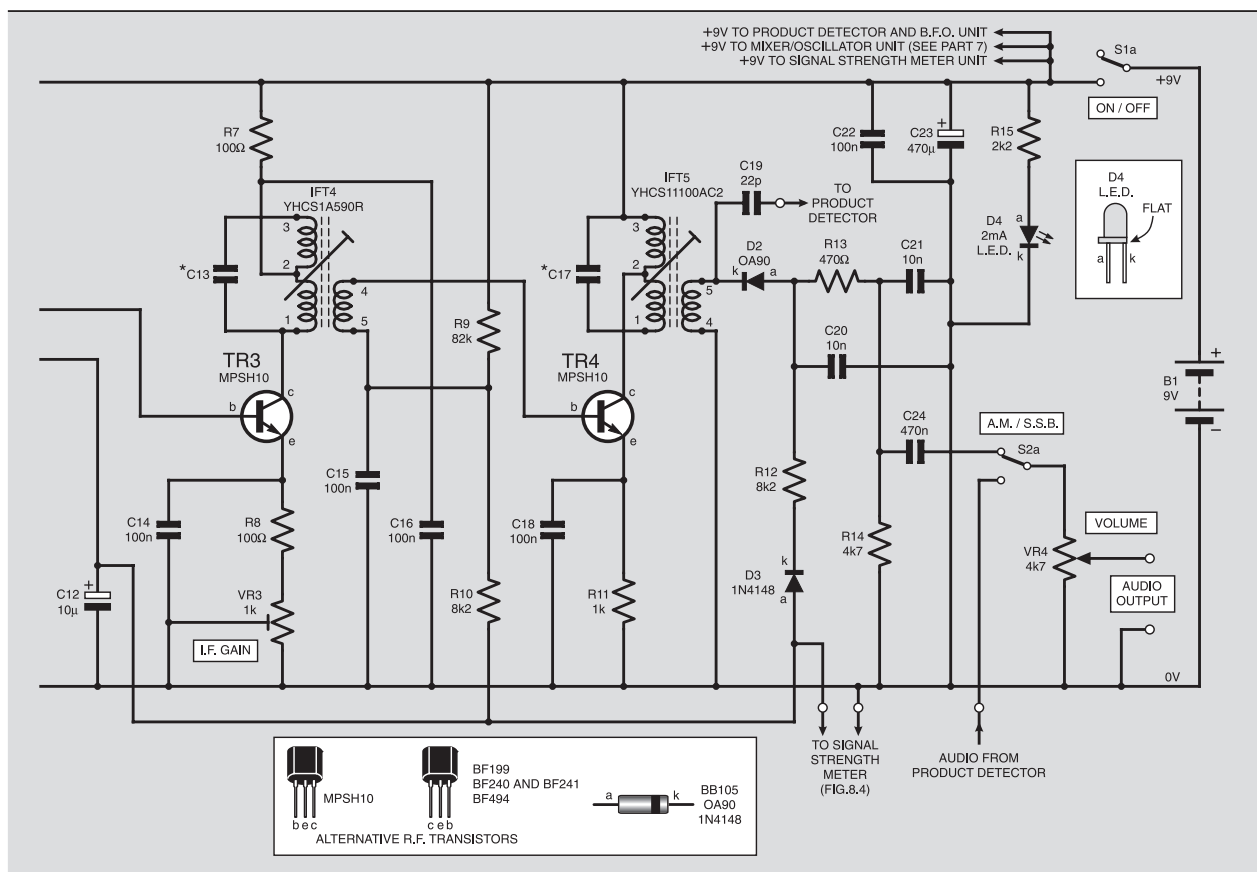
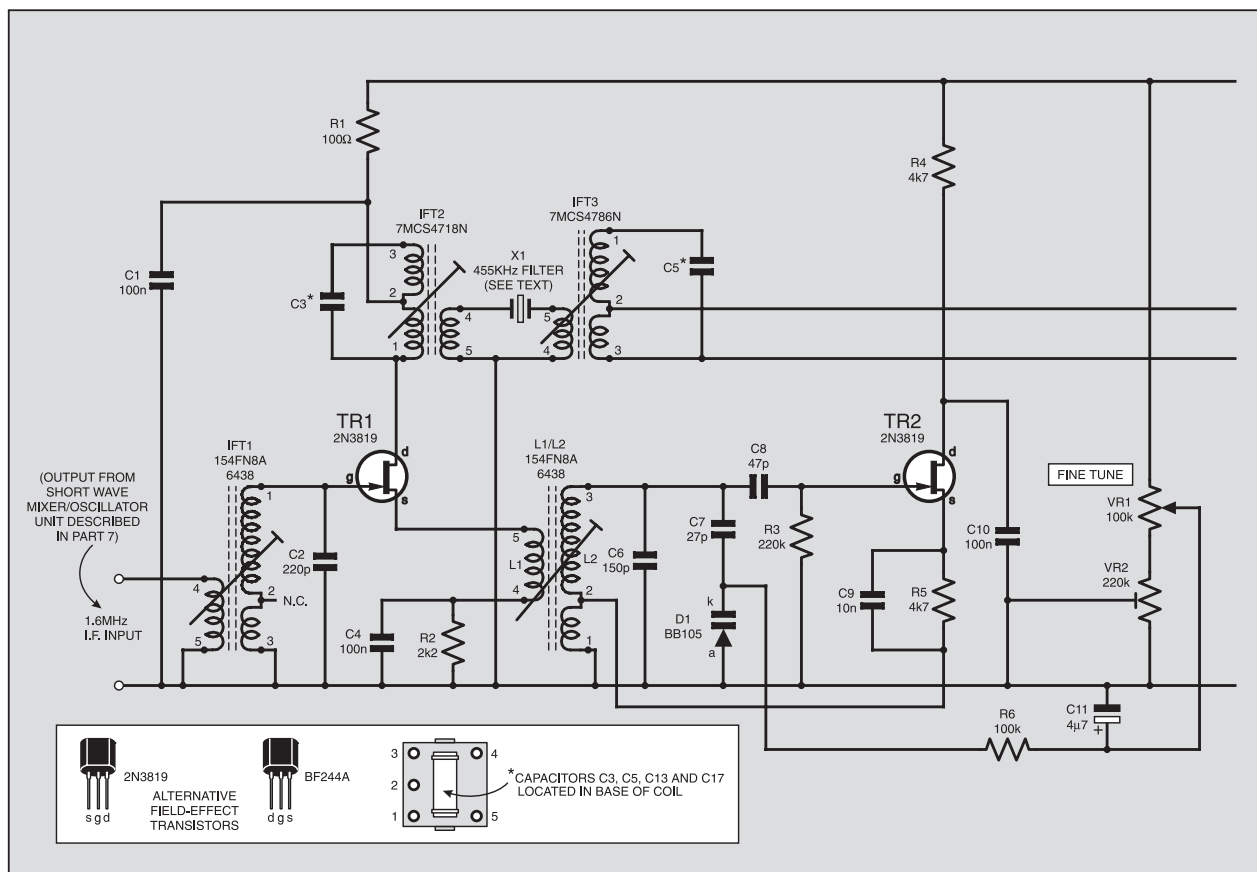


Fig.8.1. Full circuit diagram for the Second Mixer/Oscillator I.F. Amplifier for the Dual-Conversion SW Superhet Receiver. (See Part 7 for the first Mixer/Oscillator stages.)

I.F. AMPLIFIER

Bipolar transistors TR3 and TR4 provide amplification at the 455kHz second i.f. This circuit is used, with minor modifications, in all domestic superhets fabricated from discrete components.

Transformers IFT4 and IFT5 couple the stages and tune the amplifier to 455kHz. Emitter bias to TR3 is developed across R8 and Gain preset VR3. This stage is decoupled by R7 and C16, and the emitter resistors are bypassed by C14. Emitter bias to TR4 is provided by R11 with C18 as the bypass capacitor.

AUDIO DETECTOR

Point contact germanium diode D2 demodulates the a.m. signals, and residual radio frequencies are filtered by C20, R13 and C21. (Diode detectors were discussed in Part 1.) The audio output is developed across resistor R14 and coupled to the a.f. gain (Volume) control, VR4, by capacitor C24.

Provision is made for the r.f. output of the i.f. strip to be connected, via capacitor C19, to a product detector so that single side-band (s.s.b.) signals can be clarified. Toggle switch S2a selects either the a.m. output or the clarified s.s.b. signals. The other half of this switch,

S2b, connects the B.F.O. and Product Detector to the power supply (see Fig.8.6).

Supply line decoupling of the entire i.f. amplifier at r.f. and a.f. is accomplished by capacitors C22 and C23. The other half (S1b) of the On/Off switch S1 is used to connect a *separate* battery to the simple Speaker Amplifier (Part 2). Separate batteries prevent the audio amplifier's current swings disturbing the electronic tuning systems. Power "on" is indicated by low current l.e.d. D4.

AUTOMATIC GAIN CONTROL

The d.c. voltage produced by the detector diode D2 is used to control the gain of TR3 and TR4 by varying their base bias. As signal strength increases, the voltage becomes more negative. This reduces the bias and, hence, the current through the transistors, and gain falls.

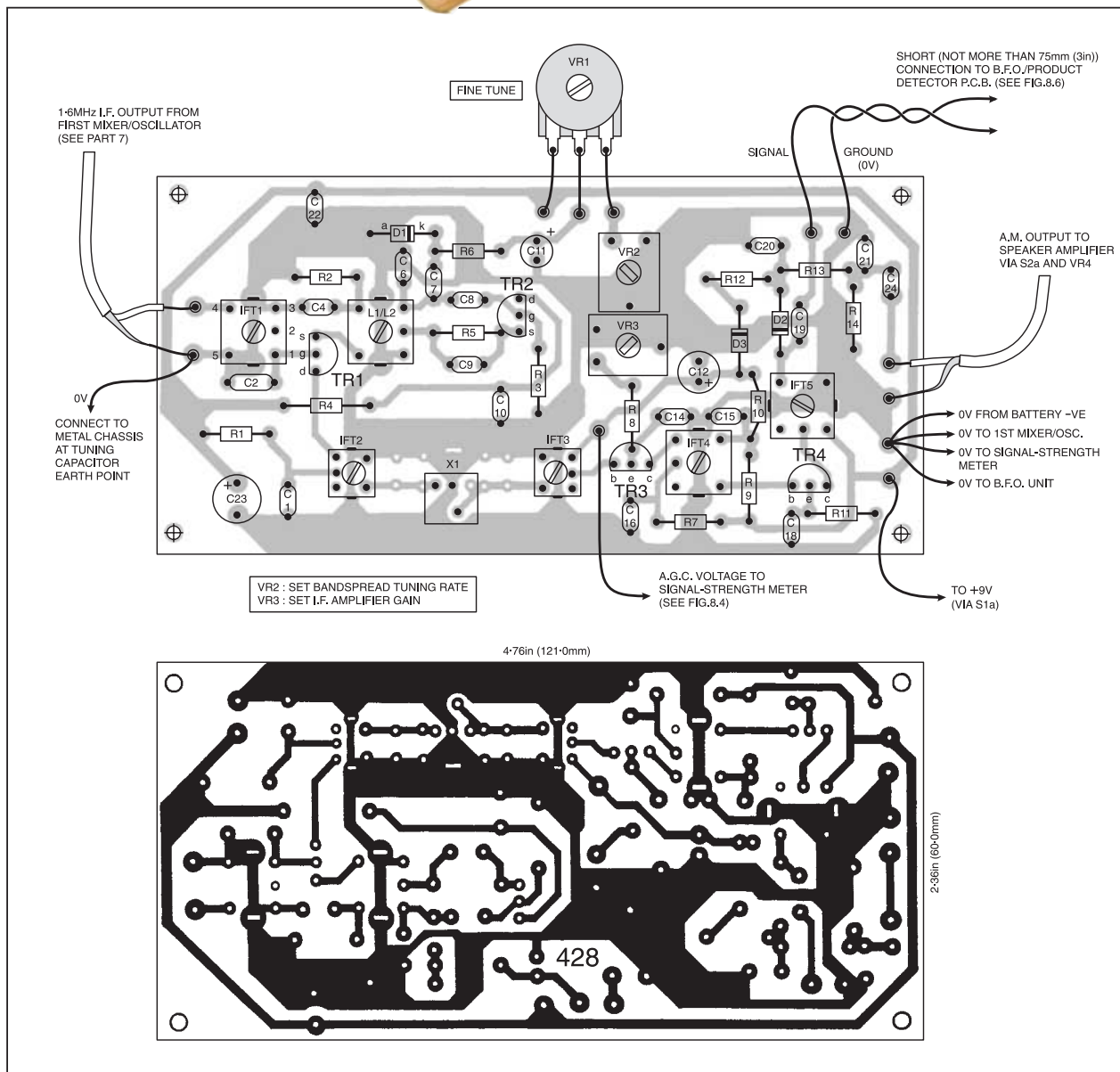
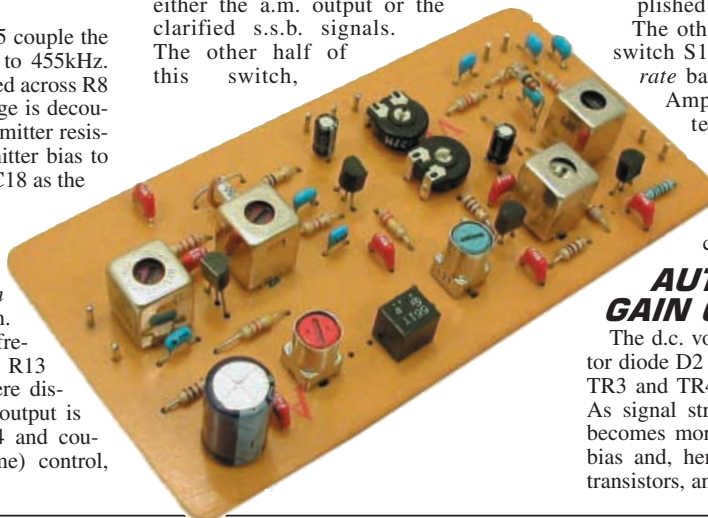


Fig.8.2. Printed circuit board topside component layout, interwiring to off-board components and full-size copper foil master for the Second/Mixer/Oscillator I.F. Amplifier.

I.F. AMP

Resistors

R1, R7, R8 100Ω (3 off)
R2, R15 2k2 (2 off)
R3 220k
R4, R5, R14 4k7 (3 off)
R6 100k
R9 82k
R10, R12 8k2 (2 off)
R11 1k
R13 470Ω
All 0.25W 5% carbon film

Potentiometers

VR1 100k rotary carbon, linear
VR2 220k enclosed carbon preset
VR3 1k enclosed carbon preset
VR4 4k7 rotary carbon, log.

Capacitors

C1, C4, C10, C14 to C16,
C18, C22 100n ceramic (8 off)
C2 220p polystyrene or ceramic "low k"

See
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C3, C5, C13, C17 included in i.f. can
C6 150p polystyrene or ceramic "low k"
C7 27p ceramic "low k"
C8 47p ceramic "low k"
C9, C20, C21 10n ceramic (3 off)
C11 4μ7 radial elect. 16V
C12 10μ radial elect. 16V
C19 22p ceramic "low k"
C23 470μ radial elect. 16V
C24 470n ceramic or polyester

Semiconductors

D1 BB105 varicap diode
D2 OA90 germanium diode
D3 1N4148 signal diode
D4 5mm low current (2mA) red l.e.d.
TR1, TR2 2N3819 *n*-channel field effect transistor (2 off)
TR3, TR4 MPSH10 high frequency transistor or similar (2 off)

Inductors

IFT1, L1/L2 154FN8A6438 Toko screened (metal can) coil (2 off)

IFT2 7MCS4718N Toko screened (metal can) coil
IFT3 7MCS4786N Toko screened coil
IFT4 YHCS1A590R Toko screened coil
IFT5 YHCS11100AC2 Toko screened coil

Miscellaneous

X1 CFU455IT Murata 4kHz bandwidth ceramic filter (see text)
S1, S2 d.p.d.t. toggle switch (2 off)

Printed circuit board available from the *EPE PCB Service*, code 428 (I.F. Amp); case, aluminium box 203mm x 152mm x 76mm (8in. x 6in. x 3in.) – 2 off (see text); white card and rubdown lettering for front panel; protective 2mm thick Perspex sheet for front panel; two large and four small plastic control knobs; aluminium sheet for tuning capacitor (Part 7) screen; l.e.d. holder; audio type screened cable; multistrand connecting wire; p.c.b. nylon stand-off pillars; battery holder and connectors; nuts, bolts and washers; solder pins; solder etc.



The a.g.c. (automatic gain control) circuit is a little obscure. A chain of components, R9, R10, D3, R12 and D2 form a shared bias network. Including detector diode D2 introduces the signal-related voltage variation. Stabilization against temperature changes is provided by diode D3 (which must be a silicon component to

provide compensation for the silicon transistors).

The a.g.c. and bias network is connected to TR3 and TR4 via the IFT's coupling windings. The full a.g.c. voltage is applied to the base of TR3. Final stage TR4 is connected via resistor R10 to limit the a.g.c. action so that, even under strong signal

conditions, sufficient output is available to drive the detector. The a.g.c. line is bypassed by C12.

Details of the printed circuit board (p.c.b.) topside component layout, full-size copper foil master and the off-board wiring details are shown in Fig.8.2. General guidance on construction is given later.

Table 8.1: Mechanical and Ceramic I.F. Filters

Ceramic Filter: Murata Type CFU

Type No.	Input/output impedance	6dB bandwidth
CFU455IT	2k	4kHz
CFU455H2	2k	6kHz
CFU455G2	2k	9kHz

(Case size: L8mm x W7mm x H8mm)

Ceramic Filter: Murata Type CFG

Type No.	Input/output impedance	6dB bandwidth
CFG455J	2k	3kHz
CFG455I	2k	4kHz
CFG455H	1k5	6kHz

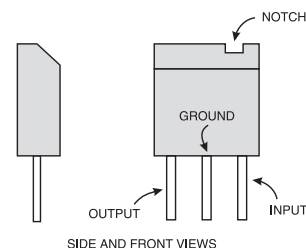
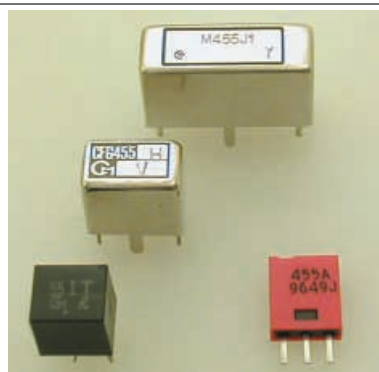
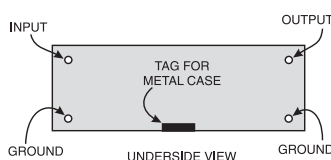
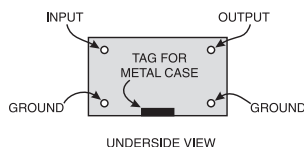
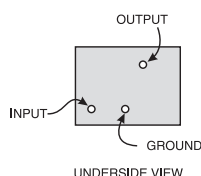
(Case size: L11mm x W7mm x H9.5mm)

Ceramic Filter: Murata Type CFM

Type No.	Input/output impedance	6dB bandwidth
CFM455J1	2k	2.6kHz
CFM455I	2k	4kHz
CFM455H	2k	6kHz

(Case size: L20mm x W7.3mm x H10.3mm)

Insertion loss for all of the filters, except the CFM455I and the CFG455J, is 6dB. Insertion loss for the CFM455I is 7dB; for the CFG455J, 8dB.



Mechanical Filter: Toko Type HCFM

Type No.	Input/output impedance	6dB bandwidth
HCFM2455A	1k/1k5	4kHz
HCFM2455B	1k5/2k	6kHz
HCFM2455C	2k	8kHz

(Case size: L8.2mm x W3.5mm x H9.5mm)

SIGNAL-STRENGTH METER

Check the reception conditions with this simple circuit

A Signal-Strength Meter is useful for monitoring reception conditions and assessing different aerial systems. It can also be of assistance during the setting up process.

The Signal-Strength Meter bridge circuit given in Fig.8.3 enables the standing voltage on the a.g.c. line to be nulled out so that the meter pointer can rest at zero under no-signal conditions.

Transistor TR1 and collector load resistor R2 form two arms of the bridge: preset

potentiometer VR2 provides the other two. Setting the slider (moving contact) of VR2 to the same potential as the collector of TR1, in the absence of a signal, brings the meter pointer to zero.

The base of TR1 is connected to the a.g.c. line via current limiting resistor R1. The a.g.c. voltage becomes more negative as signal level increases, current through TR1 decreases, and the voltage at its collector becomes more positive, driving over the meter pointer.

Panel meter full-scale deflection (f.s.d.) is set by preset VR1, and the bridge is stabilized against thermal drift by diode D1, which mirrors the base/emitter junction in TR1.

Meters of lower sensitivity can be used if the value of R1 is reduced. It ought not, however, to be taken below 100 kilohms. With this value it should be just possible to use a 1mA meter. Meters of higher sensitivity should be shunted to around 100 μ A.

Details of the printed circuit board top-side component layout, full-size copper foil master and interwiring are given in Fig.8.4. General guidance on construction is given later.

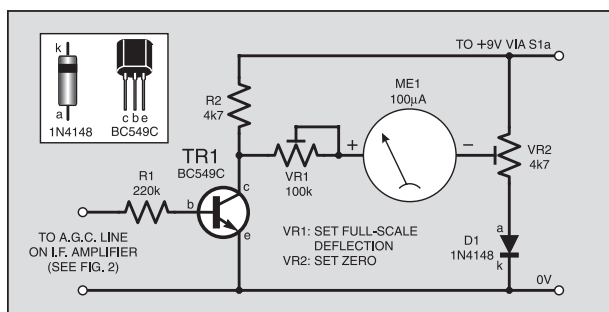


Fig.8.3. Circuit diagram for the Signal-Strength Meter.

COMPONENTS

SIGNAL-STRENGTH METER

Resistors

R1 220k (see text)
R2 4k7
All 0.25W 5% carbon film

See
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page

Potentiometers

VR1 100k enclosed carbon preset
VR2 4k7 enclosed carbon preset

Semiconductors

D1 1N4148 signal diode
TR1 BC549C npn small signal transistor

Miscellaneous

ME1 100 μ A moving coil panel meter

Printed circuit board available from the EPE PCB Service, code 429 (Sig. Meter); multistrand connecting wire; solder pins; solder etc.

Approx. Cost
Guidance Only

£5.50
excl. meter

Panel Meter and circuit board mounted in one corner of the receiver top chassis.

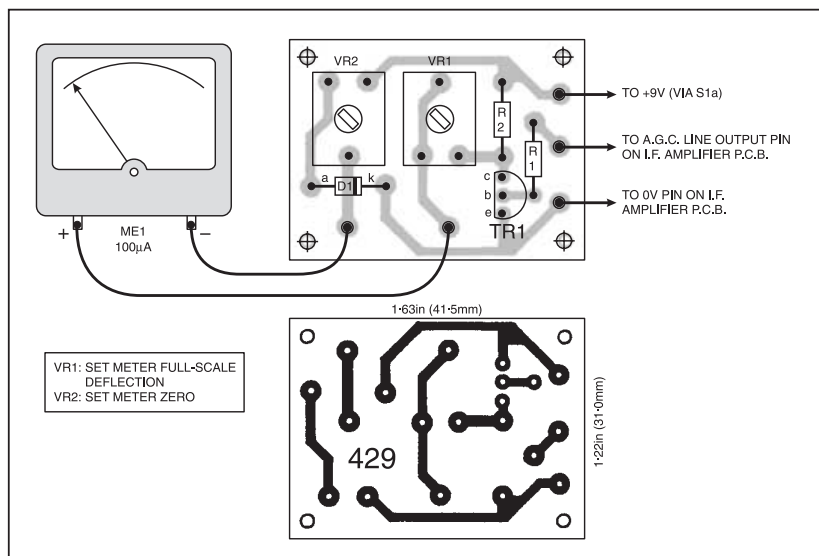
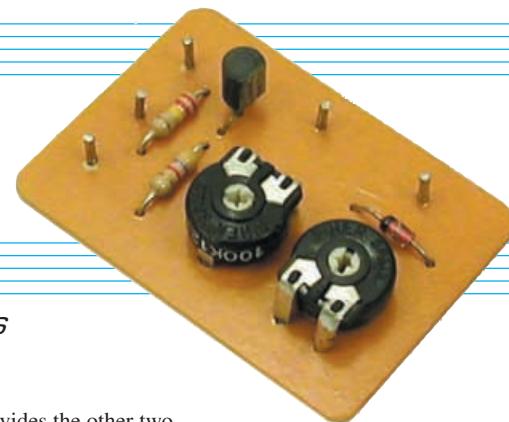


Fig.8.4. Signal-Strength Meter printed circuit board component layout, wiring and full-size copper foil master.

B.F.O. AND PRODUCT DETECTOR

An additional circuit for receiving single-side-band transmissions.

Readers interested in Morse and single side-band (s.s.b.) speech transmissions will require a beat frequency (b.f.o.) and carrier replacement oscillator.

Morse is transmitted by interrupting the carrier, and the receiver must contain an oscillator to beat with these signals and make them audible. Single side-band transmissions have their carrier suppressed at the transmitter and it must be restored, by an oscillator in the receiver, so that they can be demodulated (see Part 6).

The simplest arrangement, widely adopted during the valve era, is to inject the oscillation directly into the i.f. strip, just ahead of the detector. Unfortunately, this activates the a.g.c. system and depresses receiver sensitivity. Accordingly, a simple product detector has been included to ensure the complete isolation of the oscillator.

CIRCUIT DETAILS

The full circuit diagram for a B.F.O. and Product Detector is shown in Fig.8.5. Transistor TR2, coil L2 and capacitor C6 form a 455kHz Hartley oscillator. Its frequency can be altered slightly by varicap

diode D1 in order to change the beat note or to accommodate the upper and lower side-band transmission modes. This oscillator circuit is almost identical to the second mixer/oscillator, and the function of the various components has already been described.

The oscillator's output is coupled, via coil L1, to the source pin of product detector TR1. Signals are applied to TR1

gate, and the audio output is developed across drain load resistor R3. Residual radio frequencies are filtered out by C2, R5 and C4. C5 is the d.c. blocking capacitor. Choke RFC1 prevents the leakage of oscillations into the supply rail.

The B.F.O. board housed in an aluminium screening box.

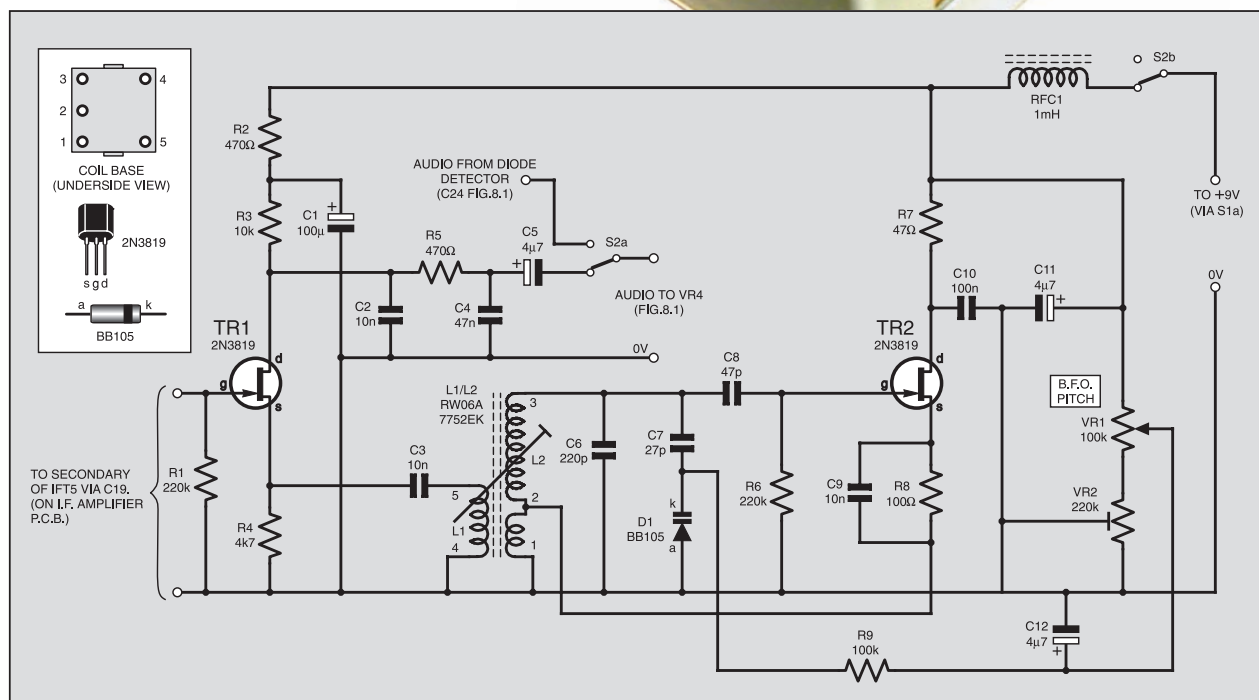
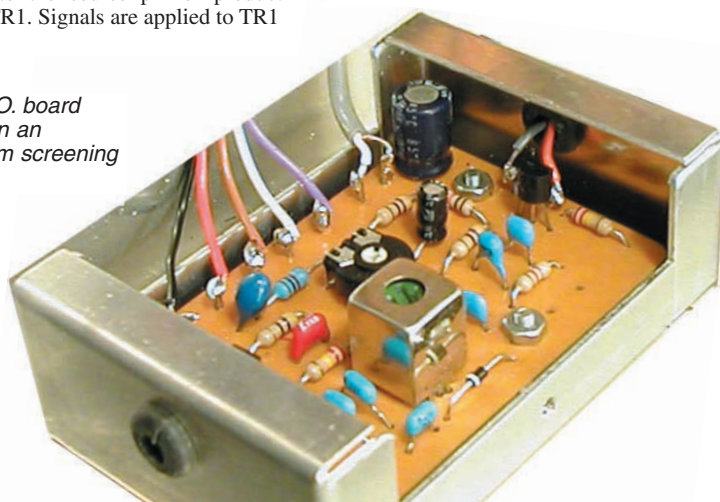
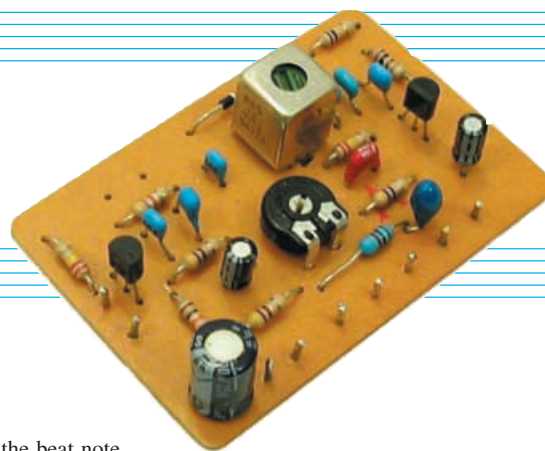


Fig.8.5. Complete circuit diagram for the B.F.O. and Product Detector. For clarity, switch S2a is also shown on the I.F. Amp circuit. This circuit is required for the reception of s.s.b. transmissions.

B.F.O. and PROD. DETECT

Resistors

R1, R6	220k (2 off)
R2, R5	470Ω (2 off)
R3	10k
R4	4k7
R7	47Ω
R8	100Ω
R9	100k

All 0.25 5% carbon film

Potentiometers

VR1	100k rotary carbon, lin.
VR2	220k enclosed carbon preset

Capacitors

C1	100μ radial elect. 16V
C2, C3, C9	10n ceramic (3 off)
C4	47n ceramic
C5, C12	4μ7 radial elect. 16V (2 off)

See
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C6	220p polystyrene or ceramic "low k"
C7	27p ceramic "low k"
C8	47p ceramic "low k"
C10	100n ceramic
C11	4μ7 tantalum bead, 16V

Semiconductors

D1	BB105 varicap diode
TR1, TR2	2N3819 <i>n</i> -channel field effect transistor (2 off)

Miscellaneous

L1/L2	RWO6A7752EK Toko screened (metal can) coil
RFC1	1mH r.f. choke
S2	see I.F. Amp listing

Printed circuit board available from the *EPE PCB Service*, code 430 (B.F.O./Prod. Detect.); screening box for B.F.O., size 76mm x 51mm x 25mm (3in. x 2in. x 1in.) – see text; audio type screened cable; multi-strand connecting wire; p.c.b. nylon stand-off pillars; solder pins; solder etc.

Product detectors were discussed in Part 6. They function in the same way as mixers but combine close radio frequencies to deliver an audio signal at the output port.

Details of the printed circuit board top-side component layout, full-size copper foil master and interwiring are shown in Fig.8.6. General guidance on construction is given later.

COMPONENTS

Transistor types for the three circuits are not critical and alternatives, with base connections, are included in Fig.8.1. Other f.e.t.s, including the BF245B, J304 and J310, have been in-circuit tested and found to be satisfactory.

Detector diode D2 must be a point contact *germanium* type. The specified OA90 is often used in this circuit, but the OA47 and others should perform equally well.

The Murata CFU455IT filter is recommended, but the i.f. printed circuit board will accept any of the units scheduled in Table 8.1. Readers whose requirements are less demanding can dispense with the filter and link the coupling windings of IFT2 and IFT3 with a 100pF low-k ceramic capacitor. The performance implications of this are discussed later.

Full details of the preselector and first mixer/oscillator stages, and the switched coil pack, were given in Part 7. Details of a simple Speaker Amplifier were given in Part 2.

GENERAL CONSTRUCTION

The three circuits are assembled on separate printed circuit boards (p.c.b.s.). This permits the complete screening of the b.f.o. unit and makes it easier for constructors to omit items they do not require. These boards are available from the *EPE PCB Service*, codes 428 (I.F. Amp), 429 (Sig. Meter) and 430 (B.F.O./Prod. Det.).

The component side of the I.F. Amplifier printed circuit board, together with a full-size copper foil master, is given in Fig.8.2. Component and foil sides of the Signal-Strength Meter p.c.b. are shown in Fig.8.4 and the two sides of the B.F.O. and Product Detector board are depicted in Fig.8.6.

Off-board wiring is made easier by the use of solder pins at the p.c.b. lead-out points. They should be inserted first. Follow these with the resistors, then the coils, and then the capacitors, smallest first.

The semiconductors should be soldered in place last, their lead lengths just long enough to attach a miniature crocodile clip to act as a heatshunt. (Heat shunting is good practice with f.e.t.s and germanium diodes).

Filter matching transformers IFT2 and IFT3 are only 7mm square (the 10mm versions are no longer retailed), and particular care should be taken to avoid bridging tracks when they are soldered onto the p.c.b. Avoid stressing the pins of the coils: this can result in open-circuit windings.

On completion, double-check each board for bridged tracks and poor soldered joints. Check the orientation of the semiconductors and polarized capacitors, and check coil and i.f.t. placements.

Connect a fresh 9V battery and check current drain. The I.F. Amplifier should consume around 4mA, the B.F.O. and Product Detector around 6mA.

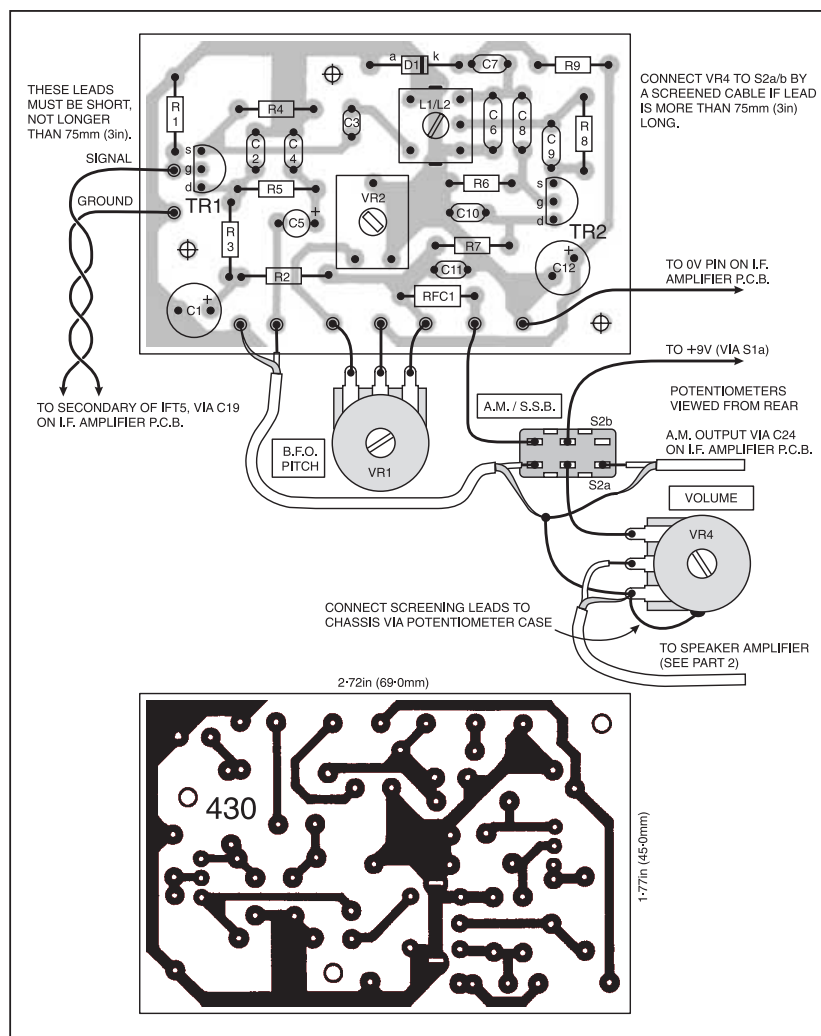


Fig.8.6. Printed circuit board topside component layout, interwiring to off-board components together with the underside copper foil master.



RECEIVER ASSEMBLY

The chassis and front panel described in Part Three could be used for this receiver. Construction of a double-conversion super-het does, however, represent a considerable effort, and many readers will want a more "finished" look. The arrangement adopted for the prototype receiver is shown in the various photographs.

Case and chassis are formed from two standard aluminium boxes, with their U-shaped covers fixed back-to-back. The coil pack and first mixer/oscillator p.c.b., from last month, is mounted, along with the various controls, below the chassis. The tuning capacitor, i.f. amplifier, b.f.o. unit, signal-strength meter and audio amplifier are located above the chassis. Receiver and audio amplifier batteries are secured, by strong rubber bands, to a hard-board platform fixed alongside the coil pack.

A small screening box encloses the b.f.o. unit, and a metal screen is fixed around the tuning capacitor. These measures are not absolutely essential, but they do help to prevent spurious responses.

The front panel is marked out on white card and annotated with rub-down lettering, see photograph. Acrylic sheet, 2mm thick (the kind used for DIY double glazing), protects the panel. The speaker is mounted beneath the top of the case, which is finished with car spray paint. Rubber feet protect the underside.

INTERWIRING

Details of the interwiring connections between the printed circuit boards are also shown in Fig.8.2, Fig.8.4 and Fig.8.6. Screened cable must be used where indicated, but it can be of the ordinary audio variety.

Note the use of the 0V pin on the i.f. amplifier board as the *common negative* connection for *all* of the receiver p.c.b.s. Do not rely on the outer braiding of screened leads to act as negative returns for the power supply.

The negative supply lead for the Speaker Amplifier is connected directly to the appropriate pin on its p.c.b. (see Part 2). Connections to the battery positive terminals are, of course, via switch S1a for the receiver boards, and S1b for the Speaker Amplifier.

Provision is not made on any p.c.b. for the l.e.d dropper resistor R15. This component is included in the wiring to the Power On l.e.d. D4.

Mount the p.c.b.s on insulated stand-offs, and connect the "earthy" side of the i.f. board input to the metal chassis, close to the tuning capacitor. This point should also be used as the chassis connection for the first mixer/oscillator p.c.b. (see Part 7). Connect the audio amplifier board to chassis at the a.f. gain or volume control.

ALIGNMENT – Second Mixer/Osc.

Alignment of the completed Double-Conversion SW Receiver cannot be undertaken without the aid of a signal generator covering 1-6MHz to 30MHz. The procedure is as follows:

- (1) Switch receiver and signal generator on and allow a thirty-minute warm-up time. Always keep the generator output as low as possible. Sensitivity will increase as alignment progresses, and eventually a direct connection between receiver and generator will no longer be required: just place the generator's output lead close to the injection point.
- (2) Coil and i.f. transformer cores, especially the small slug type, are brittle. Use a *plastic* trimming tool for the adjustments.
- (3) Potentiometers, VR1, VR2 and VR3, associated with the I.F. Amplifier, should be set at mid-travel. Switch reception mode to a.m. and turn up Volume control VR4.
- (4) Connect a high impedance voltmeter (a digital testmeter is suitable) across the Signal-Strength Meter output points on the i.f. board and switch it to a low (say 2V) range.

(5) Using the signal generator, inject a modulated 455kHz signal at the drain of the second mixer, TR1. Adjust the cores of IFT2, IFT3, IFT4 and IFT5 for maximum reading on the testmeter.

(6) Filter X1 determines the i.f. frequency, and this may not be precisely 455kHz. Rock the generator tuning control knob, very gently, in order to set its output exactly at the filter resonance. If this changes the generator setting, refine the alignment of IFT2 to IFT5.

(7) Remove the voltmeter and connect the Signal-Strength Meter p.c.b. in its place. Switch off the generator and adjust preset VR2 on the meter board to bring the pointer to zero. Reconnect the generator and inject a low-level signal. Adjust preset VR1 on the meter board to set the pointer at mid-travel. The testmeter is no longer required.

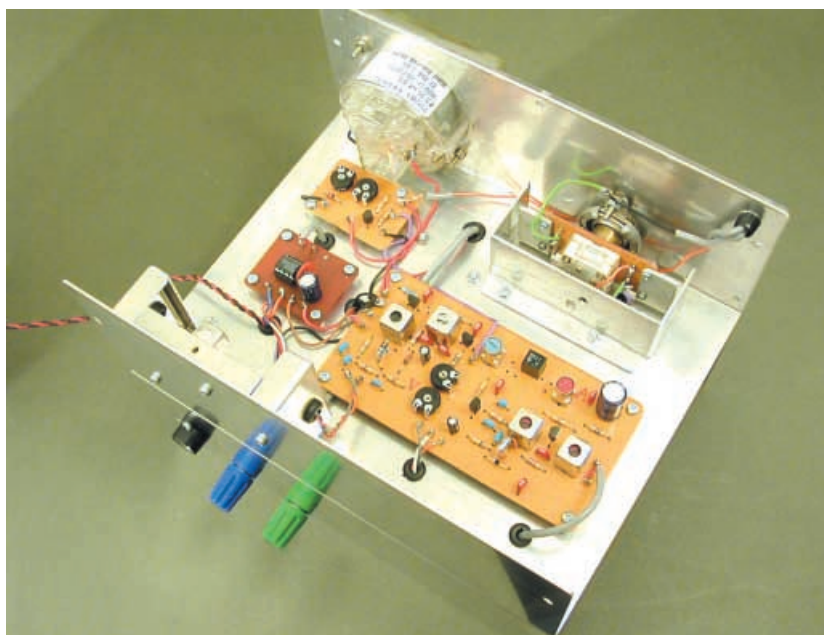
(8) The first i.f. can range from around 1600kHz to 1650kHz. It should be chosen to avoid interference from any medium wave stations that are strong in the reception area. For the purpose of this guidance, it will be taken as 1600kHz.

(9) Set the signal generator to 1600kHz and inject a weak signal at the input to the i.f. amplifier board. Adjust the core of L1/L2 (the second oscillator coil), then the core of IFT1, for maximum reading on the meter. Refine the adjustment of IFT2.

This completes the alignment of the second mixer/oscillator and the i.f. amplifier.

– First Mixer/Osc.

Readers should now refer back to Part 7 for the circuit details and Component Numbers to be quoted in connection with the alignment of the preselector and first mixer/oscillator stages.



General layout of p.c.b.s within the topside chassis. Note the screening bracket around the tuning capacitor. The small p.c.b., to the side of the main board, is the Speaker Amp from Part 2.

Padder capacitors, C6a to C6c, have been calculated on the basis of a 5pF to 130pF tuning capacitor, VC2/VC4. Fixed capacitors should be wired in series with higher value polyvaricons (tuning capacitors) to reduce their swing to not much more than 130pF. Trimmers inside the case of the tuning capacitor are best not used for Range Three in this application. Set them at zero and mount separate trimmers on the p.c.b.

Remember that the receiver will function with the oscillator running at 1.6MHz above or below the signal frequency. The oscillator core setting that produces the *lowest inductance* (giving the highest frequency) is the correct one.

Screw large cores down to increase inductance. With the small cores, inductance is at maximum when they are flush with the top of the can.

Frequency coverage is determined wholly by the setting of the oscillator coil cores, L2, and trimmers, VC3. Signal frequency cores, L1, and trimmers, VC1, are adjusted to optimize alignment, thereby peaking sensitivity and minimizing second channel interference.

(10) Inject a 1600kHz signal at the gate of first mixer, TR1. Adjust the core of IFT1 for maximum meter reading.

(11) Switch to Range Three. Set trimmers, VC1c and VC3c, at about 10 percent mesh and turn tuning capacitor, VC2/VC4, to maximum value. Inject a 10MHz signal at the aerial terminal and set the core of oscillator coil, L2c, for maximum response. Adjust the core of signal frequency coil, L1c, to further peak the response.

(12) Set tuning capacitor, VC2/VC4, at its minimum value. Inject a 30MHz signal at the aerial terminal and adjust oscillator trimmer, VC3c, for maximum response. Adjust signal circuit trimmer, VC1c, to further peak the response.

(13) Swing the tuning capacitor back to maximum and refine the adjustment of the coil cores. Then back to minimum and peak the trimmers again.

(14) Repeat this process on Ranges One and Two, injecting the appropriate frequencies (see Table 7.2) at the tuning limits. Carry out refining adjustments on all ranges to ensure continuous coverage.

(15) When the three ranges have been aligned, finally peak the response with the tuning capacitor set at around 15 percent, and then 85 percent, mesh. This will help to optimize tracking over the tuning capacitor's swing.

This completes the alignment of the receiver.

– B.F.O./Prod. Det.

The beat frequency oscillator can now be tuned, i.f. gain adjusted, and the signal-strength meter settings refined.



Receiver front panel layout and lettering.

(16) Switch to single-side-band mode, set b.f.o. tuning potentiometers, VR1 and VR2, to mid position, and precisely tune the receiver to a steady signal. Adjust the core of b.f.o. coil, L1/L2, for zero beat in the loudspeaker.

(17) Adjust i.f. gain preset, VR3. Mid-position should suit most users, but if the reception area is difficult and/or the aerial very inefficient, maximum gain may be required. This will, however, increase inter-station receiver noise.

Readers blessed with a good aerial in an ideal location may choose a minimum setting. Altering VR3 affects the adjustment of the signal-strength meter.

PERFORMANCE

The receiver is sensitive and internally generated noise is comparatively low: the field-effect transistor mixers are probably contributing to this.

Adopting a 1.6MHz first i.f. results in a significant reduction in second channel interference, but the problem is not completely eliminated. Two tuned circuits in the preselector would make performance very acceptable in this respect (see Part 7).

The specified filter provides good selectivity but there is a noticeable attenuation of the upper audio frequencies. With the filter in circuit, weak signals sandwiched

between powerful ones can be received free from side-band-splatter.

Without the filter, the weak stations cannot be heard. Some top note cutting is not too high a price to pay for the clear reception of weak and "difficult" stations.

High selectivity makes tuning critical. The simple reduction drive on the main tuning control is not adequate. A reduction of 36-to-one or 100-to-one would be more appropriate. The constant-rate fine tuning or bandspread control does, however, ensure that the arrangement is workable.

DRIFT

If the superhet's oscillator is not crystal controlled it will drift. High selectivity only makes the problem more apparent.

With this receiver, after a ten-minute warm-up, drift is unnoticeable up to 12MHz or so and small enough not to be a problem at higher frequencies. Special measures were not taken to minimize it, and performance in this respect could no doubt be improved.

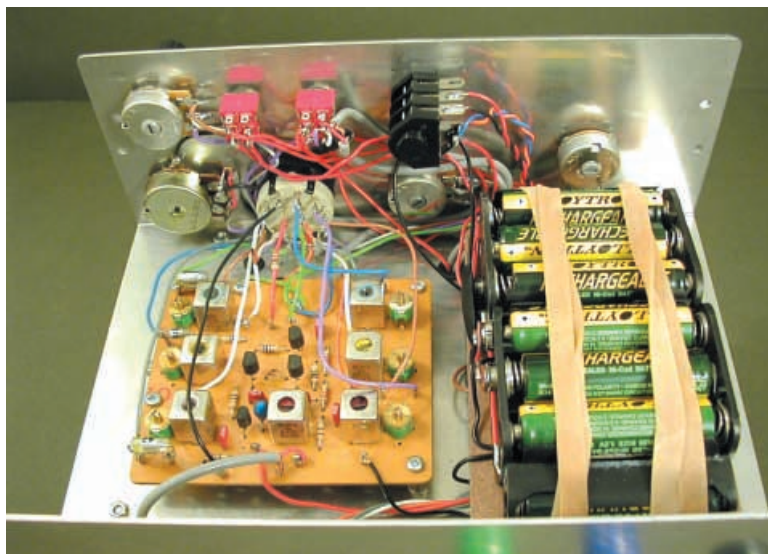
Mounting the speaker under the top of the cabinet caused microphony when weak signals were reproduced at good volume. This was cured by loosely packing the top compartment with plastic sponge.

The aluminium box chassis and case are no more than adequate. To get the best out of the receiver, its various sections should be enclosed in diecast boxes and an (expensive) air-spaced tuning capacitor fitted.

COMPARISONS

In a simple comparison test with a modern, high-performance communications receiver (price tag in excess of £1000), tuning was swept from 5MHz to 12MHz. Every station picked up by the communications receiver could be heard equally well on this radio. The test did, however, expose four, second-channel responses. These took the form of "phantom" stations (see Part 7).

A sweep across the 3-5MHz amateur band revealed the superiority of the commercial receiver, but very little would have been missed by a user of the set described here. □

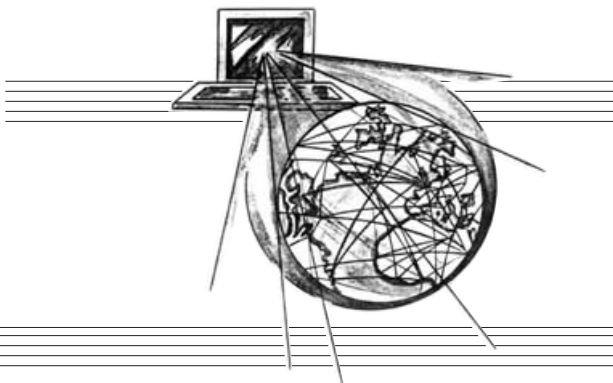


Underside chassis showing wiring to rear of front panel controls, coil pack p.c.b. (Part 7) and arrangement of the battery packs on a hardboard platform.

SURFING THE INTERNET

NET WORK

ALAN WINSTANLEY



Archive News

EVER since its *beta* days, Google has grown to become the largest “pure” search engine available. Users like Google’s minimalist appearance and its speed of searching, while the sophisticated indexing and constant “learning” algorithms ensures that Google generally delivers accurate and relevant results very quickly.

A very useful toolbar is available from www.google.com that integrates directly with Microsoft Internet Explorer browser. Google is, however, more than a web search engine, and the toolbar allows you to access many of Google’s other features. Experienced Internet users will know that the Usenet archive of Deja News was acquired by Google and integrated into “Google Groups”. Web users often overlook this archive but it preserves a wealth of useful information that can be gleaned from the messages posted over many years by other users.

Usenet, or “newsgroups” is a fundamental means of communicating with like-minded users. Newsgroups are formed around a particular topic, and if you have a specific query then it is quite possible that someone else has asked the same thing, so you can use the Google toolbar and search Google Groups to see if anyone else has supplied the answer.

Practical Newsgroups

A recent practical example of Google Group’s usefulness relates to the author’s Onstream digital tape backup system: when Onstream’s Dutch operation collapsed another company (Onstream Data) rose from the ashes, which mercifully helped to guarantee the supply of tapes and software for the immediate future. Eyes narrowed when Onstream’s web site suddenly vanished, and there was no answer from tech support either.

What had happened? After searching Google Groups for “Onstream”, other newsgroup users affirmed the writer’s fears that Onstream had collapsed a second time, this time for good. Armed with this information, the search was on for Onstream 30GB tapes, and Ebay UK soon yielded a lucky bargain of three such tapes and a spare USB drive thrown in, all for less than £90 (in keeping with the author’s make-do policy of not constantly buying the latest or fastest in IT equipment any more).

Ebay’s listings (search for “Onstream”) also highlighted a web site that had all the necessary software downloads to support the product at least for the time being. It got better: a Google Group search also connected the writer with one of the original Onstream design engineers, an interesting American who lived in Holland but had returned to the US and now worked for another drive manufacturer. All of this goes to show that with just a little detective work, the answers are out there on the Internet: you just need to Google it.

Some newsgroups that are of interest to electronics enthusiasts include sci.electronics.basics, sci.electronics.design or perhaps comp.arch.embedded for microcontroller applications. (Also see <http://www.piclist.com/techref/piclist/index.htm>). You can access www.groups.google.com or use the Google toolbar, or use a Usenet software client such as Outlook Express, Free Agent or Turnpike.

Confusingly, another feature of Google’s toolbar is the “News” button, which is not related to Newsgroups. Instead Google will attempt to access the news services of media web sites and try to list results based on the latest news headlines. Another toolbar option is to search the “Google Web Directory” which draws results from DMOZ, the Open Directory at www.dmoz.org. When you visit the site you will see a familiar icon, the Netscape dinosaur mascot (see last month’s *Net Work* for the potted history of Mozilla).

The Google toolbar links over to dictionary.com where the definitions of words can be checked: access it via the toolbar’s Search Web drop-down list. As mentioned in this month’s *Circuit Surgery*, Google’s Glossary (<http://labs1.google.com/glossary>) provides

extracts from the Internet to help you home in on a particular glosary definition. There is also a useful pop-up blocker that prevents distracting pop-ups from appearing. This action can be overridden using the CTRL key when clicking, and you can “enable” preferred sites to show pop-ups.

One feature that is probably less popular with web site owners than Google users themselves is Google Images: you can search for an image by asking Google to scour the web and produce a gallery of thumbnails. This feature is also available from the Search Web toolbar button, or go to <http://images.google.com/>.

Images

Web owners are often less keen to see their image contents indexed and displayed in this way, as it merely consumes their bandwidth and has no commercial benefit. On the other hand, owners of web site shopping carts probably won’t object to their products being listed in Froogle <http://froogle.google.com/> which is fully searchable, even for Onstream tape drives! Froogle is heavily US\$ orientated, and is currently only in beta release, but in the future could form a useful hub for shopping cart searches.



Dogpile is a useful search engine with downloadable toolbar that is worth trying out.

Digging Beyond Google

Google has other features that make it especially suited to the electronics enthusiast, including its ability to parse PDF documents such as data sheets or technical literature. If Google isn’t enough to meet your needs, there are other search engines worth considering. MSN is integrated directly into Microsoft’s web browser and is the default engine launched when you click the MSIE Search button.

Another popular engine is Dogpile (www.dogpile.com or co.uk). The search engine returns results from Google, Yahoo, AltaVista, Overture, Mirago, Teoma and more. Dogpile also offers a free toolbar that puts many useful functions at your fingertips. It has an Images, News, Audio/MP3, Dictionary and Thesaurus finder as well. A built-in pop-up blocker can be configured to “woof” or growl when it’s working. Dogpile’s toolbar also has a streaming news-ticker courtesy of ABC News.

At the end of the day, there are many ways in which you can make the Internet work for you. There is no right way or wrong way – the information is out there and all you have to do is find it, using whichever tools work for you.

I’ll round off another year of *Net Work* by wishing readers around the world a happy Christmas and a safe and prosperous New Year. You can email me at alan@epemag.demon.co.uk.

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE ELECTRONICS CD-ROMS

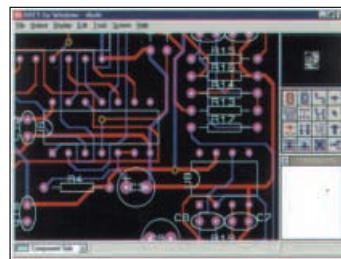
ELECTRONICS PROJECTS



Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture, circuit simulation** and **p.c.b. design** software is included. The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

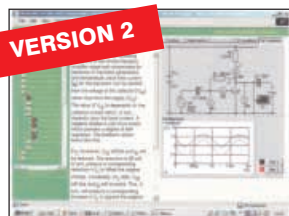
ELECTRONICS CAD PACK



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.

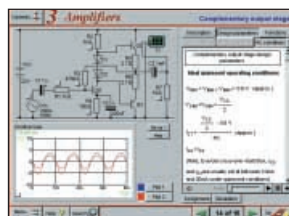
ELECTRONIC CIRCUITS & COMPONENTS V2.0



Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: **Fundamentals**: units & multiples, electricity, electric circuits, alternating circuits. **Passive Components**: resistors, capacitors, inductors, transformers. **Semiconductors**: diodes, transistors, op.amps, logic gates. **Passive Circuits**. **Active Circuits**. **The Parts Gallery** will help students to recognise common electronic components and their corresponding symbols in circuit diagrams. Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS

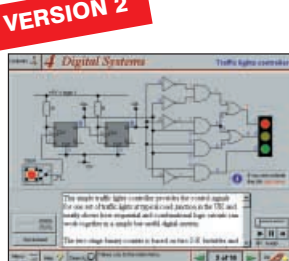


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections), Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

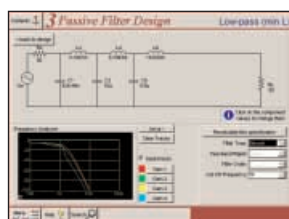


Virtual laboratory – Traffic Lights

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.

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)

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

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

PICmicro TUTORIALS AND PROGRAMMING

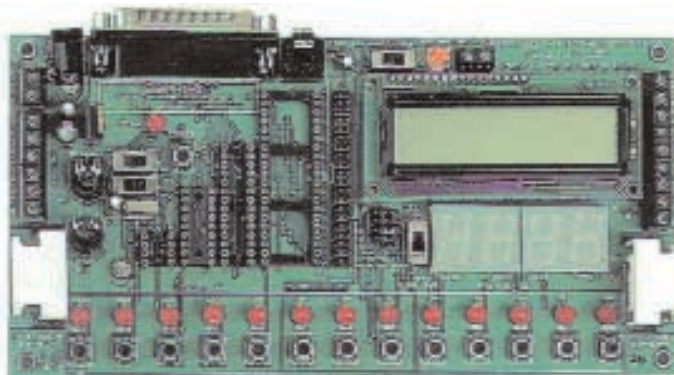
HARDWARE

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 I.e.d.s, quad 7-segment display and alphanumeric I.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 microcontroller. 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.



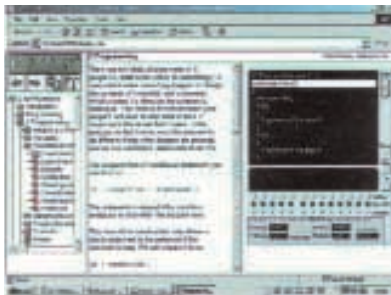
Virtual PICmicro

'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 I.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:

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

Hobbyist/Student
Institutional (Schools/HE/FE/Industry)
Flowcode Institutional
Institutional 10 user (Network Licence)
Site Licence

£45 inc VAT
£99 plus VAT
£70 plus VAT
£249 plus VAT
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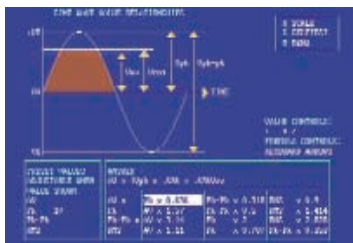
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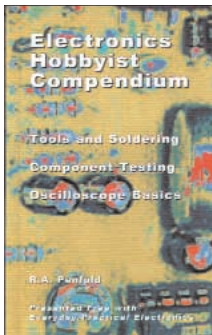
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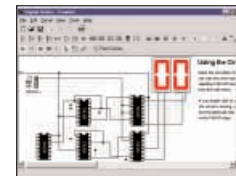


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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

IT is certainly true to say that modern construction techniques have greatly reduced the amount of hard wiring in electronic projects. I recently did some repairs to two shortwave radios from the 1960s and both were entirely hard wired! The modern way is the opposite of this, with everything on a circuit board and, ideally, no hard wiring at all.

However, probably every project includes at least a few wires and cables, and many projects are still fairly bristling with them. It is an aspect of construction where due care has to be exercised. The chances of making mistakes are generally higher with the wiring than with the circuit board, and hard wiring can live up to its name.

Stranded

On looking through a large components catalogue you will probably find a few dozen types of wire and cable spread over several pages. Many of these cables are specialist in nature, and are not the type of thing you would be likely to use in a typical project.

For most projects the only type of wire required is some form of p.v.c. insulated connecting wire. There are two basic types on offer in most catalogues, which are the *single* and *multi-core* varieties. An advantage of the single-core type is that it can be formed into complex shapes and it will accurately retain those shapes. This makes it useful for producing complex cables that run neatly around the project.

Single-core wire is little used in projects despite this potential advantage. One reason for this is simply that few projects have complex cabling that can utilise this capability. There is also a major flaw with this type of wire.

Even when using proper wire strippers it is easily damaged as the plastic insulation is stripped away. This leaves the wire weak and prone to breaking if it undergoes any flexing. While multi-core wire is not totally immune from this problem, it is much less vulnerable to it.

Use proper wire strippers and there should be no problems. Use knives, scissors, etc., and not only will the wires be weakened but you will probably injure yourself as well.

On The Right Gauge

General-purpose connecting wire may well be referred to by other names in component catalogues, such as "hook-up" or "equipment" wire. Whatever name is used, it is available in light, medium, and heavy duty varieties.

Light duty equipment wire is usually described as something like "10/0.1", which signifies that it has 10 strands of 0.1 millimetre diameter wire. Although this type of wire can only be used for currents of up to around 500mA (0.5

amps), it is still suitable for most projects. With many projects the total current consumption is only about 20mA or less, with only a tiny fraction of that going through many of the connecting wires.

Even so, a medium duty wire, such as a 7/0.2 type, is probably a better choice for general project wiring. With its maximum current rating of about 1.5A, this type of wire is suitable for the vast majority of projects but it is still easy to use.

Only a few projects such as some power supplies and power amplifiers require heavy duty equipment wire. Projects such as these often involve maximum currents of several amps. For example, 24/0.2 wire can handle currents of up to 6A and is adequate for most high-power projects. As heavy duty equipment wire is unwieldy in use it should only be used where high currents are involved.

Never use medium or light duty wires where a heavy duty type has been specified. Using wire at an excessive current will result in it getting hot, which has obvious safety implications. The voltages dropped through the wire will almost certainly stop the project from working properly anyway.

Presumably due to its lack of popularity, most suppliers only seem to have single-core equipment wire available in one size. This is likely to be 1/0.6, which is suitable for light and medium duty applications.

Other types of single-core wire are available, and most catalogues list enamelled copper wire in a wide range of diameters. The insulation on this type of wire is more or less a coat of tough varnish. There is no need for wire strippers with enamelled wire, and the insulation can be carefully scraped away using a miniature file or a penknife.

Enamelled wire is not suitable for most applications because its insulation is easily damaged. It is mainly used in home-made inductors and transformers. Tinned copper wire is another form of single-core wire. It has no insulation and in projects it is mainly used for link-wires on circuit boards.

In the past single-core wires were available in a range of standard wire gauges (s.w.g.) from about 14 to 40. This system was apparently used for all sorts of things, including knitting needles. Although we have now gone metric, you might still encounter references

to something like 32s.w.g. wire, or even 32a.w.g. (American wire gauge).

Under the metric system the diameter of the wire is specified in millimetres. 14s.w.g. wire is very thick at around 2mm in diameter, and 40s.w.g. wire is very fine at just 0.125mm. 24s.w.g. wire is 0.156mm in diameter and is a good choice for link-wires on circuit boards. Components lists usually specify the gauge and the diameter, and component catalogues mostly give both types of measure, so there should be no problems here.

Ribbon Cable

Ribbon cable is one of those "best thing since sliced bread" inventions. It is a multi-way cable that has a number of insulated wires laid side-by-side and joined together. This gives a flat ribbon-like cable that typically has from 10 to about 60 wires.

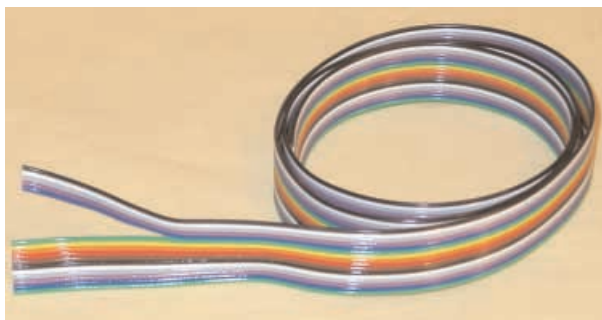


Fig.1. With ribbon cable it is easy to peel off a piece having the required number of wires.

There are two main types of ribbon cable, and one is specifically designed for use with certain types of computer connector. The 0.05 inch pitch of the wires matches the terminals on the connectors and together with the thin insulation permits a system of solderless connection to be used. This type of ribbon cable is grey in colour apart from a red lead at one edge. It is usable as equipment wire where several connections running side-by-side are needed, but it is less than ideal.

The second type of ribbon cable is far better in the current context. One small but crucial difference is that the wires have insulation of different colours. This may seem to be of no importance, but it aids the easy identification of each wire. When using ribbon cable instead of a conventional cable-form this is very important, particularly where a large number of wires are involved.

This type of ribbon cable is available in 10-way and 20-way varieties. However, a section having the required number of wires is easily peeled from a larger piece (see Fig.1). This type of

ribbon cable seems to be less widely available than the computer variety, but it is really worthwhile seeking it out.

Cross-talk

When using ribbon cable or tying individual wires together to form a single cable it is best not to group too many wires together. Capacitance between the wires can cause problems.

A capacitor consists of two metal electrodes separated by a layer of insulation that is called the dielectric. A ribbon cable consists of pairs or wires separated by a layer of insulation, and each pair or wires therefore form a capacitor. The same is true for any two insulated wires running side-by-side.

In both cases the capacitance between adjacent wires is very small, and will normally be a few picofarads or less. With some circuits this can still be enough to couple a significant amount of signal from one wire to the other.

There should be no problem with something like three wires running from a circuit board to a socket or potentiometer. Any stray coupling is likely to be too small to be of practical significance.

Using a single multi-way cable to carry the connections to input and output sockets is asking for trouble. Any stray coupling tends to feed some of the output signal back to the input. With most types of audio circuit this practically guarantees instability.

The article concerned will usually make it clear if good isolation between certain parts of the circuit is important. Where there is any doubt, always use a separate cable for each component, which will often be the easiest and neatest way of handling things.

Ribbon cable is often used with digital circuits. Although problems with stray coupling are mainly associated with sensitive audio and radio equipment, the high switching speeds of digital circuits can cause sufficient coupling to produce glitches from digital circuits.

With something like a computer add-on that connects to the printer port of a PC it could be helpful to use a connecting cable several metres long. However, in order to avoid cross coupling it is often necessary to use a cable of no more than a metre or so in length.

Screened Leads

Ordinary connecting wire and ribbon cable are fine for most purposes, but some projects require the use of screened leads. There are two possible reasons for using screened cable, and the most common one is to shield wiring in a sensitive part of the circuit from electrical interference.

Stray pick-up of mains "hum" is usually the main problem, but there are plenty of sources for electrical interference in a modern environment. The second reason is to prevent wiring that carries strong high frequency signals from radiating illegal radio interference.

In its most simple form a screened cable has an insulated wire at its centre, and this is surrounded by some

form of screen. These days the screen is usually in the form of a number of fine wires that are wrapped around the insulation of the inner wire. This is known as a lapped screen.

Some audio cables have the wires woven into a braiding, and this method is the norm for radio frequency cables. In use the screen carries the earth connection and provides a barrier between the inner conductor and the outside world.

Screened leads are mainly used externally. As a couple of examples, they are used to provide the connections between items of equipment in a hi-fi system and to connect the aerial to a television set. Screened leads are occasionally used within projects though. Stray pickup from the outside world is not usually the problem, because sensitive projects are normally housed in metal cases that provide overall screening.

Sometimes a circuit is so sensitive that even a minute amount of stray feedback from the output to the input could cause instability. Screening the input and output wiring helps to minimise any stray feedback. Another reason is to screen vulnerable wiring from an internal source of electrical noise, such as a mains transformer or an electric motor.

These days most audio projects operate with stereo signals and require stereo screened cable. The best type is effectively just two single screened leads joined together to produce a "figure-of-8" style cable. Both the cables in Fig.2 are of this type.

The cheaper type has the inner conductors sharing the same screen and outer sheath. Particularly with long cables, the latter has the disadvantage that the inner conductors are screened from the outside world but not from each other. This can result in a loss of stereo separation at higher audio frequencies, but the effect is unlikely to be of significance with short cables within a project.

With audio cables there are differences in terms of their quality and in points of detail, but electrically there is no fundamental difference. The situation is different for cables designed for use at high frequencies. They are designed to operate with sources and loads that have a specific impedance.

These are generally called coaxial (or just "coax") cables, but strictly speaking all screened cables are of the coaxial variety. The article concerned should explain the exact requirements where a special cable is required, such as a 75-ohm coaxial or very low-noise audio type.

Making Connections

Screened cable is inevitably a bit more awkward to use than ordinary equipment wire. With thin audio cables it is possible to start the process by removing some of the outer sheath from the end of the cable. For the thicker audio cables and coaxial types a special heavy-duty wire stripping tool is required.

It is not worth buying one of these for very occasional use, but there is an easy alternative. Use a modelling knife to make two longitudinal cuts through the outer sheath on opposite sides of the cable, so that the sheath can be peeled back and trimmed. The fine wires in the screen are easily damaged so exercise due care.

Lapped cables are easy to deal with, because the wires in the screen can be pulled to one side and then twisted to form a short lead, as in one section of the lower lead in Fig.2. Tin the wires with solder so that they cannot separate again.

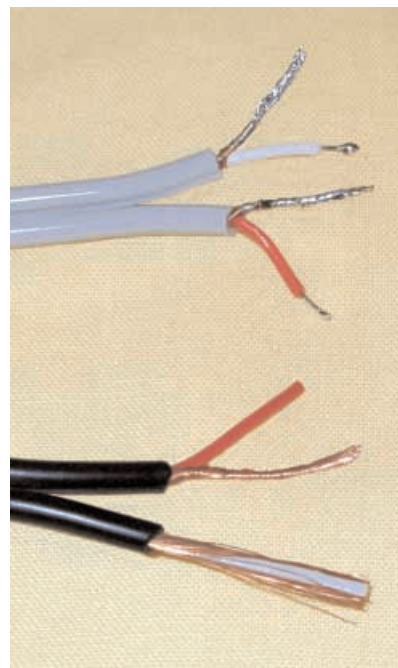


Fig.2. Lapped screened cable is easily prepared for connection. Tin the screen with solder to prevent it from splaying apart.

Finally, strip and tin the inner conductor in the same way that an ordinary lead would be prepared for connection. This gives something like the upper lead in Fig.2. The same method works quite well with some braided cables, where the wires are only loosely woven together and tend to separate once the outer sheath is removed.

With the heavier types of braiding a hole is made in the screen close to where it emerges from the outer sheath. The inner conductor is then pulled out through this hole and clear of the screen. The screen can then be formed into a lead and tinned with solder, and the inner conductor is dealt with in the usual way.

Note that with a few of the larger screened cables their lack of flexibility makes this method impractical. With these cables most of the screen can be trimmed away to leave a narrow ring. A piece of bare wire is then coiled around the screen and soldered to it, leaving a short wire to act as the lead for the screen. Obviously, due care must be taken not to seriously overheat and damage the cable.

GPS TO PIC AND PC INTERFACING

JOHN BECKER



How to extract data from a GPS handset and use it in your PIC and Visual Basic 6 programs.

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 demonstrates how such interfacing can be done with GPS handsets that support 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.

GPS PROTOCOLS

The Global Positioning System is a 24-satellite constellation in orbit around the globe. GPS handsets receive data from a selection of satellites and process it to provide a variety of navigational facts, such as telling you where you are in three dimensions, latitude, longitude and altitude. Other facts, such as current course and speed, are calculated by the handset in relation to two or more timed transmissions. Increasingly, GPS is also being used not for navigation at all, but for critical timing applications as it is basically a very cheap atomic clock!

The data transmitted from a GPS satellite consists of two parts, an *ephemeris* (containing data relating to the transmitting satellite) and an *almanac* (containing data relating to the whole GPS system). The receiver uses the almanac to determine which satellites should be visible in the sky. Signals from these visible satellites are acquired and the most accurate of the ephemerides are downloaded for positioning purposes.

Handsets typically output the data to their own l.c.d. screen as textual statements and as images generated by their software. The text data is also available for output in an RS232 serial format via a built-in connector, although the type of connector and its pin arrangement can vary between models. (User handbooks should provide the details for individual models.)

NMEA 0183 STANDARD

There are several interface format protocols under which different handset types can output the serial data. There is, though a universal standard protocol which can be selected and output for use by external equipment. The standard is that specified by the National Marine Electronics Association, NMEA. Although there are different versions of this standard, the NMEA 0183 Interface Standard is the one most widely adopted and likely to be available with all commercial GPS handsets.

NMEA 0183 defines the electrical signal requirements, data transmission protocol and specific sentence formats for a 4800 Baud serial data bus. However, compliance with the standard is not mandatory and manufacturers are free to decide how they will implement the standard. In essence, though, the most commonly required data is likely to be formatted consistently.



Typical example of a Garmin GPS 12 data screen.

This article is based upon the author's use of the Garmin GPS12 handset. It has also been proven by friend and *EPE* reader Andrew Jarvis on a Garmin eTrex handset. In essence, the information provided should be compatible with all GPS handsets that comply with the NMEA 0183 standard.

SENTENCE TYPES

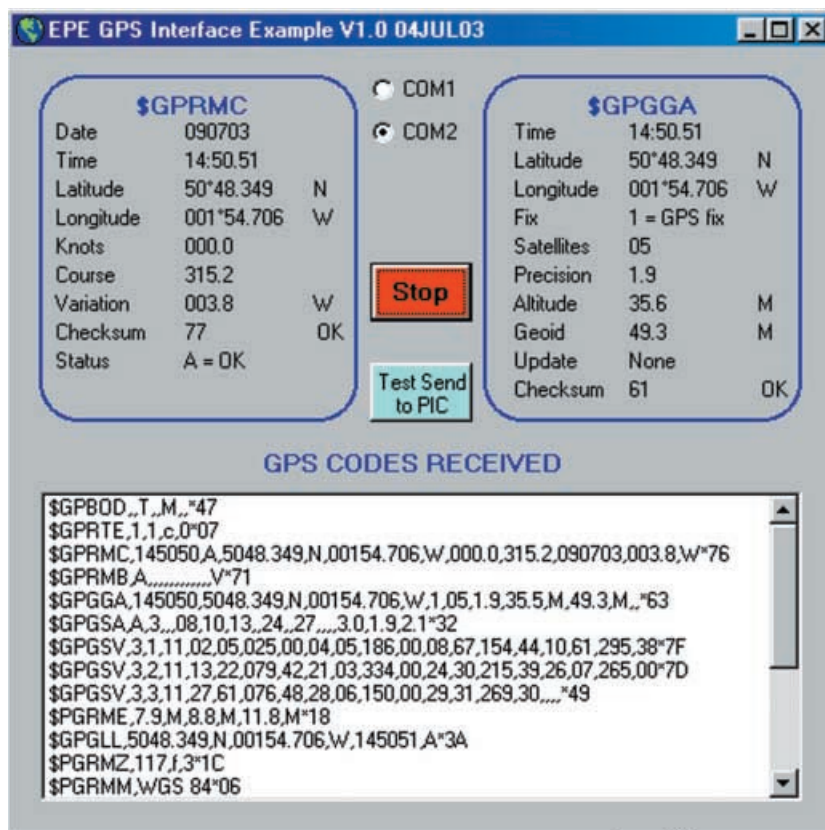
NMEA 0183 data comprises a series of ASCII sentences. The most common sentences are prefixed by an identity code of \$GPxxx, where "xxx" is a specific 3-letter infix indicating the information type that is held within a sentence. There is a document available for free download from <http://home.mira.net/~gnb/gps/nmea.html> which gives all sentence codes which are prefixed by \$GPxxx, and gives short descriptions of the sentence formats.

The descriptions are too many to include here and readers are referred to this document for more information. It should be noted that not all GPS handsets will output all the data sentences. However, there is at least one sentence that all handsets should output, that which includes the recommended minimum specific GPS/Transit data.

This sentence is prefixed by the code \$GPRMC (RMC = Recommended Minimum Content) and consists of 13 fields of data, 12 of which are separated by commas. The sentence is output in ASCII text format and, with the exception of the checksum code in the final field, does not require decoding. Table 1 shows an example of the format (the numbers below it indicate the field numbers).

It is this sentence, plus one other, that the example software has been programmed to find and interpret from the many sentences that are output from a typical handset.

The second sentence that the software example accepts is that which contains altitude data and is prefixed by the identifier \$GPGGA. This sentence is all about the positioning fix of the receiver. It too includes time, latitude and longitude data, but this is just a repeat of that in \$GPRMC. Of casual interest, though, it also states the number of satellites in view at that time (there are typically six in view from the author's home, but not visible to the naked eye!)



The PC demonstration screen showing the GPS sentence codes received and the decoded data for two of them.

PHYSICAL PROTOCOLS

The default physical data output protocol for GPS handsets is based on the familiar RS232 standard. The voltage characteristics are said to be compatible with most Host devices (e.g. PCs and other digital logic hardware). However, the GPS transmits positive voltages only, whereas the RS232 standard requires both positive and negative voltages.

Also, the voltage swing between mark and space may not be large enough to meet the strict requirements of the RS232 standard, although the GPS voltages suit most Hosts as long as the interface cable is wired correctly.

The other electrical characteristics are full duplex, serial data, 4800 Baud (although other Baud rates are supported by some GPS handsets), eight data bits, no parity bits, and one stop bit.

BASIC GPS TO PC INTERFACING

The data that is output from GPS handsets that support the NMEA 0183 standard is suitable for directly inputting to a PC via one of its serial communication ports, e.g. COM1 or COM2. It will be necessary to study your GPS handset manual to establish which pins on the output connector are used for signal output and common ground. Those for the Garmin GPS12 are shown in Fig.1.

The signal output and ground (GND) should be connected to the RS232 signal input and GND on your PC. Fig.2 shows the connections for 9-pin and 25-pin connectors.

Next consult your GPS handbook for details of how to set it for outputting data

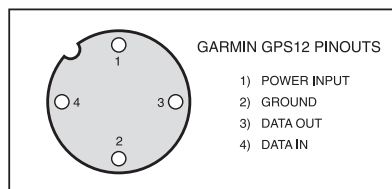


Fig. 1. Garmin GPS12 pinouts.

according to NMEA 0183. Following power-on, the author's Garmin GPS12 path selection requires several pressings of the Page button until a screen offering a link to the Setup Menu appears.

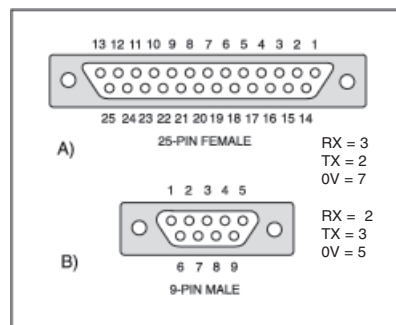


Fig.2. Pin numbering of 25-pin female and 9-pin male connectors.



Garmin GPS 12 interface screen.

Highlighting this option and then pressing Enter displays the menu. Selecting Interface, the first option then is to select the output protocol. For the GPS12 the settings are NONE/NMEA, NMEA 0183 2.0, 4600 Baud. Once selected, this handset stores the settings and implements them each time the handset is used.

HYPERTERMINAL

It is possible to read the GPS data via the Hyperterminal function that most PCs have installed as part of their basic suite of programs. To access Hyperterminal, click the Windows Start button, select the path Programs/Accessories/Hyperterminal then double-click on HYPERTERM.EXE.

A "Connection description" sub-screen should appear. Enter a name for the connection, e.g. GPStest, and choose an icon for it, or accept the default icon. Click OK. On the Phone number screen that then

Table 1. Example coding for an NMEA 0183 sentence

\$GPRMC,145050,A,5048.349,N,00154.706,W,000.0,315.2,090703,003.8,W*76
0 1 2 3 4 5 6 7 8 9 10 11 12

The interpretation of this example sentence is:

Field	Data	Description	Meaning
0	\$GPRMC	sentence identifier	information type
1	145050	time of fix	14:50:50 UTC
2	A	validity	OK (A = OK, V = invalid)
3	5048.349	current latitude	50°48.349'
4	N	North/South	North
5	0154.706	current longitude	001°54.706'
6	W	West/East	West
7	000.0	speed in knots	0.0 knots
8	315.2	true course	315.2°
9	090703	date stamp	09 July 2003
10	003.8	magnetic variation	3.8°
11	W	West/East	West
12	*76	checksum	76 (in hex)

In the most common usage, the terms UTC (Universal Time Coordinate) and GMT (Greenwich Meridian Time) are identical.

Before you get an Ordnance Survey map – it's EPE's location that's given – not the author's home!



Hyperterminal connection description screen.

appears, ignore the phone number boxes and click on the arrow alongside the "Connect Using" box. From the dropdown list select the COM port you want to use and click OK.

A "Connection Properties" screen then appears. Set "Bits per Second" (Baud) to 4800, Data Bits to 8, Parity to None, Stop Bits to 1 and Flow Control to Hardware, and click OK again. If the GPS handset is running and correctly connected to the PC, data will scroll down the screen in NMEA formatted sentences.

It is possible, though, that you may just see strings of garbage characters at this time. If so, first check that handset and Hyperterminal are set for the same Baud rate. Otherwise the output from your GPS handset probably needs its logic to be inverted via an inverter gate such as a 74LS04, 4069 or other hex inverter logic device, as shown in Fig.3.

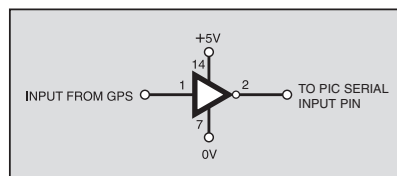


Fig.3. Inverter gate connections.

Mount the device on a piece of strip-board, or a plug-in breadboard of the type recommended for use with the *EPE PIC Toolkit TK3* assembly and programming aid (Oct/Nov '01).

Ensure that the Hyperterminal connection is closed before using the VB6 GPS demo software.

CUSTOMISED GPS TO PC SOFTWARE

Hyperterminal is fine for showing the type of data that comprises the NMEA sentences. It is not capable, however, of actually processing the data. The author has written an example program in Visual Basic 6 (VB6) that illustrates how blocks of sentences can be received by the PC from a GPS handset and then processed.

The program is a demonstration for use by readers who have VB6 installed on their PC and who wish to make use of GPS data in their own programs. It shows the way in which GPS data sentences and various fields within them can be extracted selectively. Armed with this example, the program can be modified to entirely suit the user's needs. It cannot be used by those who do not have VB6.

It is also important to note that the example makes use of Joe Farr's *EPESerialIO OCX* (see *Serial Interface for PICs and VB6*, *EPE* Oct '03) for serial communication. Joe's software must be installed within VB6 for the example source code to run. Alternatively, readers who have a version of VB6 which allows use of the MSCOMM Active-X procedure can re-write the serial I/O sections accordingly. The VB6 program has been set to the same serial transfer defaults as those just stated.

To run the program, copy the source code files into your VB6 folder, load the program and run it in the usual way. First set the COM port address required via the radio buttons at the top of the run-time screen (see photo on previous page).

PC INTERFACE SCREEN

With the GPS handset connected as described for Hyperterminal, data similar to that shown in the screen photo will be displayed when the program's Start button is clicked. The data will vary, of course, depending on your local conditions. To stop the data flow click the Stop button that is revealed once Start has been clicked.

There are three areas allocated for data display. The upper two boxes are dedicated to data extracted from sentences identified by the \$GPRMC and \$GPGGA prefixes. The lower area is a ListBox in which all sentences received from the GPS in each sampling batch are displayed. This display allows you to compare the data shown in the upper two boxes with that for their respective unsplit sentences. Studying the program will reveal the simplicity of the data extraction technique.

A point worth clarifying, though, is the Checksum format. At the end of each sentence, if it has been fully received, is a Checksum value prefixed by an asterisk ("*"). The checksum is held in the last two characters following the asterisk and the value is in hexadecimal.

The checksum is calculated by first setting an initial register to zero and then XORing with it the ASCII value of each character within the sentence, excluding the first character ("\$") and the last three characters (asterisk and checksum). The final XORed register value is then compared in decimal with the decimal equivalent of the hex value of the checksum. If the two values match, the sentence has been correctly received.

FIELD LENGTHS

Note that the fields within the sentence do not necessarily have fixed lengths. Whilst the time and date values, for example, are probably always formatted to a fixed length, there is evidence to suggest that values following decimal points in the latitude and longitude fields may have different quantities of decimal places, depending on the handset model. The author's Garmin GPS12 uses three decimal places, but it is known that some handsets have four places.

Consequently, when splitting a GPS sentence into its fields it is essential to use the comma as the separating symbol for all fields except the checksum.

As written, data is input in blocks of 1024 bytes in response to a Timer 1 event.

You can set the block length to suit your own needs and the Timer 1 interval can be set for any desired period.

Each block is input and immediately output to a disk file named *GPSReceived Text.txt*. The file is over-written with each new block of data received. Immediately the file is closed for each block, it is reopened and the data re-input for processing and screen display. There is then a pause until Timer 1 times-out again, when the next block is input and processed.

On the author's Garmin GPS12 the full cycle of sentences transmitted typically consists of about 550 bytes of data. The 1024 byte block length therefore ensures that all sentences are received, with an overlap. On re-input the sentences are sorted into alphabetical order and duplicate identity prefixes deleted, retaining the latest one.

The data can be examined in detail via the ListBox when the Stop button is clicked, and via the recorded text file.

INTERFACING A PIC

The example PIC software has been written for the PIC16F877 device running at 3.2768MHz. The source code is written in a variant of TASM and is suited for assembly and programming into the PIC via *TK3*. *TK3*'s software is also suitable for translating the TASM code to MPASM. The hex file supplied is in the MPASM format.

Install a PIC16F877 on the *TK3* board, along with a 3.2768MHz crystal. Connect the I.c.d. module to *TK3*'s allocated pins (PORTB control as usual – see Fig.4).

Connect the PC's serial output pin to the input of the inverter mentioned earlier. Connect the inverter's output to PIC pin RC7, its serial input pin. Load and run the example HEX software.

Click the Send to PIC button on the PC's screen. This action loads the file data from the last block recorded from the GPS handset and repeatedly outputs it to the PIC in response to control by Timer 2.

The PIC receives the data in bytes, looking for and then storing data for two specific sentence types, \$GPRMC and \$GPGGA. It first looks for the \$GPRMC sentence identity letters sequence, storing it to memory. Having found it, it inputs all the next several characters and also stores

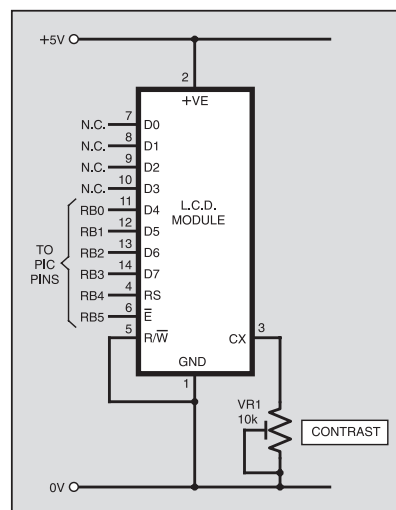


Fig.4. Connections between the PIC16F877 and I.c.d.

them to memory. While doing so it looks for the occurrence of ASCII 13 (CR – carriage return) which signifies the end of a sentence.

On receipt of ASCII 13, the software enters a checksum validation routine, in a similar XORing process to that used by the PC software. If the checksum is found to be correct, the next routine is entered in which commas are looked for. If it is incorrect, the next occurrence of the required sentence is sought.

When the checksum is correct, it is then assumed that the correct fields are present. The software then splits the data into its fields and outputs it to an alphanumeric l.c.d. screen. The fields are not stored to dedicated register locations, although they could be if the user prefers.

The data is formatted and stored by the l.c.d. in two pages of its screen memory, one visible, the other hidden. Every few seconds visibility alternates between the pages.



Example of l.c.d. screen page 1 while actively monitoring GPS.



Example of l.c.d. screen page 2.

Page one holds the clock and calendar data extracted from sentence \$GPRMC. Page two holds the latitude and longitude data, also from \$GPRMC. Just one field of sentence \$GPGGA is used, the height value, which is placed on line two of l.c.d. page one, following the calendar data. Both pages hold the Validity letter from \$GPRMC, "A" for valid or "V" for invalid. If the checksum is found to be wrong a message to this effect is placed on both pages.

Examining the PIC source code you will see that the process has been made very linear and very understandable, without any "clever programming" tricks, such as Macros or multiple-purpose sub-routines.

Having processed \$GPRMC the software now looks for the \$GPGGA identifier and then inputs and processes that sentence in a manner similar to that used with \$GPRMC. On this occasion, though, it is only the height (altitude) data that is extracted. The software then loops back to again look for \$GPRMC, etc.

Note that the PIC software allows you to change the Baud rate at which the PIC receives data. The value associated with this can be changed to suit the crystal and Baud rate that you require. TK3 since version V1.42 has a Baud calculation facility to assist in choosing the correct value.

DIRECT GPS INPUT TO PIC

To directly input live data from the GPS handset to the PIC simply connect the

PANEL 1. A BRIEF HISTORY OF GPS

1920s. Origins of radionavigation

Early WW2. LORAN, the first navigation system to employ time-difference-of-arrival of radio signals, is developed by the MIT Radiation Laboratory, but is only two-dimensional (latitude and longitude).

1957. The concept for GPS evolved from observations of Doppler shift in signals from the Russian satellite *Sputnik*.

1959. *Transit*, the first operational satellite-based navigation system, and consisting of seven low-altitude polar-orbiting satellites, is developed by the Johns Hopkins Applied Physics Laboratory (APL).

1963. The Aerospace Corporation launches a study on using a space system as the basis for a navigation system for vehicles moving rapidly in three dimensions; this led directly to the concept of GPS.

1964. *Timation*, a US Navy satellite system, is developed and its work on space-qualified time standards provided an important foundation for GPS.

1967. *Transit* made available to civilian users.

1971-1972. Ground and balloon-carried transmitters simulating satellites were tested and accuracies of a hundredth of a mile demonstrated.

1973. Approval to proceed with the *Navstar* GPS is granted and a configuration of 24 satellites was ultimately placed in 12-hour inclined orbits, commencing in 1974. They carried the first

atomic clocks ever launched into space.

1977. Testing of GPS user equipment began.

1983. Following the Soviet downing of Korean Air flight 007, President Reagan offers to make GPS available for use by civilian aircraft, free of charge. This marks the beginning of the spread of GPS technology from military to civilian aircraft.

March 1990. The US Department of Defence (DoD) activates SA (Selective Availability), the purposeful degradation in GPS navigation accuracy.

August 1990. SA is deactivated during the Gulf War. DoD purchased thousands of civilian GPS receivers to be used by the Allied forces during the war. The use of GPS proved to be the first successful tactical use of a space-based technology within an operational setting.

July 1991. SA is reactivated after the Gulf War.

8 December 1993. The US Secretary of Defense formally declares Initial Operational Capability of GPS, signifying that with 24 satellites in orbit, GPS is no longer a developmental system and is capable of sustaining 100-metre accuracy and continuous worldwide availability.

1 May 2000. SA restrictions lifted and civil use GPS receivers are able to find their positions with an accuracy to within 10 to 20 metres anywhere in the world.

A 34-page comprehensive history of GPS, from which the above has been extracted, can be downloaded from:

www.rand.org/publications/MR/MR614/MR614.apb.pdf

handset's data output to the inverter's input, in place of the PC connection.

If you wish, the handset data can be fed simultaneously to both PIC and PC.

Note that a timeout count is used to detect non-arrival of GPS data. If the l.c.d. screen top line frequently alternates between showing data and the message "WAITING SIGNAL", decrease the value allocated to TIMEOUT3 (the default is 254) to provide a longer timeout delay.

SUITING YOUR NEEDS

Study the PIC and VB source codes to see how the \$GPRMC and \$GPGGA sentences have been handled. It should be obvious how the software can be changed to deal with sentences having other identity prefixes and data fields containing other navigational data. The field contents for other sentences can be established by referring to the downloaded web file referred to earlier.

As mentioned, it is a simple matter to change the PIC's crystal and Baud rates. It is equally simple to use PICs other than the PIC16F877, providing they have serial

comms facilities and also have an area of memory where sentence data can be stored during reception and processing. The coding for the full PIC16F87x family will be the same as in the example, although the serial pin numbers will differ.

RS232 CHIP

Although direct coupling of the serial data lines to the PIC and PC is likely to be effective, greater sophistication and potentially greater reliability of data transfer can be provided if an RS232 interface chip is inserted between the data source and its destination. A suitable circuit using the familiar Maxim MAX232 device is given in Fig.5.

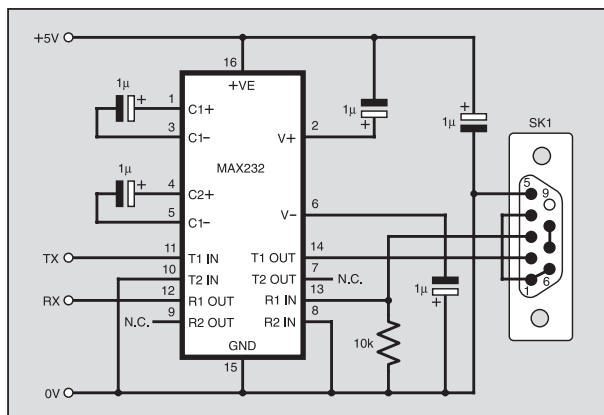


Fig.5. RS232 interface using a MAX232 device.

This device was discussed in Joe Farr's article previously referred to, and in Part 3 of the author's *EPE PIC Tutorial V2* (June '03).

GPS DATA STABILITY

As mentioned in Panel 1, GPS Selective Availability (SA) has now been removed by the US authorities. The accuracy of navigation coordinates is now said to be within 10 to 20 metres. In field tests with the Garmin GPS12, the coordinates data appeared to have a resolution of about two metres. However, repeated tests across the same area showed that the coordinate readings could vary with time. They were found to drift by two to three metres over a period of a few minutes even when the handset was kept stationary.

The conclusion is that the accuracy is amazing considering the distance between the handset and the transmitting satellites,

but that it cannot be relied on to pinpoint specific points on the ground. Consequently, the author does not propose to upgrade his *Earth Resistivity Logger* (April/May '03) to include GPS location monitoring. However, GPS is useful for identifying a small area having a diameter of just a few metres, and a GPS logging interface option is included with his forthcoming *Magnetometry Logger* design.

SOFTWARE

The demonstration software for this article is available from the *EPE* Editorial office on a 3.5in disk, for which a nominal handling charge applies, see the *EPE PCB Service* page. Is also available *free* via the Downloads click-option on the *EPE* home page at www.epemag.wimborne.co.uk.

ACKNOWLEDGMENT

The author thanks Andrew Jarvis for the

invaluable advice given in the preparation of this article, and for field-testing the software demos.

GPS MANUFACTURERS WEB LINKS

Garmin – www.garmin.com. free manual download

Lowrance – www.lowrance.com. free manual download

Magellan – www.magellangps.com

Northstar – www.northstarcmc.com

DeLorme – www.delorme.com

Icom – www.icomamerica.com/gps

Andrew says that the principle players for chipset/embedded products are Sirf, Trimble, Motorola and RoyalTek, and that the following link may be useful to some readers:

<http://home-2.worldonline.nl/~samsvl/oemtable.htm>.

SHOP**TALK**
with David Barrington

Car Computer

Some readers may have difficulty locating a source for the MAX232 RS232 interface and the 24LC64 serial EEPROM chips called for in the *Car Computer* project. Try **ESR Components** (☎ 0191 251 4363 or www.esr.co.uk) for the MAX232 and **Maplin** (☎ 0870 264 6000 or www.maplin.co.uk) for the 24LC64 64K serial EEPROM, their code RF28F.

Quite a number of our advertisers now stock 2-line 16-characters per line alphanumeric l.c.d. modules and sourcing should not be a problem. However, you should check the pinning arrangement as the p.c.b. has been designed to take both 14-pin and 16-pin (Hitachi L016 in model) types which have their take-off points in a horizontal row along the edge of the display module.

Readers may find the 100µF tantalum capacitor hard to track down. We understand, from the designer, that you could substitute a 10µF one in its place.

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 7) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 75). It is also available *Free* via the Downloads click-link option on the *EPE* 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 Car Computer**.

The double-sided printed circuit board is available from the *EPE PCB Service*, code 431 (see page 75). Note the board is *not* a plated-through-hole (pth) type.

Finally, the keypad, crystals and listed connectors are widely stocked items. The choice of case is left to individual preference.

PIC Watering Timer

The size and type of geared d.c. motor required for the *PIC Watering Timer* project will largely depend on the torque needed to operate the water isolation valve used. The prototype motor was a 12V geared type with a shaft speed of approximately 100 r.p.m.

Having only just received the new **Squires** (☎ 01243 842424) catalogue, a very quick "flip-through" the pages revealed a good section on small d.c. motors that readers might like to investigate further. The water valve used in the model was purchased from one of the large d.i.y. superstores. It should be capable of a 360° rotation.

If you wish to use a similar translucent box to house the electronic control circuit board, this was obtained from **Rapid Electronics** (☎ 01206 751166 or www.rapidelectronics.co.uk), code 30-3852 (blue) or 30-3862 (red). The 16-character l.c.d., watch crystal and a suitable Darlington transistor should be generally available.

For those readers unable to program their own PICs, a ready-programmed PIC16F84A microcontroller can be purchased from **Magenta Electronics** (☎ 01283 565435 or www.magenta2000.co.uk) for the inclusive price of £5.90 each (overseas add £1 p&p). The software is available on a 3.5in. PC-compatible disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 75). 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 Watering Timer**.

Practical Radio Circuits-8

This final installment of the *Practical Radio Circuits* series provides a second mixer/oscillator and i.f. amplifier which, together with last month's Tuner/Mixer front-end, forms a highly selective receiver for shortwave listening. Only the various inductors and ceramic filter will cause any real local sourcing problems. Transistor types are not critical and readers should have no difficulty in finding them or their equivalents shown in the main circuit diagram (Fig.8.1).

The recommended Murata CFU4551T 4kHz bandwidth ceramic filter was purchased (mail order only) from **JAB Electronic Components**, Dept EPE, PO Box 5774, Birmingham B44 8PJ (☎ 0121 682 7045 or www.jabdog.com). Having contacted Murata, the author informs us that they confirm the type numbers listed in Table 8.1 are in current production. However, they have inserted an S into the part numbers (i.e. CFUS4551T), but JAB still know them as listed in the table. If your requirements are less demanding you can, it is suggested, dispense with the filter and link the coupling windings of IFT2 and IFT3 with a 100pF low-k ceramic capacitor.

The above company also supplied all the Toko coils and the BB105 varicap diode. The coils and i.f. transformers are also obtainable from **Sycom**, Dept EPE, PO Box 148, Leatherhead, Surrey KT33 9YW (☎ 01372 372587 or www.sycomcomp.co.uk).

Any point-contact germanium diode should work as the detector diode D2; e.g. OA47, OA90 or OA91. It must, however, be a *germanium* type. Most of our component advertisers should stock a suitable 100µA moving coil panel meter for the Signal-Strength Meter. Try **ESR Components** (☎ 0191 251 4363 or www.esr.co.uk).

All three printed circuit boards are available from the *EPE PCB Service*, codes 428 (I.F. Amp), 429 (Sig. Meter) and 430 (B.F.O./Prod.). See page 75 for prices.

Bedside Nightlight (Top Tenner)

No disagreeable problems should be encountered when shopping for parts of the *Bedside Nightlight*, this month's *Top Tenner* project. Most of the components appear to be "off-the-shelf" items.

Not too sure about supplies of the miniature microphone insert, they seem to have been around for years, for the *Sound Trigger* circuit. However, they are currently listed/stocked by **Sherwood Electronics** (see their advert), **WCN Supplies** (☎ 023 8066 0700) and **Cricklewood Electronics** (☎ 0208 452 0161). We suggest you ask for one with p.c.b. mounting pins for ease of soldering.

The two small printed circuit boards are available from the *EPE PCB Service*, codes 417 (Sound Trig.) and 418 (Timing/Lamp) respectively.

Teach-In 2004 Part 3

No problems are expected to arise from this month's part of the *Teach-In 2004* series. The 741 op.amp i.c., used in the demonstration circuits, is now considered as being "ten-a-penny" and any component supplier should carry stocks. Use the popular ORP12, or its equivalent, for the light-dependent resistor (l.d.r.).

If you have not already purchased parts (see Part 1) for this new series, **Magenta Electronics** (☎ 01283 565435 or www.magenta2000.co.uk) have put together two component kits, including one with a plug-in breadboard; see their ad. on pages 8/9.



INGENUITY UNLIMITED

Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been submitted for publication elsewhere**. The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: *Ingenuity Unlimited*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown Dorset BH22 9ND. (We **do not** accept submissions for *IU* via E-mail.) Your ideas could earn you some cash **and a prize!**



WIN A PICO PC BASED OSCILLOSCOPE WORTH £586

- 100MS/s Dual Channel Storage Oscilloscope
- 50MHz Spectrum Analyser
- Multimeter • Frequency Meter
- Signal Generator

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours. Every 12 months, Pico Technology will be awarding an ADC200-100 digital storage oscilloscope for the best IU submission. In addition, a DrDAQ Data Logger/Scope worth £69 will be presented to the runner up.

SUPER STATIC SNOOPER – CLOSE ENCOUNTERS

THE circuit shown in Fig.1 is an exceedingly sensitive Super Static Snooper. When properly adjusted, it will detect the static created by someone taking off a woollen jersey at a distance of more than two metres – yet at the same time it is immune to transients, to changes in temperature or ambient static charge, and to the switching of relay RLA.

Since static charge on the body will vary considerably, the circuit's behaviour is not always predictable. However, it will virtually always detect a body at close proximity. A special feature is that the metal sensor used may be fairly large. For example, the Snooper worked satisfactorily when clipped to the author's large single-cylinder motorbike.

Circuit Details

In principle, the design is very simple. Its "front end" is a low-noise j.f.e.t. op.amp (IC1), which is balanced by means of an offset-null adjust control (VR1). A small-value capacitive potential divider (C1 and C2) presents approximately half the supply voltage at its non-inverting input.

When a static charge is presented to the metal sensor, this instantly alters the potential at the inverting input – but its effect is

delayed by R1, C1, and C2 at the non-inverting input (pin 3). Thus an imbalance is created, and IC1's output swings low. Note that the circuit is so designed that it is self-adjusting, and may take a minute to settle again if it is fundamentally unsettled by a charge at the metal sensor.

Resistor R3 and capacitor C3 represent a low-pass shunt, which filters out any rapid pulses at IC1's output – in particular mains transients or spurious electromagnetic pulses. Preset VR2 biases IC2's trigger input (at pin 2) to provide much increased sensitivity, and D1, TR1, R4, and C4 take the trigger input "high" – thus disabling it – for a brief moment after IC2 triggers. This ensures that there is some "blanking" of the action of relay RLA, so that it will not upset the extreme sensitivity of the circuit.

In Fig.1, the values of R5 and C5 are nominal, and set the period for which IC2 triggers. The period is calculated by the formula $t = 0.69 \times R5 \times C5$ seconds. If desired, a large-value capacitor may be taken from IC2's reset pin to 0V, and a large-value resistor from the reset pin to +12V to create a delay and allow for settling-in of the circuit at switch-on.

If a mains-to-12V d.c. power supply is used, this should be a *regulated*, "clean" supply, otherwise the parameters of IC1's offset-null may be exceeded. To begin with, try a generous sheet of tin foil for the metal sensor. Make sure that a sound connection is made between the R1/R2 junction and the sensor plate.

Fine Tuning

To set up the circuit, turn both VR1 and VR2 as close to their mid-positions as they will go without triggering the relay (i.e.d. D2 will also illuminate to indicate triggering). Then begin to "fine-tune" the circuit. For very fine tuning, you will need to stand back and let the circuit settle for a minute before making further adjustments.

In the absence of static, the circuit may seem unresponsive. It really comes alive once it has had time to settle, and is presented with even a modest amount of static.

Thomas Scarborough,
South Africa

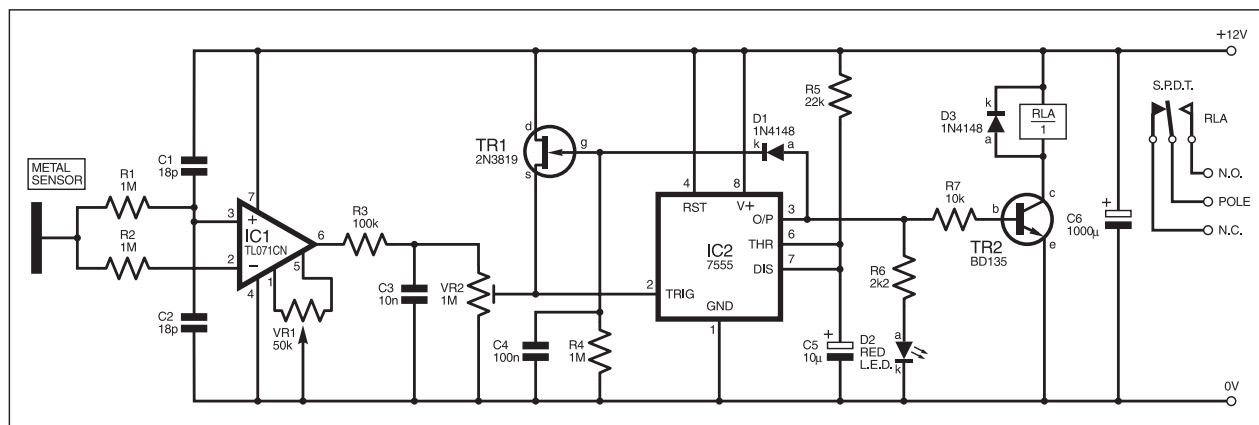
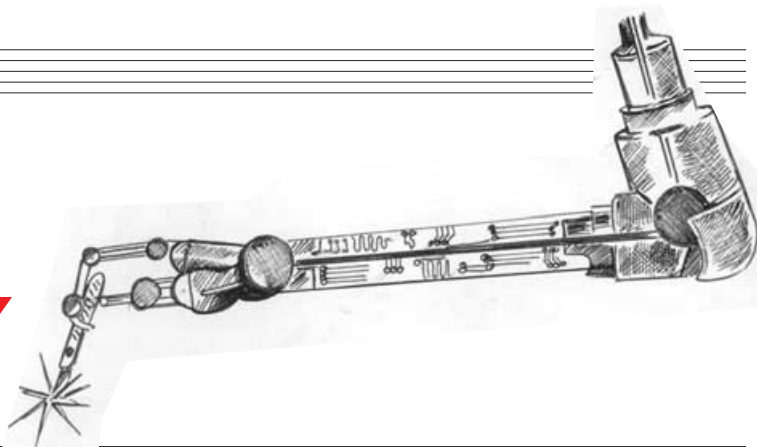


Fig.1. Complete circuit diagram for the Super Static Snooper.

CIRCUIT SURGERY

ALAN WINSTANLEY
and IAN BELL



Our monthly help-desk column shows how the Google Glossary can help you with technical definitions, we look at current sourcing and sinking, and MOSFET operation in linear mode is also outlined.

Source from the Google Glossary

Can anyone tell me the text book definitions of sourcing and sinking current? Thanks from **Steve** (in the EPE Chat Zone message board www.epemag.wimborne.co.uk).

If ever I have needed the definitive "text-book" word for anything then for twenty years I have usually started with the *Art of Electronics* by Paul Horowitz and Winfield Hill, but actually I could not pin down a specific reference there.

Over on the internet then, my next stop was the Google Glossary <http://labs1.google.com/glossary> which returned just one definition for source current, namely the "Conventional current flow out of a DUT with the active load as pull-down". Sink current is defined by Google Glossary as "Conventional current flow into a DUT with the active load as pull-up." A "DUT", the Glossary tells us, is shorthand for 'device under test'.

Note that the glossary is only Google's attempt to pull in third-party definitions from around the web, and usually a number of alternatives are offered by the glossary database. Users must decide for themselves whether there is any common ground amongst Google's various results that will let them settle on a common definition.

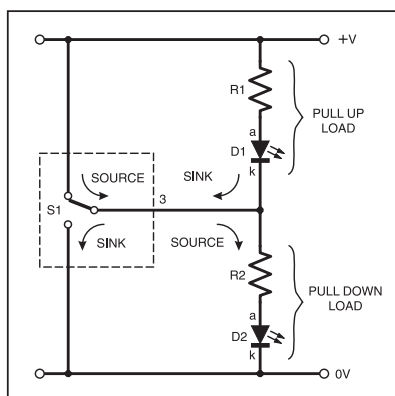


Fig.1. How pull-up or pull-down loads allow sink or source currents to flow.

The basic difference between source and sink current can be illustrated with the 555 timer. The bipolar NE555 type has a rated output source or sink current of 200mA, according to the useful data sheet supplied by SGS Thompson (download from www.st.com). The NE555 data sheet also has a full internal circuit diagram of the timer, which highlights what goes on at the output stage.

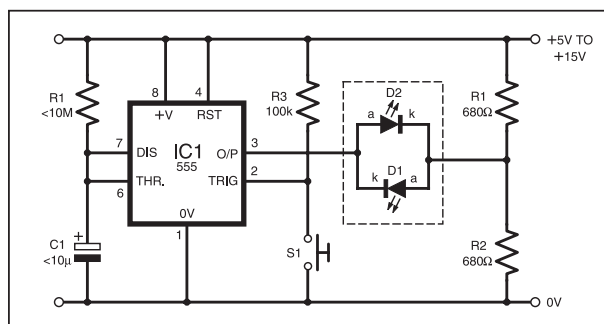


Fig.2. A 555 alternating-l.e.d. flasher uses source and sink currents through pin 3.

By connecting the 555 as an astable multivibrator, a simple alternating l.e.d. flasher can be produced which relies on the fact that the 555 will both source and sink current. In Fig.1, l.e.d. D2 will illuminate when the output (pin 3) of the 555 is high. Current flows out of pin 3 and through the l.e.d. to the 0V rail; the diode is considered as a "pull down" load because it "pulls down" the output to the 0V rail. When pin 3 goes low, then current will flow through D1 instead, which acts to pull the output up to V+.

You can consider the output stage to be like a changeover switch that connects pin 3 either to the positive supply or to 0V. This is not a perfect analogy though, because the bipolar i.c. circuit cannot switch from "rail to rail" – even when the output is "low" there may still be some measurable potential which means that D2 may still glow dimly. Similarly when pin 3 is "high" it will not reach the full supply rail voltage. An alternative arrangement using a bi-colour l.e.d. is shown in Fig.2

which combines two l.e.d.s into one package. In general, for clean rail-to-rail switching and lower power consumption, use the CMOS 7555 instead. The data sheets contain graphs that illustrate typical output characteristics at a variety of supply voltages.

Novices should note that just because a device output is "low", it does not mean that it can be used to sink much current to 0V,

because it depends on the internal design and technology used. Conversely, the output being "high" does not guarantee that you can draw much significant current from it either.

Often overlooked is that fact that some devices are actually only intended ever to sink current, a good example being traditional TTL bipolar 7400 series logic gates. A TTL logic

"high" output was not designed to drive, say, an l.e.d. pull-down load: the gates were better at sinking current because they had an internal transistor connecting to ground. Often with these things, it's only experience and checking data sheets that reveals to the hobbyist the various characteristics and correct operating modes. A.R.W.

Linear MOSFETS

Some time ago we looked at MOSFETs and their driver circuits for switching loads on and off. The physics of the MOSFET including proprietary variants such as the HEXFET were given in the January 2003 column. Following this we were asked about the *linear* operation of MOSFETs. We assume this meant use in *linear amplifiers*, although the phrase could be ambiguous as they have two main modes (or regions) of operation – **saturated** and **linear**. In this month's *Surgery* we look at the various regions of operation of MOSFETs before looking at linear circuits.

Linear amplifiers use the MOSFET in the saturated regions. In the linear region however the MOSFET acts as a voltage controlled resistor: for this reason the linear region is also known as the *ohmic* region. Of course, MOSFETs may be also be turned off and non-conducting (also known as the *cutoff* mode or region); digital MOS circuits and drivers can switch the devices quickly between saturation and cutoff.

Another MOSFET region of operation, which has received a lot of attention in the last few years in the i.c. design world, is known as the *subthreshold* region and involves using the device just below what is usually regarded as the “point of conduction”. This allows a very low current operation that can be very useful in today’s high performance, battery powered, mobile electronic devices.

Readers familiar with valves (vacuum tubes) may notice a correspondence with the behaviour of MOSFETs. For valves the saturation region is called the *pentode* region and the linear region is called the *triode* region.

Recap

Before going any further we should recap the operation of the MOSFET. Fig.3 shows a simplified cross section of a device in which we can see four terminals: *source*, *drain*, *gate* and *bulk*. Most discrete devices have only three terminals because the bulk – the silicon substrate in which the device is formed – is internally connected to the source. More generally the device can be fully symmetrical, in which case it is only the *direction of current flow* that determines the difference between source and drain. The bulk terminal can be controlled separately (and it is, in some i.c. designs).

If we apply zero, low or negative gate-source voltage then the device is turned off because the source-bulk-drain *n-p-n* regions act as two back-to-back diodes. Here, “*n*” and “*p*” refer to the type of chemical used to “dope” pure silicon to create interesting semiconductor behaviour. *N*-type silicon has more electrons free to take place in conduction than in pure silicon, *p*-type has fewer electrons, but these gaps can be regarded as mobile “holes” which act like positively charged versions of the electrons in the *n*-region. Placing an *n*-region next to a *p*-region creates a *pn*-junction, also known as a diode junction, through which current can usually flow in one direction only.

If we apply a positive gate-source voltage to the *n*-channel MOSFET, then the electrostatic attraction of this gate voltage will pull (negatively-charged) electrons from the nearby silicon to the *p*-type region just under the gate. Once we have sufficient electrons here the region will *behave as if it is n-type silicon*. At this point we will have a created a *n*-type channel connecting the *n*-type drain and source regions, thus we have an *n-n-n* path from source to drain, rather than the *n-p-n* back-to-back diodes previously described.

Conduction can now take place from source to drain. The transistor is switched on and the gate-source voltage at which this occurs is the *threshold voltage*, V_T .

Linear Circuit Operation

This explanation may be sufficient if all we need is a digital gate or simple on/off

power control – we can select conducting or non-conducting by switching the gate between two appropriate voltages, which is a typical application for a simple MOSFET switch capable of driving heavy loads.

For linear circuits, we need to know a little more detail. The creation of the conducting channel requires the gate-to-channel voltage to be larger than the threshold voltage. If both the source and drain are at 0V the situation is simple, but if a voltage (V_{DS}) is also applied between source and drain (the usual situation in a linear circuit) then the voltage difference between the gate and channel changes as we “move along” the channel from source to drain.

Imagine that we have applied sufficient gate voltage to create the conducting channel ($V_{GS} > V_T$) and that both the drain and source voltage are at 0V. We now increase the drain voltage, keeping the gate voltage the same. At first the channel behaves more or less like a resistor – increased drain voltage resulting in a proportional increase in drain current.

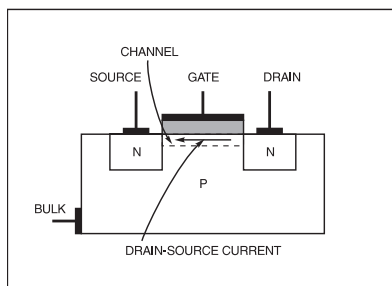


Fig.3. Schematic cross-section of a MOSFET. Note the current-carrying “channel” that allows drain-source current to flow.

The conductivity of the channel depends on how far above the threshold voltage V_{GS} is above threshold (i.e. the value of $V_{GS} - V_T$). For sufficiently small values of V_{DS} the resistance of the FET is more or less inversely proportional to $(V_{GS} - V_T)$ and device acts as linear voltage variable resistor.

As we further increase V_{DS} the drain voltage starts to have a significant impact on the gate-to-channel voltage. As V_{DS} increases the gate-to-channel voltage at the drain end of the device diminishes. For example if V_{GS} is 2V and $V_{DS} = 1V$, with the source and bulk at 0V then the gate-to-channel voltage at the source end is 2V, but it is only 1V at the drain end. This tends to reduce conductivity at the drain end of the channel, increasing its effective overall resistance.

When V_{DS} is increased beyond the point at which it is equal to $(V_{GS} - V_T)$ the gate-to-channel voltage at the drain end will be less than the threshold voltage. This does not cut off conduction, but causes the channel to reduce to a very narrow region at the surface of silicon just under the gate oxide.

Now as V_{DS} is further increased we have two opposing effects: firstly the increase in V_{DS} tends to increase the drain current, and secondly the decrease in effective gate-to-channel voltage tends to reduce drain current. These two effects more or less balance one another resulting in a constant drain current for a given V_{GS} irrespective of changes in V_{DS} . The channel is said to be *saturated*, hence the term saturation region.

The graph in Fig.4 shows the **output characteristic** of the MOSFET. The graph shows how drain current (I_D) varies with drain-source voltage (V_{DS}) for four different values of gate-source voltage V_{GS} (each of the V_{GS} curves is for a V_{GS} greater than the threshold voltage, otherwise I_D would be zero). The graph is divided into the linear and saturation regions.

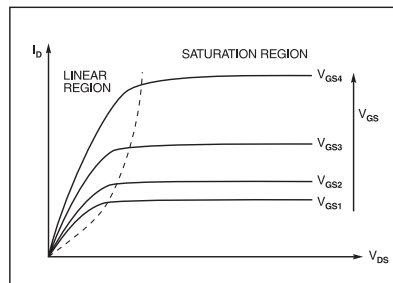


Fig.4. Idealised output characteristics for a MOSFET transistor.

If we look at one of the curves for a particular V_{GS} value we see that in the linear region, for very small values of V_{DS} , increases in V_{DS} result in a proportional increase in I_D . In this region the MOSFET behaves like a *resistor*. As V_{DS} is further increased the rate of increase of I_D slows down and as we enter the saturation region the curve flattens out to a plateau. Then, changes in V_{DS} do not change I_D , so for a fixed V_{GS} the MOSFET acts as a *constant current source*. In this region the drain current is completely controlled by V_{GS} and it is this behaviour that is exploited when making linear amplifiers.

In practice the behaviour of the MOSFET is a little more complex than described; for example the drain current is not completely constant for a given V_{GS} in the saturation region. However, we hope our basic view of the device should help with understanding basic MOSFET circuits. *I.M.B.*

Electric Meter

Regular readers who remember the *EPE* project *PIC Electric Meter* (February and March 1996) may be interested in a device that I have been experimenting with: the Wattage and Current Meter marketed by Brennenstuhl is a standard mains wall adaptor with liquid crystal display of power consumption in watts, kilowatt-hours and actual cost, so that the operating costs of electrical devices can be monitored. However, it also includes a mains voltage and frequency meter, and provides present current consumption and power factor ($\cos \phi$) values. Simply plug the appliance into the monitor and check the display.

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