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PROJECTS . . . THEORY . . . NEWS . . .
COMMENTS . . . POPULAR FEATURES . . .

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Cover illustration by Jonathan Robertson

EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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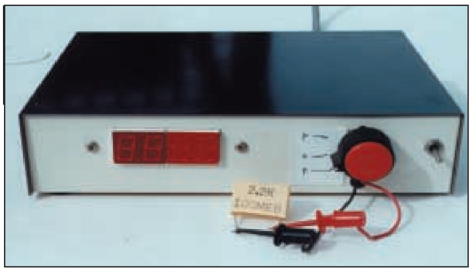

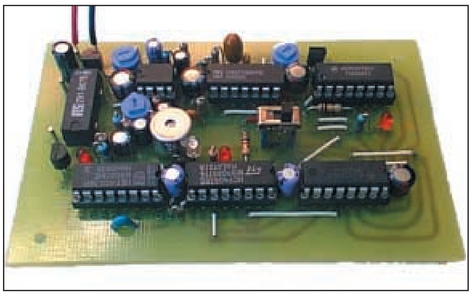

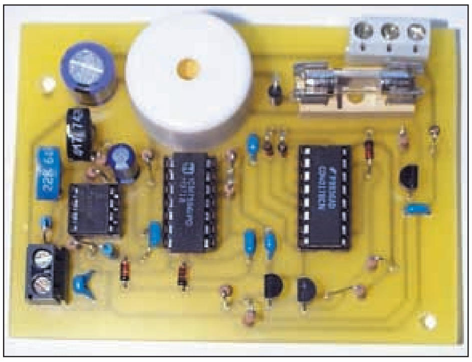

Projects and Circuits

Series and Features

Regulars and Services

FREE 16-PAGE SUPPLEMENT

Our December 2001 issue will be published on Thursday, 8 November 2001. See page 751 for details

NEXT MONTH

PIC POLYWHATSIT

PIC Polywhatsit is a novel microcontrolled compendium of some of the typical delay-based musical effects that amateur musicians have delighted in employing across many decades: echo, reverberation, phasing, flanging, chorus, vibrato, pitch multiplying, pitch halving, reverse tracking.

Despite the sophistication of modern electronic musical instruments, amateur musicians continue to enjoy enhancing their simpler instrument playing and vocalisations with auxilliary units that perform the first six functions, especially as they can be realised easily and inexpensively!

The last three are perhaps not widely encountered, but as anyone who has heard them in operation will affirm, they can add considerable interest, and even humour, when used in moderation. They are particularly easy to achieve in the design described next month.

MARCONI

This year has seen the 100th Anniversary of the first transatlantic radio transmissions. We look at the man behind this momentous achievement, Gugliemo Marconi.

During his lifetime, Marconi did more than any other person to advance the technology of radio. Although he was not a theoretical scientist, he had a very inventive mind and never let obstacles prevent him from reaching his goal. It was these qualities that enabled him to achieve greatness, and receive his rightful place in history.

TWINKLING LIGHTS

Be a star this Christmas with our highly effective Twinkling Lights project. Uses simple circuitry to control up to four strings of "fairy" lights to provide a beautiful "random" twinkling effect for your tree.

Can also be used for disco or similar purposes, a single coloured spot lamp (60W rating maximum) could be connected to each channel output.

***PLUS*: TEACH-IN 2002, Part 2**
***and* VOL. 30 ANNUAL INDEX**

NO ONE DOES IT BETTER

EVERYDAY PRACTICAL ELECTRONICS
INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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DECEMBER 2001 ISSUE ON SALE THURSDAY, NOVEMBER 8

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PROJECT KITS

Our electronic kits are supplied complete with all components, high quality PCBs (NOT cheap Tripad strip board!) and detailed assembly/operating instructions

● **2 x 25W CAR BOOSTER AMPLIFIER** Connects to the output of an existing car stereo cassette player, CD player or radio. Heatsinks provided. PCB 76x75mm. **1046KT. £24.95**

● **3-CHANNEL WIRELESS LIGHT MODULATOR** No electrical connection with amplifier. Light modulation achieved via a sensitive electret microphone. Separate sensitivity control per channel. Power handing 400W/channel. PCB 54x112mm. Mains powered. Box provided. **6014KT £24.95**

● **12 RUNNING LIGHT EFFECT** Exciting 12 LED light effect ideal for parties, discos, shop-windows & eye-catching signs. PCB design allows replacement of LEDs with 220V bulbs by inserting 3 TRIACs. Adjustable rotation speed & direction. PCB 54x112mm. **1026KT £15.95; BOX (for mains operation) 2026BX £9.00**

● **DISCO STROBE LIGHT** Probably the most exciting of all light effects. Very bright strobe tube. Adjustable strobe frequency: 1-60Hz. Mains powered. PCB: 60x68mm. Box provided. **6037KT £28.95**

● **ANIMAL SOUNDS** Cat, dog, chicken & cow. Ideal for kids farmyard toys & schools. **SG10M £5.95**

● **3 1/2 DIGIT LED PANEL METER** Use for basic voltage/current displays or customise to measure temperature, light, weight, movement, sound levels, etc. with appropriate sensors (not supplied). Various input circuit designs provided. **3061KT £13.95**

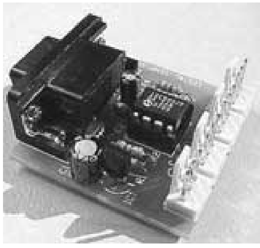
● **IR REMOTE TOGGLE SWITCH** Use any TV/VCR remote control unit to switch onboard 12V/1A relay on/off. **3058KT £10.95**

SPEED CONTROLLER for any common DC motor up to 100V/5A. Pulse width modulation gives maximum torque at all speeds. 5-15VDC. Box provided. **3067KT £12.95**

● **3 x 8 CHANNEL IR RELAY BOARD** Control eight 12V/1A relays by Infra Red (IR) remote control over a 20m range in sunlight. 6 relays turn on only, the other 2 toggle on/off. 3 operation ranges determined by jumpers. Transmitter case & all components provided. Receiver PCB 76x89mm. **3072KT £52.95**

PRODUCT FEATURE

COMPUTER TEMPERATURE DATA LOGGER
PC serial port controlled 4-channel temperature meter (either deg C or F). Requires no external power. Allows continuous temperature data logging of up to four temperature sensors located 200m+ from motherboard/PC. Ideal use for old 386/486 computers. Users can tailor input data stream to suit their purpose (dump it to a spreadsheet or write your own BASIC programs using the INPUT command to grab the readings). PCB just 38mm x 38mm. Sensors connect via four 3-pin headers. 4 header cables supplied but only one DS18S20 sensor.
Kit software available free from our website.
ORDERING: 3145KT **£23.95** (kit form);
AS3145 **£29.95** (assembled);
Additional DS18S20 sensors **£4.95** each



● **SOUND EFFECTS GENERATOR** Easy to build. Create an almost infinite variety of interesting/unusual sound effects from birds chirping to sirens. 9VDC. PCB 54x85mm. **1045KT £8.95**

● **ROBOT VOICE EFFECT** Make your voice sound similar to a robot or Darlek. Great fun for discos, school plays, theatre productions, radio stations & playing jokes on your friends when answering the phone! PCB 42x71mm. **1131KT £8.95**

● **AUDIO TO LIGHT MODULATOR** Controls intensity of one or more lights in response to an audio input. Safe, modern opto-coupler design. Mains voltage experience required. **3012KT £8.95**

● **MUSIC BOX** Activated by light. Plays 8 Christmas songs and 5 other tunes. **3104KT £7.95**

● **20 SECOND VOICE RECORDER** Uses non-volatile memory - no battery backup needed. Record/replay messages over & over. Playback as required to greet customers etc. Volume control & built-in mic. 6VDC. PCB 50x73mm. **3131KT £12.95**

● **TRAIN SOUNDS** 4 selectable sounds : whistle blowing, level crossing bell, 'clickety-clack' & 4 in sequence. **SG01M £6.95**

X FACTOR PUBLICATIONS

THE EXPERTS IN RARE & UNUSUAL INFORMATION!

Full details of all X-FACTOR PUBLICATIONS can be found in our catalogue. N.B. Minimum order charge for reports and plans is £5.00 PLUS normal P&P.

● **SUPER-EAR LISTENING DEVICE** Complete plans to build your own parabolic dish microphone. Listen to distant voices and sounds through open windows and even walls! Made from readily available parts. **R002 £3.50**

● **LOCKS** - How they work and how to pick them. This fact filled report will teach you more about locks and the art of lock picking than many books we have seen at 4 times the price. Packed with information and illustrations. **R008 £3.50**

● **RADIO & TV JOKER PLANS** We show you how to build three different circuits for disrupting TV picture and sound plus FM radio! May upset your neighbours & the authorities!! DISCRETION REQUIRED. **R017 £3.50**

● **INFINITY TRANSMITTER PLANS** Complete plans for building the famous Infinity Transmitter. Once installed on the target phone, device acts like a room bug. Just call the target phone & activate the unit to hear all room sounds. Great for home/office security! **R019 £3.50**

● **THE ETHER BOX CALL INTERCEPTOR PLANS** Grabs telephone calls out of thin air! No need to wire-in a phone bug. Simply place this device near the phone lines to hear the conversations taking place! **R025 £3.00**

● **CASH CREATOR BUSINESS REPORTS** Need ideas for making some cash? Well this could be just what you need! You get 40 reports (approx. 800 pages) on floppy disk that give you information on setting up different businesses. You also get valuable reproduction and duplication rights so that you can sell the manuals as you like. **R030 £7.50**

● **PC CONTROLLED RELAY BOARD** Convert any 286 upward PC into a dedicated automatic controller to independently turn on/off up to eight lights, motors & other devices around the home, office, laboratory or factory using 8 240VAC/12A onboard relays. DOS utilities, sample test program, full-featured Windows utility & all components (except cable) provided. 12VDC. PCB 70x200mm. **3074KT £31.95**

● **2 CHANNEL UHF RELAY SWITCH** Contains the same transmitter/receiver pair as 30A15 below plus the components and PCB to control two 240VAC/10A relays (also supplied). Ultra bright LEDs used to indicate relay status. **3082KT £27.95**

● **TRANSMITTER RECEIVER PAIR** 2-button keyfob style 300-375MHz Tx with 30m range. Receiver encoder module with matched decoder IC. Components must be built into a circuit like kit 3082 above. **30A15 £14.95**

● **PIC 16C71 FOUR SERVO MOTOR DRIVER** Simultaneously control up to 4 servo motors. Software & all components (except servos/control pots) supplied. 5VDC. PCB 50x70mm. **3102KT £15.95**

● **UNIPOLAR STEPPER MOTOR DRIVER** for any 5/6/8 lead motor. Fast/slow & single step rates. Direction control & on/off switch. Wave, 2-phase & half-wave step modes. 4 LED indicators. PCB 50x65mm. **3109KT £14.95**

● **PC CONTROLLED STEPPER MOTOR DRIVER** Control two unipolar stepper motors (3A max. each) via PC printer port. Wave, 2-phase & half-wave step modes. Software accepts 4 digital inputs from external switches & will single step motors. PCB fits in D-shell case provided. **3113KT £17.95**

● **12-BIT PC DATA ACQUISITION/CONTROL UNIT** Similar to kit 3093 above but uses a 12 bit Analogue-to-Digital Converter (ADC) with internal analogue multiplexor. Reads 8 single ended channels or 4 differential inputs or a mixture of both. Analogue inputs read 0-4V. Four TTL/CMOS compatible digital input/outputs. ADC conversion time <10uS. Software (C, QB & Win), extended D shell case & all components (except sensors & cable) provided. **3118KT £52.95**

● **LIQUID LEVEL SENSOR/RAIN ALARM** Will indicate fluid levels or simply the presence of fluid. Relay output to control a pump to add/remove water when it reaches a certain level. **1080KT £5.95**

● **AM RADIO KIT 1** Tuned Radio Frequency front-end, single chip AM radio IC & 2 stages of audio amplification. All components inc. speaker provided. PCB 32x102mm. **3063KT £10.95**

● **DRILL SPEED CONTROLLER** Adjust the speed of your electric drill according to the job at hand. Suitable for 240V AC mains powered drills up to 700W power. PCB: 48mm x 65mm. Box provided. **6074KT £17.95**

● **3 INPUT MONO MIXER** Independent level control for each input and separate bass/treble controls. Input sensitivity: 240mV. 18V DC. PCB: 60mm x 185mm **1052KT £16.95**

● **NEGATIVE\POSITIVE ION GENERATOR** Standard Cockcroft-Walton multiplier circuit. Mains voltage experience required. **3057KT £10.95**

● **LED DICE** Classic intro to electronics & circuit analysis. 7 LED's simulate dice roll, slow down & land on a number at random. 555 IC circuit. **3003KT £9.95**

● **STAIRWAY TO HEAVEN** Tests hand-eye co-ordination. Press switch when green segment of LED lights to climb the stairway - miss & start again! Good intro to several basic circuits. **3005KT £9.95**

● **ROULETTE LED** 'Ball' spins round the wheel, slows down & drops into a slot. 10 LED's. Good intro to CMOS decade counters & Op-Amps. **3006KT £10.95**

● **9V XENON TUBE FLASHER** Transformer circuit steps up 9V battery to flash a 25mm Xenon tube. Adjustable flash rate (0-25-2 Sec's). **3022KT £11.95**

● **LED FLASHER 1** 5 ultra bright red LED's flash in 7 selectable patterns. **3037MKT £5.95**

● **LED FLASHER 2** Similar to above but flash in sequence or randomly. Ideal for model railways. **3052MKT £5.95**

● **INTRODUCTION TO PIC PROGRAMMING.** Learn programming from scratch. Programming hardware, a P16F84 chip and a two-part, practical, hands-on tutorial series are provided. **3081KT £22.95**

● **SERIAL PIC PROGRAMMER** for all 8/18/28/40 pin DIP serial programmed PICs. Shareware software supplied limited to programming 256 bytes (registration costs £14.95). **3096KT £13.95**

● **ATMEL 89Cx051 PROGRAMMER** Simple-to-use yet powerful programmer for the Atmel 89C1051, 89C2051 & 89C4051 uC's. Programmer does NOT require special software other than a terminal emulator program (built into Windows). Can be used with ANY computer/operating system. **3121KT £24.95**

● **3V/1-5V TO 9V BATTERY CONVERTER** Replace expensive 9V batteries with economic 1.5V batteries. IC based circuit steps up 1 or 2 'AA' batteries to give 9V/18mA. **3035KT £5.95**

● **STABILISED POWER SUPPLY 3-30V/2.5A** Ideal for hobbyist & professional laboratory. Very reliable & versatile design at an extremely reasonable price. Short circuit protection. Variable DC voltages (3-30V). Rated output 2.5 Amps. Large heatsink supplied. You just supply a 24VAC/3A transformer. PCB 55x112mm. Mains operation. **1007KT £16.95.**

● **STABILISED POWER SUPPLY 2-30V/5A** As kit 1007 above but rated at 5Amp. Requires a 24VAC/5A transformer. **1096KT £27.95.**

● **MOTORBIKE ALARM** Uses a reliable vibration sensor (adjustable sensitivity) to detect movement of the bike to trigger the alarm & switch the output relay to which a siren, bikes horn, indicators or other warning device can be attached. Auto-reset. 6-12VDC. PCB 57x64mm. **1011KT £11.95** Box **2011BX £7.00**

● **CAR ALARM SYSTEM** Protect your car from theft. Features vibration sensor, courtesy/boot light voltage drop sensor and bonnet/boot earth switch sensor. Entry/exit delays, auto-reset and adjustable alarm duration. 6-12V DC. PCB: 47mm x 55mm **1019KT £11.95** Box **2019BX £8.00**

● **PIEZO SCREAMER** 110dB of ear piercing noise. Fits in box with 2 x 35mm piezo elements built into their own resonant cavity. Use as an alarm siren or just for fun! 6-9VDC. **3015KT £10.95**

● **COMBINATION LOCK** Versatile electronic lock comprising main circuit & separate keypad for remote opening of lock. Relay supplied. **3029KT £10.95**

● **ULTRASONIC MOVEMENT DETECTOR** Crystal locked detector frequency for stability & reliability. PCB 75x40mm houses all components. 4-7m range. Adjustable sensitivity. Output will drive external relay/circuits. 9VDC. **3049KT £13.95**

● **PIR DETECTOR MODULE** 3-lead assembled unit just 25x35mm as used in commercial burglar alarm systems. **3076KT £8.95**

● **INFRARED SECURITY BEAM** When the invisible IR beam is broken a relay is tripped that can be used to sound a bell or alarm. 25 metre range. Mains rated relays provided. 12VDC operation. **3130KT £12.95**

● **SQUARE WAVE OSCILLATOR** Generates square waves at 6 preset frequencies in factors of 10 from 1Hz-100KHz. Visual output indicator. 5-18VDC. Box provided. **3111KT £8.95**

● **PC DRIVEN POCKET SAMPLER/DATA LOGGER** Analogue voltage sampler records voltages up to 2V or 20V over periods from milli-seconds to months. Can also be used as a simple digital scope to examine audio & other signals up to about 5KHz. Software & D-shell case provided. **3112KT £18.95**

● **20 MHz FUNCTION GENERATOR** Square, triangular and sine waveform up to 20MHz over 3 ranges using 'coarse' and 'fine' frequency adjustment controls. Adjustable output from 0-2V p-p. A TTL output is also provided for connection to a frequency meter. Uses MAX038 IC. Plastic case with printed front/rear panels & all components provided. 7-12VAC. **3101KT £69.95**

SURVEILLANCE

High performance surveillance bugs. Room transmitters supplied with sensitive electret microphone & battery holder/clip. All transmitters can be received on an ordinary VHF/FM radio between 88-108MHz. Available in Kit Form (KT) or Assembled & Tested (AS).

ROOM SURVEILLANCE

● ***MTX*** **- MINIATURE 3V TRANSMITTER** Easy to build & guaranteed to transmit 300m @ 3V. Long battery life. 3-5V operation. Only 45x18mm. **B 3007KT £6.95 AS3007 £11.95**

MRTX **- MINIATURE 9V TRANSMITTER** Our best selling bug. Super sensitive, high power - 500m range @ 9V (over 1km with 18V supply and better aerial). 45x19mm. **3018KT £7.95 AS3018 £12.95**

HPTX **- HIGH POWER TRANSMITTER** High performance, 2 stage transmitter gives greater stability & higher quality reception. 1000m range 6-12V DC operation. Size 70x15mm. **3032KT £9.95 AS3032 £18.95**

● ***MMTX*** **- MICRO-MINIATURE 9V TRANSMITTER** The ultimate bug for its size, performance and price. Just 15x25mm. 500m range @ 9V. Good stability. 6-18V operation. **3051KT £8.95 AS3051 £14.95**

● ***VTX*** **- VOICE ACTIVATED TRANSMITTER** Operates only when sounds detected. Low standby current. Variable trigger sensitivity. 500m range. Peaking circuit supplied for maximum RF output. On/off switch. 6V operation. Only 63x38mm. **3028KT £12.95 AS3028 £21.95**

HARD-WIRED BUG/TWO STATION INTERCOM Each station has its own amplifier, speaker and mic. Can be set up as either a hard-wired bug or two-station intercom. 10m x 2-core cable supplied. 9V operation. **3021KT £15.95 (kit form only)**

● ***TRVS*** **- TAPE RECORDER VOX SWITCH** Used to automatically operate a tape recorder (not supplied) via its REMOTE socket when sounds are detected. All conversations recorded. Adjustable sensitivity & turn-off delay. 115x19mm. **3013KT £9.95 AS3013 £21.95**

TELEPHONE SURVEILLANCE

● ***MTTX*** **- MINIATURE TELEPHONE TRANSMITTER** Attaches anywhere to phone line. Transmits only when phone is used! Tune-in your radio and hear both parties. 300m range. Uses line as aerial & power source. 20x45mm. **3016KT £8.95 AS3016 £14.95**

● ***TRI*** **- TELEPHONE RECORDING INTERFACE** Automatically record all conversations. Connects between phone line & tape recorder (not supplied). Operates recorders with 1.5-12V battery systems. Powered from line. 50x33mm. **3033KT £9.95 AS3033 £18.95**

● ***TPA*** **- TELEPHONE PICK-UP AMPLIFIER/WIRELESS PHONE BUG** Place pick-up coil on the phone line or near phone earpiece and hear both sides of the conversation. **3055KT £11.95 AS3055 £20.95**

HIGH POWER TRANSMITTERS

● **1 WATT FM TRANSMITTER** Easy to construct. Delivers a crisp, clear signal. Two-stage circuit. Kit includes microphone and requires a simple open dipole aerial. 8-30VDC. PCB 42x45mm. **1009KT £14.95**

● **4 WATT FM TRANSMITTER** Comprises three RF stages and an audio preamplifier stage. Piezoelectric microphone supplied or you can use a separate preamplifier circuit. Antenna can be an open dipole or Ground Plane. Ideal project for those who wish to get started in the fascinating world of FM broadcasting and want a good basic circuit to experiment with. 12-18VDC. PCB 44x146mm. **1028KT. £22.95 AS1028 £34.95**

● **15 WATT FM TRANSMITTER (PRE-ASSEMBLED & TESTED)** Four transistor based stages with Philips BLY 88 in final stage. 15 Watts RF power on the air. 88-108MHz. Accepts open dipole, Ground Plane, 5/8, J, or YAGI antennas. 12-18VDC. PCB 70x220mm. SWS meter needed for alignment. **1021KT £99.95**

● **SIMILAR TO ABOVE BUT 25W Output. 1031KT £109.95**

BARGAIN BUY!!

30-in-ONE
Electronic Projects Lab

Great introduction to electronics. Ideal for the budding electronics expert! Build a radio, burglar alarm, water detector, morse code practice circuit, simple computer circuits, and much more! NO soldering, tools or previous electronics knowledge required. Circuits can be built and unassembled repeatedly. Comprehensive 68-page manual with explanations, schematics and assembly diagrams. Suitable for age 10+. Excellent for schools. Requires 2 x AA batteries.
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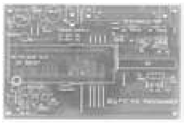
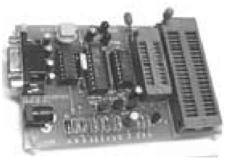
'PICALL' PIC Programmer



Kit will program **ALL** 8*, 18*, 28 and 40 pin serial AND parallel programmed PIC micro controllers. Connects to PC parallel port. Supplied with fully functional pre-registered PICALL DOS and WINDOWS AVR software packages, all components and high quality DSPTH PCB. Also programs certain ATMEL AVR, serial EPROM 24C and SCENIX SX devices. New PIC's can be added to the software as they are released. Software shows you where to place your PIC chip on the board for programming. Now has blank chip auto sensing feature for super-fast bulk programming. *A 40 pin wide ZIF socket is required to program 8 & 18 pin devices (available at £15.95).

Order Ref	Description	inc. VAT ea
3117KT	'PICALL' PIC Programmer Kit	£59.95
AS3117	Assembled 'PICALL' PIC Programmer	£69.95
AS3117ZIF	Assembled 'PICALL' PIC Programmer c/w ZIF socket	£84.95

ATMEL AVR Programmer



Powerful programmer for Atmel AT90Sxxxx (AVR) micro controller family. All fuse and lock bits are programmable. Connects to serial port. Can be used with ANY computer and operating system. Two LEDs to indicate programming status. Supports 20-pin DIP AT90S1200 & AT90S2313 and 40-pin DIP AT90S4414 & AT90S8515 devices. NO special software required – uses any terminal emulator program (built into Windows). The programmer is supported by BASCOM-AVR Basic Compiler software (see website for details).
NB ZIF sockets not included.

Order Ref	Description	inc. VAT ea
3122KT	ATMEL AVR Programmer	£24.95
AS3122	Assembled 3122	£39.95

Atmel 89Cx051 and 89xxx programmers also available.

PC Data Acquisition & Control Unit

With this kit you can use a PC parallel port as a real world interface. Unit can be connected to a mixture of analogue and digital inputs from pressure, temperature, movement, sound, light intensity, weight sensors, etc. (not supplied) to sensing switch and relay states. It can then process the input data and use the information to control up to 11 physical devices such as motors, sirens, other relays, servo motors & two-stepper motors.

FEATURES:

- 8 Digital Outputs: Open collector, 500mA, 33V max.
- 16 Digital Inputs: 20V max. Protection 1K in series, 5·1V Zener to ground.
- 11 Analogue Inputs: 0-5V, 10 bit (5mV/step.)
- 1 Analogue Output: 0-2·5V or 0-10V. 8 bit (20mV/step.)

All components provided including a plastic case (140mm x 110mm x 35mm) with pre-punched and silk screened front/rear panels to give a professional and attractive finish (see photo) with screen printed front & rear panels supplied. Software utilities & programming examples supplied.

Order Ref	Description	inc. VAT ea
3093KT	PC Data Acquisition & Control Unit	£99.95
AS3093	Assembled 3093	£124.95

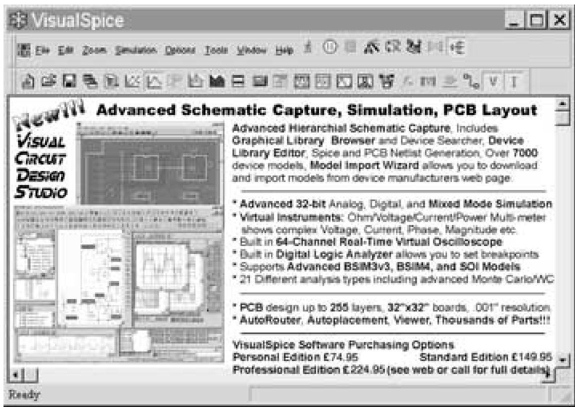
See opposite page for ordering information on these kits

ABC Mini 'Hotchip' Board

Currently learning about microcontrollers? Need to do something more than flash a LED or sound a buzzer? The ABC Mini 'Hotchip' Board 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 little Hot Chip board can be "designed-in" to a project. The ABC Mini Board 'Starter Pack' includes just about everything you need to get up and experimenting right away. On the hardware side, there's a pre-assembled micro controller PC board with both parallel and serial cables for connection to your PC. Windows software included on CD-ROM features an Assembler, BASIC compiler and in-system programmer The pre-assembled boards only are also available separately.

Order Ref	Description	inc. VAT ea
ABCMINISP	ABC MINI Starter Pack	£64.95
ABCMINIB	ABC MINI Board Only	£39.95

Advanced Schematic Capture and Simulation Software



Serial Port Isolated I/O Controller

Kit provides eight 240VAC/12A (110VAC/15A) rated relay outputs and four optically isolated inputs. Can be used in a variety of control and sensing applications including load switching, external switch input sensing, contact closure and external voltage sensing. Programmed via a computer serial port, it is compatible with ANY computer & operating system. After programming, PC can be disconnected. Serial cable can be up to 35m long, allowing 'remote' control. User can easily write batch file programs to control the kit using simple text commands. NO special software required – uses any terminal emulator program (built into Windows). All components provided including a plastic case with pre-punched and silk screened front/rear panels to give a professional and attractive finish (see photo).

Order Ref	Description	inc. VAT
3108KT	Serial Port Isolated I/O Controller Kit	£54.95
AS3108	Assembled Serial Port Isolated I/O Controller	£69.95

£1 BARGAIN PACKS – Another List

We have nearly 1,000 items of £1 Bargains. A comprehensive list will be available early November. You will get one if we are dispatching goods to you. If not, send us an SAE for this.

UNDER SCALE KNOB, engraved 0-10 for fitting under control knob, 3in. dia., pack of 2. Order Ref: 1074.
TV REMOTE CONTROLS. If it does not suit your TV, you could use it for other projects, FM bug, etc., pack of 2. Order Ref: 1068.
MES BATTEN HOLDERS, pack of 4. Order Ref: 126.
PAX TUBING, ¼in. internal dia., pack of 2, 12in. lengths. Order Ref: 1056.
2M MAINS LEAD, 3-core, black, pack of 3. Order Ref: 1021.
FERRITE SLAB AERIAL with coils, pack of 2. Order Ref: 1027.
WHITE TOGGLE SWITCH, push-in spring retain type, pack of 4. Order Ref: 1029.
HIGH CURRENT RELAY, 24V AC or 12V DC, 3 sets 8A changeover contacts. Order Ref: 1016.
FIGURE 8 MAINS FLEX, also makes good speaker lead, 15m. Order Ref: 1014.
6V SOLENOID with good strong pull, pack of 2. Order Ref: 1012.
IN-LINE FUSEHOLDERS, takes 20mm fuse, just cut the flex and insert, pack of 4. Order Ref: 969.
3·5mm JACK PLUGS, pack of 10. Order Ref: 975.
8µF 359V ELECTROLYTICS, pack of 2. Order Ref: 987.
MAINS PSU, 15V 350mA AC. Order Ref: 934.
15V + 15V 1·5VA POTTED PCB MAINS TRANSFORMER. Order Ref: 937.
12V-0V-12V 6VA MAINS TRANSFORMER, p.c.b. mounting. Order Ref: 938.
EX-GPO TELEPHONE DIAL, rotary type. Order Ref: 904.
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13A ADAPTORS to each take 2 plugs, pack of 2. Order Ref: 820.
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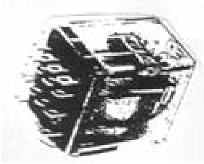
RELAYS



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Coil Voltage	Contacts	Price	Order Ref:
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24V DC	2-pole changeover	£1.50	FR12
24V DC	4-pole changeover	£2.00	FR13
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240V AC	4-pole changeover	£2.00	FR15

Prices include base

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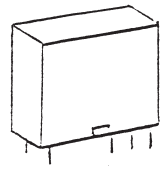

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48V Order Ref: FR20
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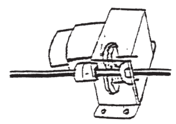

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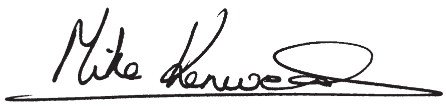
We hope that in the future technology can be used to prevent wanton destruction and that everyone can work towards using high tech skills to make the world a safer and more peaceful place.



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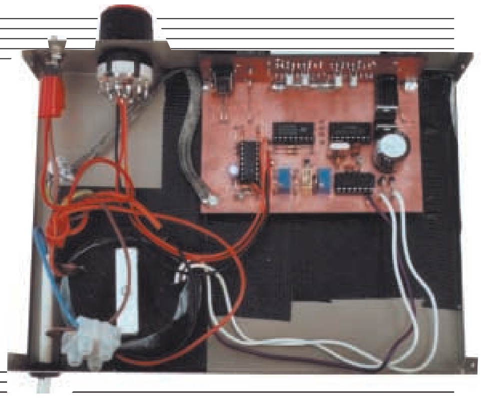
Constructional Project

CAPACITANCE METER

DAVID PONTING



Allows any capacitor type to have its true value readily measured and displayed.

WHILE it has been possible during most of the "electronics age" to measure both potential difference and current flow with good accuracy and from small values to the very large, measurement of capacitance has always presented problems.

Although some modern multimeters have capacitance-measuring capability, this is often limited to a maximum of around 10 microfarads and is often highly inaccurate at both ends of the scale.

However, the simple circuit described here allows all types of capacitor, including non-polarised, electrolytic and tantalum to be measured accurately and over a wide range. It measures capacitance from a few picofarads to 10,000 microfarads in three sub-scales (10nF, 10μF, and 10,000μF) and is accurate across the whole range.

It automatically measures high value capacitors at the low frequencies they are likely to encounter when used as reservoirs for d.c. smoothing. Also, the method for accurately measuring small capacitors is only modified, but not limited, by the stray capacitance of the meter itself.

CR TIMING

The circuit is basically a frequency counter used with two square wave oscillators. The first oscillator generates a fixed frequency, and the second generates a frequency relative to the value of the capacitor to be measured. The counter counts the number of fixed frequency pulses that occur during each cycle of the second oscillator. The displayed result represents the value of the capacitor.

The circuit diagram in Fig.1 shows how an oscillator can be made from three building blocks: an inverter, resistor R and capacitor C. The approximate time (T) for one wavelength of such an oscillator is given by the formula T = 1·1CR. In other words if R is kept constant, T and C are directly proportional: the period of one wavelength is doubled if C is doubled, halved if C is halved, and so on.

Let us consider two of these oscillators. The first, X, uses some convenient resistor and a capacitor marked as 1nF, while Y, the second oscillator, uses values of C and R which result in its producing 1000Hz while X is producing just 1Hz.

A frequency counter connected to the output of the Y oscillator can be started and stopped by the beginning and end transitions of the 1Hz output from oscillator X,

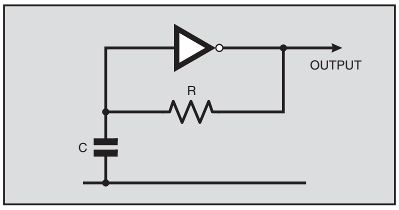


Fig.1. Simplified RC oscillator.

during which period it will count 1000 waveform cycles, i.e. it will measure the frequency as 1000Hz. So the counter's display will now show 1000 and we can say that this represents the 1000 picofarads of the 1nF capacitor used to drive oscillator X.

The accuracy of this result will depend upon a lot of variables but what we can be sure about is that when the 1nF capacitor is replaced by one marked as 2·2nF and the experiment repeated, the new period of a single wavelength from X will last more than twice as long as previously, during which time the counter will count many more pulses from the Y oscillator. In fact, if the 2·2nF component is accurate, the display will now show 2200 and we can interpret this as the capacitor's picofarad value.

Of course all this presupposes that the marked 1nF of the original capacitor used is also accurate. But even if we cannot make this assumption, we can at this stage at least get useful relative values for the capacitors tested.

So now the design problems in making our capacitance meter reduce to accurate calibration, building a frequency counter and creating the simple logic necessary to gate it and its display.

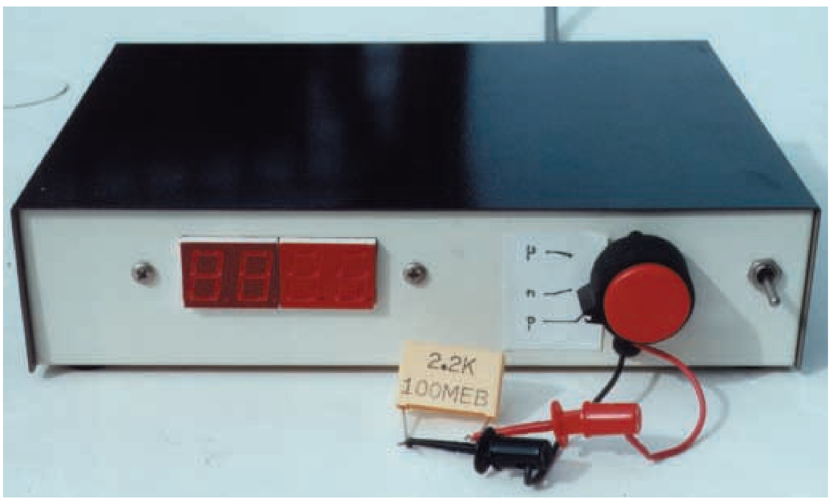
CIRCUIT DIAGRAM

The complete circuit diagram for the Capacitance Meter is shown in Fig.2.

The timing oscillator (equivalent to oscillator X just described) is formed around Schmitt inverter gate IC1a. Capacitor Cx is the component whose value we wish to measure and there are three choices of resistance range formed by presets VR1 to VR3 together with resistors R4 to R6.

Selection of the range is made via switch S1 in conjunction with the dual 4-way multiplexer IC5. The ranges are selectable for measurements in microfarads (μF), nanofarads (nF) and picofarads (pF).

The output of oscillator IC1a (see Trace 2 in Fig.3) is inverted and buffered by the parallel inverters IC1b and IC1c (Trace 3). The resulting output is differentiated by capacitor C1 and resistor R7, to produce



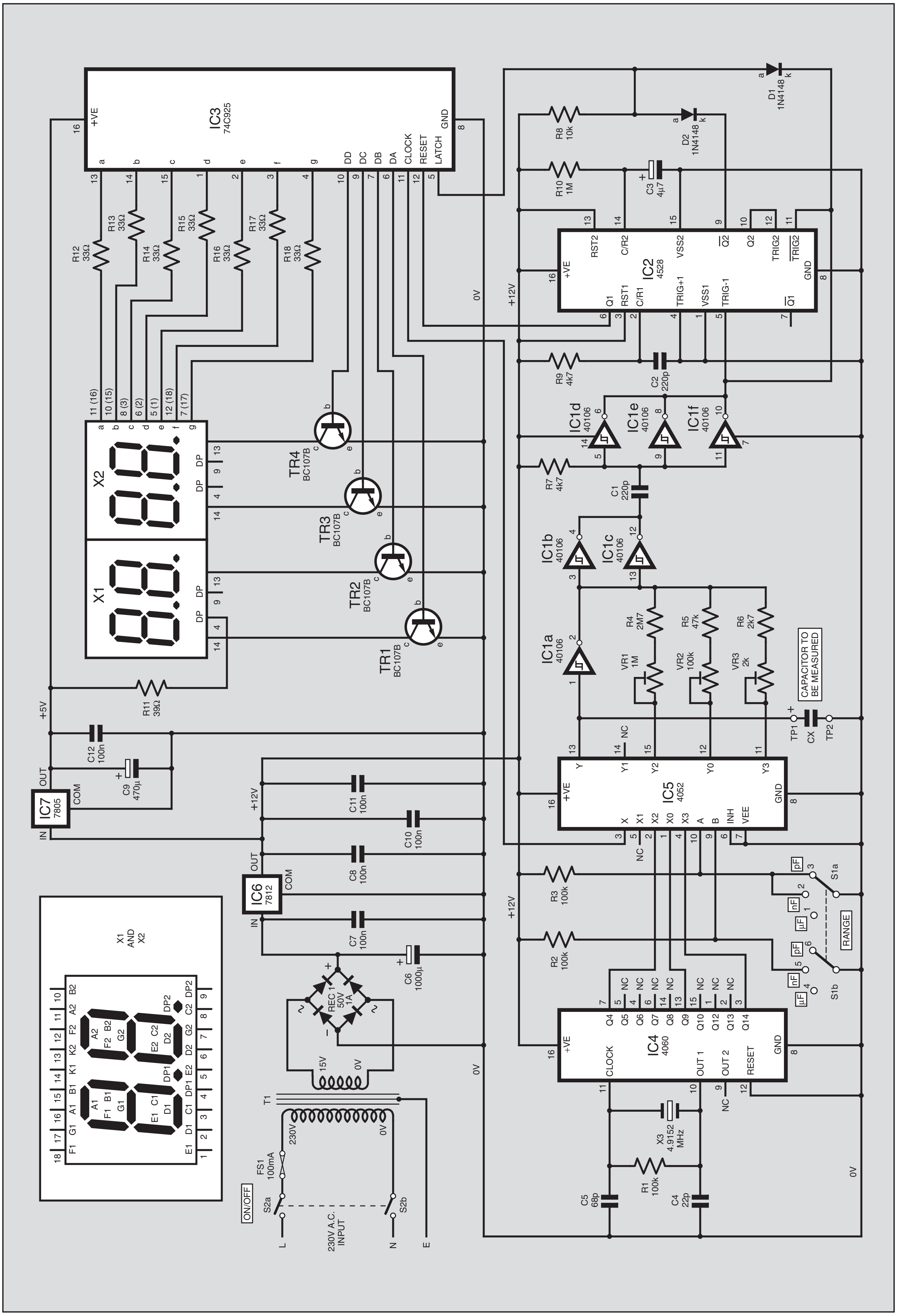


Fig.2. Complete circuit diagram for the Capacitance Meter. The dual display pinouts are shown inset.

the brief pulse waveform shown in Trace 4. This is fed to the three parallel inverters IC1d to IC1f whose output results in the waveform of Trace 5.

Inverters IC1b/IC1c and IC1d to IC1f are paralleled for convenience since the inputs of otherwise unused gates need to be tied to one or other logic level. The paralleled gates also provide increased buffering of the wanted signal.

Two monostables, IC2a and IC2b, are triggered by negative-going pulses from IC1d to IC1f. IC2a produces positive-going pulses from its Q1 output (see Trace 6), which are used to reset counter IC3. The pulse duration is about 1μs, as set by components R9 and C2.

IC2b produces a negative-going pulse at its $\overline{Q2}$ output, having a duration of about one second, as set by components R10 and C3. Feeding back the Q2 output into the trigger input prevents the monostable from being retriggered during its timing period.

Diodes D1 and D2 plus resistor R8 form an AND gate wired so that the pulses from IC1d-f are ANDed with the $\overline{Q}$ output of IC2b. The resultant pulses (Trace 8) control counter IC3's latch input.

It might be thought that triggering the latch would be achieved more conveniently by the direct use of the pulses output from IC1d-f. However, when testing capacitors on the lower ranges this would result in high frequency flickering of the display's least significant digits causing, for example, 0100 to be misread as 0188. ANDing the short and long pulses means that the displays are never updated faster than once a second.

Although Fig.3 is not drawn to scale, it still reveals two important parameters. The first is that the counter's reset pulses (Trace 6) are delayed by the width of the triggering pulses from IC1d-f (Trace 5).

Secondly, both these pulses take up time during oscillator X's waveform period when the counter ought to be counting. Consequently, the combination values of C1/R7 and C2/R9 are as small as possible so that very narrow but still reliable pulses are produced. In practice, the counting time lost due to the width of these pulses can be considered negligible relative to the period of X's waveform cycle.

STANDARD FREQUENCY

The final part of the circuit is for oscillator Y, which provides the standard against which oscillator X is compared.

In the first prototype, oscillator Y was built using a spare inverter with a standard C-R configuration. The thinking was that since both X and Y inverters would be part of the same chip and so be equally affected by any temperature variation, both oscillators would produce proportional frequency changes which would cancel out.

Regrettably, this was not true in practice and it was necessary to settle on the greater stability of crystal control for the standard Y frequencies. Temperature variation can still introduce small errors but these should not amount to more than about one per cent at normal room temperatures.

A type 4060 oscillator/divider, IC4, is used with a 4·9152MHz crystal (X3) to provide three convenient reference frequencies via the second half of multiplexer IC5, selectable by switch S1.

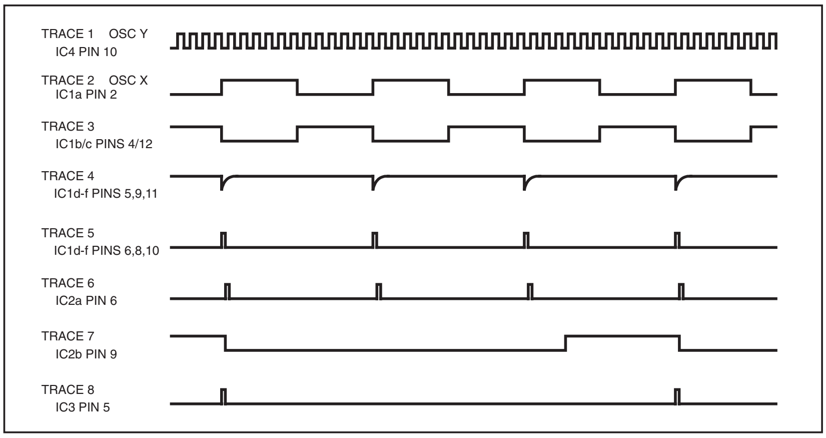


Fig.3. Timing pulses at different points in the circuit.

COUNTER

Pulses from the reference oscillator/divider are fed via IC5 output X to counter/decoder IC3, a 74C925 device. IC3's four internal decade counters count the pulses while its reset pin is held low. On receipt of a positive-going latching pulse, the count total reached at that moment is latched into internal registers.

The registers are internally multiplexed and cyclically output the count values in a form suitable for driving four 7-segment displays via outputs *a* to *f*. Outputs DA to DD control transistors TR1 to TR4 to switch on the correct display digit at the right time.

This multiplexing operates at a refreshment rate of about 1000 times per second, which of course the eye perceives as continuous. Resistors R12 to R18 limit current flow through the seven segments. The decimal point of the most significant digit, X1, is turned permanently on via ballast resistor R11. The transistors do not require base resistors since current-limiting is automatically provided by IC3.

The count continues for as long as reset pin 12 is held low, and the new total will be displayed and latched every time pin 5 is taken high and then low again. Taking pin 12 high resets the counter and the display to zero.

POWER SUPPLY

The power supply circuit is also shown in Fig.2. Transformer T1 has a secondary winding whose 15V a.c. output voltage is rectified by bridge rectifier REC1. Capacitors C6 and C7 smooth the resulting d.c. which is then regulated down to +12V by IC6. This supplies power for the circuit around IC1, IC2, IC4 and IC5. Regulator IC7 then reduces the 12V to +5V to supply counter IC3.

Capacitors C8 to C12 decouple the power lines at appropriate places on the printed circuit boards.

It is worth noting that a well smoothed and stable 12V d.c. supply is essential to this design since the frequency of the X oscillator is a function of the positive supply voltage.

CONSTRUCTION

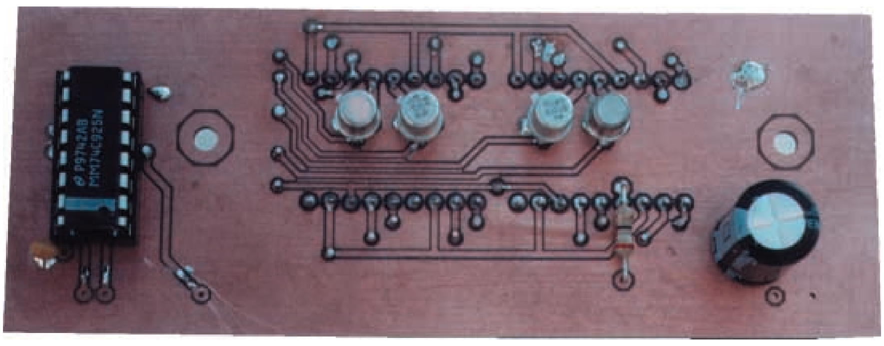
This design is mains powered and its construction should only be undertaken by those who are suitable experienced.

There are two double-sided printed circuit boards (p.c.b.s) for the Capacitance Meter. They are both available from the *EPE PCB Service*, codes 323 (Main) and 324 (Display). Their component layout and tracking details are shown in Fig.4, Fig.5, Fig.6 and Fig.7.

If you purchase your p.c.b.s. from *EPE*, small pieces of interconnecting wire ("vias'') must be soldered to opposite pads on both surfaces at the points where top and bottom tracks need to be joined.

Four of these vias lie underneath the 7-segment displays so they need to be wired early in the construction. For these four in particular, surplus linking wire and solder must be trimmed close to the surface of the board to allow proper seating of the displays.

Tracks and the earth planes are often very close together and great care is needed to avoid solder migrating from track to track or earth. To avoid heating adjacent copper, use a soldering iron temperature of



Component side of the prototype Display board (which differs slightly from the final).

200°C or 400°F if you can control the tip temperature, or a low wattage heating element if you cannot, and a very sharp tip.

Sockets should be used for all the dual-in-line (d.i.l.) i.c.s. Note that some components are mounted vertically and that three inter-board links have to be made when the boards are soldered together (see photo).

It is best to set the multiturn trim-potentiometers (VR1 to VR3) to their mid-positions before soldering them into the board since the position of the wipers cannot be seen and *in situ* resistance measurement may be distorted by adjacent components.

ON DISPLAY

The displays are mounted on one side of their board while the other components are mounted on the reverse. It is best to solder in the displays after the other components have been installed.

One leg of capacitor C12 needs to be soldered on both faces of the board and one leg of both R11 and R18 need to be surface-soldered to the track on the same side of the board on which they are mounted. Similarly the four transistors are surface mounted on the rear of the display panel.

The suggested resistance for R4 is 2M7 ohms but the author found considerable variation in the needed value for the VR1/R4 combination depending upon the manufacturer of the 40106 used for IC1. Consequently, the value of R4 may need to be modified and this component should not be permanently wired in until the board has been completed and fully tested.

Capacitor test leads are brought out through the front panel, via a hole protected by a grommet. They should be terminated by red and black probe clips, to indicate the correct polarity (black to capacitor –VE, red to capacitor +VE when polarity is important).

MAINS CONNECTIONS

The mains cable should be brought into the case via a clamping grommet. Although not used on the prototype, a rear-panel mounted fuseholder and 100mA fuse should be included, wired as shown in Fig.6.

The transformer should be firmly bolted to the base of the case, and the mains earth lead soldered to a crimp tag secured to one of the transformer bolts.

All mains connections should be covered by insulating tape to prevent accidental contact with them.

SETTING UP

When construction is complete and fully checked, the two p.c.b.s should be link-wired together at four points: 5V to 5V, and the tracks from pins 5, 11 and 12 of IC3 to their counterparts on the components board. Solder together the ground planes of both boards in order to make the 0V link and to provide rigidity to the assembly.

Before inserting any d.i.l. i.c.s, check that the power supply is working correctly, *ensuring that you take adequate safety precautions due to the presence of mains voltages*.

Check that +12V is present at the output of IC6, and +5V is present at the output of IC7. Switch off immediately if the correct voltages are not present and recheck your assembly.

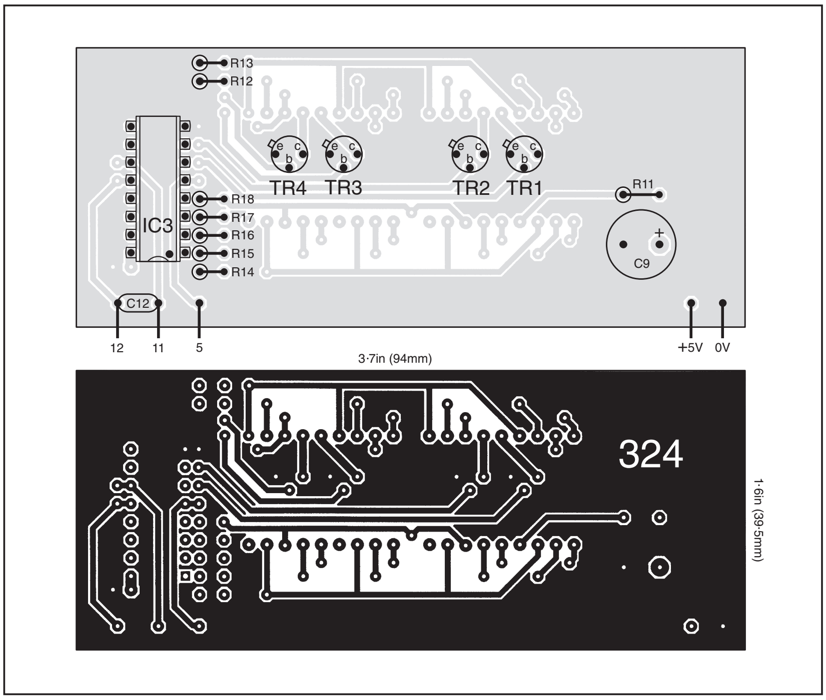
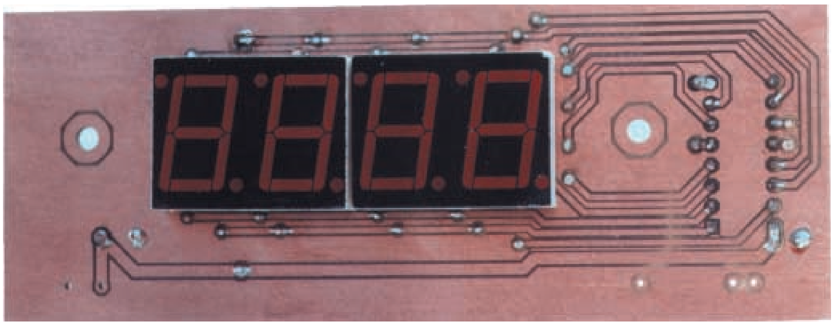


Fig.4. Display p.c.b. underside component layout and foil master.



Prototype Display printed circuit board.

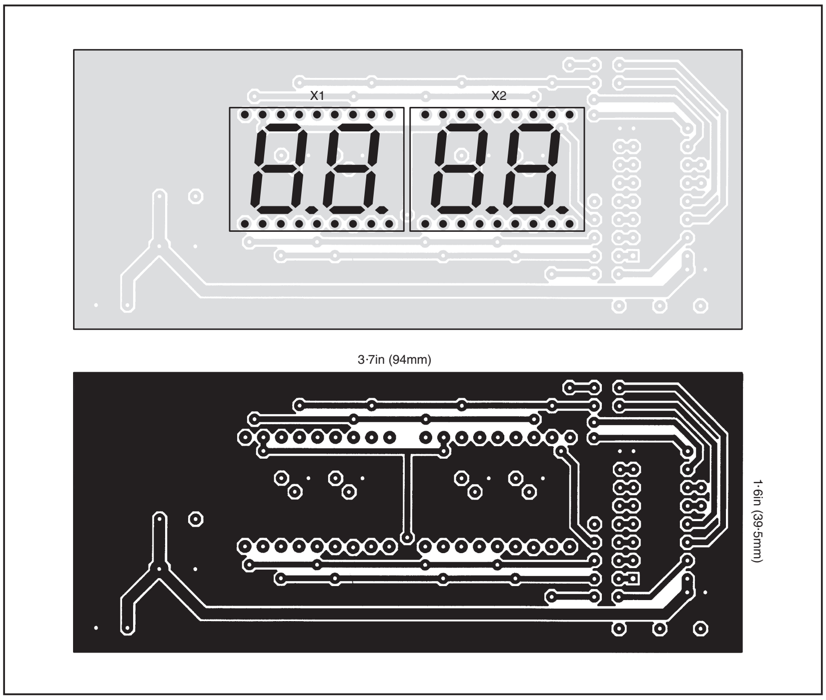


Fig.5. Dual 7-segment display mounted on the Display board and full-size topside copper foil master pattern.

COMPONENTS

See SHOP TALK page

Resistors

R1 to R3	100k (3 off)
R4	2M7 (see text)
R5	47k
R6	2k7
R7, R9	4k7 (2 off)
R8	10k
R10	1M
R11	39Ω
R12 to R18	33Ω (7 off)

Potentiometers

VR1	1M multiturn, vertical adjustment
VR2	100k multiturn, vertical adjustment
VR3	2k multiturn, vertical adjustment

Capacitors

C1, C2	220p polyester (2 off)
C3	4µ7 radial elect. 16V
C4	22p polyester
C5	68p polyester
C6	1000µ elect, 35V
C7, C8, C10 to C12	100n ceramic (5 off)
C9	470µ elect. 16V

Semiconductors

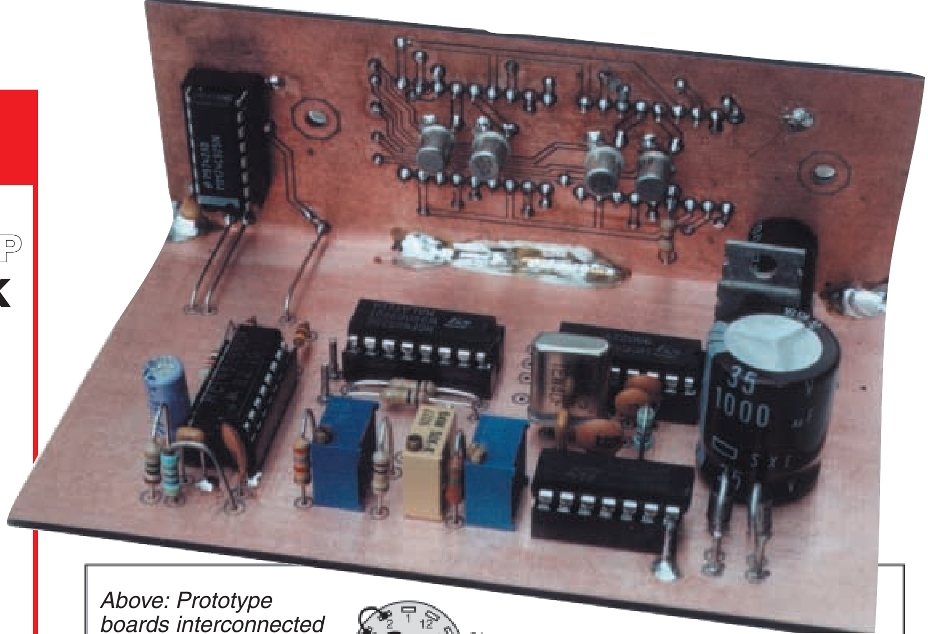
D1, D2	1N4148 signal diode (2 off)
REC1	50V 1A bridge rectifier
TR1 to TR4	BC107B or similar gen. purpose *npn* transistor (4 off)
IC1	40106 hex Schmitt inverter
IC2	4528 dual monostable
IC3	74C925 4-digit counter-driver
IC4	4060 14-stage binary counter
IC5	4052 2-pole 4-way multiplexer
IC6	7812 +12V 1A voltage regulator
IC7	7805 +5V 1A voltage regulator

Miscellaneous

FS1	panel-mounting 20mm fuseholder and 100mA fuse
S1	4-pole 3-way rotary switch
S2	d.p.s.t. or d.p.d.t. mains switch, 1A
T1	mains transformer, 15V a.c. secondary 3VA
X1, X2	dual 7-segment, common cathode l.e.d. display (2 off)
X3	4·9152MHz crystal

Printed circuit boards, available from the *EPE PCB Service*, code 323 (Main), 324 (Display); 14-pin d.i.l. socket; 16-pin d.i.l. socket (4 off); metal case to suit; knob; mains cable clamping grommet; grommet for test leads hole; probe clips, one each red and black; insulating tape; connecting wire; solder, etc.

Approx. Cost Guidance Only £42 excluding case



Above: Prototype boards interconnected (differs slightly from final version).

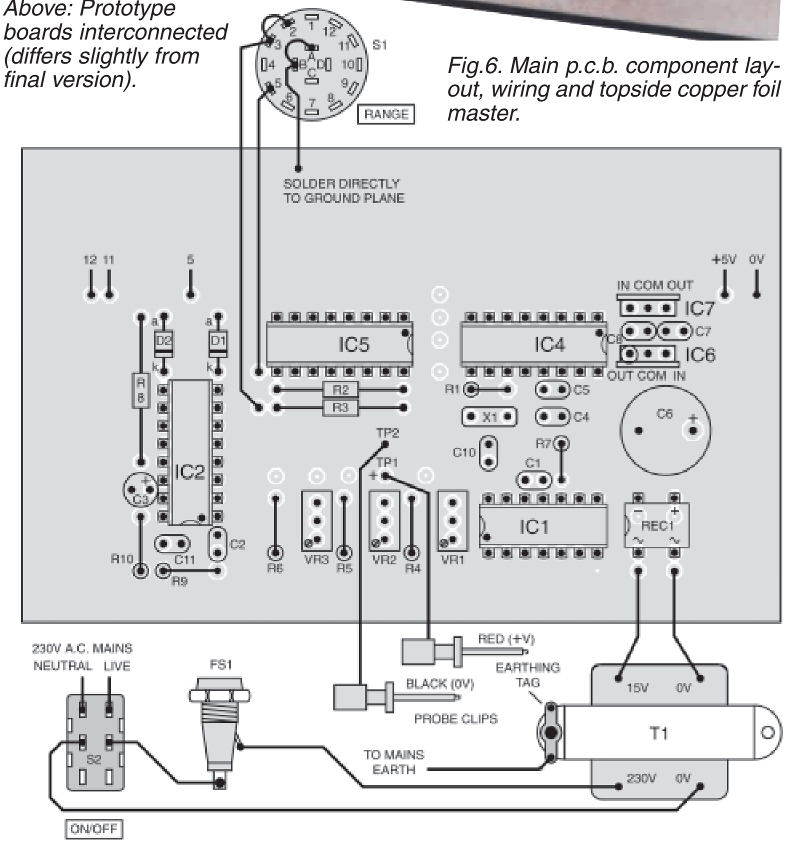
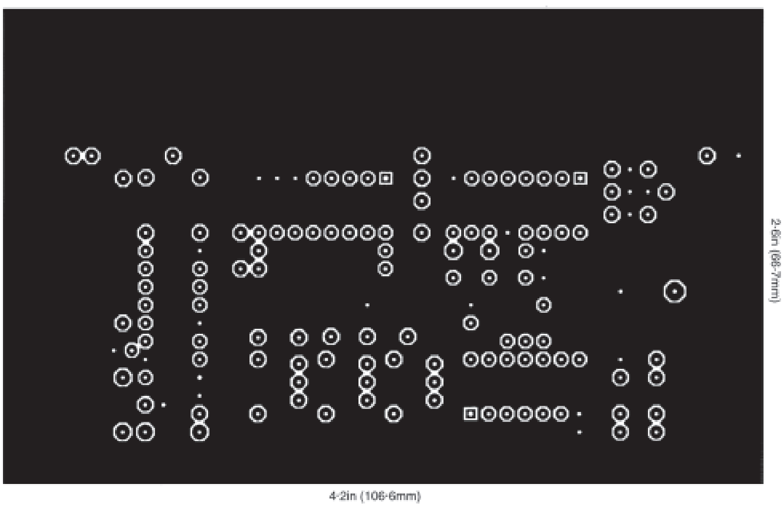


Fig.6. Main p.c.b. component layout, wiring and topside copper foil master.



With no capacitor connected, select the Picofarad range and switch on. The display should show a low value reading. On the prototype it was 0030 and this represents 30pF of stray capacitance caused by the Capacitance Meter itself.

Keeping leads short to the capacitor under test will minimise this figure but its value is of little importance since it can easily be subtracted from all the readings taken when the range is set to picofarads. For higher ranges this error becomes insignificant.

FIRST CALIBRATION

Calibrating the picofarad range should ideally be done using a 1000pF one per cent silvered mica capacitor, adjusting VR1 until the meter reads 1000, plus the amount of stray capacitance. If necessary, by experiment select a different value for resistor R4 if VR1 cannot be adjusted to provide the correct reading.

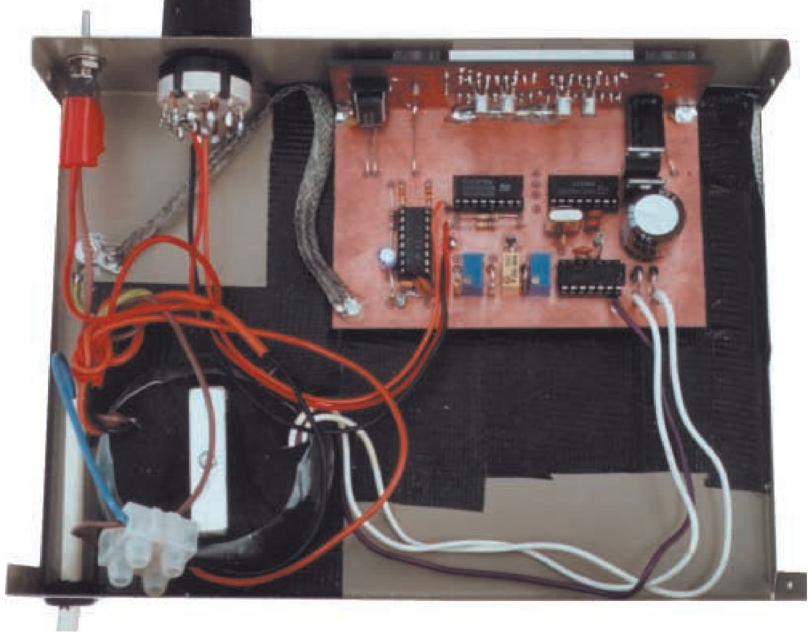
If a one per cent capacitor is not available, it is possible to get very good and ultimately highly accurate readings by an averaging method, using a wide selection of broader-tolerance capacitors in the range being set up.

With VR1 set to its mid-position, use the meter to read and tabulate the displayed values of all the capacitors against their marked values. Even after one set of readings it should be obvious whether in general the values are all too high or too low.

If discrepancies are all or mostly in the same general direction, slightly adjust VR1 and measure again. Repeat this until readings generally fall into line. Remember that capacitors on this range need to have their readings reduced by the value of the stray capacitance. Also consider that more weight should be given to the reading of a modern quality capacitor rather than the one salvaged from your first black-and-white telly!

Keep in mind that, other than some one per cent polystyrene and silvered mica types, modern capacitors in this range usually carry tolerances of either five or ten per cent. Check your catalogues to determine the expected accuracy of the ones you are using for these tests.

All readings on the picofarad scale are up-dated every second or so and a small variation in the lower digits of the count is to be expected.



General component positioning inside the prototype Capacitance Meter. Note the "earthing" braiding from the p.c.b. to the main case earth tag.

When adjustment of VR1 and R4 have allowed calibration of the picofarad scale, solder R4 in permanently.

FURTHER CALIBRATION

Now choose a good quality, mid-range capacitor (say 1nF to 4·7nF), measure and record its value and then carefully put it away for future re-calibration if necessary.

Adjusting any one trim-potentiometer has no effect on the setting of the other two so the order in which the ranges are calibrated is immaterial. Choose a capacitor value that falls within the range selected.

Adjust VR2 to set up the 9·999 (10) microfarad range and adjust VR3 for the 9·999 (10,000) microfarad range. It is suggested that for these ranges also, two "standard" capacitors are subsequently selected, their measured values recorded on them, after which they should be safely stored.

Remember that the face value of large capacitors can be very inaccurate indeed, differing from their real capacity by 50 per cent or even more!

RECONDITIONING

Capacitors left unused for long periods lose form and need to be "reconditioned" before their real capacitance is reached. Using this meter to measure the component will help reform it and, while this is happening, you will see a slight drift during the short interval before a stable value is achieved. Any regular drifting in readings over a long period should make you suspicious of a capacitor's quality.

A somewhat similar but reverse problem will be encountered when measuring the largest capacitors. For these, the waveform period of oscillator X will be very long and you may need to wait for perhaps half a minute or so before a reading appears, and even that is not likely to represent the real capacitance.

Just connecting test leads to the capacitor will create a stream of extraneous pulses and so the first reading will probably be far too high. Add the "reconditioning" factor and you may have to wait for the third or fourth reading before it becomes stable and repeatable.

Polarised capacitors need to be connected with their negative side joined to the Earth test lead.

DESIGN THOUGHTS

While developing this design, the author frequently came up against problems connected with needing to use components close to the limit of what is conveniently available and practically sensible. For example, starting with the X oscillator, the requirement for resistance R was determined experimentally when measuring capacitance in the lowest range.

Resistance R clearly had to have a large value in order that X would produce a low

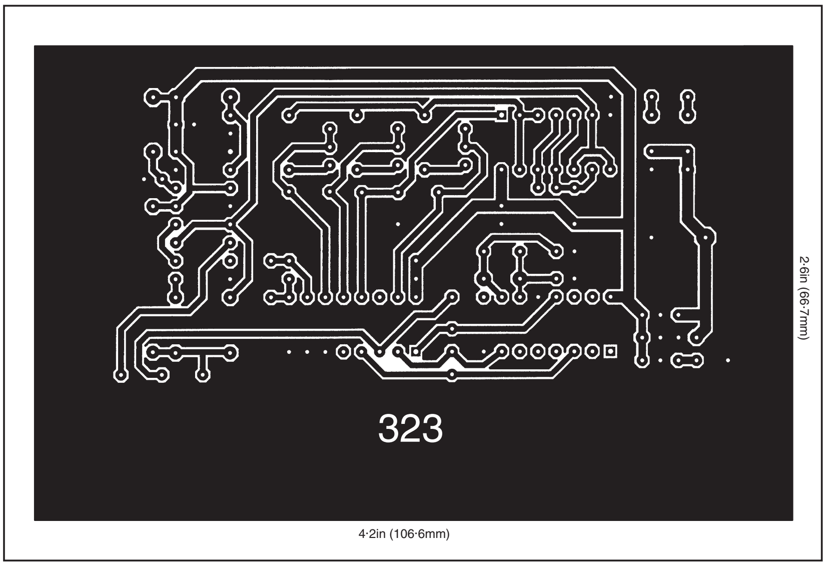


Fig.7. Full-size foil master for the Main board topside.

enough frequency for oscillator Y's output to be feasible, bearing in mind that the latter has to run faster than X by a factor of 1000. It was found that R had to be somewhere around 3M3 ohms, close to a reasonable limit but a potential source of hum pickup.

Using a 3M3 ohms resistor and a 1nF capacitor, the frequency of oscillator X was found to be 307Hz. This meant that oscillator Y had to provide a frequency of 307,000Hz. This figure was then repeatedly multiplied by two until the result was close to the value of an easily available crystal.

In fact, 16 times 307,000 gave 4,912,000, close enough to a standard 4,915,200 crystal. Using this with a 4060 oscillator/divider resulted in an output of 307,200Hz at pin 7. The small difference is accommodated by varying the value of R with VR1.

That solved the problem for the lowest range on the meter. The next step was consideration of the highest range.

It would have been convenient if the output from Y could be the same frequency for all ranges, with a variable R in the X oscillator providing the scale changes. But it quickly became evident that this was impossible.

There is a 1,000,000:1 ratio between the highest and lowest ranges. Consequently, if all scale changes were to be achieved by only varying R, which is 3M3 ohms in the lowest range, it would consequently need to be 3·3 ohms for the highest range, when the theoretical charging current becomes 3·6 amps!

The simple answer to this problem was to share the 1,000,000:1 ratio equally between the two oscillators. Consequently R for the X oscillator is divided by 1000 and becomes 3.3kΩ (i.e. the series connection of a 2·7kΩ resistor and an approximately mid-set 2kΩ potentiometer) while the Y frequency also needs to be divided by 1000.

The easiest way of doing this is to divide by 1024 (2^{10}) and allow the 2kΩ potentiometer to adjust for the error. The 4060 i.c. omits division by certain powers of two, but 2^{10} is available at pin 3.

IN THE MIDDLE

This leaves the middle range of the meter which it seems desirable to set half way between the other two. Initially this did not seem very straightforward. What was required was a number which when divided into 3,300,000 ohms gave the same value as when it multiplied 3,300 ohms.

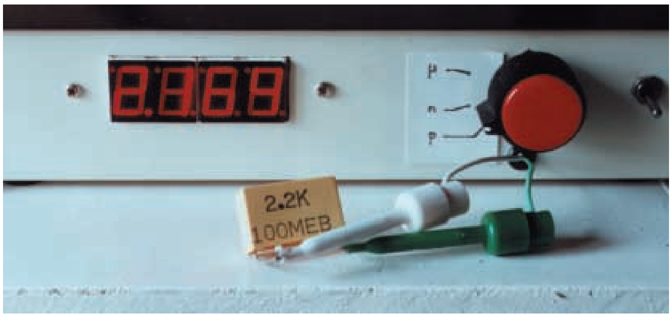
Put like that the answer was obvious: it was the square root of 1000, or approximately 31·6. So the middle value for R becomes 3,300,000 divi-ded by 31·6 which is 104,430, making the series connection of a 47kΩ resistor and a mid-set 100kΩ pot an easy solution. And of course 31·6 is near enough to 2^5 to use the output from pin 13 of the 4060.

DISCHARGING

As a final comment, when large value capacitors are disconnected from the meter after they have been tested, they may very well be fully charged and could remain so for days.

At 12 volts this is of little danger to the operator. But if testing the component immediately precedes its being wired into a circuit board, the capacitor's charge might very well destroy other components already connected. So, after testing large capacitors, they should be carefully discharged before use.

You are advised, though, not to simply short the leads together with a screwdriver, but to touch a 10kΩ resistor between them, to allow a less brutal discharge to occur. □



News . . .

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

DVD RW INCOMPATIBILITY

They never learn, says Barry Fox, highlighting the latest format standards conflict.

DVD is the fastest selling consumer electronics product, ever. Just about everyone who owns a DVD player – and plenty of people who are still waiting to buy one – wants a recorder that "tapes" onto erasable blank discs. With unhappy memories of VHS and Betamax, people want a single standard.

At *IFA*, the giant consumer electronics show held recently in Berlin, three rival consortia have given up all hope of agreeing a single standard for recordable DVD and are unveiling three slightly different and completely incompatible home recorders. Consumers must now hope they do not back the losing standard.

Standard Contestants

Philips has won the race to market, with the format called DVD+RW. The DVDR-1000, now going into European shops at around 2000 Euros (£1300), and due for the US before the end of the year, makes recordings on erasable discs that can be taken straight from the recorder and played in some existing DVD players. The recorder automatically creates an index of thumbnail images that display on screen to tell what is on the disc. But only simple editing, with scenes skipped or cut, is possible.

Pioneer's DVD-RW consumer recorder, the DVR-7000, will go on sale early next year for 3000 Euros. This records in two modes. Video Mode has similarly limited editing, and claims similar compatibility to +RW with existing players; Video Recording (VR) Mode can extensively juggle the order of scenes, but produces discs that cannot be played on ordinary players.

Panasonic already sells computer data recorders that use the DVD-RAM format. The first truly consumer DVD-RAM video recorder, the DMR-E20 Time Slip, goes on sale in the West in October for around 1500 Euros. It writes and reads video at twice the usual 11·08 Mbps speed, so can play and pause a live TV programme while continuing to record it. The downside is that the DVD-RAM disc has low reflectivity and does not store data on the disc in the same places as an ordinary DVD. So the laser optics in almost all existing DVD players cannot read a RAM recording.

Plus Write-once

All three formats can also record onto write-once DVDs. These play back on just about every existing DVD player, and cost around 15 Euros, half the price of erasable discs. But write-once discs cannot be re-used. And once again the makers could not agree on a single system. RAM and +RW recorders use DVD-R blanks; but DVD+RW recorders need different DVD+R blanks. Backwards compatibility is the key issue, and likely to prove a can of worms.

Philips says DVD+RW recordings should play on the "vast majority" of existing DVD players after testing around a hundred. The list is on the Philips web site (**www.ce-europe.philips.com/**) but it does not identify players which will not play DVD+RW recordings. First practical tests with a +RW disc suggest there will be a lot of surprises. For instance, although Sony helped Philips develop DVD+RW, recordings from a Philips recorder will not play on Sony's Playstation 2 console.

SNAP, CRACKLE AND K-PHUT!

By Barry Fox

ALIEN monsters are hiding in the bar codes on cornflakes packets and electronics games. So says company Radica China, and it has developed a gadget which will soon let them out (**www.skannerz.com**).

A handheld game console has a barcode reader on the back. Wipe it over any barcode you can find and the console uses individual characteristics of the standard format code to modify the appearance of graphic images that have been pre-programmed into the console – and so "compile the molecules" for a new monster that appears on screen. When two players lock matching consoles together, whatever monsters are inside them fight to the death.

FARNELL AND EDUCATION

A FACILITY specially set up for the higher education sector has been established by Farnell, the distributor of electronic, electrical and industrial products, and sister company CPC, distributor of appliance spares.

Named *onecall*, the facility brings together the best features of Farnell and CPC to provide a "one-stop-shop" service from the combined stock of 200,000 products.

Farnell Education Sector Manager, Steve Puset says, "The aim of *onecall* is to provide all Universities with a single point of ordering. Premier Farnell's sales in the UK higher education sector for the last year grew by over 32 per cent."

The Farnell Road Show 2001 will be touring UK Universities in October.

For more details call Sam Pettman on 0870 122 7711. Farnell's web site is at **www.farnell.com**.

AUDIO CAPACITORS

A RANGE of capacitors specifically suited to audio applications is being developed by leading capacitor manufacturer ICW in conjunction with several leading loudspeaker manufacturers.

Entitled Claritycap, there are four ranges of metallised polypropylene film capacitors offering a wide range of capacitances and voltages and which are ideally used in crossover units within hi-fi speakers and studio monitors.

For more information contact Industrial Capacitors (Wrexham) Ltd., Dept EPE, Miners Road, Llay Industrial Estate, Wrexham, N. Wales LL12 0PJ. Tel: 01978 853805. Fax: 01978 853785. E-mail: sales@icwltd.co.uk. (Web not quoted.)

CASIO DIGICAM

CASIO has launched the new QV4000 digital camera. The QV4000 features a 3× optical zoom Canon lens with a seamless 3.2× digital zoom, and has a 4.13 megapixel CCD that records very high resolution images. It comes fully equipped with practical photographic functions, which enable manual adjustment of exposure, light metering and white balance settings, making it ideal for the more experienced photographer, says Casio.

For more information contact Casio Electronics Co. Ltd., Dept EPE, Unit 6, 1000 North Circular Road, London NW2 7JD. Tel: 020 8450 9131. Fax: 020 8452 6323. Email: ravi@casio.co.uk. (Web not quoted.)

FILM RESTORATION

A PROJECT using new technology to restore old film footage has been given the European seal of approval. In a press release from the DTI, we are told that the Picasso Project, involving Kent company Pandora International Ltd, will use innovative digital and software techniques to restore the footage by eliminating the wear-and-tear scratches that have accumulated on its surface.

Another project announced is to design new lamp posts that are less dangerous if hit by on-coming vehicles. Are brick walls and trees next?

Constructional Project

TEACH-IN 2002 POWER SUPPLY

ALAN WINSTANLEY

Power to the people – and especially those following Teach-In 2002! Provides regulated d.c. supplies of ±12V and +5V at 600mA.

THE mains-driven power supply (p.s.u.) described in this article has been designed principally for powering the demonstration circuits offered in *Teach-In 2002* Lab Work. It will, though, also prove handy as a bench-top power supply for general workshop use. It offers ±12V d.c. and +5V d.c. rails at a total current capacity of approximately 600mA.

The constructional details supplied should make it possible for most hobbyists and beginners to assemble this without difficulty, provided that they have some experience of using a pencil-type soldering iron and have access to "normal" workshop tools such as a power drill, screwdrivers, etc.

We reiterate our general warning, however, that it is a mains powered design and you should not attempt to build it unless you are experienced at constructing mains powered circuits, or can be supervised by someone who is.

CIRCUIT DIAGRAM

The complete circuit diagram for the power supply is shown in Fig.1. The mains transformer T1 has twin 12V a.c. secondaries which are wired in series, their junction being treated as 0V as shown.

The a.c. output is full-wave rectified by bridge rectifier REC1 to produce an unregulated voltage of roughly 34V d.c. across its positive and negative terminals. The two smoothing capacitors, C1 and C2, smooth the d.c. output voltage and provide roughly +17V (relative to the 0V common rail) input to IC1, a +12V regulator, and –17V d.c. input to IC2, a –12V regulator. Both regulators share the common 0V rail.

Additionally, regulator IC3 is powered from the +12V regulated supply and provides an output of +5V d.c. All the regulators are short-circuit proof and thermally protected, and are unlikely to be damaged should a minor mishap occur during experimentation.

The power supply outputs use colour-coded connectors (see Fig.1). In addition, each regulator output is connected to a "power on" light emitting diode (l.e.d.). The idea is that if an l.e.d. is off, this hints of a possible fault (short circuit) in the circuit under test.

Capacitors C3 to C8 help with supply rail stability and decoupling.

The unit has a mains on-off switch, S1, and is protected by a mains fuse, FS1.

Readers outside the UK must use a mains transformer with a primary winding and fuse suited to their local supply.

Whilst each regulator is capable of supplying 1A or so (depending on adequate heatsinking), clearly the transformer rating limits the total current which may be drawn.

As a rule of thumb, roughly 600mA or so total output current from the power supply corresponds to about 1A r.m.s. as "seen" by the

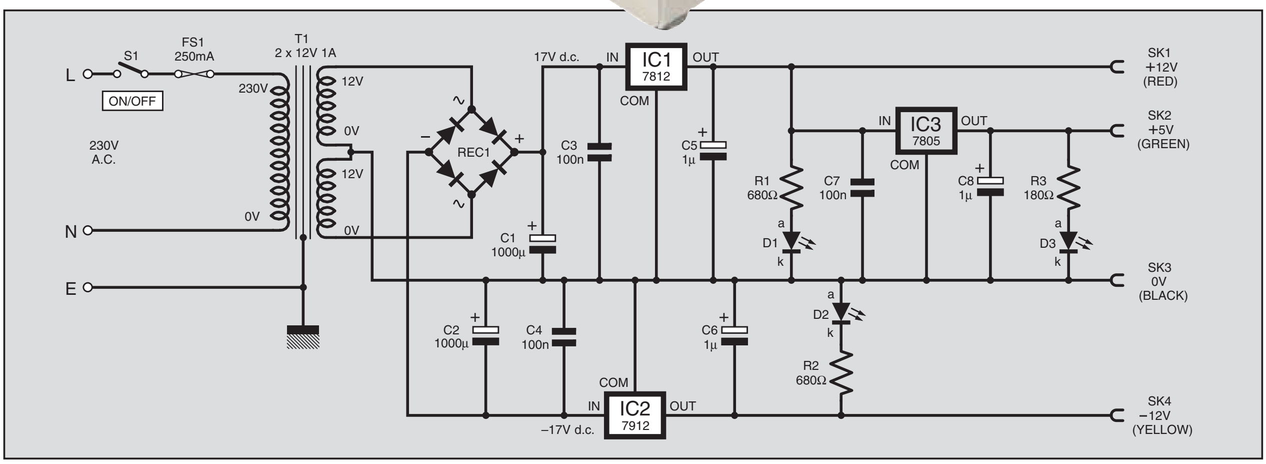


Fig.1 Complete circuit diagram for the Teach-In 2002 Power Supply.

transformer. For maximum reliability these limits should not be exceeded. However, the design is probably rugged enough to allow it to be over-extended for short periods.

CASE PREPARATION

The prototype was built into an all-aluminium box measuring 135mm × 65mm × 105mm (l × h × w), which is the minimum size necessary to accommodate the parts, the dimensions of the transformer being the main determining factor.

The case should be drilled to accommodate the four insulated terminals (binding posts), l.e.d.s and on-off switch on the front panel (see photo). The floor of the case is drilled to carry the three regulators, printed circuit board and mains transformer. Lastly, the rear panel must be drilled to accept a mains cable inlet (with locking cable gland) and panel fuseholder.

Once the printed circuit board (p.c.b.) is assembled, holes should be drilled in the floor of the case to line up with the regulators' mounting tab holes.

Obviously, the internal components should be arranged so they do not interfere with each other, so locate the transformer first and then position everything else around it.

CIRCUIT CONSTRUCTION

The p.c.b. on which the majority of the components are mounted has its layout details shown in Fig.2. This board is available from the *EPE PCB Service*, code 320.

Assemble this board in order of component size, leaving the regulators until last, and then taking care in their mounting so that they can be bolted (without stress to their legs) to floor of the case, which acts as a heatsink.

Note that some components are polarity sensitive, and it could prove dangerous to connect them the wrong way round.

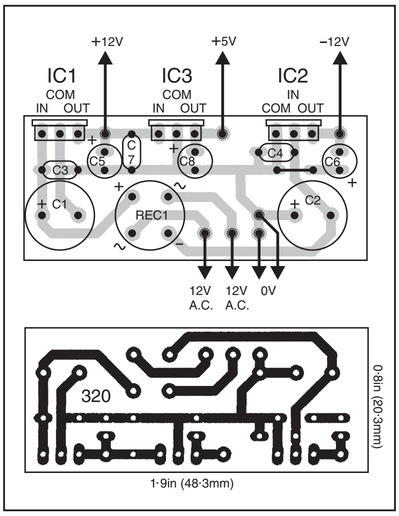
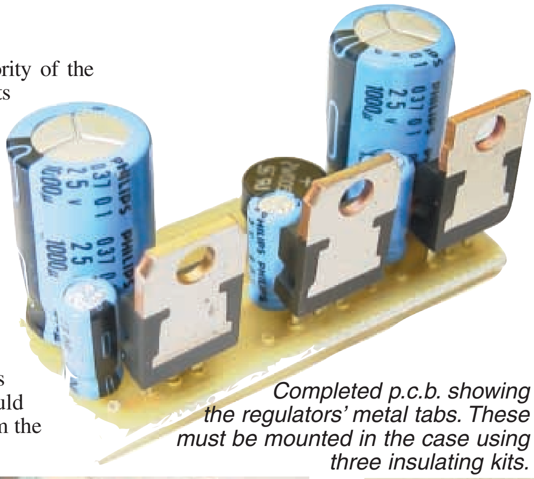


Fig.2. Power supply printed circuit board component layout and full-size copper foil master.

Having assembled the board, drill mounting holes for the regulators. *Ensure that the holes are fully de-burred of their rough edges.*



Completed p.c.b. showing the regulators' metal tabs. These must be mounted in the case using three insulating kits.

COMPONENTS

Resistors

R1, R2	680Ω (2 off)
R3	180Ω

All 0·25W 5% carbon film.

See SHOP TALK page

Capacitors

C1, C2	1000µ radial elect. 25V (5mm pitch) (2 off)
C3, C4, C7	100n min. ceramic (3 off)
C5, C6, C8	1µ radial elect. 25V (2·5mm pitch) (3 off)

Semiconductors

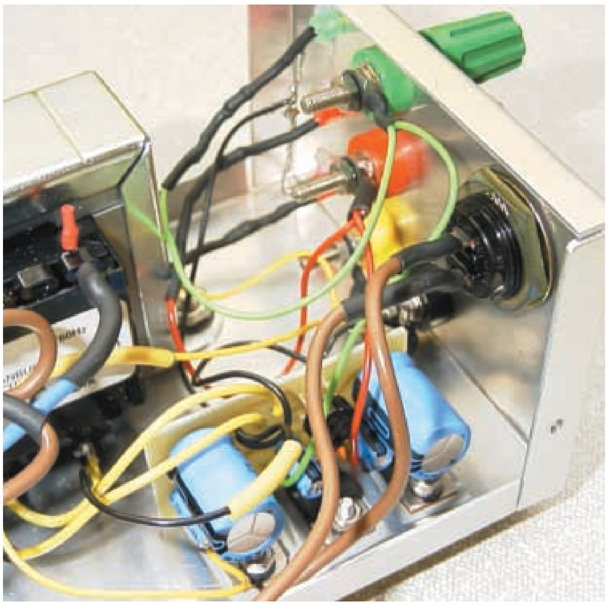
IC1	7812 +12V 1A voltage regulator
IC2	7912 −12V 1A voltage regulator
IC3	7805 +5V 1A voltage regulator
D1, D2	min. red l.e.d. (2 off)
D3	min. green l.e.d.
REC1	100V 1A bridge rectifier

Miscellaneous

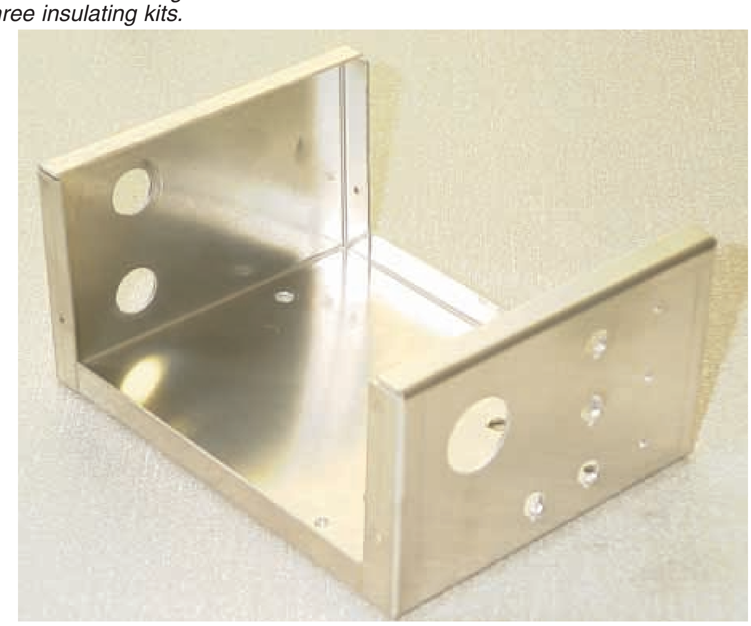
T1	mains transformer, 0-12V 1A, 0-12V 1A twin secondaries
S1	s.p.s.t. switch, mains rated, panel mounting
FS1	250mA 250V fuse (see text)

Printed circuit board, available from the *EPE PCB Service*, code 320; aluminium case, 135mm x 105mm x 65mm minimum; 4mm terminal (binding post), one each red, yellow, green, black; TO-220 insulating kit (3 off); M3 x 10mm Pozidriv screws, nuts and washers (3 off each); l.e.d. clip, panel mounting (3 off); 6A mains rated power cable (length as required); cable gland, locking; cabinet feet (4 off); multistrand connecting wire; solder, etc.

Approx. Cost Guidance Only **£30**



Close-up of one area of the case interior showing the p.c.b. secured to the chassis floor by the voltage regulators' metal tabs. All solder joints/tags should be covered with insulating sleeving, especially mains wiring.



The aluminium chassis drilled for the front and rear panel mounting components. Use the transformer and circuit board as a template to mark the drilling positions on the base of the case.

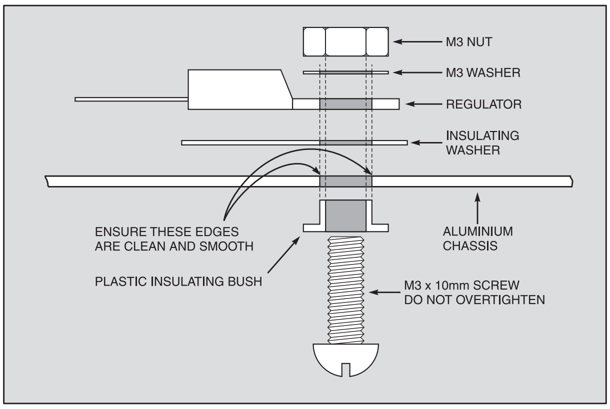


Fig.3. Typical TO-220 insulating kit assembly.

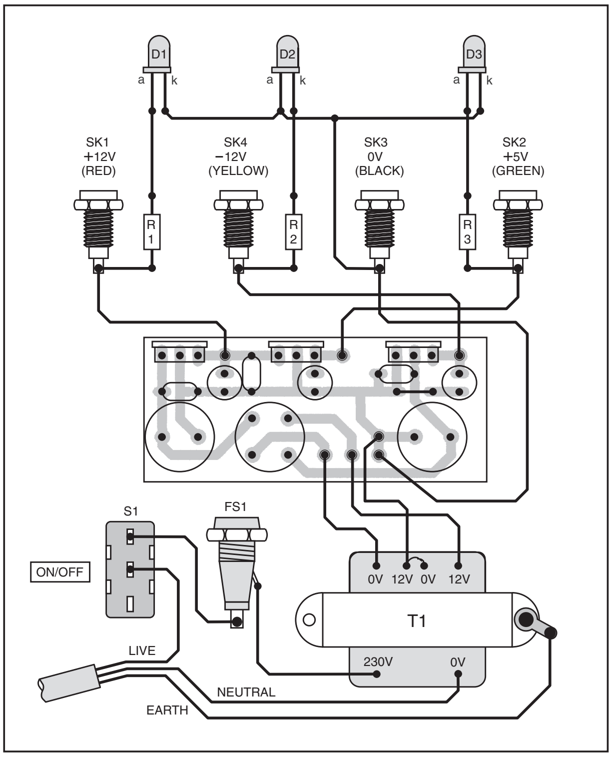


*Fig.4. Interwiring between off-board components and the printed circuit board. A minimum of 3A rated multistrand wire **must** be used for the mains voltage internal wiring.*

REGULATOR MOUNTING

Each regulator is mounted to the chassis via its metal tab, so that the metal box dissipates heat away from the devices. However, the tabs are also "live", being internally connected to their GND (common) or input terminal, depending on the type.

A standard TO-220 insulating mounting kit *must be used* to prevent the mounting bolt making electrical contact with the tab. Details of a typical mounting kit are given in Fig.3. Use an M3 × 10mm Pozidriv screw for fitting. The mounting hole (approx 3·5mm to 4mm diameter) must "clear" the plastic insulating bush which passes through it.

You must make completely certain that each metal tab is fully insulated. Use a multimeter to check for infinite resistance between the tab and the screw. If there appears to be a short-circuit, it is likely that the insulating washer has been punctured, possibly by swarf or rough edges around the mounting hole. Problems can also be caused by over-tightening the mounting screw. If problems arise, you must use a new mounting kit or repair the defect before proceeding to the other regulators.

INSTALLATION

Mount the four colour-coded terminals which, by their construction, are fully insulated from the case. Use clips when installing the l.e.d.s. A dab of hot melt glue will help to retain them.

The l.e.d. ballast resistors (R1 to R3) must be soldered direct to the l.e.d. anode (a) leads before being connected back to the p.c.b. The joints should be protected with insulating tape or heatshrink film. Continue to instal and wire-up the other components, leaving the bulky mains transformer until last.

Standard multistrand hook-up wire can be used for the low voltage side of the transformer and you should complete the interconnections as depicted in Fig.4, insulating all joints as necessary, e.g. with heatshrink sleeving.

The interwiring is relatively straightforward but you should make a point of working methodically when connecting the board to the transformer (note how the secondaries are wired in series) and regulators.

As this power supply is mains-powered, remember that your safety and that of others may be at risk if you fail to implement reasonable standards of assembly. Heed the earlier warning, and allow yourself plenty of time.

MAINS RATED

Looking at the mains voltage side, a minimum 3A rated multistrand wire should be used internally and all joints must be insulated to prevent accidental shock (especially any mains tags standing proud on the transformer, a notorious source of potential accidents).

The three-core mains cable should be rated at 6A and brought in through a locking cable gland, which acts as a strain relief to prevent chaffing, and also prevents the cable being pulled out.

Connect in the switch, fuseholder and transformer primary winding last of all, noting that the mains Earth (ground) input is soldered to a tag placed under one of the transformer mounting bolts. **It is essential that the case is grounded properly**. The mains plug must be fused at 3A (see earlier).

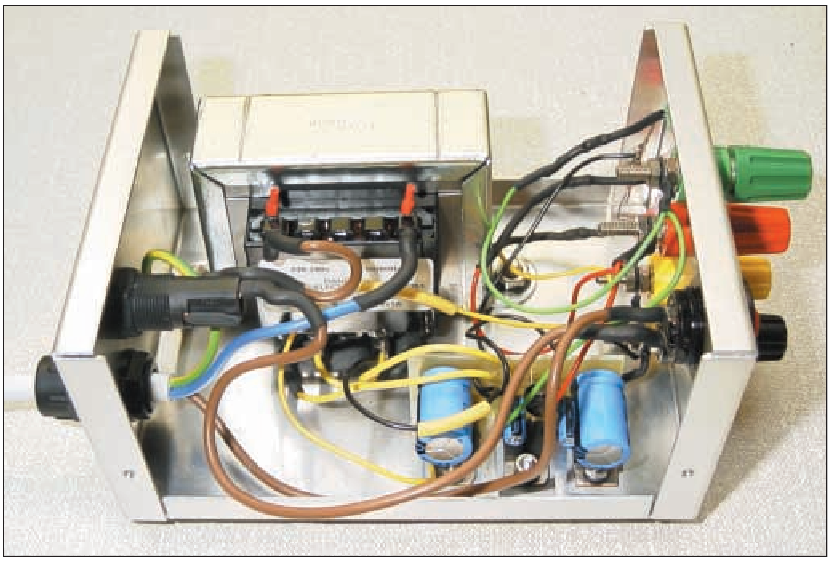
COMPLETION

Finish off assembly by applying four self-adhesive cabinet feet underneath the case.

Double-check that the regulators are fully insulated from the chassis, also examine the interwiring, looking for any errors or omissions. Especially ensure all capacitors are correctly polarised.

Proceed to test the circuit as follows: clip a 50V d.c. voltmeter across the bridge rectifier positive (+) and negative (–) terminals then plug in and switch on at the mains. The meter should read approximately +34V d.c.

Test each d.c. output and polarity with respect to 0V, measuring ±12V and +5V d.c. on the output terminals. Test readings from the prototype are shown on the circuit diagram. If the tests are satisfactory, then the unit is complete and ready for use in *Teach-In 2002*. □

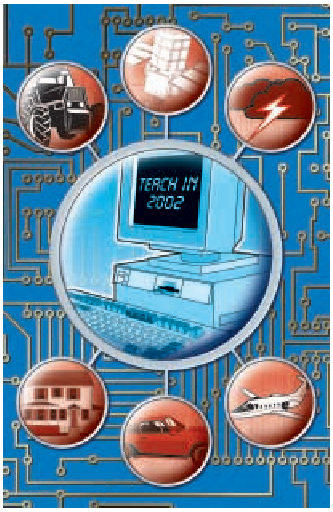


Completed Power Supply with cover removed.

TEACH-IN 2002

Part One – Sensors, the Environment, Units and Equations, Temperature

IAN BELL AND DAVE CHESMORE



Making Sense of the Real World: Electronics to Measure the Environment

WELCOME aboard our new 10-part educational series *Teach-In 2002: Making Sense of the Real World* – giving you an insight into the world of sensors, explaining their operation and helping with the design of associated circuitry.

More than ever before, sensors of all types are being deployed to measure environmental parameters, so *Teach-In 2002* demonstrates what sensors are all about and how to use them effectively. Alongside this we shall discuss the fundamentals of *making measurements electronically*. We shall also describe some of the key circuits generally involved in sensing and measuring, including amplifiers, filters, comparators and analogue-to-digital converters (ADCs), as well as giving specific circuits for various sensor applications.

We aim to give *Teach-In 2002* a broad appeal, so that every reader will gain something from the series in one way or another. Included will be a little background information on the environment and how sensors are needed to monitor it. Also highlighted will be more advanced sensing and measurement topics including, for example, radio-telemetry and remote sensing. Some topics are presented in separate boxes that can be read individually without interrupting the flow of the main discussion.

We know that the theory will be highly relevant to schools and university students, as today's younger readers (and tomorrow's electronic engineers) need to be acutely aware of the challenges created by environmental pressures, which are increasingly affecting us all. Readers should not be afraid to "pick and mix" those aspects of *Teach-In 2002* which are most relevant to their interests.

The series concentrates mainly on sensor applications, and will not handle advanced processing techniques, such as microcontroller programming. There are other resources available through *EPE* which already cover these aspects.

There is plenty of practical work to do as well – each part includes practical "Lab Work" demonstrating some of the sensors, circuits and concepts discussed within it. These labs are intended to help reinforce some practical principles that you can then incorporate into your own project designs.

Elsewhere in this issue are constructional details of a suitable mains dual power supply for the lab experiments.

PICOSCOPING SIGNALS

Teach-In 2002 has enlisted the support of Pico Technology Ltd., manufacturers of Picoscope PC-based oscilloscopes. Their 'scopes are very compact, easy to use and recommended for demonstrating our practical Lab Work circuits without the need for expensive test equipment. You can display waveforms comfortably on a computer screen, and capture screen shots that can then be printed or pasted into your own documents.

Picoscope ADC-40 oscilloscope module.

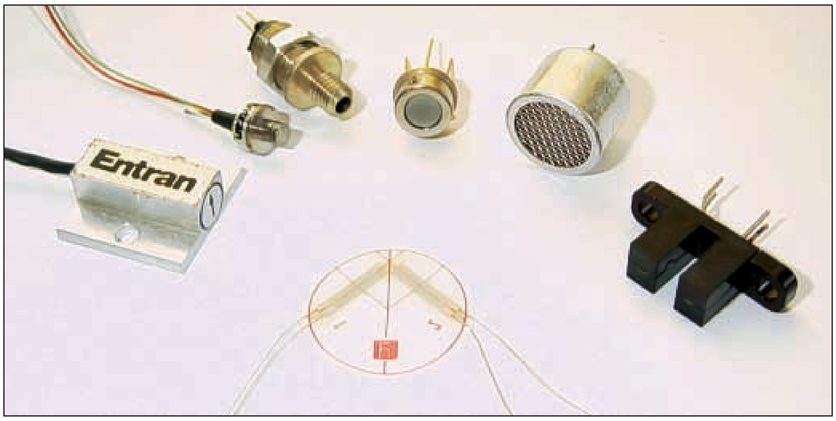
The recommended Picoscope ADC-40 is available at a special discount price as detailed on our Special Offer page.

The Picoscope ADC-40 (also see Panel 1.7) also has a modest built-in digital voltmeter and other functions to help monitor signals. The 'scope runs under all versions of Microsoft Windows and plugs on to a parallel port. Many software drivers are also available to allow Picoscopes to be integrated into more advanced data capture and logging duties, e.g. under Linux.

There is much more data available on the Picoscope CD-ROM which is shipped with each product, and you can also visit their web site at **www.picotech.com**.

It is worth noting that an ordinary multimeter can be used to monitor many of the experiments, although not providing the full display benefits of using the Picoscope, of course.

Now settle down and fasten your seatbelts – it's time to embark on the first of ten instalments of *Teach-In 2002*!



A wide variety of sensors is available for measuring almost every parameter imaginable (left to right: accelerometer, pressure transducer, fibre optic receiver, passive infra-red detector, ultrasonic transducer, optical switch; bottom, strain gauge).

MAKING SENSE OF THE REAL WORLD

One often gets the impression that the world has gone completely digital in nature, with telephones, television, music, photography and radio all following this trend. None of this allows us to escape the fact that the real world is actually *analogue*

– a world in which many electronics applications must obtain information from their environment and condition it correctly, before it can be handed over for digital processing.

For this we need to use sensors – for heat, light, sound and many other things. We need to use analogue circuits to amplify and filter the signals created by those sensors. We also need comparators and analogue-to-digital converters (ADCs) to prepare our data for digital processing, perhaps utilising microcontrollers or computers along the way.

Anyone who has been reading *EPE* for a while will have noticed that sensor-based projects appear quite frequently in these pages. So this series will be of interest to hobbyists who like to experiment with systems involving sensors, such as weather measurement, domestic environmental monitoring and a wide variety of other projects. We also believe that the series will be of use to schools and colleges for science projects, as well as those studying basic electronics on a wide variety of courses.

At this stage we must say that *Teach-In 2002* is not aimed at complete novices; we assume a basic knowledge of electricity and electronic components such as resistors, capacitors and transistors. The articles will not be heavily mathematical, although we cannot avoid mathematics altogether. We felt that doing so would prove too restrictive, particularly for those readers, including University students, who should find its inclusion so useful.

To help those unfamiliar with the "language of equations", we attempt to interpret it in a separate call-out section. Ideally, you should possess a basic scientific calculator. Microsoft Windows includes a limited calculator accessory program worth trying.

PANEL 1.1

Teach-In 2002 is the result of a lot of teamwork. Its tutorial authors are Ian Bell and Dave Chesmore, supported by *EPE*'s Alan Winstanley who has co-ordinated the series and helped develop the Lab Work projects and power supply.

Ian is a lecturer at The University of Hull, UK, where his teaching and research includes circuit design, test and manufacture, and computer aided design of electronic circuits and systems. *EPE* readers know him as co-writer of our popular *Circuit Surgery* and also as one of the authors of our acclaimed series *Teach-In 1998 – An Introduction to Digital Electronics*.

Dave is a lecturer at York University, UK, where his teaching and research interests include instrumentation, and electronics and information systems in agriculture and biology.

Alan is *EPE*'s On-Line Editor, co-writer of *Circuit Surgery* with Ian, the host of *Ingenuity Unlimited*, and scribe-laureate of *Net Work*.

If you have any queries related to the material published in this series, you can E-mail the authors at **teach-in@epemag.demon.co.uk** (no file attachments will be accepted, and no general electronic questions please). We hope to publish more support material on the *EPE* web site (**www.epemag.wimborne.co.uk**) as the series evolves.

Table 1. Various Forms of Energy available for Transduction.

Type of Energy	*Example*	*Examples of Transducers*
Radiant	visible light, IR, radio waves	photodiode, light dependent resistor, radio antenna
Gravitational	gravitational attraction between two or more bodies	accelerometer
Mechanical	forces, motion (velocity), movement (displacement)	strain gauge
Thermal	kinetic energy of molecules	thermocouple, thermistor
Electrical	current, voltage, electrical field	current probe, fibre-optic electric field sensor
Magnetic	magnetic fields	Hall effect probe
Molecular	binding energy in molecules	electrochemical sensors (e.g. pH)
Atomic	nuclear forces in atoms	photospectrometer, mass spectrometer
Nuclear	binding energy inside the nucleus	nuclear magnetic resonance
Mass energy	energy given by $E=mc^2$	none

MEASURING THE ENVIRONMENT

Before we go any further, we need to get an idea of the range of things that might be sensed in the environment. We also need to understand very clearly the terminology relating to the use of sensors and making measurements.

First, what is meant by "the environment"? To the majority of people, it means the natural world, but it can also refer to the inside of buildings, aircraft, the operational conditions in many industries and even outer space. In fact, outer space is probably the most hazardous environment for humans and vehicles imaginable, with extremes of temperatures, no atmosphere and high levels of energetic particles from the sun and stars.

All environments have characteristics that often need to be measured. To illustrate this, consider three examples of different environments, potential effects on them and what might be measured.

Built Environment:

The environment inside buildings is mostly designed for humans to live and work in. Get this wrong, and inhabitants may suffer "Sick Building Syndrome". Buildings must operate within certain temperature and humidity ranges at which humans are most comfortable.

Many workplaces and offices contain potentially hazardous chemicals – computers and printers produce ozone and many printer inks produce solvent vapours. Therefore, amongst the many measurements that need to be made are temperature, relative humidity, air flow, light level, sound level and the presence of certain chemicals.

Farming Environment:

The agricultural environment has many different facets. The weather is obviously highly important – too cool and crops won't ripen soon enough. Too much rain (or too little!) can have severe impacts. Soil quality is also important: fertilizers may be added to increase growth rate, yet they can sometimes pollute watercourses (causing eutrophication, an increased rate of biomass production). Pesticides must often be used to reduce crop damage from pests.

The importation of foot and mouth disease into the UK during 2001 highlighted a number of problems. Effluent from buried materials could leach into water courses, but burning it could release harmful dioxins. There are many possible measurements that could therefore be made: air and ground temperature, barometric pressure, wind speed and direction, humidity, soil quality and chemicals (fertilizers, insecticides, herbicides, dioxins, etc.). Some of these are very difficult to measure without resorting to laboratory analysis.

Process Industry:

Process industries range from petrochemical plants to power stations and incinerators. It is well known that burning fossil fuels produces sulphur dioxide ("acid rain") and carbon dioxide, but it also produces hydrochloric acid gas and copious amounts of dust.

Acid rain is normally considered to be damaging to lakes, trees and wildlife but, interestingly, it also acts as a fertilizer (sulphate) and is a good fungicide with which to kill fungus on crops! When a power station near to the authors was upgraded, some farmers actually complained when deprived of their "free" source of fungicide!

There are many measurements that must be routinely made in addition to meteorological data – water flow, water temperature, concentrations of gases such as sulphur dioxide, levels in reservoirs and tanks, furnace temperature and so on.

It is obvious that the list of things that may be sensed is large and we only have space in this series to describe a small proportion of them. We can usefully divide the measurements into two groups:

Physical measurements such as air flow, temperature, etc., and **chemical measurements** such as pH (acidity), salinity, fertilizers, pesticides, etc. It can be said that physical measurements are in general simpler than chemical measurements and sensors are more robust and easier to use.

Table 1 shows the range of energy forms that can be sensed.

SO WHAT IS A SENSOR?

Next, we lay some important foundations and definitions related to the world of using sensors and making measurements:

A sensor is a device that accepts energy from one part of a system and emits it in a different form to another part of the system. The more correct term to use is *transducer*, and the term **transduction** is given to this process. However, since the common term is *sensor*, it is the one we shall use in this series.

Because we are concerned here with using sensors in electronic circuits, we shall regard the most common form of energy "emitted" by a sensor to be *electrical* energy.

A good example of a sensor is a **thermistor**, which is a temperature sensitive resistor (more about this later). The resistance of the thermistor changes with temperature, so measuring its resistance will enable us to tell the temperature being sensed by it.

Another common sensor is a strain gauge whose resistance is proportional to the strain or movement applied to the gauge. Other sensors will be discussed later in the series.

There are three basic forms of sensor:

- **Modulator**
- **Self-generator**
- **Modifier**

A **modulator** must have a signal applied to it before any measurements can be made. For example, in order to measure the resistance of a thermistor, a current must be applied to it and the voltage generated will be proportional to the resistance (V = I × R). Here, the current is the **modulating signal** and the voltage is the output.

A **self-generator**, on the other hand, produces its own signal. Examples include **thermocouples**, in which a voltage is generated at the junction of two dissimilar metals when they are at different temperatures, and **photovoltaic cells** where light is converted into a voltage. Self-generators generally have very small output voltages, which must be greatly amplified to make them useful.

A **modifier** is a device that does not change the signal type. For example, an electrical input produces an electrical output.

Modulators are the commonest form of sensor.

PANEL 1.2. AGREEING HOW TO MEASURE – STANDARDS AND SI UNITS

Throughout the passage of time, a vast number of measurement units have been used, with obvious problems occurring when people who use different systems try to communicate with one another. A good example was the loss of the Mars Climate Orbiter satellite in 1999, which was caused by confusion in the units of measurement used during programming.

To avoid such difficulties, and to allow scientists from anywhere in the world to use one "language of measurement", the **International System of Units** was agreed at an international conference in 1960. These units are all metric (using base 10 numbers) and are called the SI units (*Système International d'Unités*).

Units of measurement require a *standard* against which all measurement instruments or devices can be compared for accuracy. Mass is still based on a block of platinum-iridium alloy held at the International Bureau of Weights and Measures at Sèvres, near Paris (known as the **Kilogram Prototype**).

However, it is important to science that the accepted definitions of units of measurement relate to the *real world* by means of fundamental physical constants. For instance, the *metre* is defined as the distance travelled by light during 1/299,792,458th of a second; one *second* is defined as 9,192,631,770 periods of the radiation related to a particular electron energy transition in caesium-133 atoms.

When devising a system of units, the interdependence of quantities must be taken into account. *Force* is defined by the acceleration of mass, and *acceleration* is defined in terms of length and time. As we have fundamental definitions of mass, length and time we do not need one specially for force.

In the SI system, force is measured in *Newtons*, which is defined as the force required to give a mass of 1kg (one kilogram) an acceleration of $1m/s^2$ (one metre per second squared).

The term **base units** is used for those units which have been given a fundamental definition (e.g. length and time) or which are based on artifacts such as the 1kg Prototype. Other units, which are defined with reference to the base units, are called **derived units**.

The base units in the SI system are:

- amount of substance (Q) in mols (mol)
- electric current (i) in amperes (A)
- length (l) in metres (m)
- luminous intensity (I) in candela (cd)
- mass (m) in kilograms (kg)
- temperature (t) in Kelvin (K)
- time (t) in seconds (s)

MAKING QUALITY MEASUREMENTS

Sensors enable us to measure things electronically, and whenever we make measurements we must be concerned about the quality of the data we obtain. You would not be too happy buying apples from a grocer whose scales gave a different weight each time the apples were weighed! Likewise, you would be concerned if two filling stations sold you 20 litres of petrol but one quantity was 20 per cent smaller than the other.

Quality of measurement is important in science as well as in commerce – we cannot prove or disprove a theory if the measurements we make in an experiment are not good enough. Engineers need good quality measurements too, as part of control systems for example, in order to verify their designs. Engineers are also responsible for designing the sensor and instrumentation systems that are used to make measurements.

So how do we describe the quality of a measurement? What specifications should we look for when selecting sensors and instrumentation circuits? We can use a number of terms with which most people are familiar and which, to some extent, get used interchangeably in "everyday" speech: terms might include *accuracy, precision, resolution*, and *sensitivity*.

In actual fact, these terms have very specific meanings and must not be mixed up if we are discussing science or engineering. To this list we also have to add less familiar terms such as *repeatability* and *reproducibility*, and a vocabulary for discussing errors: *random* and *systematic*. So here come the definitions:

● ***Accuracy***

Absolute accuracy is the closeness of a measurement to its standard value or true value, this being determined by international agreement. *Relative* accuracy is the closeness of the measurement to a reference value other than the main standard.

Accuracy is often quoted as plus/minus percentage (±%) of the value measured, or ±ppm (parts per million). For measurement instruments, accuracy may be quoted as a percentage or ppm of the full scale (maximum) reading of the meter. This means that the percentage error in measurements of small values may be much larger. The accuracy of sensors and instruments may vary with time (ageing) and temperature.

● ***Precision***

Precision is a more general term related to the level of uncertainty in the measurement – it must not be used in place of the term *accuracy*. The term *precision* is sometimes used to indicate resolution or repeatability.

Measurements can be high resolution (or high precision), but low accuracy. If we use two voltmeters to measure a voltage which has true value of 11·105V and one instrument displays 11V and the other 11·573V, then the first measurement is more accurate, but the second has a higher resolution.

● ***Resolution***

Resolution is the smallest portion of the signal or quantity that can be observed and is often quoted as a percentage or ppm value. The resolution of a measurement in digital form can be expressed in terms of the number of binary digits (bits) or decimal digits (e.g. on a instrument display) which are used to hold or convey the data.

A resolution of 0·01 per cent is equal to 100ppm and equivalent to four decimal digits and 13·3 bits. We examine the digital aspect of resolution in more detail later in the series when we look at analogue-to-digital conversion.

● ***Sensitivity***

Sensitivity is the smallest change in the measured quantity that can be detected and may be quoted as such (e.g. 0·1°C, 1mV, etc.). Sensitivity may be quoted in terms of the ratio of the output of the sensor or instrument to the input signal or measured quantity (e.g. 10mV/°C).

PANEL 1.3. SETTING THE STANDARDS

An agreed system of measurement units is not the complete story – we also need something that can be used to *calibrate* measurement instruments, so that the measurements will be consistent throughout the world. A process of *international*, *primary*, *secondary* and *working* standards has evolved.

International standards are maintained at the International Bureau of Weights and Measures, and are checked against the fundamental definitions of the units. National laboratories in each country maintain primary standards, which are then used to calibrate secondary standards that are sent to the national laboratories. The secondary standards are, in turn, used to calibrate the working standards used to calibrate everyday instruments.

The international standards evolve over time: for example in 1990 new standards were adopted for the Volt and the Ohm. These are based on quantum effects in a *Josephson tunnel junction* and the *quantum-Hall effect* – fundamental physical effects, which can be related to constants such as the charge on an electron and *Plank's Constant*.

The change in the standard required the adjustment of large numbers of instruments and electronic systems throughout the world. For example, in the USA the standard for the Volt changed by nearly 10ppm (parts per million).

For more information on SI units and international agreements on units of measurement and measurement standards, visit the web site of the International Bureau of Weights and Measures (*Bureau International des Poids et Mesures (BIPM)*) at **www.bipm.fr**. Also visit the UK's National Physical Laboratory web site at **www.npl.co.uk**.

A study of the physics of a measurement situation, including the time taken to make the measurement and the temperature, allows a theoretical maximum sensitivity to be calculated. This is usually only of relevance for measuring very small quantities.

● ***Repeatability***

Repeatability indicates the degree of closeness of a series of measurements made under the same conditions. Ideally, of course, all results should be the same, but in practice factors such as noise prevent this from being the case.

● ***Reproducibility***

Reproducibility is like repeatability except with a specific *change* of conditions. For example, the same quantity measured at different temperatures.

● ***Error***

Error is the deviation of the measured value from the true value. This can be expressed as the actual difference value as a percentage or in ppm.

● ***Random Errors***

If we make a large number of measurements of the same quantity, each measurement will be different. If we take the average of all the measurements and this is equal to the true value, then we are dealing with *random errors*.

Again we have to be careful with the terminology we use. The *average* in this case is the *mean*: obtained by adding up all the values and dividing by the number of values used (if you know statistics you will know that the *mean* is not the only kind of *average*).

● ***Systematic Errors***

If we take the *mean* of a set of values and it is different from the *true* value, we are dealing with a *systematic error*.

The analysis of measurement errors is a very serious subject with deep implications for science and engineering. It involves the use of statistical analysis and therefore requires some advanced mathematics.

We will not be looking at the statistical theory of measurement in great depth in this series – we want to keep it relatively "maths-light" – and we will be mainly concentrating on the sensors and associated circuitry.

However, you must always be aware of potential sources of error (and their implications!) when using any measurement system, particularly for science experiments.

CHARACTERISTICS OF SENSORS

Errors in measurements may occur due to the non-ideal characteristics of the sensors used. Each type of sensor will have different characteristics depending on its method of transduction. There are a number of ideal characteristics that we would really like a sensor to have, such as *linearity* (the output is exactly proportional to the input); these are listed in Table 2.

Life isn't perfect, however, and no sensor is ideal, so many suffer from very undesirable characteristics, some of which are listed in Table 3.

Many of the undesirable characteristics can be difficult to overcome. For example, it is not a good idea to try to measure the temperature of a flame using a plastic encapsulated thermistor because it would melt – a good example of a restricted working range!

A fundamental part of the design of sensing systems lies in so-called **preprocessing**, where the output from the sensor is modified to make it more suitable for the application. Examples of preprocessing include **linearisation** to make the output as linear as possible, amplifying small signals, filtering unwanted signals such as 50Hz/60Hz mains signals, matching ranges and analogue-to-digital conversion and so on.

Don't worry if you don't understand all the information in these tables – we shall be covering these topics in more detail during later parts of *Teach-In 2002*.

TEMPERATURE SENSORS

Next we turn our attention to using appropriate sensors to measure the first physical parameter we investigate, *temperature*.

A temperature sensor, as its name suggests, gives an output that is a function of the temperature of the sensor. There are several different types of temperature sensor, some of which will be very familiar to regular readers, such as *bimetallic strips, thermistors* and *thermocouples*, for instance, which we shall examine shortly.

First, though, we must consider temperature scales themselves. There are three common scales in use today:

● **Celsius** – named after its inventor Anders Celsius: formerly the centigrade or "one-hundredths" scale

● **Fahrenheit** – named after its creator Gabriel Fahrenheit

● **Kelvin** – named after Lord Kelvin, the British scientist

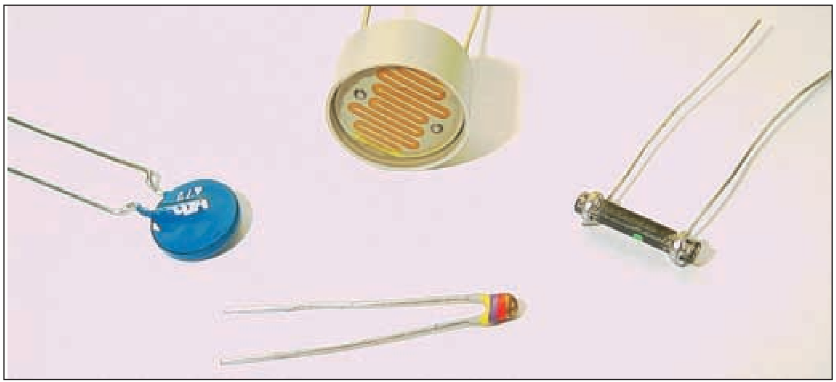
Celsius is the preferred scale for **meteorology** (the study of weather patterns) as opposed to **metrology** (the science of measurements themselves), with Fahrenheit sometimes being used. Kelvin is the "absolute" scale and 0K is absolute zero (–273·15°C). Conversion between scales is straightforward, shown in Table 5 later.

Table 2. The Characteristics of an Ideal Sensor.

Characteristic	*Ideal Value*
Response to input	exactly linear and noise free
Response time	zero (instantaneous)
Bandwidth	infinite (will react to very fast changes)
Full-scale reading	equal to the calibrated maximum
Working range	infinite (will work with any values)
Sensitivity	as high as possible (will react to very small changes in the input)
Resolution	infinite

Table 3. Some Undesirable Characteristics of Sensors.

Characteristic	*Meaning*
Non-linearity	output is not proportional to input
Slow response	takes time to react to rapid changes
Small working range	operating range is restricted
Low sensitivity	output responds only to large changes in the input
Drift	output changes with time for a constant input
Offset, offset drift	a systematic error in the output (also subject to drift over time)
Ageing	output changes with time (much longer time scale than drift)
Interference	output sensitive to external influences, e.g. electromagnetic waves
Hysteresis	systematic error in the input-output curve
Noise	output contains unwanted random signals (e.g. thermal noise)



A selection of opto and thermal-sensitive sensors (left to right: disc thermistor, light-dependent resistor, bead thermistor, rod thermistor).

Usually the degrees symbol (°) is used for Fahrenheit and Celsius but not always for Kelvin.

BIMETALLIC STRIP

The most primitive of all temperature sensors is the bimetallic strip, which even today still forms the heart of many domestic heating thermostats.

Crude but reliable, they contain a sandwich of two different metals which expand at different rates when the temperature changes. This causes the strip to bend, making or breaking an electrical contact to control the heating or refrigeration.

Fortunately for us, there are far more sensitive and reliable electronic solutions available that have no moving parts and are a lot more predictable.

THERMISTORS

A thermistor is a temperature-sensitive resistor made of semiconducting material, usually oxides of chromium, manganese, iron, cobalt or nickel. A thermistor's resistance decreases with temperature, i.e. it has a **negative temperature coefficient** and is referred to as an **ntc** thermistor. Other types of thermistor have **positive temperature coefficients**, or **ptc**.

The circuit symbols for both types are shown in Fig.1.1a and a graph of a typical *ntc* thermistor characteristic is shown in Fig.1.1b.

The way in which the resistance changes with temperature is given by the following equation:

$$R_\theta = R_{\theta 0} e^{\beta \times \left(\frac{1}{\theta} - \frac{1}{\theta 0}\right)}$$

where R_θ is the thermistor resistance at temperature θ in Kelvin

$R_{\theta 0}$ is the resistance at a reference temperature $\theta 0$ (usually taken as 25°C = 298K)

β is a constant (beta) determined by the thermistor material.

(If you'd like a quick maths refresher, see our separate Panel boxes.)

The resistance varies very strongly with temperature, and to give an idea, a typical thermistor that has a resistance of 12kΩ at 25°C will reduce to 955Ω at 100°C for a β value of 3750. If necessary, have a look at our separate section entitled "Interpreting the Equations" (Panel 1.5).

Thermistors come in many forms – rod or disc-shaped for general use, as well as delicate high sensitivity glass-encapsulated types which are considerably more expensive. The tolerance for a typical device is ±7% at 25°C and ±5% at 100°C.

One drawback is that thermistors suffer from self-heating due to their relatively high resistance. Their heat dissipation coefficients range from 0·1 to 1mW°C^{-1} so the error may be 0·1°C for a 2kΩ thermistor at 20°C for a current of 7mA. This can be a relatively large error in some applications.

THERMOCOUPLE

A thermocouple consists of two metals joined together, which generate a potential across the junction; this is an example of the *generator* transducer. Its symbol is given in Fig.1.2a.

The potential depends on the two metals. For example, an iron-constantan junction has a voltage equal to:

$E_T = 5{\cdot}037T + 3{\cdot}043\times10^{-2}T^2 - 8{\cdot}567\times10^{-5}T^3 + ...\mu V$

where T is in °C.

This voltage is very small and must be amplified by at least 1,000 times to suit many applications. Thermocouples can operate over a wider temperature range than thermistors because of their higher

PANEL 1.4. WRITING UNITS OF MEASUREMENT

Quantities that correspond with basic units of measurement can be expressed simply in terms of those units – distance in metres, current in amps, mass in kilograms, etc. Other quantities do not have a fundamental unit of measurement of their own, and so they are expressed in terms of the more basic units. For example, area in metres squared, speed (or velocity) in metres per second.

The fundamental quantities each have symbols which avoid the need to write out the unit's name in full each time. We can write, for example, 5m, 2·3A or 0·56kg, etc. For other quantities there are no special symbols so we use combinations of the basic ones. We can write square metres as "sq. m.", but it is preferable to write m^2 (metres squared) for engineering and scientific use. Similarly, we would write m^3 for volume measurement in cubic meters.

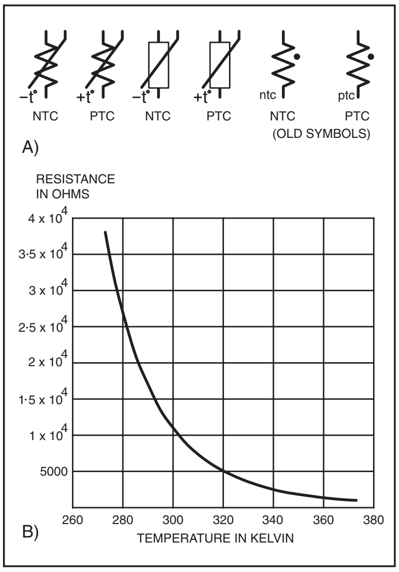
For speed described in metres per second, for example, we can write m/s, but also ms^{-1}. The "s to the power of minus one" simply indicates we are dividing by time in seconds. In fact any number to the power of minus one is equal to one divided by that number: 10^{-1} is 0.1 and 4^{-1} is 0·25.

Multiplying by "something to the power of minus one" is the same as dividing by it, so expressing metres per second as m/s (metres divided by seconds, i.e. distance divided by time), is the same as saying ms^{-1} (distance times time to the minus one).

Acceleration is measured in metres per second per second, no less, which we write as ms^{-1}/s or as ms^{-2} – distance divided by time squared. For example, if an object goes from standing (speed = 0ms^{-1}) to 20ms^{-1} in 10 seconds, it has accelerated at 20/10 = 2ms^{-1} per second, or 2ms^{-2}.

The units for some quantities in science and engineering can get quite complicated. For instance, a quantity called **mobility**, which is used to measure the ease of movement of electrical carriers in semiconductor devices, is measured in units of m^{2}s^{-1}V^{-1} (square meters per second per volt), and noise in some components and circuits in indicated in VHz$^{-1/2}$ (volts per root Hertz).

Note that the "power of a half" indicates square rooting, and "power of minus a half" indicates dividing by the square root.



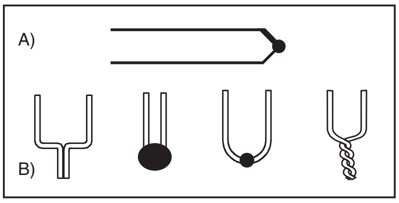


Fig.1.1 (left). (a) Thermistor symbols, (b) Temperature characteristic of a typical NTC thermistor.

Fig.1.2 (above) (a) Thermocouple symbol, (b) Typical junction formations of thermocouples.

melting point, so they are useful in industrial processing equipment, furnaces, ovens and so on. They are specialist items that will not be covered in this series.

PLATINUM RESISTANCE SENSORS

Platinum resistance sensors are temperature sensitive resistors which are linear in response and exhibit a 39% change in resistance between 0°C and 100°C. They are fragile and expensive. The resistance at T°C is:

$$R_T \approx R_0(1 - \alpha T)\ \Omega$$

where R_0 is the resistance at a reference temperature (usually 25°C)

α is a constant (alpha) dependent on the sensor material (typically 0·04 for platinum)

They are highly accurate and are used as an international standard for temperatures between 150K and 1100K. It is also possible to resolve temperatures of 10^{-4}K (100 microKelvin!).

SEMICONDUCTING SENSORS

An ordinary diode can be used as a temperature sensor, since its output voltage changes by approximately -2mV°C^{-1}. The diode's temperature sensitivity has been exploited for many semiconducting temperature sensors, ranging from those which have simple linear outputs to highly sophisticated devices with digital outputs.

One of the commonest and lowest cost devices is the LM35 manufactured by National Semiconductor which has an output voltage of 10mV°C^{-1}, which means that at 0°C the output will be 0·0V and at 100°C it will be 1·0V. We demonstrate this device in our Lab Work experiments this month.

Variants on the LM35 include the LM335 which has an output of 10mVK^{-1}, i.e. at 0°C the output will be 2·73V and at 100°C it will be 3·73V. You can obtain data sheets directly from the National web site at **www.national.com**.

As we pointed out earlier, sensors suffer from a number of potential problems, including having **offsets** (outputs not at zero) or outputs not being of a useful enough magnitude.

If we consider the LM35 as an example, the datasheet shows that it has an accuracy of about 1°C, which is sufficient for most applications. However, its output is 10mV°C^{-1} which may be too small for many applications (e.g. where an output of 0V to 5V may be needed).

It may also have a small offset, which means that the output will not be exactly 0V at 0°C. We therefore need to remove any offset and possibly amplify the output.

PANEL 1.5. INTERPRETING THE EQUATIONS

Mathematics is a powerful tool for understanding, analysing and designing circuits – just beyond where we go with *Teach-In 2002* – in the real world you will find that a lot of advanced mathematics is needed for many design tasks. However, in this *Teach-In 2002* series we have kept the mathematics to a minimum, although we have not ruled it out altogether; hopefully our "maths explanation panel" will help you to understand what is going on.

For example, the resistance of a thermistor is given by the formula:

$$R_\theta = R_{\theta 0} e^{\beta \times \left(\frac{1}{\theta} - \frac{1}{\theta 0}\right)}$$

where R_θ is the thermistor resistance at temperature θ in Kelvin

$R_{\theta 0}$ is the resistance at a reference temperature $\theta 0$ (usually taken as 25°C = 298K)

β is a constant (beta) determined by the thermistor material.

We have two different resistance values (R) that are identified using **subscripts** (θ and $\theta 0$) to give R_θ and $R_{\theta 0}$. This is like using subscript numbers to identify the different resistors in a circuit as R_1, R_2, R_3 etc.

Take care when reading equations to note the subscripts! In this equation, do not confuse the *subscripts* θ and $\theta 0$, which are just labels, with the *values* θ and $\theta 0$ which also occur in the equation.

The value β is a constant – its value stays the same for a particular thermistor, but may vary for different types of thermistor. The value of e is 2·718281828 to nine decimal places; e is an important number in mathematics, like pi (π), but less well known and less easy to relate to!

In the equation, e^x (e to the power of x) is known as the **exponential function** and is sometimes written *exp(x)*.

In this case, x is:

$$\beta\left(\frac{1}{\theta} - \frac{1}{\theta 0}\right)$$

so β is first multiplied by the result of the equation shown in brackets. Note that brackets are always calculated first, and the multiply (×) sign is often omitted.

On a typical scientific calculator, the button for the exponential function is labelled e^x, but don't confuse this with *EXP* or *EE* (Enter Exponent) which is just for using "powers of ten" multiples and submultiples (see Panel 1.6).

The opposite (or "inverse") function to e^x is the **natural logarithm**: the natural logarithm of x is written *ln*(x), and is often labelled *ln* on scientific calculators. Your calculator may give the value of e if you enter 1 × INV ln(x) =.

In the thermistor formula, start with the brackets, using Kelvin as units throughout. Recall that our typical thermistor has a resistance of 12kΩ at 25°C (298K) reducing to 955Ω at 100°C (373K) for a β value of 3750.

The values of $1/\theta$ and $1/\theta 0$ are 1/373 and 1/298 respectively. The net value of the equation's brackets is **–0.0006747**. Using a scientific calculator, β multiplied by this (negative) value gives **–2·53027**.

Raising e to this power gives **0·0796375**. All that remains is to multiply $R_{\theta 0}$ (12kΩ) by this, 12,000 × **0·0796375** is 955·6501 ohms, the thermistor's resistance at 373K.

The formula $R_T \approx R_0(1-\alpha T)$ described in the section on Platinum Resistance Sensors is a lot more straightforward as it only involves multiplication and subtraction, but note that symbol ≈ means "is approximately equal to" rather than the more familiar "equals" sign of "=".

PANEL 1.6. MULTIPLES AND SUBMULTIPLES

You will be familiar with unit prefixes such as kilo- and milli- for multiples and submultiples of units of measurement, for example in the values 10 kilograms (10kg) and 20 milliamps (20mA). The complete list of internationally agreed multiples and submultiples is given in Table 6 at the end of Lab Work.

Note the difference between upper case and lower case characters. The exponent represents the power of ten by which the quantity is multiplied or divided.

For example, *kilo* means multiply by 10^3 (ten to the power three), or 1,000. Note a pattern here: 10^3 equals 10 × 10 × 10, or ten multiplied together three times, and also note that 10^{-3} is a 1 followed by three zeros when written out in full.

Milli- means multiply by 10^{-3} (ten to the minus three), or 0·001, which is the same as saying divide by 1,000.

Most of the multipliers and dividers in Table 6 are 1,000 times greater or smaller than the next one in the list. For example, 1,000 meg(a)ohms (1000MΩ) is equal to 1 gig(a)ohm (1GΩ), and 0·001 millivolts (0·001mV) is one microvolt (1μV). The exceptions are deca, deci, centi and hecto, which are not recommended for scientific use.

LAB WORK

If you've made it this far, well done! Now proceed to our practical section entitled Lab Work, in which we look at some simple experiments to get you started.

In Lab Work, you will also find details of how to install and use the Picoscope ADC-40 PC-based oscilloscope which is recommended to aid your understanding of sensors and their operation.

A mains operated power supply is described elsewhere in this issue and which offers ±12V and +5V rails, the voltages variously required for the practical experiments throughout the series.

NEXT MONTH

In Part Two next month we continue with more temperature experiments, and then we examine light sensors. We also explore the world of the operational amplifier (op.amp), which is a fundamental building block often needed to make sensors do really useful things. There will be more practical work to do in our hands-on Labs as well.

TEACH-IN 2002 – Lab Work 1

ALAN WINSTANLEY

Temperature Sensing

THROUGHOUT *Teach-In 2002* we shall offer a number of practical experiments in Lab Work, utilising some of the principles outlined in the corresponding theory section. It is hoped that you will be able to incorporate the ideas demonstrated into your own future applications.

Also included in Lab Work is any technical data you may need to build these circuits on solderless breadboards, or whichever system you prefer to use, including stripboard if preferred. We shall not actually provide any assembly details for the experiments, although the photographs of our own assemblies should help you.

An appropriate power supply is required to run the Lab experiments. We opted for a mains-operated ±12V d.c. split supply for use with op.amps, and +5V d.c. for compatibility with the recommended Picoscope ADC-40 PC-based oscilloscope. Full constructional details for the power supply are given elsewhere in this issue.

The Picoscope can be used for monitoring waveforms, taking d.c. measurements using its built-in digital voltmeter and for capturing data onto your computer. Check the separate Panel 1.7, for outline information and some essential do's and don'ts.

COMPONENTS

Lab Work 1

Resistors

R1	47k
R2, R3	4k7 (2 off)
R4, R5	100k (2 off)
R6, R7	10k (2 off)
Rx	see text

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers

VR1	1k min. preset or multiturn trimmer
VR2	10k min. preset or multiturn trimmer

Semiconductors

IC1	LM35DZ temperature sensor, TO-92 case
IC2, IC3	OP177 low offset op.amp (2 off)

Miscellaneous

Plug-in breadboard (0·1-inch pitch); RTH1, *ntc* thermistor (e.g. 2k2 or 10k at 25°C, see text); materials for probe; single core co-axial cable; min. crocodile clips (2 off).

Approx. Cost Guidance Only **£10**

PANEL 1.7. INSTALLING AND USING THE PICOSCOPE

The Picoscope range by Pico Technology Ltd consists of compact PC-assisted test instruments which are versatile and easy to use. With a 1MΩ input impedance and 8-bit sampling rate, the recommended Picoscope ADC-40 is a perfect introduction to the world of using computer-assisted test gear.

See our *EPE Special Offer* page for details on obtaining a Picoscope ADC-40 at a special discount price.

Using the Picoscope for Windows software (supplied with the Picoscope), you can monitor signal voltages and waveforms on a computer screen, and capture and paste them into your own documents. It also contains a modest "virtual" digital voltmeter facility.

The PicoLog Windows software application (also supplied) enables you to record events, plot graphs in real time, capture data for spreadsheets, and also set simple on-screen alarm set points. For more advanced users, there are many program and driver options available that permit the Picoscope to be integrated into custom created applications. A number of screen shots from our own experiments are provided in Lab Work 1.

The Picoscope ADC-40 plugs directly onto a free parallel (printer) port. *It is not compatible with a parallel port to USB adaptor*.

For our prototype Lab Work experiments, we used a one-metre BNC extension lead plugged into the Picoscope behind the PC, bringing the socket out to the front. The supplied scope test probe was plugged into this extension. Be aware that the ground input of the Picoscope connects directly to the ground (= earth lead) of your computer, in order to minimise electrical interference. Therefore, do not connect the ground input of the Picoscope probe to anything which may be at some voltage other than ground, as you may risk damage to the circuit under test, the Picoscope or the computer.

The Picoscope is intended for working with low-level signal voltages within the range ±5V. Although the input is protected up to +30V d.c. maximum, **definitely do not use this instrument for investigating voltages higher than ±5V, especially not the mains supply!**

Installation is easy – having plugged the ADC-40 into a free parallel port (or unplug your printer temporarily), insert the CD-ROM to install the Picoscope and PicoLog software, following the instructions supplied.

The Pico CD contains a wealth of technical data, user manuals in PDF format and more besides, and is well worth browsing.

The authors are extremely grateful for the help provided by Pico Technology Ltd., and we hope readers will enjoy using a Picoscope for the duration of *Teach-In 2002* – and beyond!

It is worth noting that many of the measurements can be taken using a digital multimeter, recording the values on paper, where appropriate.

Lab Work 1.1: Thermistors

This first Lab describes aspects of using thermistors as temperature sensors. The circuit of Fig.1.3 attempts to linearise the thermistor's highly non-linear resistance. The value of resistor Rx is calculated to be equal to the thermistor's resistance at the midpoint of the temperature range at which the circuit is to be used.

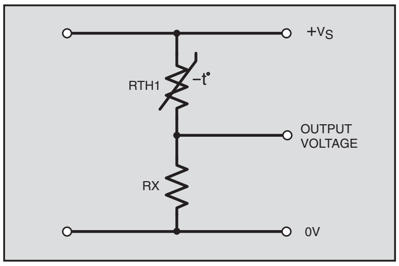


Fig.1.3. Using an ntc *thermistor to measure temperature. The value of Rx is calculated to be equal to the resistance of RTH1 at the mid-point of the desired thermal range.*

The positive supply voltage is notated as $+V_S$ (although the notation $+V_{DD}$ would also be legitimate). The voltage across resistor Rx is measured with the Picoscope. The voltage range of the Pico ADC-40 is ±5V, therefore it is necessary to use the +5V rail to power this circuit.

TEMPERATURE RANGE

Suppose we want to measure 20°C to 40°C using a 2·2kΩ thermistor (at 25°C) with β = 3500. Using the thermistor equation explained in the Tutorial section, we can calculate what the thermistor's resistance will be at the midpoint (30°C), remembering to add 273.15 (Kelvin) to the temperature in °C.

So, for this thermistor and this temperature range, resistor R1 needs to be 1800ΩW (1·8kΩ). The output voltage will not be linear at low and high temperatures but quite good around the midpoint.

Using an *ntc* rod or bead thermistor of your choice (e.g. 2·2kΩ or 10kΩ at 25°C – but not an expensive glass bead type unless you really feel the need!), practice calculating the correct value of resistor Rx for a temperature range of 0°C to 40°C (a typical range for domestic use). Test your results by assembling the circuit on a breadboard.

You should be able to plot a graph of output voltage against temperature if you have a thermometer available (preferably mercury-based for accuracy). Also explore the voltage output at differing temperatures using the Picoscope.

Using the PicoLog software, practice recording values over time, and saving them to your hard disk, referring to the online Help and the Pico CD-ROM for more guidance if needed.

Alternatively, use your digital multimeter to take measurements at various intervals, recording their values on paper.

The calibration of sensors can be a problem and is something we investigate next.

PANEL 1.8. BREADBOARDS – SIMPLY PLUG AND PLAY!

Most of the *Teach-In 2002* experimental circuits can be assembled on a solderless "breadboard". These are widely available prototyping units that enable you to experiment with circuits and reuse parts, without the need for soldering. Such breadboards are a real boon to help you develop and test your circuits with the minimum of fuss.

Unlike earlier *Teach-In* series, we shall not publish breadboard layout diagrams with *Teach-In 2000*. It is felt that the procedures are fairly intuitive and self-explanatory. We shall give the necessary technical data needed for pinouts etc., so that you can follow the practical labs successfully. Photographs of the experiments will be included as appropriate to give you an excellent idea of what is required.

The following practical tips will help to ensure that your visits to the *Teach-In* Labs are successful:

Always use solid core, insulated tinned copper wire to make the links – simply strip back a few millimetres of insulation and push firmly into the breadboard. Colour coding will help with checking. Use long-nose radio pliers to help insert wire ends into any fiddly, inaccessible areas. Avoid uninsulated leads (e.g. resistor wires etc.) shorting out and touching each other accidentally.

If you're not sure how the sockets and "buses" (internal connection strips) of your breadboard are laid out, find out by using a continuity tester or ohmmeter.

Integrated circuits are always identified with a polarity mark, either a notch or a dimple (or both) near pin 1, to show which way round it must be orientated. Be extra careful to observe this. Sometimes, components such as miniature potentiometers are tricky to insert into breadboards, but you must ensure that each wire leg is pushed firmly home into the relevant strip.

The power supply rail(s) should only be connected after the layout has been fully checked. You can clip the supplies onto the legs of components, e.g. suitable resistors, using test leads and crocodile clips, or insert generous lengths of insulated single-core wire into the breadboard and take them to the power supply terminals. The use of 1mm double-side terminal pins aids clipping probes to circuit points that you wish to monitor.

Overall you should have no problems in assembling the circuit successfully using the data we provide throughout the series – and remember, help is only an E-mail away if you get stuck. Write to **teach-in@epemag.demon.co.uk** (no file attachments or queries unrelated to the series please).

Lab Work 1.2: Using the LM35 Temperature Sensor

The National Semiconductor LM35 sensor is a 3-pin temperature-sensing device that is easy to use. The LM35 data sheet is downloadable from National Semiconductor's web site at **www.national.com**. Different versions of the LM35 are optimised for different temperature ranges. For our purposes, we'll use the LM35D which is the plastic TO-92 version. Table 1.4 summarises the major characteristics of the family.

In Fig.1.4a are shown the connections typically needed in the most basic setup. Fig.1.4b shows pinouts for the LM35DZ, the Z suffix denoting the plastic TO-92 version. The output voltage is 10mV per °C and you can directly read the temperature on a digital meter.

Demonstrate the functioning of the LM35DZ sensor by plugging it into a breadboard directly, and use your Picoscope oscilloscope or digital voltmeter to measure its output. Bear in mind that the Picoscope maximum input is 5V, therefore use a 5V d.c. rail to power this demonstration.

Hold the LM35DZ device between finger and thumb to raise its temperature and see how the Picoscope responds. Again, you can also practice using the PicoLog software to check readings and display a rolling graph of voltage (temperature) over time. Some readers may be able to export the PicoLog spreadsheet of values into Microsoft Excel to produce enhanced graphs from the data captured onto disk.

Lab Work 1.3: Calibrated Temperature Sensor

The LM35D has a quoted accuracy of ±0·6°C which means that we need a more complex circuit should we wish to be able to calibrate the sensor more accurately.

Before moving on, it is a good idea to make a sealed temperature probe which can be placed into water or steam without causing electrical problems. Fig 1.4c illustrates a suitable temperature probe, using

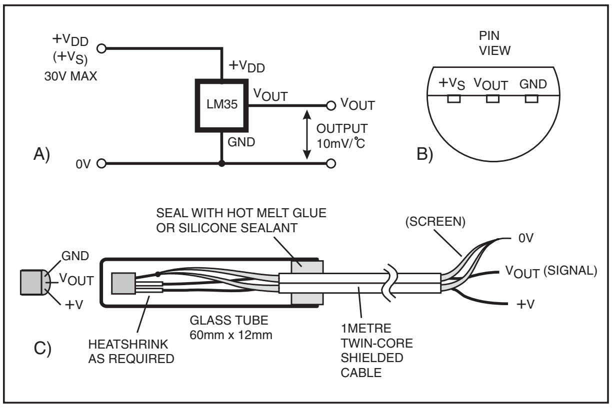


Fig.1.4. (a) Basic LM35 circuit, (b) pinout of LM35D, (c) simple temperature probe using LM35DZ.

e.g. a small glass phial with a tight stopper or an empty ballpoint pen body.

Using a one metre length of twin-core sheathed cable (e.g. twin audio cable), solder the cores to the corresponding leads on the LM35DZ, ideally insulating them with heatshrink or PVC sleeving. The sheath (outer braid) of the wire connects to the GND (0V) pin (see photo).

The device can be encapsulated in a small glass tube (e.g. a fragrance sampler), the end of which can be sealed using hot melt glue, silicone sealant or epoxy before sliding the cap over the end. The other end of the lead should be stripped and tinned, these will then be hooked to the breadboard using crocodile clips.

CALIBRATION CIRCUIT

Lab 1.3 illustrates the foregoing by building a calibration circuit for the LM35 (see Fig.1.4) which adds or subtracts a small voltage, and has an overall gain which can be varied around 1.

Readers by now familiar with the LM35 could argue that it is already accurate enough not to need calibration. However, our purpose now is to illustrate the issues involved, rather than produce a design for a particular application.

The circuit uses two operational amplifiers (op.amps), IC2 acts as a subtractor to remove any offset (varied by VR1) and has a gain of 2, IC3 provides a variable gain from about –1 to +1 (varied by VR2) which will nominally be set to +0·5. This gives the circuit an overall gain of 1.

Both VR1 and VR2 can be single turn or multiturn presets. As we are concerned with offsets, IC2 and IC3 should be low-offset op.amps – we used the readily-available OP177. Note that the op.amps run from a split supply, i.e. +12V and –12V as shown.

Having constructed this circuit, connect the LM35 temperature probe to the input at resistor R1, and then monitor the output at IC3 pin 6 using the Picoscope.

The LM35DZ enclosed in a sealed glass tube.

Table 4

Parameter	*LM35*	*LM35A*	*LM35C*	*LM35D*
Supply range (V)		+4 to +30V		
Operating Temp. Range (°C)	–55 to +150	–55 to +150	–40 to +110	0 to +100
Quiescent Current (mA) (typ., Vs= +5V)	105	91	91	91
Accuracy (°C) (at 25°C)	±0·4	±0·2	±0·4	± 0·6

Table 5. Temperature conversion.

Celsius to Kelvin:	Add 273·15 to the temperature in Celsius. 0°C is 273·15K and 100°C is 373.15K. 1K is equivalent to 1°C
Kelvin to Celsius:	Subtract 273·15 from the temperature in Kelvin
Celsius to Fahrenheit:	Multiply the temperature in Celsius by 1·8 and add 32. 0°C is 32°F and 100°C is 212°F
Fahrenheit to Celsius:	Subtract 32 from the temperature in Fahrenheit and divide by 1·8.

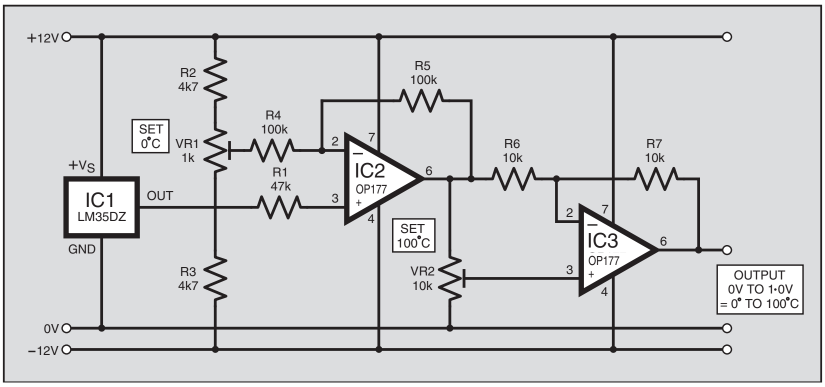


Fig.1.5. Calibrated temperature sensor using an LM35DZ.

CIRCUIT CALIBRATION

Calibration of the circuit requires two known temperatures which can easily be created: 0°C and 100°C. For 0°C, place the probe into a mixture of ice and water and leave for several minutes to allow the sensor to equilibriate. Monitor the voltage at IC3's output with your digital multimeter and vary VR1 until it reads 0·0V.

To obtain 100°C place the probe into the spout of a kettle full of boiling water and monitor the output until the reading is steady. Adjust VR2 until a correct reading of 1·0V is obtained.

Repeat the 0°C and 100°C calibration procedure again. The sensor is now calibrated and should be accurate to about 0·1°C. Note that this circuit will NOT measure below 0°C.

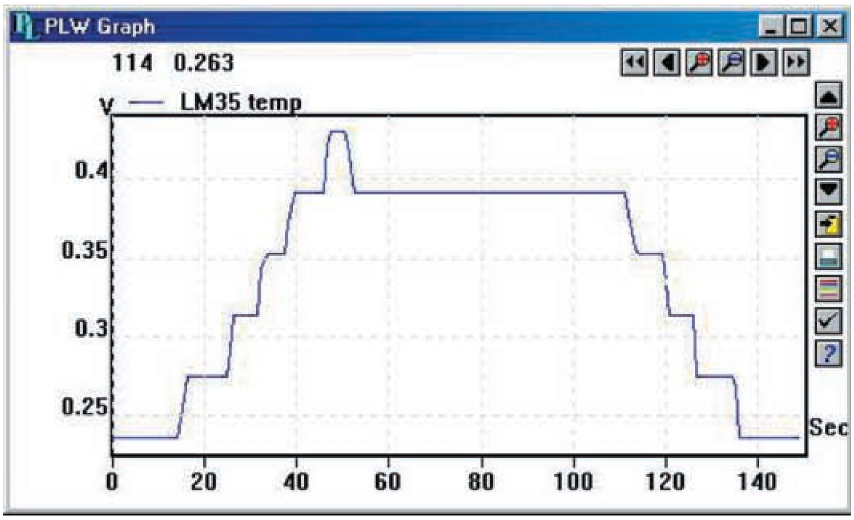
MAKING MEASUREMENTS

You are now ready to make measurements! Try measuring your body temperature by placing the probe under your arm. What temperature is measured? How close is it to 37·2°C (the "normal" human body temperature)?

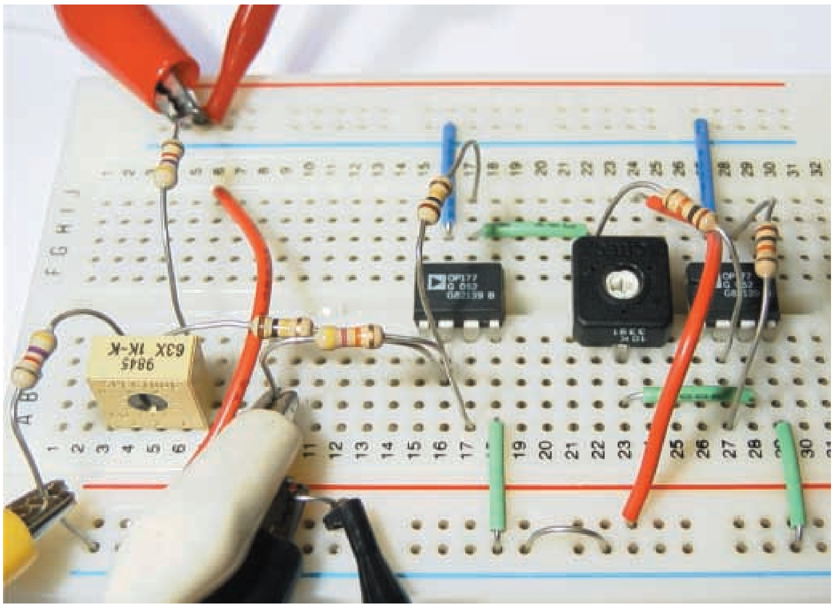
Measure room temperature as well, practising with the Picoscope and PicoLog Windows software to capture data and record any trends.

Note, however, that if you live at high altitude or have impure water your boiling water may have been at a temperature other than 100°C.

Unless you are very ill, your body temperature is probably more reliable, but more difficult (and more uncomfortable) to



Example display using the Picolog software and ADC-40 module to monitor the LM35 temperature sensor.



Breadboard assembly for the calibration circuit shown in Fig.1.5.

Table 6
Multiple and submultiple prefixes

Exponent	Prefix	Symbol
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	m
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Multiple and submultiple prefixes in common use (and some that aren't!). The symbols are case-sensitive.

measure. Calibration is not necessarily straightforward and easy!

One effect you will notice when calibrating the sensor is that the sensor takes time to reach the final reading – this is known as the *time constant* and can be a problem if trying to make measurements on rapidly changing signals. Luckily environmental temperature changes are relatively slow and we do not need to worry about the time constant. When we look at other sensors, this may not be the case!

If we wish to scale and offset the voltages by larger amounts we can do so by simply modifying the values of components in Fig.1.3 to change the offset voltages and gain. We will explain the operation of this circuit in more depth in Part 2 next month.

NEXT MONTH

Join us next month for more *Teach-In 2002* Lab Work. If you have any queries directly related to this series, you can write to the authors c/o the Editorial address, or you can E-mail them to **teach-in@epemag.demon.co.uk** (no file attachments or general electronic queries please).

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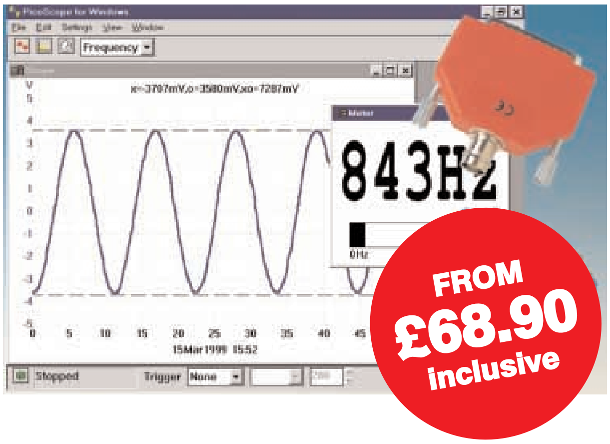

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New Technology Update

Conservation matters are highlighted with news of a new fuel cell and research into biochemical switches, reports Ian Poole.

THIS month a couple of ideas that are hitting the technology news at the moment. The first looks at some improvements being made in fuel cell technology, an area that is of considerable interest because of the improvements to environmental pollution when compared to other options. The second looks into putting bacteria to work in an application that is similar to that used in many electronic circuit configurations.

More Efficient Fuel Cells

With the impetus for conserving energy and reducing greenhouse gases increasing, new methods and more efficient methods of providing energy are always being sought. At the moment fuel cell technology has many limitations and as a result it is not widely used. If improvements can be introduced, their popularity may increase and their use become widespread.

The concept of a fuel cell is that it converts chemical energy directly into electrical energy. Normally they take in air and use the oxygen together with a fuel that usually consists of a hydrocarbon or hydrogen. A fuel cell differs from a battery in that it operates continuously whilst fuel is available. Once all the fuel has been used, the generation of electricity can be restarted simply by replenishing the fuel.

The cells consist of a positive and negative electrode separated by an electrolyte. The electrodes themselves are generally coated with platinum and this acts as a catalyst to enable the reaction to take place at a suitable rate.

As the hydrogen, or in some cases a hydrogen rich hydrocarbon such as methanol, is passed into the cells it comes into contact with the negative electrode and splits into two: electrons and positive ions. In the case of a hydrogen atom the positive ion is a proton. The electrons leave the cell through the negative electrode and the positive ions move across the separator membrane and come into contact with the oxygen molecules. Here they combine along with electrons returning to the cells through the positive electrode.

New Electrolytes

Today many fuel cells use polymer electrolytes. Unfortunately cells using these electrolytes must be humidified for the cells to be able to operate satisfactorily. Additionally, they can only operate over a limited temperature range and this means that they often require additional systems to be able to operate satisfactorily.

To overcome these problems research is being undertaken in a number of areas. In one development Professor Sossina Haile from Caltech has developed a fuel cell that does not need hydrating. The electrolyte is based not on a polymer but instead it uses what is termed a solid acid.

These are compounds whose properties fall between those of conventional acids such as sulphuric acid and salts including potassium sulphate. An example of a solid acid is potassium hydrogen sulphate. From its name it can be seen that its molecule includes potassium as in a normal salt, and hydrogen as in an acid.

The solid acids conduct electricity as well as polymers but they do not need to be hydrated. In addition to this they are able to operate at temperatures up to 250°C. A further advantage is that these solid acids are generally easy to manufacture and quite inexpensive.

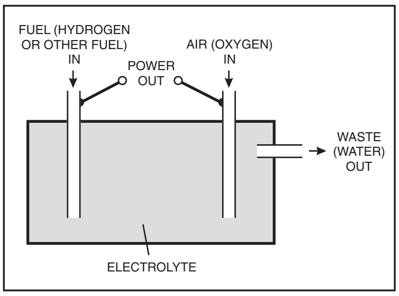


Fig.1. Diagram of a typical fuel cell

Currently investigations are proceeding into the operation and manufacture of fuel cells using these solid acids. Although a number of compounds have been assessed, the one that is currently being used is $CsHSO_4$. This provides a number of advantages over other compounds including the fact that it is not particularly prone to shape changes, a difficulty that was experienced with other compounds.

For the future the researchers are hoping to reduce the thickness of the electrolyte. High on their target list is to prevent the reaction that can occur with prolonged exposure to hydrogen.

Despite the amount of development that remains to be done, the researchers believe these new fuel cells have considerable potential.

E. Coli Work as Switches

Normally E.Coli bacterium is considered to be highly harmful. However, it has been discovered that it can be used in a genetic nano-scale toggle switch. In this development researchers at Cellicon Biotechnologies in Boston Massachusetts have started to assemble the first building blocks of a biological state machine. This was described at the recent International Solid-State Circuits Conference.

The action of the toggle can be considered like that of an RS flip-flop. Using the toggle switch, a single pulse of one chemical activates the expression of a target gene, while a single pulse of a second chemical inactivates the expression of that gene.

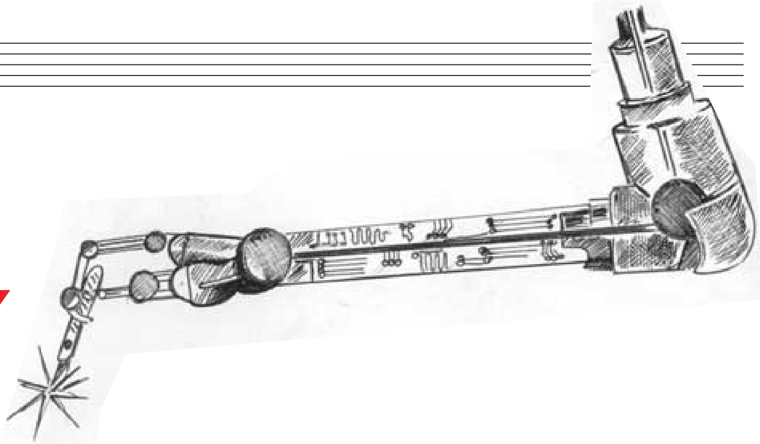
A further development was to arrange three genes and their associated DNA elements in a negative feedback loop in the bacterium. When three genes are engineered with the appropriate kinetic energies, a biological circuit or genetic applet is created producing an oscillatory gene expression.

The effectiveness of the concept was demonstrated with the construction of Cellicon's genetic toggle switch in Escherichia coli (E. coli). The design and implementation of the toggle switch was guided by a mathematical model that accurately described the principal features – bi-stability and "perfect" switching thresholds – of the experimental gene network, and the experimental manipulations necessary to generate or destroy bi-stability.

Practical Applications

As a practical device, the genetic toggle has significant implications for gene therapy and drug discovery. Because the toggle theory is qualitative, and thus general, the fundamental design is applicable to any organism, including mammalian cells. The toggle switch, for example, might be utilised to regulate the synthesis of erythropoietin (epo) in a gene therapy treatment of anaemia. Past research demonstrated the controllable expression of a recombinant epo gene in mice. The drawback of this system is that it requires the sustained ingestion of tetracycline. Long-term ingestion of tetracycline may be inconvenient or impractical for medical reasons. However, under the control of the toggle switch, the expression of epo will remain at the desired level, without drug ingestion, until it is later adjusted or switched off by the transient ingestion of an appropriate drug.

However before these can be realised as practical tools, efficient and scaleable methods of producing long DNA sequences must be devised. Once this has been achieved it will be necessary to investigate ways of binding these sequences to form the desired circuit. Although these biological circuits will not replace electronic circuits, they will be able to provide means of biochemical control at cellular levels.



CIRCUIT SURGERY

ALAN WINSTANLEY
and IAN BELL

Our troubleshooting team investigate the pros and cons of wiring transistors in parallel

THIS month a query from ***Ian Hartland*** of Worksop asks if it is possible to use several transistors in parallel, that is to wire the bases, collectors and emitters (or sources, drains and gates) of two or more transistors together (see Fig.1). The answer is yes, though it is a lot easier to do with MOSFETs than with BJTs (bipolar junction transistors – *npn* or *pnp*).

A Hot Problem

The reason for wanting to connect transistors in parallel is usually to boost the current that can be handled by the circuit, or to try to reduce the effective resistance when the transistor is turned on. The problem with BJTs is the tendency for one of the transistors in the set to "hog" the current, which is exactly what you don't want to happen if you are paralleling them to drive a high load.

In fact, the problem occurs due to the positive temperature coefficient of the collector current. The parallel transistors will all be slightly different and have differing gains, and so one of them will inevitably take a little more current than the others. This one will become hotter, therefore causing its current to increase, so it becomes hotter still: a process known as *thermal runaway* which may ultimately lead to its destruction.

The problem can be reduced by including a ballast resistor in the emitter circuit of each transistor, chosen to give around 0·2V drop at full load current (see Fig.2). This voltage will therefore develop across each resistor, offering the transistors some headroom or "slack" to help prevent one device from shunting the other transistor.

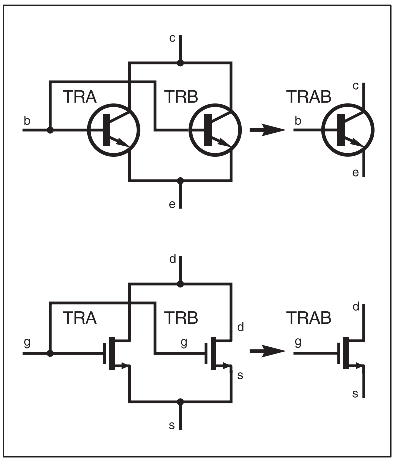


Fig.1. In a perfect world transistors in parallel would behave like a larger (more powerful) transistor. In practice this is easier with FETs than it is with BJTs.

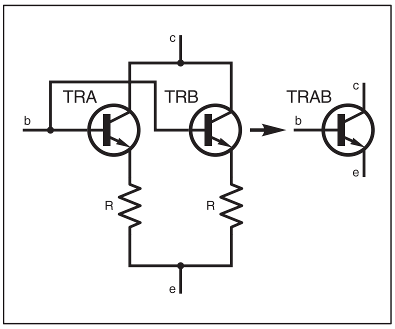


Fig.2. Parallel BJTs need emitter resistors to help reduce current hogging and thermal problems. MOSFETs do not suffer from this problem.

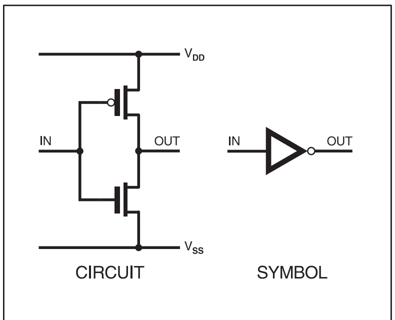


Fig.3. A MOSFET inverter.

On the other hand, MOSFETs have a *negative* coefficient of drain current so they do not suffer from the current hogging and thermal runaway problems just described. Resistors in the source connections are not required. Although the current may not be exactly equal in all the parallel MOSFETs (unless they are perfectly matched and held at the same temperature), the problem will not worsen to the point of self-destruction as it may with bipolar transistors. So you can drive higher loads with parallel MOSFETs relatively easily.

In Common

Another common application of the fact that you can parallel MOSFETs together with relative impunity is in the paralleling of CMOS logic inverters. A typical schematic of a basic MOSFET inverter is shown in Fig.3. In Fig.4 we show a MOSFET inverter with paralleled transistors. This is equivalent to two inverters in parallel, which in turn is equivalent to a larger, "beefier" inverter with twice the current source and sink capacity as the single transistor version. CMOS inverters such as the 4049 can be paralleled for increased drive.

It is also not uncommon to see voltage regulators paralleled in the same way to provide higher currents, but again it is a good idea to include a series ballast resistor to help prevent one device doing all the work. It is worth noting that i.c. designers often make use of parallel transistors with chip designs, or to look at it another way a transistor divided into several pieces, in both analogue and digital circuits, in order to produce the optimum layout of the circuit on silicon. *IMB.*

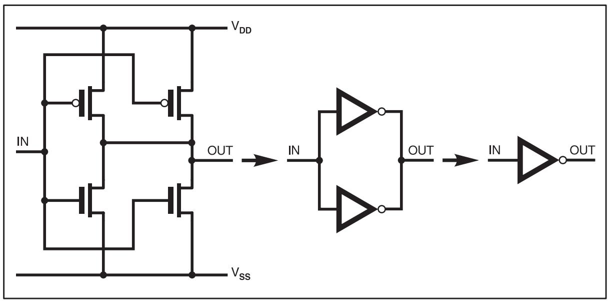


Fig.4 (right). Paralleling transistors in a MOSFET inverter is equivalent to using parallel inverters and provides higher sink and source currents.

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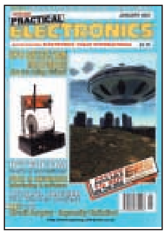

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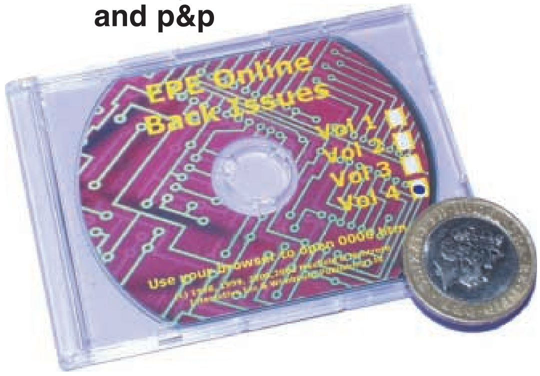

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★ LETTER OF THE MONTH ★

GRAPHIC BITMAPS

Dear EPE,

Thank you for your February's special supplement "Using Graphics L.C.D.s with PICs"!

After getting hold of a graphics l.c.d. and looking into John Becker's demos, I decided to move on and create a big bitmap image to be displayed on a graphics l.c.d. This could be used as a background image over which text is displayed, or simply as a nice splash-screen!

Big images such as these have to be generated in a "paint-type" program but, how do you convert the image from this program to suitable source code?

A short net-search revealed an extremely interesting application note available from Hantronix Inc. at **ftp://wfp62508.w1.com/imageapp.pdf** (**www.hantronix.com/app-note** "A Simple Way to Create Bitmap Images for Graphics LCDs").

Hantronix's article is excellent. However, and after some investigations, I believe the reader can miss (as I did) some of the subtleties of the process that I would like to share with all *EPE* readers.

Tagged Image File Format (TIFF) is the appropriate image format for our plans. An uncompressed black and white TIFF image file can be basically considered as a data matrix (bitmap is the operative word) in which a logical 1 is a white pixel and a black pixel is a logical 0. A logical 1 will turn "on" a pixel on the l.c.d. thus the image should be inverted for our l.c.d. purposes. So, set up a canvas that is 128 × 64, set the colour pallet for B&W, invert (negative) the image and save it in uncompressed TIFF (.tif) format.

Nevertheless, the generated file size is never the expected 1KB (128 × 64 bits). It includes unwanted TIFF headers and footers, whose size seem to depend highly on the particular "paint" software used. According to my own experiments, the header was never 25 bytes long as Hantronix's article stated.

So where is the "raw" image information? The best way to unravel the mystery is to generate a completely white image and take a look at the saved file using your favourite hex-editor. Find the 256-bytes long block of "FF", and write down the offset to use it later. The rest is unwanted garbage that can be safely removed!

Follow Hantronix's app-note directions to convert the TIFF file, which is in binary format, to hexadecimal format. Use your word processor to reformat the data to fit your PIC assembler instructions. Displaying it is an easy task following John's article.

The image data must be stored in Flash program memory due to its big size. Program memory locations may be read easily on PIC16F87x devices.

A simple demo source code I made myself can be downloaded at **www.ctv.es/USERS/javiergf/home.html**. It should work fine with John's demo circuit.

Javier Gonzalez Fernandez, Tenerife, Canary Islands, via the Net

Well, well! It had never even occurred to me that such a thing was possible with the l.c.d. Fascinating. Thank you Javier!

IT SKILLS PATH

Dear EPE,

I read with interest Brian Wintle's letter in the September issue regarding the skills shortage in electronics. He seems to be caught in the age-old "Catch 22" situation. With no experience, he can't get a job – but without a job (etc).

I have worked for an electronic contract manufacturer for several years and recently learned I am to be made redundant in a few months, due to the "general economic slowdown". There may well have been a shortage of skilled workers in the field a short time ago, but soon the jobs market will be flooded with experienced and well qualified engineers and technicians – all because there is nothing for them to build.

It occurred to me a few months ago that the electronics manufacturing industry has been this way for a long time (booming for two or three years – bust the next) and I have resolved to move into the field of IT, where there really is a skills shortage, and the job market seems to be more stable.

During my search for a new job I have seen lots of opportunities for jobs involving embedded controllers, ASICs and the like, something I believe is a field where small companies can thrive – especially when there are magazines such as yours which give so many an insight into the programming and development of such devices (albeit on a simpler level).

My advice for anyone considering a career in electronics is to think seriously about their choice. I would strongly advise against joining an industry which is so competitive and profit-driven to the detriment of its workforce (but not its shareholders). I am of course referring to manufacturing – the servicing and supply industry may not be as prestigious or profitable, but it's steady. After all – we're always going to need folks who can repair our domestic gear aren't we? (Or *are* we?)

Congratulations on maintaining a very high quality magazine!

Justin Hornsby, via the Net

Thank you for the advice Justin which we are pleased to share with other readers. You obviously have a positive approach to a difficult situation, and we wish you success in your search.

On your last point, we too believe that, despite our "throw-away" society, there will continue to be a need for service and repair engineers. It is this area to which our sister publication Electronics Service Manual *is dedicated.*

Another area that we believe has a long-term requirement is electronic education, and EPE *is heavily devoted to fulfilling this need.*

WANDERER FLIES BACK

Dear EPE,

I've re-commenced taking *EPE* after a break of many years (I have just bought a 2-year subscription). I hope that it will help you to know why, so as to reassure you that your format is exactly right and to encourage you to keep up the good work.

In the early 1970s I started to teach myself elementary electronics as a hobby while at school. Both *PE* and *EE* (I still have Issue No. 1 of the latter!) helped enormously. I presume your current title reflects that both publications are now rolled into one, as it were.

Anyway, I must confess, Maplin's new magazine appeared more suitable in the 1980s as *PE* started to concentrate on 8-bit microprocessors (which I had by then studied to degree level) and Maplin concentrated on projects with easy-to-order kits of parts.

This year it's about-turn. The Maplin magazine is no longer suited to my needs. How refreshing to see that *EPE* is now back to the well-balanced character that I remember of old. Also, the adverts offer a long-forgotten "Aladdin's Cave" of parts that are either hard-to-get or usually too expensive for a hobbyist. It's easy to read yet learn from, not so long that it's a chore, not overwhelmed with computers when it's circuit ideas that I'm after.

Why am I bothering to tell you all this? Well, the message is, don't be fooled by the actions of your rivals, they've failed for me.

I was also a regular columnist on a radio magazine for 14 years, specialising in aviation (I also run an aircraft museum as a hobby). When I was suddenly axed (never having missed a month in 14 years) a huge number of E-mails came from readers by way of complaint. The Editor just wanted to ". . . change the brand image, because it works for supermarkets . . ." or so he told me. It hasn't worked, readers are being lost. Don't make the same mistake!

As I'm an aviation enthusiast, I hope you'll let me add some information to Owen Bishop's interesting *Controlling Flight* article in Sept '01.

Spoilers dump lift to prevent the aircraft bouncing back into the air on touchdown and they have little direct retarding effect on the ground. Their true name is therefore "lift spoilers."

The article appears Airbus orientated, these machines are a little different to most others! They do have side-sticks but most other modern airliners (including those by Mr Boeing) still have conventional control yokes and, for the most part, hydraulic rather than electric control surface actuators.

I hold flight VHF, air/ground and offshore radio licences as well as the amateur callsign G4GLM and the GMDSS Short Range (marine radio) Certificate.

In summary, keep up the good work and *don't* change the character of the magazine (you are *not* running a supermarket!).

Godfrey Manning, via the Net

Editor Mike comments: "Rest assured we will not change things just for the sake of it. We are well aware of what happened with PE and ETI since they were both absorbed into EE from other publishers when they failed."

Thank you too for the flight-wise info, and welcome back!

SUPER TORCH L.E.D.S

Dear EPE,

Regarding Andy Flind's *L.E.D. Super Torches* designs in Sept '01, I suggest that those considering building the low-cost red version should instead consider using similarly low-cost very hi-intensity yellow l.e.d.s (no other component changes necessary).

Yellow is much better for reading, and nearly as good as white for use as a torch. Yellow l.e.d.s such as the Toshiba TLYH180P (Maplin o/c PF08J) are brighter and cheaper (and also take higher currents) than Farnell o/c 993864 white l.e.d.s (7cd @ 77p versus 3cd @ 324p respectively).

I have tested an RFI-free transistor-boosted LM334 current regulator circuit which can run yellow (or red) l.e.d.s from two economical AA cells wasting only the 60mV to 70mV across the sense resistor and the transistor's V_{sat} (usually below 0·2V). This circuit only requires six components. It could also be used to run white l.e.d.s from four AA/AAA cells (with no RFI). The reason I have made it is to replace the bulb in a DynoTorch.

A while ago I modified a cycle lamp into a yellow l.e.d. headtorch but it would now be cheaper to buy and modify a low-cost two to four AA cell headtorch. (The Petzl company sells a white l.e.d. headtorch but, strangely, it runs from three rather than four AAA cells).

When buying cases I have discovered that one marked as having a PP3/2AA battery compartment was actually mainly suited to PP3s and fitting two AA cells required some bodging: I will check such claims more carefully in future.

In my previous "C Sources" letter (June '01), the files **C99RATIONALE.pdf**, and **c9x_faq.pdf** may be more easily found as **N897.pdf**, and **N843.pdf** respectively in the ANSI sites pointed to from *Dr Dobbs Journal* magazine's website at **www.ddj.com/topics/cpp/**.

Alan Bradley, via the Net

Thank you Alan for both sets of useful information.

8-BIT COMPUTING ALIVE

Dear EPE,

For years now, *EPE* has been my "electronic link" between the southern tip of Africa and the rest of the world! The debate around what PC hardware and what programming language to use in conjunction with the projects, made me write this letter.

I am very interested in telephony – process control, weather monitoring and microcontroller projects. Time after time I sit with the dilemma that I need a computer to control something, but do not want to use my home PC. Simply for the reason that I do not want my PC and hard-disk to run 24 hours a day, seven days a week.

My dilemma was overcome when somebody gave me two BBC Acorn home computers! I can now easily test my projects via the 8-bit user ports and read analogue values with the analogue-to-digital converter ports. Interfacing to most of my projects is fairly easy. No running hard drives and a power consumption that makes any 24/7 control possible.

As an IT professional, it was very relaxing to sit down and program on a computer that is a level nearer to the electronics! It is all nice and easy to create stunning GUIs on a PC, but that is not what *EPE* is there for.

The programming language on the BBC is BASIC, quite powerful and easy to grasp. It would be interesting to know how many people are still using their BBC Acorns, as more than a million were apparently sold in the UK.

The developers of projects for *EPE* can keep their projects as generic as possible. If a computer must be involved, let the interface be serial or even parallel. This way it is up to the reader to use his own computer and programming language. I must however agree that it is not always possible and that not everybody is into programming.

The idea of Joe Farr (Sept '01) of having a web site where readers can post their own versions of software, is to me a good one. This way we can then even have software for inexpensive but powerful computers like the BBC Acorn, available to anyone interested. See **http://8bs.com** for 8-bit inspiration!

Finally, it is also time for a telephony project in *EPE*! I am struggling to read caller-id (CLI where I live) from my phone line. It can be a very interesting project, capable to be connected to any type of computer!

Johan Maritz, South Africa, via the Net

I recognise your feelings Johan, but as we have commented before in these pages, we do not feel justified in now supporting pre-PC computers, however good they were originally. I too had great success with the BBCs and PETs etc of many years ago but am equally at home with PCs of the modern era.

Nonetheless, I fully support the idea of using replaced computers in a workshop role. I have two workshops in different locations and in each I have two PCs side by side, one of them otherwise obsolete, so that I can run a main program on one and run tests or related matters on the other.

One of the aims of my Teach-In 2000 *series was to show how a PC can be used as an item of test gear. The idea is taken a step further with the current* Teach-In 2002 *series, in which a Picoscope ADC-40 plug-in module turns your PC into a very versatile oscilloscope.*

Regarding software submissions, this too has been discussed before. To summarise, in principle it is a good idea, but it would take too much of our time to manage the site for it to be realistic at present. However, I have initiated a PIC Tricks folder on the site in which I am placing short routines of reader-submitted PIC code that other people may find useful. Potential submissions, which must be kept short, should be sent to me at HQ.

Telephony projects, though, we cannot become involved in since there are stringent regulations about what may or may not be connected to a phone line, due to safety requirements.

PIC BANKS AND INTERRUPTS

Dear EPE,

I agree with Malc Wiles (*Readout* Sept '01), the use of interrupts has been somewhat neglected. What is needed is a ground up introduction and I am sure readers will find Malc's tutorial interesting. I will be looking forward to it as I cannot imaging writing a PIC program without interrupts (well, mostly anyway).

Malc briefly explains RPO/RP1/IRP bits in the status register, but another register that can cause havoc in ISRs is PCLATH, which is essentially bank switching for program memory. When an interrupt occurs PCH and PCL are loaded with $00 and $04 respectively, but PCLATH remains unchanged so the first MOVWF PCL, ADDWF PCL, CALL or GOTO instruction encountered may cause unexpected results.

Having said that, the ISRs in two of my "fun" PIC projects (unpublished) did not save/restore any registers at all, not even STATUS. But then I have been using interrupts for a good many years and have a few tricks up my sleeve.

Peter Hemsley, via the Net

Thank you Peter. Whilst I have never felt the need to make extensive use of interrupts, I am sure that many readers will benefit from Malc's article, currently scheduled for Jan '02.

Readers, Peter's various offerings regarding PIC Tricks that I have highlighted in several Readouts (and some that have not been) are on our ftp site under PICS/PicTricks. *There are other snippets of PIC code there too, which are well worth downloading. Thank you again Peter for yours.*

SENTINEL BIRD

Dear EPE,

It might interest readers that my *Gate Sentinel* (Oct '01) gave rise to a curious case of spurious triggering. The *Gate Sentinel* would regularly sound at five or six in the morning – but without giving the required number of "pips". There was no explanation to be found – until it was traced to a bird that was mimicking the sound. A case of a spuriously triggered bird?

I would also like to compliment Alan Winstanley on *Ingenuity Unlimited*. He has introduced a homogeneity to the column that makes it a pleasure to read.

Thomas Scarborough,
South Africa, via the Net

Obviously a potential circuit problem that a 'scope cannot predict for! In fact, many birds are capable of mimicking all types of sounds, including mobile phone and modem tones. In the UK, the Blackbird is renowned for its vocal mimicry and versatility.

Constructional Project

LIGHTS NEEDED ALERT

TERRY de VAUX-BALBIRNIE

Keep on the right side of the law when driving at night.

IT SEEMS that an increasing number of motorists are forgetting to switch on their car lights when they should. Can any of us, honestly, say that we have never done it ourselves?

It may have something to do with better road lighting or to a more relaxed driving style. Whatever the reason or reasons, it is a hazard and driving without lights after lighting-up time runs the risk of causing an accident or prosecution.

PROMPT ACTION

Suppose you are driving along as the light level slowly falls. The road is well lit and you can see perfectly well. If you are not prompted, possibly by seeing other cars with their lights on, it is easy to forget to switch on your own. This circuit helps you to keep out of trouble by giving an audible signal when the ambient light falls to some pre-determined value.

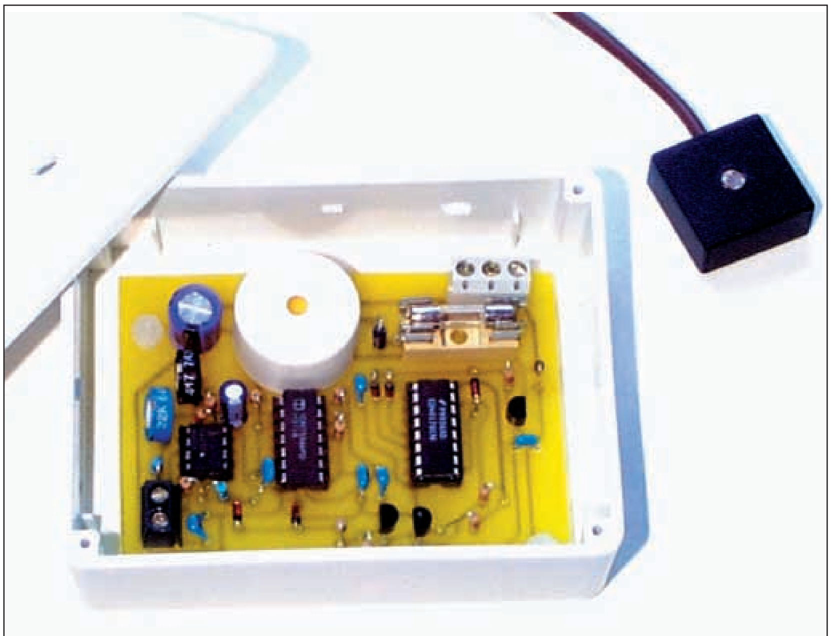
Although the circuit itself is straightforward to construct, there are some connections to be made between the main unit and the car electrical system. ***Anyone who is unsure of being able to carry out this work safely must seek the advice of a competent person. Also, you must be aware that you can possibly invalidate any warrantee covers you have on the vehicle – you should check this out!***

OVERVIEW

With the ignition switched *off*, nothing happens and the circuit requires no current. With the ignition *on* and the light level above the predetermined value, the circuit is in "standby" mode and draws a few milliamps from the supply (the exact value depends on circuit adjustments but may be regarded as negligible). When the light level falls below the preset value, a distinctive audible signal is given which stops as soon as the lights are switched on.

The audio tone has been designed to be different from other sounds likely to be heard in the car. It takes the form of groups of three short high-pitched bleeps which repeat continuously. This attracts the attention of the driver without it needing to be particularly loud.

An important feature of the circuit is an adjustable time delay built in the light-sensing section. When the illumination falls to the threshold value, this holds off operation for a certain time. If the light level increases again during this period, the circuit will not be activated. This prevents spurious operation when the illumination falls temporarily as might happen when the car passed under some trees near the critical point. The delay may be adjusted within the range 0·5 to 50 seconds for best effect.



CIRCUIT DESCRIPTION

The complete circuit diagram for the *Lights Needed Alert* is shown in Fig.1. When the ignition switch is on, current flows from the 12V car system via fuse FS1 and diode D6 to the rest of the circuit. Diode D6 provides reverse-polarity protection.

If the unit were to be connected to the supply in the opposite sense, the diode would be reverse-biased and nothing would happen. Incorrect polarity would otherwise ruin semiconductor devices in the circuit. Fuse FS1 provides protection in the event of a short-circuit.

The circuit will be connected to the supply through an existing fuse. However, FS1 has a very low value and it is this one which would be more likely to blow under a fault condition.

While the car engine is running, the alternator produces a very "noisy" output and capacitor C7 connected across the supply smoothes it.

LIGHT WORK

The first stage of the circuit proper is the light-sensing section based on operational amplifier (op.amp) IC1 and associated components. Both the non-inverting (pin 3) and inverting (pin 2) inputs are connected to potential dividers placed across the nominal 12V supply.

The potential divider associated with the non-inverting input (pin 3) consists of equal-value fixed resistors, R3 and R4. The voltage at pin 3 will therefore be one-half that of the supply (nominally 6V). The potential divider associated with the inverting input consists of the series arrangement of fixed resistor R2 and preset potentiometer VR1 in the top arm and light-dependent resistor (l.d.r.) R1 in the lower one. The l.d.r. is connected remotely through the 2-way section of terminal block TB1.

An l.d.r.'s resistance changes with the intensity of light reaching its sensitive surface (the "window"). With the specified unit, bright daylight will result in a resistance of only a few hundred ohms. In total darkness it will be several megohms. In measurements on the prototype unit, a view of the sky at the critical light level (a little earlier than UK "lighting-up time") gave a resistance of 15 kilohms approximately.

Due to the potential divider action, a certain voltage will therefore be developed across the l.d.r. which depends on the light level. As the illumination falls the voltage will increase.

At the setting-up stage, VR1 will be adjusted so that the resistance of the R2/VR1 combination is equal to the resistance of the l.d.r. at the critical light level. The voltage at IC1 pin 2 will then be one-half that of the supply (nominally 6V) and therefore equal to that at pin 3.

When the illumination of the l.d.r. is greater than the critical value, the voltage at IC1 pin 2 will be less than that at pin 3. Under these conditions, the op.amp will be *on* with the output at pin 6 high (positive supply voltage). When the light level falls below the switching point, the conditions of the inputs will reverse and the op.amp will switch *off* with pin 6 going *low* (0V).

Resistor R5 introduces a little positive feedback into the system and has the effect of sharpening the switching action at the critical point. Thus, small fluctuations in the light level will not cause repeated on-off switching.

Capacitor C1 bypasses any a.c. (alternating current) which may be picked up along the l.d.r. connecting leads (since the light sensor is connected remotely from the main section). Without this, the operating point could become "blurred".

Note that the switching point is largely independent of the supply voltage. This is because the potential dividers associated with both op.amp inputs are connected across the same supply. If the voltage fluctuates, that appearing at each op.amp input will rise or fall by the same factor so the relative conditions will remain the same.

ON TIME

The following stage of the circuit is a monostable based on IC2a and associated components. It is one half of dual timer IC2 (that is, it contains two identical sections). The other one, IC2b, is used for another purpose and will be looked at presently.

Monostable IC2a provides the time delay aspect of the light-sensing section mentioned earlier. When the light level falls below the critical point, IC1 output goes low and a momentary low state is applied to IC2a trigger input at pin 6, via capacitor C2.

This causes IC2a to begin a timing cycle. During this time, the output (pin 5) will go high for a certain period then revert to low.

The length of the period is related to the values of fixed resistor R7, preset potentiometer VR2 and capacitor C3. With the specified values, VR2 will provide an adjustment between some 0·5 sec. and 50 sec. approximately. Except while the trigger pulse is being applied, IC2a pin 6 is maintained in a high condition by fixed resistor R6 and this prevents possible false triggering.

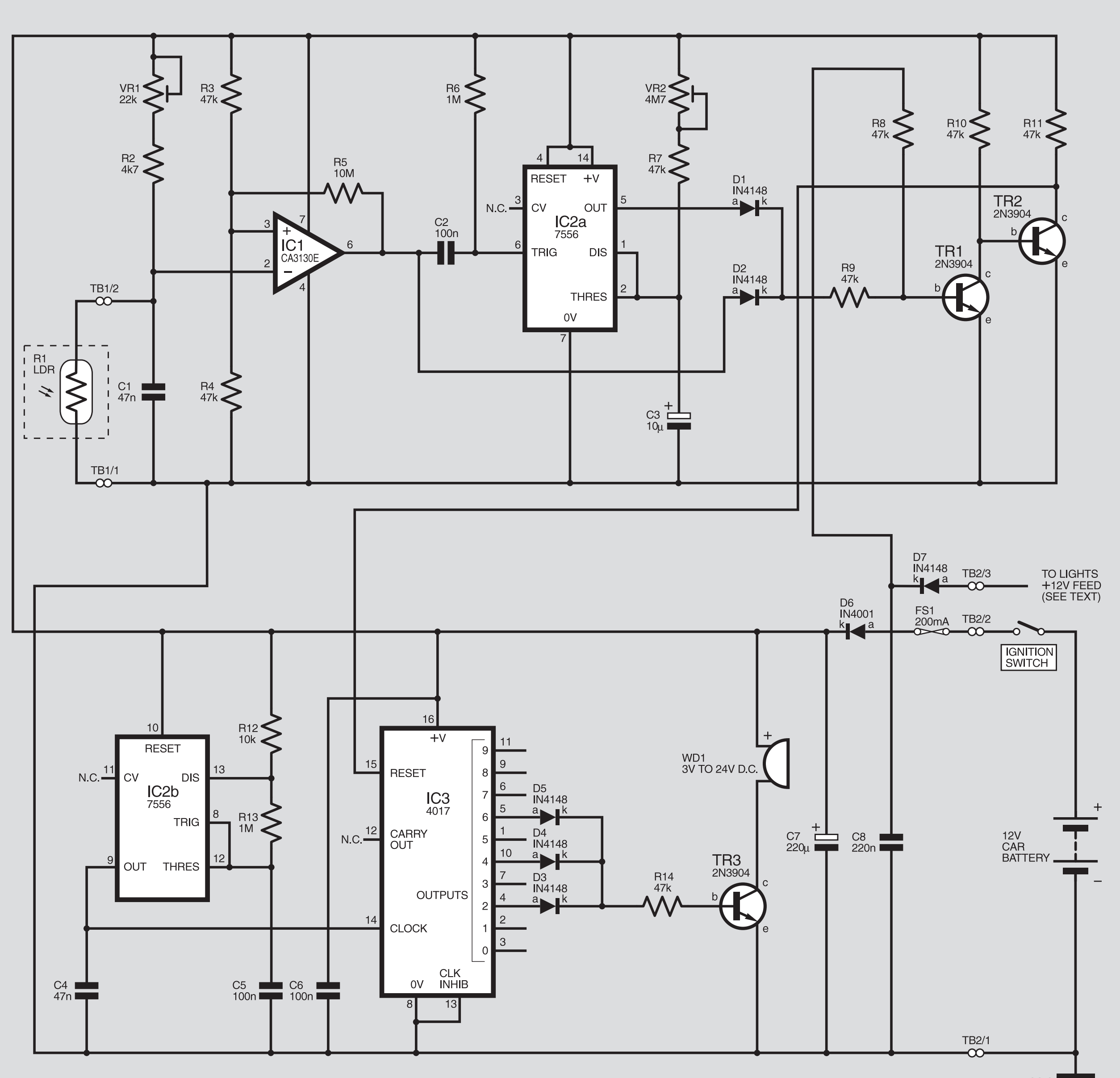


Fig.1. Complete circuit diagram for the Lights Needed Alert.

OPERATING CONDITIONS

During IC2a timing cycle the output, pin 5, allows current to flow through diode D1 and resistor R9 to the base (b) of transistor TR1. Additionally, when IC1 output (pin 6) is high (due to a light level above the critical value) current will flow into the base of TR1 via D2 and R9.

There is a further method by which TR1 base may receive current. This is from the "lights +12V feed" (which provides a positive supply voltage when the car lights are switched on) via diode D7 and resistor R8. Capacitor C8 removes any "noise" picked up by this part of the system.

It can be seen that the only time TR1 base will receive *no* current is if (a) the light level is *below* the threshold value *and* (b) the monostable is not in the course of timing *and* (c) the car lights are switched off.

Transistor TR1's collector will then be high. This will allow current to enter transistor TR2 base though resistor R10 and its collector will go low.

If any of the above conditions are not met, TR1 base receives current and its collector will go low. No current enters TR2 base so its collector will be high via resistor R11.

Transistor TR2's collector is connected to the Reset input (pin 15) of decade counter IC3. With a high state here, the device is placed in reset mode which, in effect, means that nothing further happens. With a low state at pin 15, IC3 is enabled.

Suppose the car lights are switched off and the light level falls below the threshold value. Monostable IC2a will begin a timing cycle and this will place IC3 Reset input pin 15 in a high state so disabling it.

Suppose, during timing, the light level increases again (due to, say, the car having passed under a bridge). When the monostable ends its timing cycle, IC1 pin 6 will have become high so IC3 is maintained in a reset condition. Only if the monostable ends its timing cycle *and* the light level is still below the threshold value (and the lights are still off) will the reset state be removed from IC3.

PULSE GENERATOR

The section of circuit based on IC2b (the as-yet unused section of IC2) is configured as an astable. Thus, it provides a continuous stream of on-off pulses at its output (pin 9). The frequency of operation is related to the values of fixed resistors R12 and R13 in conjunction with capacitor C5. With the values specified, the frequency will be some 5Hz (five pulses per second). Since this is not particularly critical, no adjustment is provided.

These pulses are applied to the clock input of IC3 at pin 14. Capacitor C4 bypasses any stray signals which tend to be picked up along the printed circuit board track between IC2b pin 9 and IC3 pin 14. Without this, IC3 tends to "see" them as additional "real" pulses and this can result in erratic operation.

If IC3 reset input (pin 5) is high, the pulses arriving at the clock input (pin 14) have no effect. However, if the reset input is low, they cause IC3 outputs 0 to 9 to go high in turn at nominally 0·2 sec. intervals and this repeats indefinitely. The number of each output is shown *inside* IC3's circuit symbol in Fig. 1 while the pin number corresponding to each output is shown *outside.*

Only outputs 2, 4 and 6 (pins 4, 10 and 5) are used. When one of these goes high, current will flow through one of the diodes D3 to D5 and enter the base of transistor TR3 through resistor R14. The audible warning device, WD1 (solid-state buzzer) in the collector circuit then sounds.

As each of the three outputs go high, there will therefore be three bleeps given (the spaces between these are provided when outputs 3 and 5 go high) followed by a period if silence (while outputs 7, 8, 9, 0 and 1 go high). The sequence then repeats.

CONSTRUCTION

Construction is based on a single-sided printed circuit board (p.c.b.). The topside component layout and full size underside copper foil track master are shown in Fig. 2. This board is available from the *EPE PCB Service*, code 321. Note that all components (apart from l.d.r. R1) are mounted on this p.c.b.

Commence construction by drilling the two board fixing holes as indicated. Follow with the fuseholder, i.c. sockets and the two sections of p.c.b. terminal block, TB1 and TB2.

Solder in position the resistors (except l.d.r. R1) including presets VR1 and VR2, and capacitors C1, C2, C4 to C6 and C8. Next, add the polarity-sensitive components, capacitors C3 and C7, diodes D1 to D7, transistors TR1 to TR3 and buzzer WD1; double-check the orientation of these as they are inserted on the p.c.b.

Note that transistors TR1 and TR2 have their flat faces placed to the *left* while TR3 has it facing *right* (see Fig.2 and the photograph). Also note, the buzzer WD1 must be of the *d.c. operating* variety as specified. It must not be of a type which requires a separate drive circuit.

Adjust preset potentiometer VR1 fully anti-clockwise (to operate in dim light) and VR2 fully clockwise (as viewed from the left-hand edge of the p.c.b.) for minimum time delay. Insert the fuse in the fuseholder.

TESTING

Basic testing must be carried out using a separate temporary 9V battery (a PP3 or PP9 type will be satisfactory). In this way, any small problems may be resolved before the p.c.b. is mounted in its box and wired to the car electrical system.

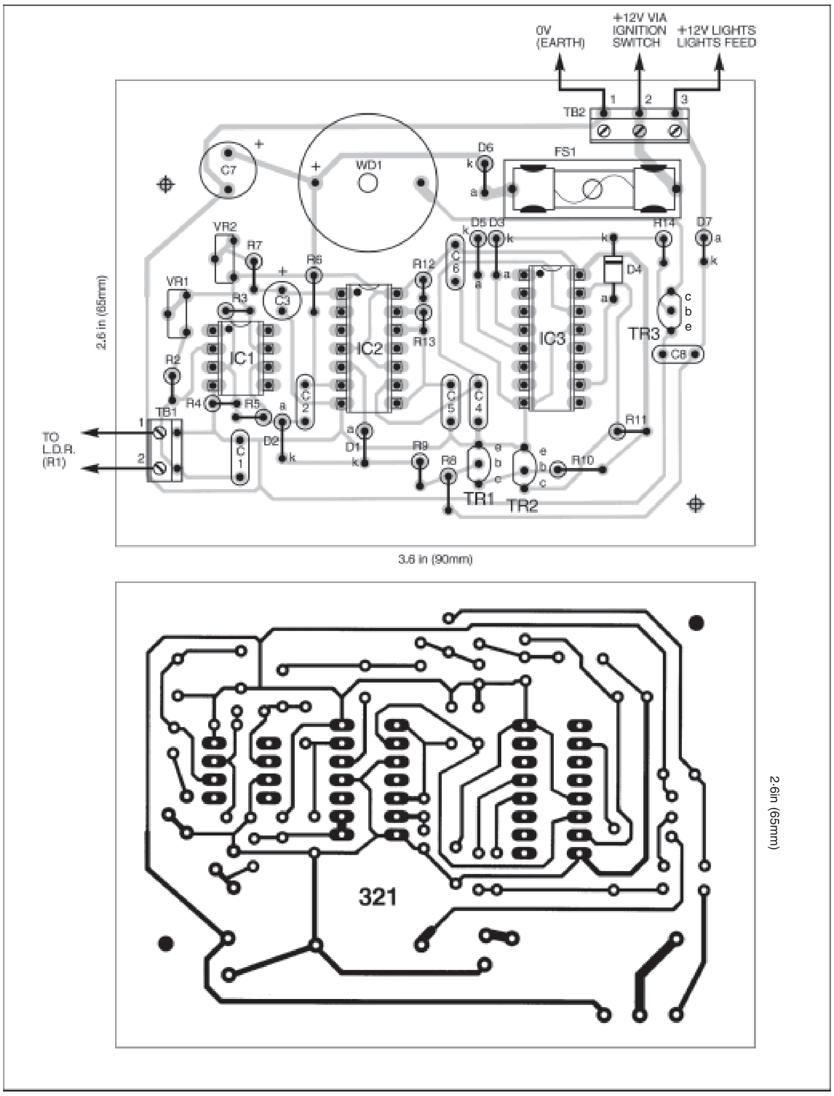


Fig.2. Printed circuit board component layout, wiring and full-size underside copper foil master pattern for the Lights Needed Alert.

Connect the light sensor, l.d.r. R1, direct to terminal block TB1 (polarity unimportant). Wire the battery connector to terminals TB2/2 and TB2/1, observing their polarity. Connect a piece of insulated connecting wire, having a bare end, to TB2/3; the "+12V lights feed" terminal.

Work in a place where normal room lighting will reach the l.d.r. sensitive surface (near a window for example). Now connect up the temporary test battery.

Buzzer WD1 should remain silent. If it begins sounding, allow more light to reach the l.d.r. Cover the l.d.r. with the hand and keep it covered. After a short delay (less than one second), the buzzer should begin to sound in groups of three short bleeps. If necessary, adjust VR1 for correct operation.

Preset potentiometer VR1 will be set to provide the correct degree of sensitivity to light. However, this cannot be done until the l.d.r. unit has been mounted in its final position since this will affect the amount of light reaching it.

While the buzzer is sounding, allow light to reach the l.d.r. again. The sound should stop. Again, with the buzzer sounding, touch the "lights feed" wire on to terminal point TB2/2 (which connects to the battery positive terminal). The buzzer should stop sounding (because this simulates the lights having been switched on).

Check that the hold-off time may be adjusted by rotating VR2 sliding contact. However, return the timing to minimum afterwards because it will be easier to set the final operating light level that way.

BOXING UP

If all is well, the p.c.b. should be mounted in its box. Any *plastic* box which is large enough to accommodate it will be satisfactory.

Place the p.c.b. on the base and mark through the fixing holes. Mark out a hole in the side walls near each terminal block position for the external wires to pass through and a further hole in the lid above sounder WD1 position for the sound to pass out. Remove the p.c.b. and drill these holes through.

Mount the p.c.b. using plastic stand-off insulators on the bolt shanks so that the buzzer is close to the lid of the box (for maximum sound output). If it proves to be too loud at the end, it may be taped over.

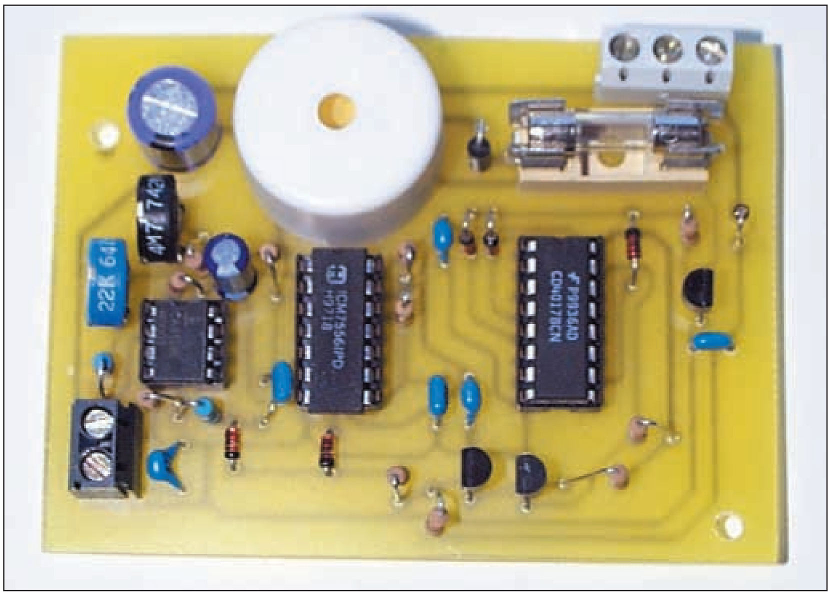
LIGHT-SENSING UNIT

The remote light-sensing unit, containing the l.d.r., should now be constructed. If the specified sub-miniature type of l.d.r. is being used, a very small box will be sufficient. In the prototype, a "potting box" was used (see photographs).

This was cut down to a depth of 10mm approximately. A small hole was then drilled in the side for the connecting wire to pass through and a further one in the top which was a push fit for the l.d.r.

Cut the l.d.r. pinout leads down to a length of 10mm approximately. Sleeve them to reduce the chance of them touching.

Cut off a suitable length of light-duty twin-stranded wire to reach between the proposed positions of the two units. If this distance is more than three metres (which is unlikely), it may be found necessary to use miniature *screened* cable to prevent the possible pick-up of electrical "noise" which could upset operation.



Pass the end of the inter-connecting lead through the potting box hole and solder the ends to the l.d.r. end wires. Take care to avoid excessive heat during soldering or the characteristics of the l.d.r. may change. Apply strain relief to the wire so that it cannot pull free in service. In the prototype, this was done using a tight cable tie.

Push-fit the l.d.r. body into the hole drilled for it and secure the whole assembly using quick-setting epoxy-resin adhesive (see photograph). Make sure the soldered joints are kept well separated. Glue a cardboard base to the box.

Decide on a suitable position for the light-sensor unit where it will be unobtrusive and where light will reach the l.d.r. from the sky. A good position is at the top corner of the windscreen. This will allow the l.d.r. to have a good "view" of the sky.

The interconnecting wire may be pushed under the trim and routed to a position behind the dashboard. In the prototype, the unit itself was secured using two strips of sticky "Velcro".

WIRING UP

Before proceeding any further, disconnect the car battery positive terminal. If you

COMPONENTS

Approx. Cost Guidance Only **£20** *excluding connectors*

Resistors

R1	miniature l.d.r. – dark resistance 5MΩ approx
R2	4k7
R3, R4, R7 to R11, R14	47k (8 off)
R5	10M
R6, R13	1M (2 off)
R12	10k

All 0·25W 5% carbon film, except R1.

See SHOP TALK page

Potentiometers

VR1	22k min. enclosed carbon preset, vert
VR2	4M7 min. enclosed carbon preset, vert.

Capacitors

C1, C4	47n ceramic – 5mm pin spacing (2 off).
C2, C5, C6	100n ceramic – 5mm pin spacing (3 off).
C3	10μ min. radial elect. 35V
C7	220μ min. radial elect. 35V
C8	220n ceramic – 5mm pin spacing

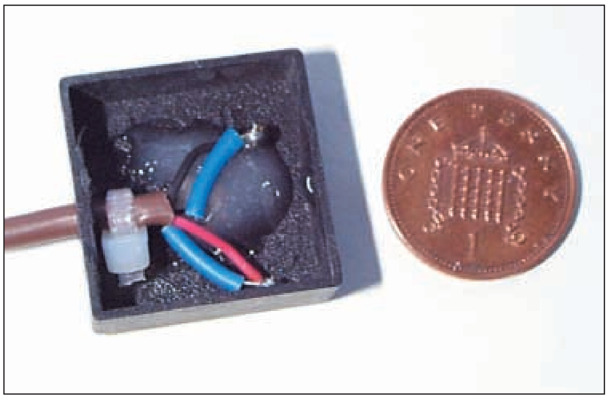
Semiconductors

D1 to D5, D7	1N4148 signal diode (6 off)
D6	1N4001 50V 1A rect. diode.
TR1 to TR3	2N3904 *npn* low power transistor (3 off)
IC1	CA3130E op.amp.
IC2	ICM7556IPA low power dual timer.
IC3	HCF4017BEY decade counter

Miscellaneous

WD1	d.c. piezo buzzer 3V to 24V operation at 10mA maximum.
TB1	2-way low profile p.c.b. terminal block – 5mm spacing.
TB2	3-way low profile p.c.b. terminal block – 5mm spacing.
FS1	200mA 20mm fuse and p.c.b. mounting fuseholder

Printed circuit board available from the *EPE PCB Service*, code 321; 8-pin d.i.l. i.c. socket; 14-pin d.i.l. socket; 16-pin d.i.l. socket; plastic case, size 102mm x 76mm x 38mm; small potting box or other small plastic box; auto-type wire; light-duty twin wire; auto-type snap-lock connectors; quick-setting epoxy resin adhesive; solder, etc.



The light-dependent resistor (l.d.r.) is pushed into a hole in the light sensor box and secured in position using quick-setting epoxy adhesive.

have a "coded" audio system, make sure you have the code available to re-enter this when the supply is re-established.

Decide on a suitable position behind the dashboard or elsewhere for the main unit. It will need to be sited close to a wire which becomes "*live*" only when the ignition is switched on. ***This must receive its supply through an existing fuse.***

Often the most convenient wire to use is the feed for the radio or audio system. Note, however, that there are usually *two* +12V wires here. One is made via the ignition switch but there is also a continuous +12V one which is used to maintain the memory settings, clock, etc.

If you decide to make a connection here, take care to select the correct wire. If a continuous +12V feed was used, the buzzer would sound at night when the car was left parked without lights. At the same time, find a suitable car chassis (earth) connection. Again, the audio system could provide this.

LIGHTS FEED

You now need to locate a wire which becomes "live" when the side lights are switched on. *Again, this wire **must** obtain its supply through an existing fuse.* It may be possible to make the connection at the wire leading from a fuse controlling one of the sidelights or at one of the lighting units.

Cut off three pieces of light-duty stranded *automotive* type wire long enough to make the positive supply lights feed and chassis (earth) connections. Leave sufficient slack to allow the unit to be accessible to make adjustments before finally securing it in place. ***On no account use ordinary (non-automotive) wire***.

Use red wire for the +12V feed, black for the chassis and a different colour if possible for the lights one. If two red wires must be used, take special care to keep track of which is which. *If any wire passes through a hole in metal, a rubber grommet must be used to protect it from cutting by the sharp edges.*

Pass the wires through the hole in the side of the unit and, leaving a little slack, connect them to terminal block TB2 inside the unit *before* making the connections to the car system. Take care to connect the correct wire to the correct terminal. Apply a tight cable tie or cable clamp around the wires to prevent them pulling free in service.

Connect the free ends of the wires to the car wiring using "snap-lock" type connectors. ***On no account use makeshift methods such as taped joints***.

Route the sensor wire as necessary and pass it through the hole in the main unit close to terminal block TB1. Connect the ends to the terminal block. If miniature screened cable has been used, connect the screening to TB1/1 which connects to the 0V line (chassis). Leave the lid off the box for the moment to allow adjustments to be made.

FINAL ADJUSTMENTS

After inspecting all wiring and checking everything is in order, connect the car battery and test the system. Adjust preset VR1 for the correct degree of sensitivity to light. You do not need to drive around to make the initial adjustment, simply park the car where the l.d.r. has a clear "view" of the sky.

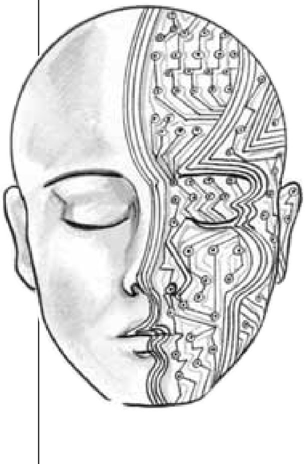
Wait until the light level falls to the point where lights are needed, switch on the ignition and adjust preset VR1 until the buzzer begins to sound. Check that it stops when the lights are switched on. If the buzzer begins to sound before it becomes dark enough despite adjusting VR1 fully anti-clockwise, increase the value of resistor R2 to about 22 kilohms (22kΩ) and try again.

You now need to test the system and make final adjustments under real driving conditions. You will need the help of an assistant to do this as you go along.

Wait for the light level to fall to within, say, half an hour of the "lights needed" point. As the critical point is reached (it is best to err on the bright side), VR1 should be adjusted so that buzzer WD1 just begins to sound.

With the hold-off time set to minimum, there will be many "false alarms". Adjust VR2 for a hold-off time of around 12 sec. to 15 sec. and re-check the following day. This was the timing used in the prototype unit but it will depend on conditions. Make sure it is long enough to allow you to drive out of a dim garage without the buzzer sounding.

Finally, attach the lid of the case and secure the unit in position – taping it to the wiring loom will probably be sufficient. □



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: Alan Winstanley, *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

- 50MSPS Dual Channel Storage Oscilloscope
- 25MHz 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 six months, Pico Technology will be awarding an ADC200-50 digital storage oscilloscope for the best IU submission. In addition, two single channel ADC-40s will be presented to the runners-up.

Automatic Day Indicator – Wake-up Call

READERS who have ever woken up convinced that the weekend had arrived, only to realise to their dismay that it is a working weekday after all (*life can be hard! – ARW*), will welcome the circuit of Fig. 1. It utilises a light-dependant resistor (l.d.r.) R1 attached to a window frame. At sunrise, the resistance of R1 gradually falls until transistor TR1 (which can be any general purpose *npn* transistor) conducts. This sends a high input via the shaping circuit of resistor R2 and capacitor C2 to the clock input of IC1, which is held at 0V by resistor R3 at night times.

The first seven outputs of IC1 drive an l.e.d. that indicates the day of the week, e.g. Q0 = Sunday etc. As only one l.e.d. is ever illuminated at a time they share a common resistor R4 connecting them to the 0V rail. The preset potentiometer VR1 adjusts the sensitivity and capacitor C1 provides overall smoothing, which is essential if running from a power supply.

Switch S1 is used to manually set the day when the unit is first switched on, however it can only operate when transistor TR1 is turned off (i.e. when the l.d.r. is dark). It should run from a 9V to 12V mains adaptor.

If the unit suffers from multiple triggering caused by a badly regulated power supply during the critical dusk/dawn periods when transistor TR1 is just changing state, then increasing the capacitance of C2 should solve this. It is, of course, essential to mount the l.d.r. in such a way that it can detect daylight, without suffering false triggering during the night from e.g. security lights or passing cars.

The prototype has operated reliably now for five years, the only occasions on which it has given false readings is after night-time thunderstorms where each bolt of lightning caused the unit to advance by one day. The odd solar eclipse also triggered it!

Ian Hill, Plymouth, Devon

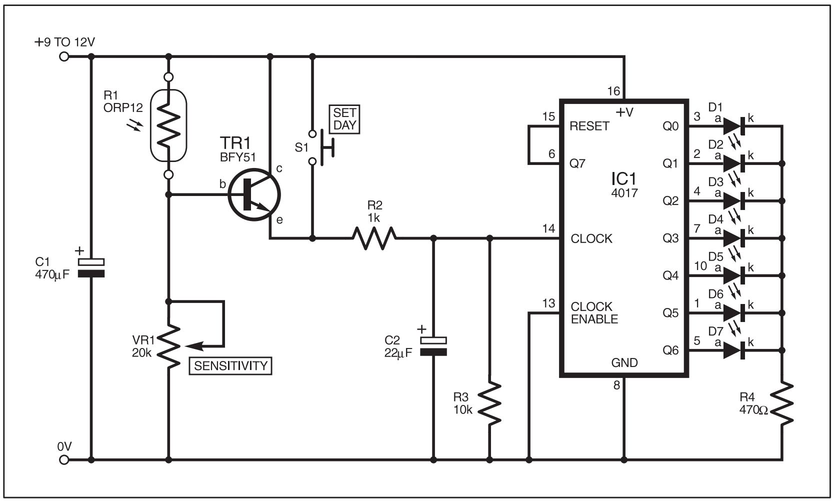


Fig.1. Circuit diagram for the Automatic Day Indicator.

Christmas Star – A Simple Solution

A VERY SIMPLE table or Christmas tree decoration which can be made in half-an-hour is shown in the circuit diagram of Fig.2. It uses five red high-brightness l.e.d.s. D1 to D5 together with a 9V battery. A decoration – e.g. a Christmas Star – can be made from cardboard and the l.e.d.s inserted from behind into the "points" to enhance the decoration.

When a typical l.e.d. is conducting, usually 2V or so appears across it. A series resistor is then connected to drop the remainder of the supply voltage and to limit the current. The true voltage across an l.e.d. depends on various factors such as the current flowing, the colour and type. The forward voltage of a typical high-brightness or "superbright" red l.e.d. is approximately 1·7V at 10mA. By connecting five similar l.e.ds in *series*, they can safely be operated direct by a 9V battery with no series resistor, as shown.

It was found that five superbright l.e.d.s drew some 30mA with a new battery (having a terminal voltage of 9·5V). At 8V they became dim and around 7·5V they did not operate at all. An alkaline PP3 unit should provide about 20 to 30 hours of operation. Alternatively use six AA size alkaline cells in a suitable holder or consider using a mains adaptor.

Ivan Patrick Gore, Peterborough

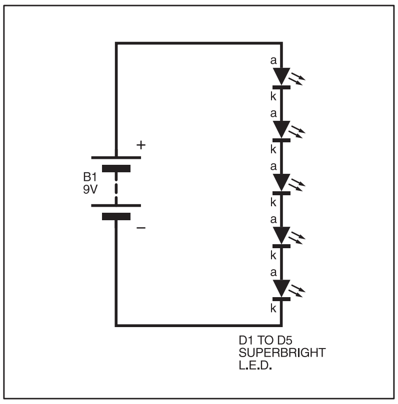


Fig.2. Simple Christmas Star circuit.

Emergency Light Unit – Lights the Way

THE SIMPLE emergency lighting circuit of Fig.3 provides a low-voltage light for around 20 minutes after the mains has failed. The first part of the design is a bulb driver circuit, consisting of a transistor switch formed by driver TR1 and power transistor TR2 which operates the 3·5V bulbs LP1 to LP3.

The second part is the mains voltage detector and battery charger. Transistor TR1 is switched off when the mains supply is present (its base being held below 0·7V), and when the mains fails, TR1 switches on and the bulbs illuminate.

A low voltage power supply is provided by the transformer T1 and diodes D1 to D4. The usual way of connecting the secondary of a centre-tapped transformer is to have two positive voltage outputs and one centre zero tap. However, in this design the centre tap is the positive and the two outer taps are zero voltage.

Assuming mains voltage is present: on the positive half cycle current flows from the centre tap of T1 via fuse FS2, and through the Nickel Cadmium D-size batteries B1 to B3. This current is limited by resistor R3 to keep the NiCad cells trickle charged. The current then flows back to one of the "zero" voltage secondary terminals via one of the diodes D1 or D2.

On the other half cycle the current flows the same way but returns to T1 via D3 or D4. Driver transistor TR1 is kept switched off by the current flowing from the centre tap via FS2, through resistor R1, and returning to one of T1's zero terminals, by either D3 or D4. In effect diodes D3 or D4 ground TR1 base terminal, preventing it from turning on.

When the mains voltage fails, current from the positive terminal of the batteries flows through resistor R1 to the base of transistor TR1 which turns on. This biases transistor TR2 into conduction and causes the bulbs to illuminate for as long as the battery voltage remains high enough – in practice around 27 minutes. No current flows through transformer T1 secondaries, or diodes D1 to D4 as all their terminals are at the same potential, i.e. the 3·6V battery voltage.

When the mains returns, the transistors will switch off extinguishing the bulbs and the batteries will begin to trickle charge once more.

Steve Cartwright,
Kilbarchan, Renfrewshire

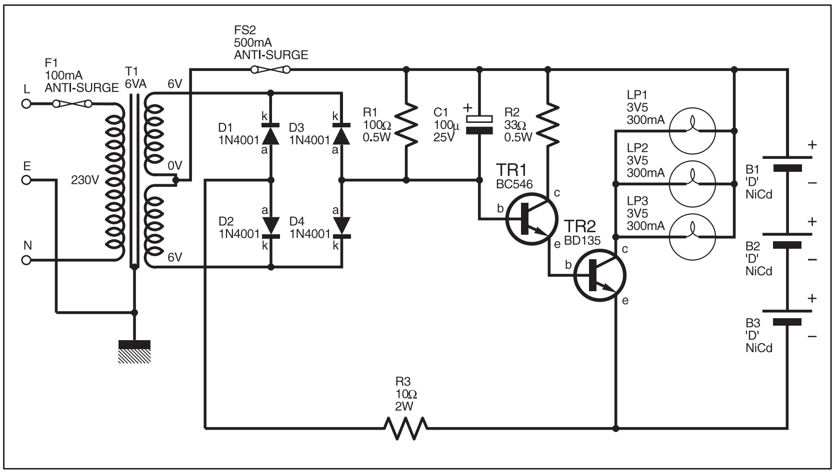


Fig.3. Complete circuit diagram for the Emergency Light Unit.

SHOP TALK
with David Barrington

Capacitance Meter

The choice of *metal* case for the *Capacitance Meter* is left entirely to personal taste and pocket. However, choose one that has ample all-round space and check that there is enough height to give plenty of clearance above the selected mains transformer used. The prototype case appears to be one of the low-cost (£6 to £7) vinyl-effect aluminium boxes which most of our component advertisers stock.

If you wish to use a toroidal type mains transformer, as shown in the photos, you could try contacting **ILP Direct Ltd** (☎ ***01233 750481*** or ***Fax 01233 750578***), who should be able to advise. A standard 3VA 15V secondary mains transformer specified in the component listing should be readily available.

Regarding the semiconductors, only the 74C925 4-digit counter/driver i.c. may be hard to locate. The one in the model was purchased from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code QY08J. Looking up the 4528 dual monostable in their listing they refer you to the HCF4098BEY, code QX29G – so you have two possible choices here. Don't forget to specify you want a "common cathode" type when ordering the dual display. Check out the pin line-up before purchasing and that it will fit on the p.c.b.

The two double-sided printed circuit boards are available from the *EPE PCB Service*, codes 323 (Main) and 324 (Display), see page 817.

Teach-In 2002 Power Supply

Most of the components needed to build the *Teach-In 2002 Power Supply* are standard items and should be easy to find locally. Our components advertisers should be able to recommend suitable parts or alternatives. Some may even make up a kit for you.

The large 20/25VA mains transformer came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code WB25C. They also supplied the round-faced miniature rocker switch (code FG47B), the W01 bridge rectifier (AQ95D) and the aluminium box, code LF16S. Arranging the components in the case is a tight squeeze, so readers may care to opt for the larger one, code XB69A.

The small printed circuit board is available from the *EPE PCB Service,* code 320.

Teach-In 2002 Lab Work 1

The plug-in "breadboard" required for the *Lab Work* projects is available in many sizes and prices and any one will do for these exercises; choose one with the most contacts that your pocket can afford! Regarding the negative temperature coefficient thermistor, these are commonly stocked in bead, disc and rod types. The preference was for a general purpose bead but any type rated from 2k2 to around 10k at 25°C will do. One at 4k7 seems to be most popular.

Finding the Analog Devices OP177GP ultra-precision, low-offset, op.amp could be troublesome and was found listed by **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code NP16S. The LM35DZ temperature sensor should be available from your local supplier and advertisers.

See the Special Offer page (782) for details of the PICO ADC-40 PC-based oscilloscope used throughout the *Teach-In 2002* series.

Lights Needed Alert

Very few problems should arise when shopping for parts for the Lights Needed Alert project. The 3V to 24V d.c. piezoelectric buzzer (code KU56L) and the miniature light-dependent resistor (code AZ83E) both came from Maplin (☎ ***0870 264 6000*** or ***www.maplin.co.uk***). You can, of course, use the ubiquitous ORP12 l.d.r. if you wish.

The printed circuit board is obtainable from the *EPE PCB Service*, code 321 (see page 817).

Pitch Switch

Only the miniature d.i.l. relay and the HT7250 5V low-dropout voltage regulator, used in the *Pitch Switch*, could give local sourcing problems. The Holtek HT7250 regulator came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code LE79L. They informed us they had about 2,000 in stock but it would be discontinued when these had been sold. A suitable replacement would be the LP2950CZ, but this has a different pinout.

The d.i.l. relay is an RS component and can be ordered from any *bona-fide* stockist or by credit card from **RS** (☎ ***01536 444079*** or ***rswww.com***), code 291-9675. An alternative would be the sub-min. 5V Omron relay, RS stock code 376-593.

The printed circuit board is available from the *EPE PCB Service*, code 322.

Toolkit TK3 for Windows (Supplement)

The software program for the *Toolkit TK3 for Windows*, this month's free supplement, is available on a CD-ROM from the *EPE PCB Service,* see page 817. A small charge of £6.95 is made for setting up and admin costs. It is also available *Free* from the *EPE* web site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/ToolkitTK3**.

PLEASE TAKE NOTE

PIC Pulsometer *(November '00)*

Resistors R2 and R3 should have the values shown in the circuit diagram (Fig.2), not those in the parts lists.

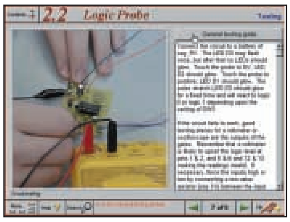
PIC-Monitored Dual PSU *(December '00)*

Page 890, Fig.10 should be amended as follows: Link 24 to A11 (not A9); Link 25 to A12 (not A5); Link 26 to A5 (not A12) and Link 27 to A9 (not A11). Having the above links incorrectly connected will not have caused damage to the PIC. Ignore statement saying B14 no connection.

Resistors R43 to R46 should read R35 to R38 (10k).

ELECTRONICS CD-ROMS

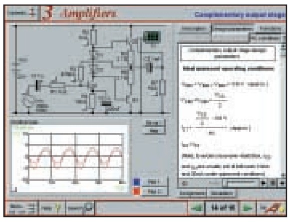
ELECTRONICS PROJECTS



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.

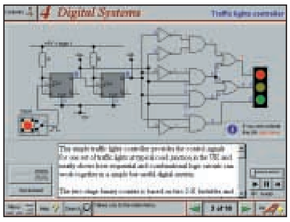
ANALOGUE ELECTRONICS



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.

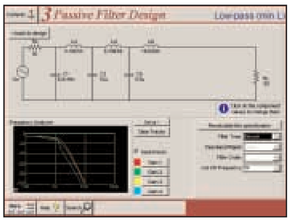
DIGITAL ELECTRONICS



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.

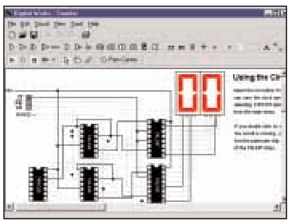
FILTERS



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.

DIGITAL WORKS 3.0

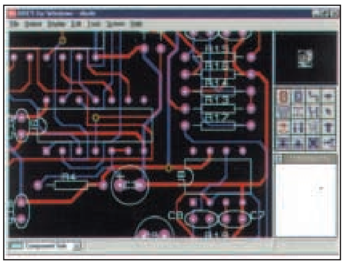


Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability.

- Software for simulating digital logic circuits
- Create your own macros – highly scalable
- Create your own circuits, components, and i.c.s
- Easy-to-use digital interface
- Animation brings circuits to life
- Vast library of logic macros and 74 series i.c.s with data sheets
- Powerful tool for designing and learning

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.

"C" FOR PICMICRO MICROCONTROLLERS

C for PICmicro Microcontrollers is designed for students and professionals who need to learn how to use C to program embedded microcontrollers. This product contains a complete course in C that makes use of a virtual C PICmicro which allows students to see code execution step-by-step. Tutorials, exercises and practical projects are included to allow students to test their C programming capabilities. Also includes a complete Integrated Development Environment, a full C compiler, Arizona Microchip's MPLAB assembler, and software that will program a PIC16F84 via the parallel printer port on your PC. (Can be used with the *PICtutor* hardware – see opposite.)
Although the course focuses on the use of the PICmicro series of microcontrollers, this product will provide a relevant background in C programming for any microcontroller.

PRICES

Prices for each of the CD-ROMs above are:

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

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

Interested in programming PIC microcontrollers? Learn with PICtutor

The Virtual PIC

This highly acclaimed CD-ROM by John Becker, together with the PICtutor experimental and development board, will teach you how to use PIC microcontrollers with special emphasis on the PIC16x84 devices. The board will also act as a development test bed and programmer for future projects as your programming skills develop. This interactive presentation uses the specially developed **Virtual PIC Simulator** to show exactly what is happening as you run, or step through, a program. In this way the CD provides the easiest and best ever introduction to the subject. Nearly 40 Tutorials cover virtually every aspect of PIC programming in an easy to follow logical sequence.

HARDWARE
Whilst the CD-ROM can be used on its own, the physical demonstration provided by the **PICtutor Development Kit**, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work.
Two levels of PICtutor hardware are available – Standard and Deluxe. The **Standard** unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials. The **Deluxe** Development Kit is supplied with a plug-top power supply (the **Export** Version has a battery holder), all switches for both PIC ports plus l.c.d. and 4-digit 7-segment l.e.d. displays. It allows users to program and control all functions and both ports of the PIC. All hardware is supplied **fully built and tested** and includes a PIC16F84.

PICtutor CD-ROM

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

HARDWARE

Standard Development Kit . . . .£47 inc. VAT
Deluxe Development Kit . . . . .£99 *plus* VAT
Deluxe Export Version . . . . . .£96 *plus* VAT

Deluxe PICtutor Hardware

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

ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 JPG images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).
Also contains a **FREE** 30-day evaluation of Paint Shop Pro 6 – Paint Shop Pro image editing tips and on-line help included!

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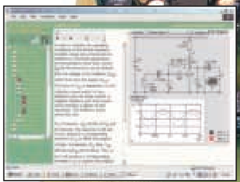
NEW VERSION 2



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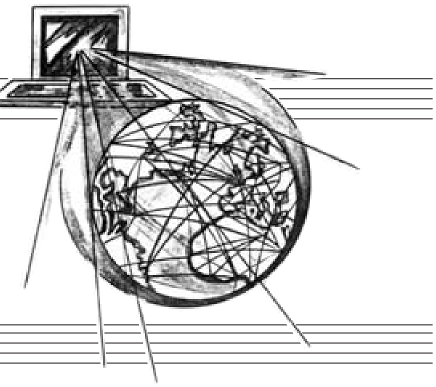


NET WORK

ALAN WINSTANLEY

In last month's *Net Work* I described the problems caused by the Sircam Worm, one of the latest in a line-up of particularly nasty E-mail infections which propagates itself by using, amongst other means, the Windows Address Book. It rampages around networks and targets hundreds or even thousands of other users, with the potential to wreak havoc on their systems as well as those of the ISPs caught in the middle: the Network Manager of one Internet Service Provider reported that one user received the Sircam Worm over 1,000 times, causing their mailbox to swell to over 800 *megabytes* in size. Systems clogged up, slowed down or packed up altogether.

Two months later it is hard to believe that unsuspecting people are still E-mailing the Sircam Worm out to equally unsuspecting parties. I lost count of the number of infected mails that have been received, and I gave up sending out an E-mail to the sender warning them of the infection. Most Internet users utilise ordinary dial-up accounts, but even if they have up-to-date virus software such as Norton Anti Virus (**www.symantec.com**) or McAfee Anti Virus (**www.mcafee.com**), there is still the problem of the time and money wasted in downloading E-mails carrying potentially infected file attachments.

In practice the vast majority of ordinary users simply hit the "Send/Receive" button of Microsoft Outlook Express and wait to see what arrives. (The writer's Turnpike software allows for either Send or Receive to be disabled.) Any incoming E-mail is fetched onto disk, only then does it become apparent that some infected files may have been received.

There are better ways of dealing with E-mail than fetching the whole lot every session. For starters, you can try to configure the filter rules of your E-mail client software – for example Outlook Express has options to filter out mail (e.g. flag it, highlight it or do not download it from the server) if the mail has an attachment. Go to Tools/Message Rules/Actions and experiment with some of the options available. If necessary, send yourself some sample E-mails to test the settings.

Take Control of Your Mail

A smarter way of dealing with E-mail is to check it on the server and screen out anything not wanted first. This avoids the possibility of downloading the likes of the Sircam Worm (the one good thing about it being that all Sircam mails look the same, it is only the subject and file attachment that differ).

Handling mail this way is a form of virtual fly-swatting, and even though it means a little human intervention is needed, I can confirm that it is extremely satisfying to "swat" worms and junk directly from the server, so you avoid being bothered by these nuisances ever again. You can actually *save* time this way.

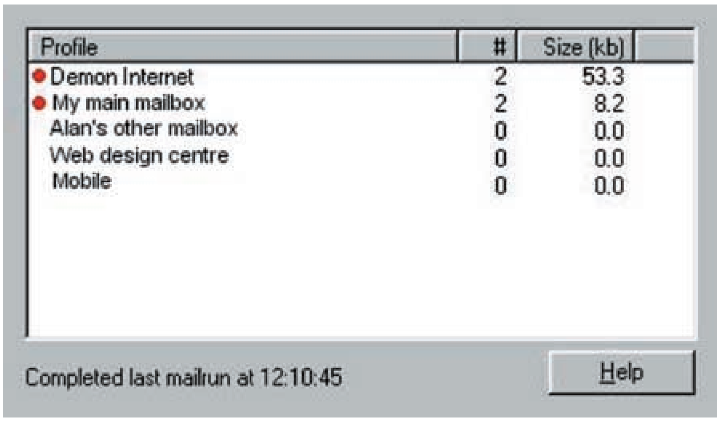
The workings of a typical POP3 mailserver are a mystery to many, but it is easy to check your mail on the server by using a small POP3 client package. Using such a program, you can rapidly check (poll) your POP3 mailbox(es) and delete any suspicious or unwanted mails *directly from the server.* This is a powerful option, and be warned that there is no reassurance of a Recycle Bin or "Deleted" folder – once you hit the Delete button, the mail could be gone for ever!

Imagine what this means to a user who is inundated with the Sircam Worm though; instead of calling a technical support person at their ISP, users can browse their mailbox on the server and delete any unwanted material for themselves. After that, they can download remaining mail onto their computer.

There is one minor safety valve with POP3 mail – having deleted any unwanted mail, if you do not "save" the session, then the deleted mail will be restored when you close your client. After saving and exiting, though, be aware that any mail marked for deletion is lost. Although it is true that checking your mail this way takes a little time (say a minute), in practice I have found that the benefits of deleting unwanted mail at source outweigh the short time spent previewing it. Everything is done "on the fly" using a raw connection to your mail server.

A Therapeutic Jem

One program, which the author has been using for some time, is **JBMail** ($35, demo available, free upgrades) available for download from **www.pc-tools.net**. It is a lightweight but versatile POP3 mail client that is especially useful for previewing POP3 mailboxes. Any junk mail can be deleted instantly, but more importantly any Sircam Worms etc. stand out a mile and can be dealt with accordingly. There are no inboxes or out trays in "light" mail clients such as this but JBMail's creator Jem Berkes in Canada tells me that an address book is being worked on.



JBMail is a "light" POP3 mail client that lets you check multiple POP3 mailboxes. You can also open each mailbox directly on the server.

A very handy feature is JBMail's ability to poll multiple POP3 mailboxes simultaneously, and any changes in contents are flagged. You can then skim through the contents of each mailbox – subjects, senders and file sizes are summarised. Individual E-mails can then be previewed, and you can also reply to them on the fly: perfect for sending out quick replies to messages that you don't want to download or store on your system.

After this initial checking of mailboxes, you can start up your usual mail client and download the remaining E-mails onto your machine. JBMail works very well and in terms of time saved, it has proved to be a good investment for a busy Internet worker. You can be merciless with unwanted mail, reduce the risk of importing a virus or worm, and you can dismiss junk mail out of hand, which has a therapeutic value as well! It is worth downloading the demo. version from their web site.

Another program to investigate is Pop Corn (**www.ultrafunk.com**), a freeware client that also handles multiple user POP3 mail using "profiles" but presently it does not appear able to poll multiple boxes at the same time. It may be more than enough for some users though.

See you next month for more *Net Work*. You can E-mail me at **alan@epemag.co.uk**.

Constructional Project

PITCH SWITCH

THOMAS SCARBOROUGH

A versatile, highly selective frequency switch that can be triggered by a "penny whistle".

VARIOUS types of sound switch exist, including the well known clap switch, whistle switch, and telephone/doorbell extender.

Most sound switches, however, are characterised by their distinct lack of selectivity. At best, they will respond to a spread of frequencies several hundreds of Hertz wide. In effect, this means that almost anyone who can clap or whistle would be able to trigger such a switch.

The Pitch Switch described here responds to a narrow passband, or *pitch*, which has the width of a single tone at all frequencies (to be exact, 55Hz at concert pitch *A*, or 440Hz). This means that it will "hear" only those sounds which fall within one semitone of a selected frequency.

Also, since the Pitch Switch detects frequencies digitally, in theory it will fail to respond to frequencies which fall so much as a single Hertz outside the selected passband. This means that it would be particularly difficult for "just anybody" to trigger the switch – it is under the control of the person who holds a specific tin whistle or signal generator.

Besides this, it is exceedingly sensitive, and will trigger at a considerable range. A range of at least 40 metres is achieveable with a tin whistle.

EXTENDED RANGE

This range can also be extended electronically. In the author's most interesting test, a trumpet was blown several times in a cricket stadium in Georgetown, St. Vincent, reliably triggering the Pitch Switch in Cape Town, South Africa, via a normal f.m. radio broadcast. This represents a range of 10,000 kilometres!

A small slider switch on the printed circuit board (p.c.b.) provides for instant conversion to a standard sound switch covering the entire audio spectrum. In this mode it is also exceedingly sensitive, being able to "hear" a pin drop at three metres.

ORIGINATION

The Pitch Switch was originally conceived as a means of remote control to steer a model rowing boat. Other methods of remote control seemed either too expensive, or too bulky – or were simply incapable of controlling a model boat spinning in the sun.

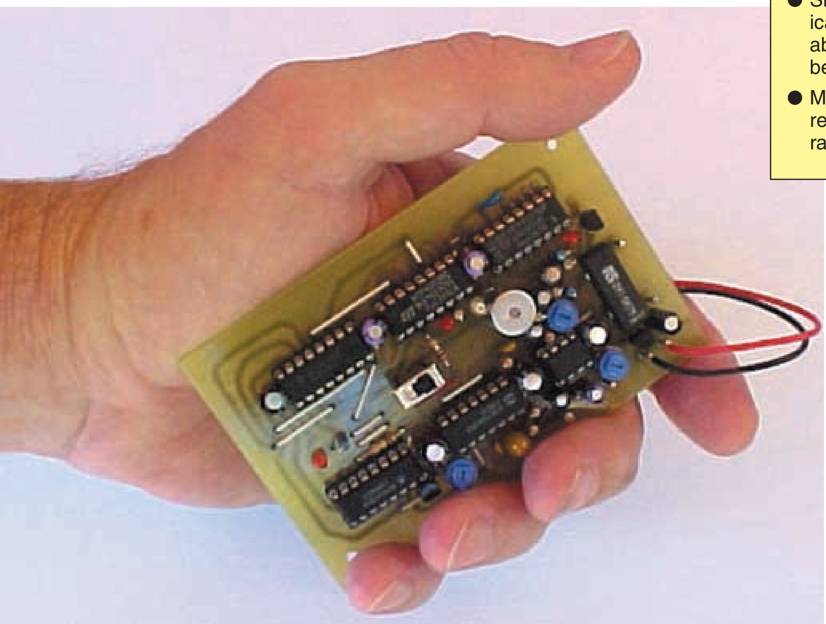
Control by sound, it seemed, presented an attractive alternative, being relatively lightweight and cheap, with a good range. Not least, it would provide an appealing audio-visual effect to control a little man in a model boat with a tin whistle.

Sound, incidentally, also has special advantages where one wishes to control a device through fog or dense atmospheric particles – even through solid materials or water, or down a length of piping. Such applications would be beyond the scope of a number of other methods of remote control.

BROAD APPLICATIONS

While the Pitch Switch has a great many specific applications, here are some major areas of application in broad outline:

- The Pitch Switch may be used as a flexible form of remote control by sound or ultrasound. This was its original purpose.
- The Pitch Switch may be used through mediums which would stump many other forms of remote control – through solid barriers, water, dense atmospheric particles, or down piping.
- Since the Pitch Switch employs digital electronics, its theoretical limits lie between 0Hz (extremely slow sampling) and about 4MHz. Its usefulness can be extended far above or below the audio spectrum.
- Many an existing communication system may be turned into a remote control through the Pitch Switch - a telephone line, a radio transmission, or a doorbell.



GENERAL CHARACTERISTICS

The characteristics of the Pitch Switch are much the same as the human ear. The more background noise there is, the harder it finds it to distinguish a single note, and the less sensitive it becomes. It works best where a single note stands out above a relative silence.

It can, however, be adjusted to exclude a certain level of background noise, such as the wind in the trees or traffic on a nearby road, by decreasing its sensitivity. The author was able to adjust it to respond to a whistle in a room in which a piano was being played at the same time. In fact, background noise had less effect on it than anticipated, since such noise was mostly superimposed on the incoming frequency, but didn't override it.

The Pitch Switch has been customised to respond to a useful frequency bandspread at a good distance. The component values shown in the main circuit diagram give it a range in the audio spectrum above *Middle C*.

This can easily be altered to "hear" well into the ultrasound region – with some loss of sensitivity. In this case, simple modifications are made to the microphone input circuit. An ultrasonic receiver transducer is then used instead of a standard microphone, and the operating frequency is raised.

TUNING-IN

It is not as practical to *lower* the Pitch Switch's frequency as it is to raise it, since a longer sampling of the incoming frequency is required (489ms at *Middle C*, which doubles with each decreasing octave). However, at the same time there is no lower frequency limit, which could be used to "hear" the frequency of very slow events, such as the number of cars travelling on a road. More of this latert.

A two-state indicator (red l.e.d.) indicates whether an incoming frequency is "high" or "low" of the selected frequency (one of the two states indicates nothing – but in this case, "nothing" is something)! This makes it far easier to zero in on an incoming frequency when adjusting the unit.

It would be worth noting, incidentally, that few frequencies are perfectly "pure". A tin whistle or a guitar string, for instance, will each have their own "colour" of sound, even though they play at the same pitch. A recorder, for instance, has a very pure note. A piano key or a jet engine, on the other hand, are less pure, and will not be found to be as effective in triggering the circuit.

The handheld "remote" in this system is sure to be one of the most compact and energy-efficient on earth. If, for instance, a tin whistle is used, no batteries are required, and the size of the remote will be smaller than that of most keyfobs!

The Pitch Switch may be triggered by a wide range of sounds – among them various musical instruments, a dog whistle, a church bell, or a BBC time signal. It could also be clocked directly by frequencies generated within an electronic circuit.

DESIGN CONSIDERATIONS

The system block diagram for the Pitch Switch is shown in Fig.1 and the full circuit diagram in Fig.2. The core concept behind the Pitch Switch is to isolate specific frequencies, and draw these out from all others.

The immediate impulse was to use a standard audio bandpass filter for this purpose. However, it was realised that these filters have significant limitations in this application. A single filter cannot easily be tuned across the entire audio range – also, such filters do not cope well with changes in amplitude, such as those encountered when blowing a tin whistle over varying distances and at varying intensity.

The stumbling block was a conceptual one. At first, the author was trying to pick up sound, then *preserve* certain frequencies, while blocking out the rest. He soon realised that no frequencies needed to be preserved, or indeed to be blocked out. Instead, the whole of the incoming sound was converted to a digital stream, which was stored in a dual binary counter (IC4) serving as an 8-bit memory. This was then compared (IC5) with a benchmark frequency (IC2b).

One could add a simple bandpass filter to improve the Pitch Switch's performance in noisier situations – however, for most purposes, no such filter is required. This would also complicate what in its present form is a very easy method of tuning.

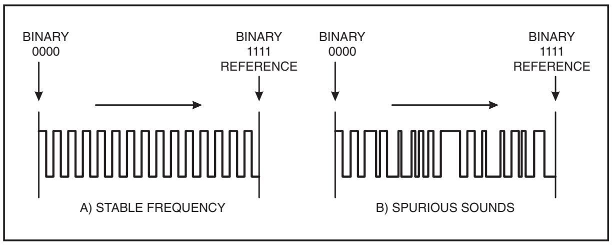


Fig.3. How spurious triggering occurs with a small sample.

In rare instances, it may be triggered by spurious sounds. This is because it triggers when IC4 has received a certain number of pulses within a certain time period. It is a "dumb" device that cannot tell the difference between a digital stream of a certain numerical length, and a specific frequency (see Fig.3). Note that spurious triggering is significantly reduced the higher the tuned frequency. One special measure has been taken here to exclude such spurious sounds, and this is described below.

BLOCK DIAGRAM

The first stage of the block schematic (see Fig.1) is a micropower voltage regulator. This ensures that IC2b, the benchmark oscillator, will maintain a stable frequency. The Pitch Switch is thus not confined to a single battery arrangement, nor is there the danger that it will be compromised by an inadequate power supply. Virtually any battery or power supply between 6V and 24V may be used.

The next stage is a two-stage preamplifier, IC1, which amplifies the incoming sound. This is capable of covering the audio spectrum between about 100Hz and 12kHz – depending on the microphone used. A high quality microphone would widen the bandspread to, say, 18kHz.

The preamplifier circuit is straightforward (see Fig.2), employing an inverting amplifier (IC1a) feeding a non-inverting amplifier (IC1b), with two variable presets (VR1 and VR2) to control gain. The gain of the preamplifier may be set between unity and 100,000 times.

The amplified signal is converted to a square wave by means of IC2a, which is wired as a Schmitt trigger. IC2a presents a clean digital stream at the clock input of dual binary counter IC4. This digital stream (the dominant incoming frequency) clocks dual 4-bit binary counter IC4, which has been cascaded so as to form a single 8-bit binary counter. This serves as a small memory.

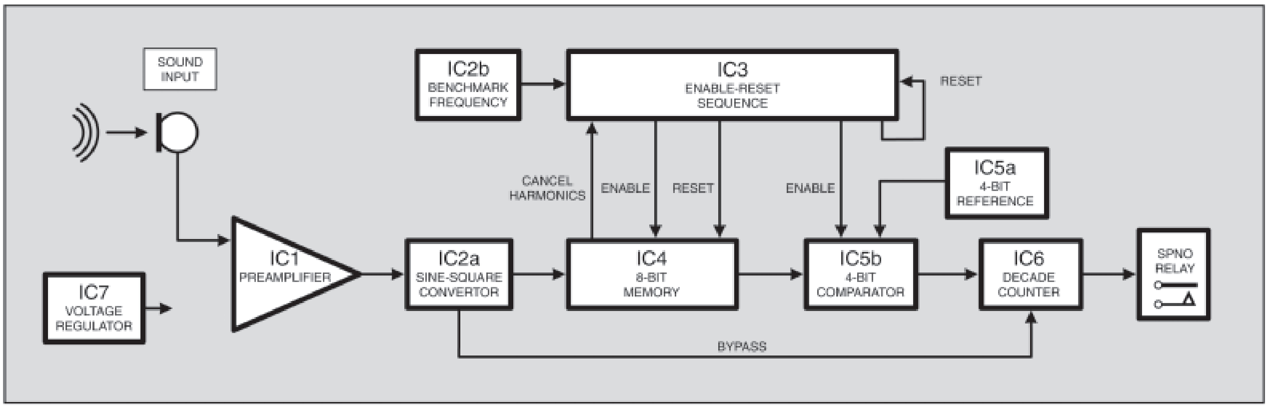


Fig.1. Block schematic diagram for the Pitch Switch. Note the "all frequency" bypass from IC2a.

Oscillator IC2b and decade counter IC3 together permit the binary counter to receive clock pulses only for a specific time period, which is calculated as follows:

$$t \text{ (time period)} = 1 / (f / 128) \text{ seconds.}$$

This means that the Pitch Switch will require around a tenth of a second to "hear" a tin whistle. After this, the clock input is cut off, and a certain number of clock pulses remain stored as an 8-bit binary number in memory.

This binary number is now fed to 4-bit comparator IC5, which is enabled by decade counter IC3. One half of the comparator (the "A" inputs – IC5 pins 10, 12, 13, 15) is taken "high", so as to represent the binary number 1111 (decimal 15). This is used as a reference. If the incoming frequency is also binary 1111, IC5 pin 6 goes high, and decade counter IC6 is clocked.

A decade counter is chosen for the output here, since this is capable of switching anywhere between one and ten outputs sequentially. So, for instance, a single Pitch Switch could cause a model rowing boat to row (sequentially) forwards, backwards, right, left, and stop, with a further five outputs still available.

BARTERING BITS

At this point, it might have been noticed that the binary number stored in "memory" is an 8-bit number, while only four bits are taken to the comparator. What has happened to the remaining bits?

In fact one could take any series of IC4's outputs to binary comparator IC5 (e.g. Q1A to Q4A, or Q3A to Q2B), and the Pitch Switch would seem at first to function in just the same way. However, it does make some difference which series of four bits one takes to the comparator.

If the four least significant bits are chosen (Q1A to Q4A), the Pitch Switch only samples 16 incoming pulses, instead of 128, as is the case in the present design. This multiplies the chances of spurious triggering – although it also shortens the length of the required sample eight times. This could provide some advantage in certain applications.

As things stand, outputs Q4A to Q3B are used. This, of course, still leaves the most significant bit (Q4B) spare – and this is now put to important use.

Until now, the Pitch Switch will not recognise any sounds below a selected frequency – however, it will trigger on every harmonic (every octave) *above* it. This is because, when the binary counter is clocked at frequencies higher than the selected frequency, the seven least significant bits begin to repeat (the counter IC4 "rolls over"). If the count finishes on a binary 1111 at comparator IC5's "B" inputs, then decade counter IC6 is clocked.

Therefore as soon as binary counter IC4 begins to repeat, its most significant bit (Q4B) goes high. This is taken to the reset pin of decade counter IC3, via TR1, with the effect that all further incoming sound is instantly cancelled – and so also are all harmonics.

In the block schematic Fig.1, the purpose of decade counter IC3 might be further clarified. This is clocked by oscillator IC2b, and ensures that the following sequence is carried out within the circuit:

1. Binary counter IC4 is reset. This must occur first in the sequence if the blocking of harmonics is to succeed.
2. Binary counter IC4 is enabled for a specific period, to store the incoming frequency in "memory".
3. Comparator IC5 is enabled. If A=B, then decade counter IC6 is clocked.
4. Decade counter IC3 resets itself.

CIRCUIT DETAILS

Little now needs to be added about the circuit, although some explanatory notes might be useful.

Preamplifier IC1 amplifies minute signals to the point where they are capable of clocking a digital circuit. This means that the circuit needs to cope simultaneously with minute analogue signals as well as "heavy" digital switching. A few preamplifier designs were tried here before a suitable one was selected.

Supply decoupling (capacitors C1 to C6) is employed throughout the circuit, and this very significantly improves stability and sensitivity. A special arrangement (R1, R2, C7) is used to stabilise the microphone input.

The Pitch Switch circuit consumes less than 4mA on standby, which is good enough to see it through an entire week

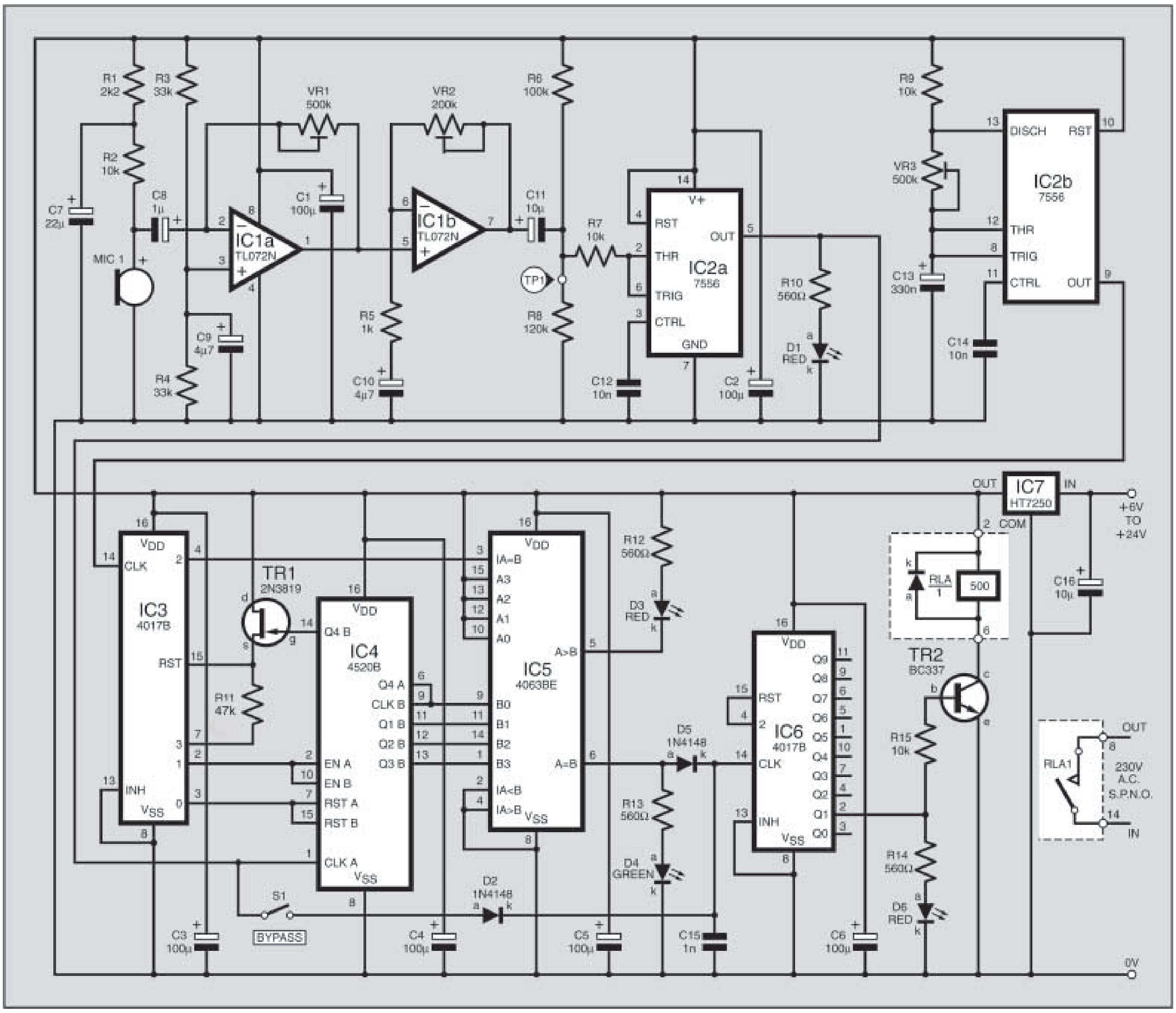


Fig.2. Complete circuit diagram for the Pitch Switch. For additional relay option see Fig.5.

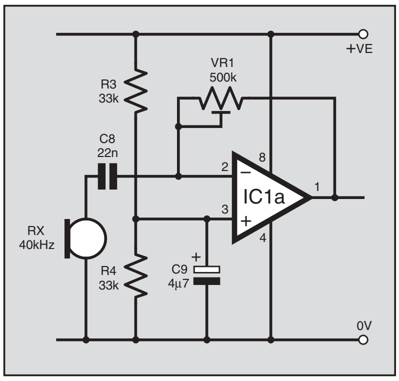


Fig.4. Circuit modification for receiving ultrasound.

when using a quality alkaline PP3 battery – longer than most other remote control systems. Power consumption when the relay is triggered is around 30mA.

Schmitt trigger IC2a is one half of a 7556 dual timer, and is used here in a less common configuration, namely as a high-performance sine-square converter.

Resistors R6 and R8 bias the input terminals, pins 2 and 6, of IC2a at a quiescent value just above half the supply line voltage. The sinewave input signal is then superimposed on this point via capcitor C11. Resistor R7 is wired in series with the input signal to ensure that it is not adversely influenced by the switching actions of the 7556 i.c. The square wave output signal is taken from IC2a pin 5.

The benchmark frequency is generated by IC2b, components R9, VR3 and C13 set the operating frequency. This frequency may be calculated as follows:

f (frequency) =
{1·46 / [(R9 + VR3) × C13]} × 16 Hz.

Modifications for ultrasound operation are shown in Fig.4, R1, R2 and C7 are omitted, C8 is changed in value and an ultrasonic transducer is used.

L.E.D. D1 indicates that a digital stream is reaching IC4 pin 1, the Clock input, and serves as a form of "On" indicator. L.E.D. D4, at IC5 pin 6, illuminates when the selected frequency is detected. L.E.D. D3 illuminates either *at* or *above* the selected frequency, thus giving a simple "high" or "low" indication (it fails to illuminate when a sound is "low"). L.E.D. D6 illuminates when transistor TR2 switches on and indicates that the relay RLA is operational.

EXTRA SWITCHES

How each output of IC6 may be wired up to switch additional relays is shown in Fig.5. Holes have been provided on the printed circuit board for hard wiring to extra relays, which are mounted off-board. In Fig.5, decade counter IC6 switches in sequence from top (output 0) to bottom (output 9).

When connecting additional relays, the link between IC6 pins 4 and 15 is detached at pin 4, and taken instead to the output at the end of the desired sequence. If your sequence ends, say, at output 5, pin 15 is now connected to output 6 (pin 5).

As shown the circuit diagram provides just one on-off (flip-flop) output, since this is likely to be the most common application. A small capacitor (C15) holds IC6 pin 14 high when clock pulses are received, thus preventing decade counter IC6 from clocking more than once with a single sound input.

COMPONENTS

Approx. Cost Guidance Only £20 excluding batts.

Resistors

R1	2k2
R2, R7, R9, R15	10k (3 off)
R3, R4	33k (2 off)
R5	1k
R6	100k
R8	120k
R10, R12, R13, R14	560Ω (4 off)
R11	47k

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers

VR1, VR3	500k single-turn cermet trimmer (2 off)
VR2	200k single-turn cermet trimmer

Capacitors

C1 to C6	100µ sub-min. radial elect. 6·3V (6 off)
C7	22µ sub-min. radial elect. 6·3V
C8	1µ sub-min. radial elect. 6·3V
C9, C10	4µ7 sub-min. radial elect. 6·3V (2 off)
C11	10µ sub-min. radial elect. 6·3V
C12, C14	10n resin dipped plate ceramic (2 off)
C13	330n resin coated aluminium elect.
C15	1n resin dipped plate ceramic
C16	10µ submin. radial elect. 25V

Semiconductors

D1, D3, D6	3mm red l.e.d. (3 off)
D2, D5	1N4148 signal diode (2 off)
D4	3mm green l.e.d.
TR1	2N3819 *n*-channel j.f.e.t.
TR2	BC337 *npn* medium power
IC1	TL072CN low-noise dual op.amp
IC2	ICM7556 low power dual timer
IC3, IC6	4017B decade counter
IC4	4520B dual 4-bit binary counter
IC5	4063 4-bit comparator
IC7	HT7250 5V low dropout voltage regulator

Miscellaneous

S1	s.p.d.t. ultra-miniature slider switch, vertical mounting
RLA	5V 500 ohm coil min. relay, with s.p.n.o. contacts rated at 240V a.c.
MIC1	ultra-miniature omni-directional electret microphone insert

Printed circuit board available from the *EPE PCB Service*, code 322; 8-pin d.i.l. socket; 14-pin d.i.l. socket; 16-pin d.i.l. sockets (4 off); optional PP3 type battery clip; optional PP3 alkaline battery; sheathed link wires; solder pins, solder, etc.

CONSTRUCTION

Component values and types are not critical – however, be sure to use a low-power 7556 dual timer i.c. to conserve power, and use modern miniature components throughout to ensure good fits on the board – particularly the smallest diameter miniature electrolytic capacitors. Space is at a premium on this printed circuit board (p.c.b.).

Since the Pitch Switch is likely to be fitted into scale models or mounted in odd places, all the components are mounted on a single p.c.b. without a case. The topside component layout and full-size copper foil master pattern are shown in Fig.6. This board is available from the *EPE PCB Service*, code 322.

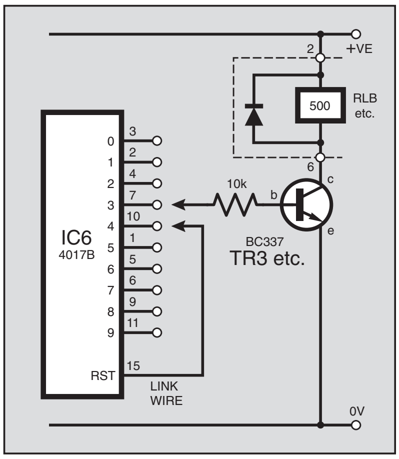


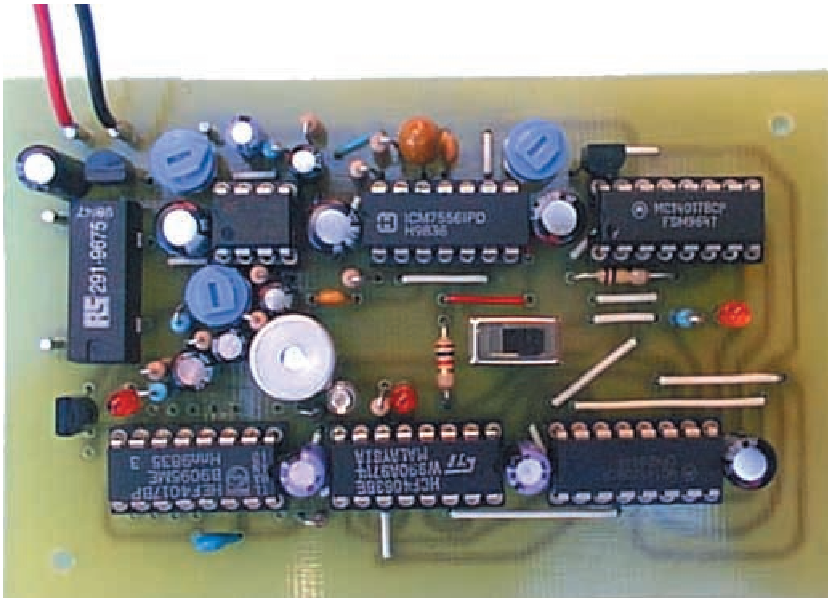
Fig.5. Circuit arrangement for connecting additional relays/channels to the main circuit.

Commence construction by inserting the wire links. It is recommended that sheathed wire be used here to avoid any short circuits. There are 26 wire links in all. Note that some links are mounted underneath the i.c. sockets.

Continue by inserting the solder pins, then the dual-in-line sockets, then the resistors and cermet presets, continuing with the relay, diodes, capacitors, transistors, microphone insert and switch S1. Solder voltage regulator IC7 into place. Do not insert IC1 to IC6 in their sockets until the correct (+5V) voltage from IC7 has been proved and then observe normal anti-static precautions.

Be careful to observe the correct polarity of the electrolytic capacitors, and the correct orientation of the transistors, diodes, and i.c.s. The cathode (k) of diodes D2 and D5 is banded. The specified relay includes an internal "back e.m.f." protection diode and constructors who use a different one, without such a diode, will need to wire one across the coil contacts. A 1N4148 small signal diode can be used here.

The author used an extreme brightness green l.e.d. for D4, since this enables easy setting up at a distance. An ordinary green l.e.d. may also be used, and would cost considerably less.



Component layout on the completed circuit board.

The specified relay is rated at 300V d.c./240V a.c. 10W, with a maximum switched current of 0·5A. Other relays could be used – particularly the Omron 5V subminiature s.p.c.o. relay, which is mains rated and will switch up to 60W/50VA.

Once all the components have been mounted on the p.c.b., check that there are no solder bridges on the underside copper tracks of the board. Finally, plug in a suitable power supply, which can be a regulated or unregulated d.c. power supply between 6V and 24V – being sure to observe the correct polarity. If at any time the circuit does not behave as described, switch off immediately, and check the wiring carefully.

CALIBRATION

A good way to calibrate the Pitch Switch is to wire it up to a high impedance earpiece, connected between 0V and Test point TP1.

Next, set S1 to its narrow passband setting (sliding it towards relay RLA). Turn presets VR1 and VR2 fully anti-clockwise. Then turn them up gently for maximum volume in the earpiece before serious feedback occurs. This will provide a good level of sensitivity – though not yet the maximum available.

Now produce a constant note with a recorder or tin whistle, one or two octaves above *Middle C*, within one or two metres of the microphone. Ensure that there is minimal background noise. Turn preset VR3 until l.e.d. D4 pulses. If only l.e.d. D3 pulses, your adjustment is "low" (and your note "high"). If D3 does not illuminate, your adjustment is "high".

Once the Pitch Switch is triggering satisfactorily (indicated by D4 and D6), nudge up presets VR1 and VR2, observing carefully through trial and error what effect this has on the sensitivity of the circuit. Too high a sensitivity is not necessarily a good thing, since background noise creeps into the dominant incoming frequency.

If it is correctly set, a range of 40 metres with a tin whistle should be well within its reach.

MATHEMATICAL MUSINGS

The mathematics of frequency detection in the Pitch Switch are interesting. When these are understood, there is much scope for experimentation.

The bandwidth of the Pitch Switch may be determined by using the following formula (MSB = most significant bit, LSB = least significant bit):

Bandwidth =
f (incoming frequency) / (MSB / LSB).

If, for instance, the incoming frequency = concert pitch *A*, or 440Hz, and MSB = 128 (IC4's Q3B), and LSB=16 (IC4's Q4A), then bandwidth = 440Hz/8 = 55Hz, or about a semitone to either side of 440Hz. You may refer to Fig.7 for the frequencies of Octave +1 (*Middle C* upwards). With every increasing octave, these frequencies double – with every decreasing octave, they are divided by two.

Now let us assume that we widen the binary comparison by one bit – now including IC4's Q3A (we would now need to replace IC5 with an 8-bit comparator to accomplish this). We would then have 440Hz/16 = 27·5Hz. This would narrow the

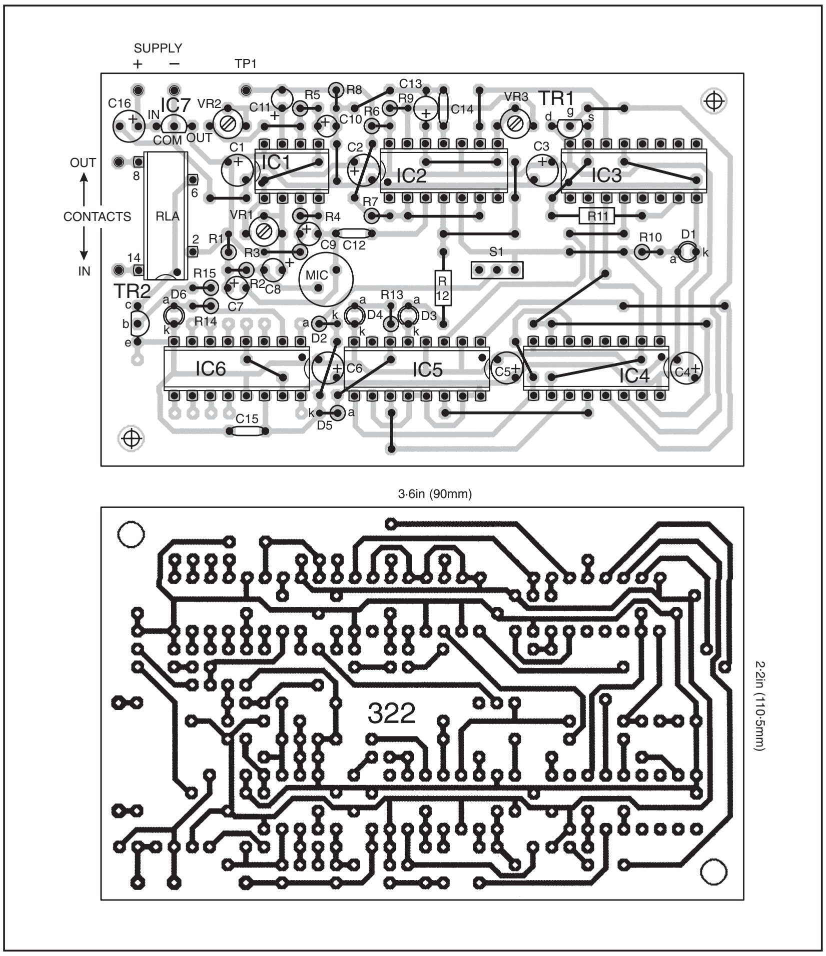


Fig.6. Pitch Switch printed circuit board component layout and full-size underside copper foil master. Note there are 26 link wires.

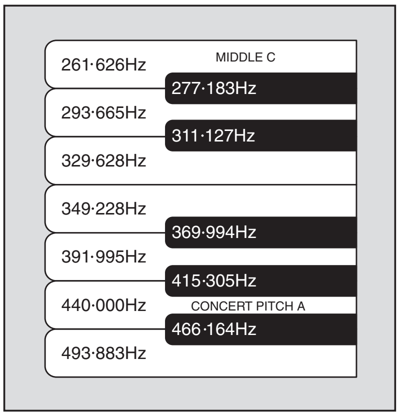


Fig.7. Frequencies at Octave +1 to six significant figures.

bandwidth to a quarter tone (a demi-semitone) at either side of the selected frequency.

If all seven of IC4's outputs Q1A-Q3B were employed, this would narrow the Pitch Switch's bandwidth to around 7Hz at concert pitch *A*. This represents less than two musical "cents" (hundredths of a semitone) at each side of the selected frequency.

Having said this, one may also make it more "tolerant". This may be desirable especially with "wind instruments" such as a tin whistle, which can vary in pitch according to the air pressure applied to them.

For example, by tying comparator IC5's inputs B0 and B1 "high" (one would need to break the existing connections at pins 9 and 11), bandwidth is increased to about four full tones to either side of the selected frequency.

APPLICATIONS

Apart from the applications already mentioned, the Pitch Switch offers several more:

It will respond to a specific car horn at a considerable distance (on condition that this is a single horn, and not a double or multiple horn). It could thus be used as a form of remote control for a garage door – if the neighbours don't object, that is!

Since it is capable of displaying frequencies "high" and "low" of the selected passband, it may be used as a rough aid to tuning musical instruments (however, it would need modification as described above to achieve better than one semitone accuracy). The Pitch Switch could also monitor the speed of machinery, where speed is critical.

It could trigger events at the far end of an intercom system or telephone line – or, as the author found, at the far end of a radio transmission across the Atlantic.

If preset trimmer VR3 is replaced with a rotary potentiometer with a calibrated scale, the Pitch Switch could be used as a quick and easy means of measuring component tolerances. Components under test would form part of an oscillator feeding the resistor R6-R8 junction (Test Point 1). The unit can also be clocked directly at Test Point 1 by frequencies from other circuits.

The Pitch Switch could also give a visual demonstration of the Doppler effect, with approaching sounds being "high" of a selected frequency, and receding sounds going "low".

FURTHER IDEAS

How a light-dependent resistor may be used to clock the Pitch Switch as a beam of light is interrupted is shown in Fig.8. This could be used to monitor the speed of machinery. If the Pitch Switch is set "high", slowing machinery will trigger the switch. If it is set "low", quickening machinery will trigger the switch. Or a deviation both "high" and "low" of a selected speed may be registered.

As already mentioned, the Pitch Switch may also be used to detect far slower events, such as the number of shoppers increasing beyond a critical point, or increasing wind (anemometer) speed. In this case, IC2b will need to be slowed according to the formula given earlier.

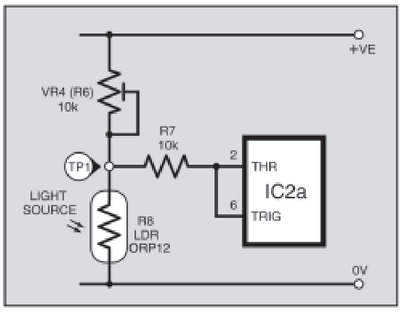


Fig.8. Clocking the Pitch Switch with a light beam.

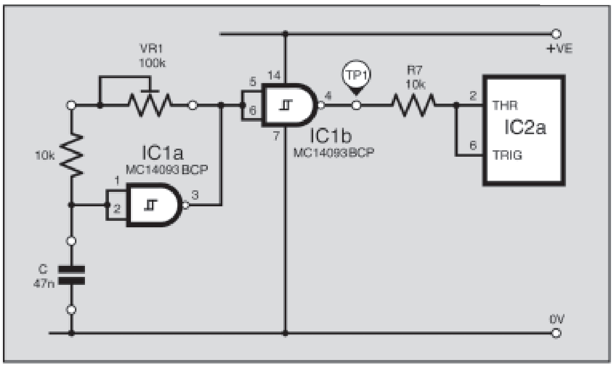


Fig.9. Measuring component tolerances.

How the Pitch Switch may be used to measure component tolerances is shown in Fig.9. For example, to measure capacitor tolerances, preset VR1 is adjusted to find the ideal value, then *C* is exchanged. A capacitor which lies inside of the required tolerance will illuminate l.e.d. D4. Resistor tolerances may be tested in a similar way, by substituting *R* instead.

Preset VR1 may also be replaced by a thermistor of similar value. In this case, the Pitch Switch will be triggered by rising or falling temperature, or both. ☐

PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

DISCRETE transistors are no longer an essential part of every project, having been to some extent ousted by integrated circuits. However, they still feature in a fair percentage of projects, and are an essential part of modern electronics. You will certainly find a fair sprinkling of them if you look at some of the recent projects in *EPE*.

Various types of transistor are available, and bipolar transistors are the original and still most common variety. Bipolar transistors are subdivided into two categories, which are the *pnp* and *npn* types. They are essentially the same but operate with different supply polarities. Never try to use a *npn* device instead of a *pnp* type, or vice versa.

Following Leads

A normal bipolar transistor has three leads that are called the **emitter** (**e**), **base** (**b**), and **collector** (**c**). There are actually a few that have four leads, although most of them are now obsolete. The fourth lead merely connects to the metal case of the component and is called the shield (s).

The construction diagrams normally make the correct method of connection perfectly clear, and there may also be a base diagram to help further. Perhaps rather confusingly, transistors that have the same encapsulation often have different leadout arrangements. Base diagrams for three transistors that use a common plastic encapsulation but have three different pinout configurations are shown in Fig.1.

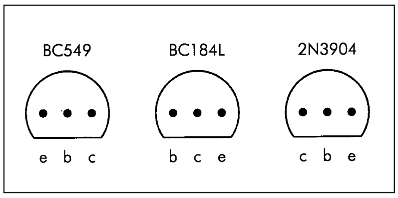


Fig.1. Transistors that have the same encapsulation do not necessarily have the same leadout configuration. Also, their base diagrams are nearly always underside views, that is, looking directly at the pins.

It is important to note that transistor leadout diagrams are normally *base* views, and that the device is always viewed looking on to its leadout wires. This is different to the convention for integrated circuits (i.c.s), which are normally shown as top views in pinout diagrams.

Where there is any doubt about the correct method of connection, always refer to a leadout diagram before connecting the device. Most electronic component catalogues include base diagrams for all the transistors on offer, so it should not be too difficult to find the information you need. If you have access to the Internet it is worth bearing in mind that data on just about any electronic component is available online and is not usually too difficult to track down.

If all else fails, it is possible to identify the leads and the type (*npn* or *pnp*) using a bit of trial and error with a continuity tester that has a diode checking facility. The transistor appears to be two diodes connected as shown in Fig.2. Once you have correctly identified the leadout wires the correct method of connection to the circuit board is usually pretty obvious.

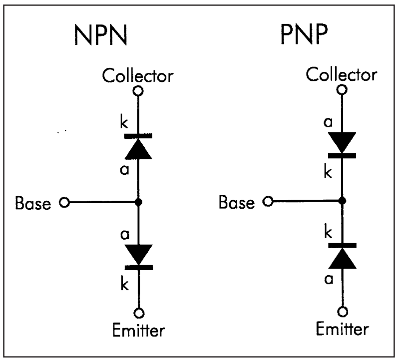


Fig.2. When making continuity checks a transistor appears to be two diodes connected back-to-back.

A Case of Identity

When dealing with transistors there are frequent references to things like TO92 and TO220. Transistors use a range of standard encapsulations, and this is what codes such as TO92 and TO220 refer to. The transistor base diagrams of Fig.1 are all for devices that use the TO92 plastic encapsulation.

Because there is more than one configuration for many case styles, a single letter suffix is often added to the code number in order to distinguish between the various leadout configurations. These suffix letters seem to be used in a rather arbitrary fashion, and are not always used at all, so do not assume that a the TO92c configuration in one catalogue is the same as the TO92c arrangement used elsewhere.

Hot Stuff

From the electrical point of view there is not much difference between a power transistor and an ordinary type, apart from the fact it can handle higher voltages and currents. Physically, power transistors are usually very different from low power devices.

The problem with power transistors, and other power semiconductors, is that they generate significant amounts of heat. So much heat in fact, that most devices would soon overheat in normal use without the aid of a heatsink.

A heatsink is just a piece of metal to which the power device is bolted. Actually, small heatsinks often clip directly onto the power device, and there are also heatsinks of this type for ordinary transistors that have metal encapsulations. In order to extract the heat from very high power semiconductors it is necessary to resort to larger and more exotic aluminium extrusions that have numerous fins – see Fig.3.

Where a heatsink is needed, the components list for the project should give details of the minimum requirements, and there may well be some amplification in the main text. When dealing with heatsink ratings there is a potential trap that you need to avoid. On the face of it, a heatsink with a rating of (say) 10 degrees per watt is bigger and better than one rated at 5 degrees per watt. In fact, the 5 degrees per watt heatsink is the one that is larger and more efficient.

The rating is the temperature increase that will be produced by applying one watt of power to the

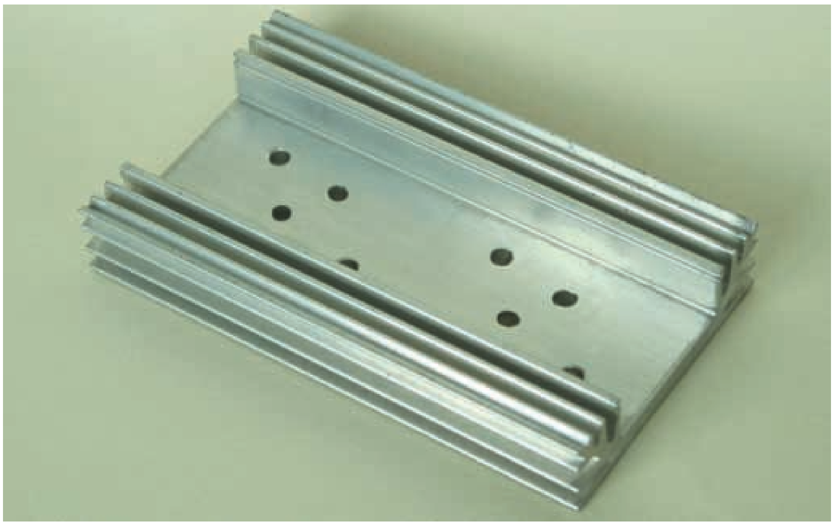


Fig.3. An extruded aluminium heatsink drilled to take two TO3-cased devices.

heatsink. The lower the increase in temperature produced by applying a given power, the better the heatsink.

Never use a heatsink that has a lower rating than the one specified in a components list. In other words, use a heatsink that has a rating in degrees per watt that is equal to or lower than the rating in the components list. If power devices are allowed to overheat they can and do explode, so it is important to avoid overheating for safety reasons. Also, apart from the cost of replacing the destroyed power devices, a lot of expensive damage can be done to other components in the project.

In Isolation

Some power semiconductors have cases or heat-tabs that are electrically isolated from the terminals of the works just as well if the bush is used to insulate the transistor from the bolt, but the method shown in Fig.4 seems to be the preferred one.

Metal cased power devices such as those having the TO3 case style are fitted in much the same way. They are more awkward to fit because four mounting holes are required in the heatsink. Some heatsinks are ready-drilled to take one or two TO3 cased devices, and these will also take plastic power devices.

However, most heatsinks are supplied with no pre-drilled holes. The easiest way to mark the positions of the mounting holes for a TO3 semiconductor is to use the insulating washer as a template. Be careful when handling these washers because many of them are very thin and easily damaged.

Try to get the compound to fully cover the underside of the transistor.

Note that the insulating washers that are made from a rubber-like material obviate the need for any heatsink compound. They are made from a material that both insulates and ensures a good thermal contact.

Other Types

Bipolar transistors are not the only type produced. Unijunction transistors (u.j.t.s) were once quite popular but are largely obsolete these days. They can be used in relaxation oscillators and as trigger devices for use with triacs or thyristors. They have no collector terminal, but instead have two emitters called emitter 1 (e1) and emitter 2 (e2). They look much like any other small signal transistors.

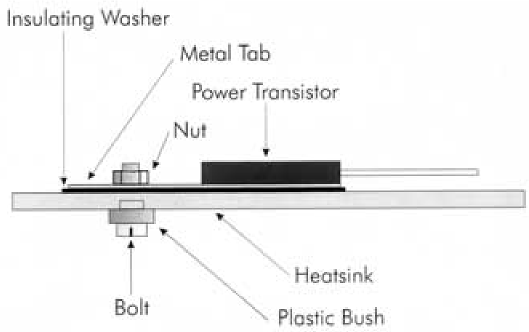


Fig.4. Insulating a plastic power device from the heatsink.

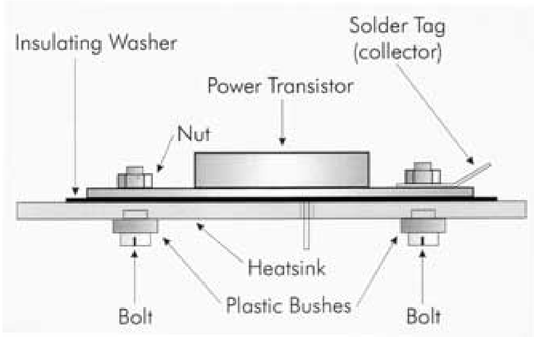


Fig.5. Two plastic bushes are needed for metal cased power devices.

devices. However, few, if any transistors fall into this category. In most instances the metal case or heat-tab connects internally to the collector terminal. Simply bolting a power transistor straight onto its heatsink therefore results in the heatsink being connected to the collector terminal as well.

In most cases the heatsink connects to the metal chassis of the project, which is normally "earthed" to the 0V supply rail. Some projects have an earthed metal case, which is itself used as the heatsink. Consequently, in practice a power transistor almost invariably has to be insulated from the heatsink.

There are special insulating kits available, but make sure that you obtain one that is a correct match for the encapsulation of the power device you are using. These days most power transistors have one of the plastic encapsulations (TO220, etc.) that require a single mounting bolt. The insulating kit consists of a plastic bush and a mica or plastic insulating washer. There is now a trend towards high-tech plastic washers made from a rubber-like material.

Whatever type of washer is supplied, the kit is used in the same way. The washer is fitted between the power device and the heatsink – see Fig.4. This insulates the transistor from the heatsink, but further insulation is needed to prevent the mounting bolt from providing a connection between the transistor and the heatsink. The plastic bush on the underside of the heatsink provides this function by insulating the mounting bolt from the heatsink. It

Two of the four holes take the two pins on the underside of the device, which are normally the base (b) and emitter (e) terminals. These can be as little as 2·5mm in diameter, but a greater diameter of about 4mm or so reduces the risk of a pin coming into contact with the heatsink. The larger holes take the mounting bolts, and a plastic bush is needed on each of these – see Fig.5. Their diameter should match the size of the plastic bushes, which in practice normally means a 5mm diameter hole.

The connection to the collector (metal case) of the transistor is made via a solder tag fitted on one of the mounting bolts. Note that this makes it *essential* to use the plastic bush to insulate the bolt from the heatsink rather than from the transistor. The results are likely to be pretty dire if the insulation should fail, so having fitted an insulating set always use a continuity tester to make sure that insulation is effective.

Heatsink Compound

Particularly with very high-power devices, it is important to have a good thermal contact between the power device and the heatsink. This is normally achieved by smearing a small amount of heatsink compound on the underside of the transistor prior to fitting it on the heatsink.

It is important to use nothing more than a smear of the heatsink compound, since an excess could reduce rather than increase thermal conduction from the transistor to the heatsink.

This is also true of the various field effect devices (f.e.t.s). Junction gate field effect transistors (j.f.e.t.s) are probably the most common type. They are available as *n*-channel and *p*-channel devices, and these roughly correspond to *npn* and *pnp* bipolar transistors. The three terminals of a field effect device are the **drain** (**d**), **gate** (**g**) and **source** (**s**), which are roughly equivalent to the collector, base and emitter of a bipolar transistor.

There are also various types of MOSFET (metal oxide silicon field effect transistor). At one time dual-gate MOSFETs were the most common type, but these are virtually unobtainable these days and little used in new designs. However, various types of power MOSFETs are still very much in demand, as are low power devices for use in switching applications.

The all-important point to bear in mind when dealing with any type of MOSFET is that it is vulnerable to damage from static electricity. Many devices have built-in protection diodes that reduce the risk of damage, but most manufacturers still recommend the use of anti-static precautions.

The low-power types can be fitted to the circuit board via holders, but direct soldered connections are needed to power devices. Always use a soldering iron having an earthed bit when making soldered connections to static-sensitive components.

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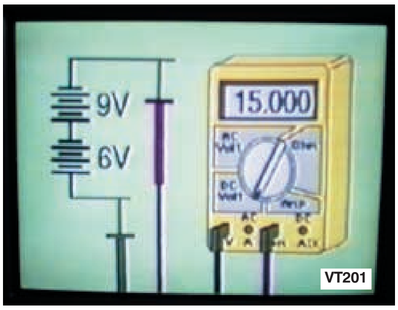

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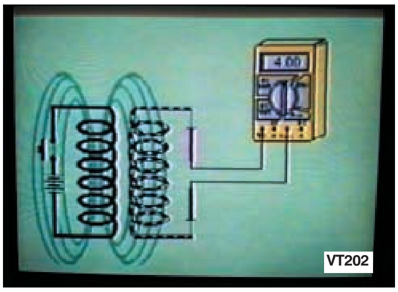

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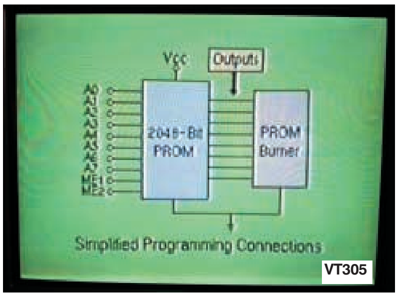

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FOR A FURTHER SELECTION OF BOOKS SEE THE NEXT TWO ISSUES OF EPE.

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EPE TEACH-IN 2000 CD-ROM

The whole of the 12-part *Teach-In 2000* series by John Becker (published in *EPE* Nov '99 to Oct 2000) is now available on CD-ROM. Plus the *Teach-In 2000* interactive software covering all aspects of the series and Alan Winstanley's *Basic Soldering Guide* (including illustrations and Desoldering).

Teach-In 2000 covers all the basic principles of electronics from Ohm's Law to Displays, including Op.Amps, Logic Gates etc. Each part has its own section on the interactive software where you can also change component values in the various on-screen demonstration circuits.

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ONLY **£12.45** including VAT and p&p

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PROJECT CONSTRUCTION

PRACTICAL REMOTE CONTROL PROJECTS
Owen Bishop

Provides a wealth of circuits and circuit modules for use in remote control systems of all kinds; ultrasonic, infrared, optical fibre, cable and radio. There are instructions for building fourteen novel and practical remote control projects. But this is not all, as each of these projects provides a model for building dozens of other related circuits by simply modifying parts of the design slightly to suit your own requirements. This book tells you how.

Also included are techniques for connecting a PC to a remote control system, the use of a microcontroller in remote control, as exemplified by the BASIC Stamp, and the application of ready-made type-approved 418MHz radio transmitter and receiver modules to remote control systems.

160 pages **Order code BP413** **£6.49**

PRACTICAL ELECTRONIC MODEL RAILWAY PROJECTS
R. A. Penfold

The aim of this book is to provide the model railway enthusiast with a number of useful but reasonably simple projects that are easily constructed from readily available components. Stripboard layouts and wiring diagrams are provided for each project. The projects covered include: constant voltage controller; pulsed controller; pushbutton pulsed controller; pulsed controller with simulated inertia, momentum and braking; automatic signals; steam whistle sound effect; two-tone horn sound effect; automatic two-tone horn effect; automatic chuffer.

The final chapter covers the increasingly popular subject of using a computer to control a model railway layout, including circuits for computer-based controllers and signalling systems.

151 pages **Order code BP384** **£5.49**

A PRACTICAL INTRODUCTION TO SURFACE MOUNT DEVICES
Bill Mooney

This book takes you from the simplest possible starting point to a high level of competence in handworking with surface mount devices (SMD's). The wider subject of SM technology is also introduced, so giving a feeling for its depth and fascination.

Subjects such as p.c.b. design, chip control, soldering techniques and specialist tools for SM are fully explained and developed as the book progresses. Some useful constructional projects are also included.

Whilst the book is mainly intended as an introduction it is also an invaluable reference book, and the browser should find it engrossing.

120 pages **Order code BP411** **£5.49**

FAULT-FINDING ELECTRONIC PROJECTS
R. A. Penfold

Starting with mechanical faults such as dry joints, short-circuits etc, coverage includes linear circuits, using a meter to make voltage checks, signal tracing techniques and fault finding on logic circuits. The final chapter covers ways of testing a wide range of electronic components, such as resistors, capacitors, operational amplifiers, diodes, transistors, SCRs and triacs, with the aid of only a limited amount of test equipment.

The construction and use of a Tristate Continuity Tester, a Signal Tracer, a Logic Probe and a CMOS Tester are also included.

136 pages **Order code BP391** **£5.49**

TEST EQUIPMENT CONSTRUCTION
R. A. Penfold

This book describes in detail how to construct some simple and inexpensive but extremely useful, pieces of test equipment. Stripboard layouts are provided for all designs, together with wiring diagrams where appropriate, plus notes on construction and use.

The following designs are included:-
AF Generator, Capacitance Meter, Test Bench Amplifier, AF Frequency Meter, Audio Mullivoltmeter, Analogue Probe, High Resistance Voltmeter, CMOS Probe, Transistor Tester, TTL Probe. The designs are suitable for both newcomers and more experienced hobbyists.

104 pages **Order code BP248** **£4.49**

AUDIO AND MUSIC

VALVE & TRANSISTOR AUDIO AMPLIFIERS
John Linsley Hood

This is John Linsley Hood's greatest work yet, describing the milestones that have marked the development of audio amplifiers since the earliest days to the latest systems. Including classic amps with valves at their heart and exciting new designs using the latest components, this book is the complete world guide to audio amp design.

Contents: Active components; Valves or vacuum tubes; Solid-state devices; Passive components; Inductors and transformers; Capacitors, Resistors, Switches and electrical contacts; Voltage amplifier stages using valves; Valve audio amplifier layouts; Negative feedback; Valve operated power amplifiers; Solid state voltage amplifiers; Early solid-state audio amplifiers; Contemporary power amplifier designs; Preamplifiers; Power supplies (PSUs); Index.

250 pages **Order code NE24** **£21.99**

AUDIO AMPLIFIER PROJECTS
R. A. Penfold

A wide range of useful audio amplifier projects, each project features a circuit diagram, an explanation of the circuit operation and a stripboard layout diagram. All constructional details are provided along with a shopping list of components, and none of the designs requires the use of any test equipment in order to set up properly. All the projects are designed for straightforward assembly on simple circuit boards.

Circuits include: High impedance mic preamp, Low impedance mic preamp, Crystal mic preamp, Guitar and GP preamplifier, Scratch and rumble filter, RIAA preamplifier, Tape preamplifier, Audio limiter, Bass and treble tone controls, Loudness filter, Loudness control, Simple graphic equaliser, Basic audio mixer, Small (300mW) audio power amp, 6 watt audio power amp, 20/32 watt power amp and power supply, Dynamic noise limiter.

A must for audio enthusiasts with more sense than money!

116 pages **Order code PC113** **£10.95**

RADIO / TV VIDEO

ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS
R. A. Penfold

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

109 pages **Order code BP356** **£5.45**

SETTING UP AN AMATEUR RADIO STATION
I. D. Poole

The aim of this book is to give guidance on the decisions which have to be made when setting up any amateur radio or short wave listening station. Often the experience which is needed is learned by one's mistakes, however, this can be expensive. To help overcome this, guidance is given on many aspects of setting up and running an efficient station. It then proceeds to the steps that need to be taken in gaining a full transmitting licence.

Topics covered include: The equipment that is needed; Setting up the shack; Which aerials to use; Methods of construction; Preparing for the licence.

An essential addition to the library of all those taking their first steps in amateur radio.

86 pages **Order code BP300** **£4.45**

EXPERIMENTAL ANTENNA TOPICS
H. C. Wright

Although nearly a century has passed since Marconi's first demonstration or radio communication, there is still research and experiment to be carried out in the field of antenna design and behaviour.

The aim of the experimenter will be to make a measurement or confirm a principle, and this can be done with relatively fragile, short-life apparatus. Because of this, devices described in this book make liberal use of cardboard, cooking foil, plastic bottles, cat food tins, etc. These materials are, in general, cheap to obtain and easily worked with simple tools, encouraging the trial-and-error philosophy which leads to innovation and discovery.

Although primarily a practical book with text closely supported by diagrams, some formulae which can be used by straightforward substitution and some simple graphs have also been included.

72 pages **Order code BP278** **£4.00**

25 SIMPLE INDOOR AND WINDOW AERIALS
E. M. Noll

Many people live in flats and apartments or other types of accommodation where outdoor aerials are prohibited, or a lack of garden space etc. prevents aerials from being erected. This does not mean you have to forgo shortwave-listening, for even a 20-foot length of wire stretched out along the skirting board of a room can produce acceptable results. However, with some additional effort and experimentation one may well be able to improve performance further.

This concise book tells the story, and shows the reader how to construct and use 25 indoor and window aerials that the author has proven to be sure performers. Much information is also given on shortwave bands, aerial directivity, time zones, dimensions etc.

50 pages **Order code BP136** **£2.25**

CIRCUITS AND DESIGN

AN INTRODUCTION TO PIC MICROCONTROLLERS
Robert Penfold
Designing your own PIC based projects may seem a daunting task, but it is really not too difficult providing you have some previous experience of electronics.

The PIC processors have plenty of useful features, but they are still reasonably simple and straightforward to use. This book should contain everything you need to know.

Topics covered include: the PIC register set; numbering systems; bitwise operations and rotation; the PIC instruction set; using interrupts; using the analogue to digital converter; clock circuits; using the real time clock counter (RTCC); using subroutines; driving seven segment displays.

166 pages **Order code BP394** **£6.49**

PRACTICAL OSCILLATOR CIRCUITS
A. Flind
Extensive coverage is given to circuits using capacitors and resistors to control frequency. Designs using CMOS, timer i.c.s and op.amps are all described in detail, with a special chapter on ``waveform generator" i.c.s. Reliable "white" and "pink" noise generator circuits are also included.

Various circuits using inductors and capacitors are covered, with emphasis on stable low frequency generation. Some of these are amazingly simple, but are still very useful signal sources.

Crystal oscillators have their own chapter. Many of the circuits shown are readily available special i.c.s for simplicity and reliability, and offer several output frequencies. Finally, complete constructional details are given for an audio sinewave generator.

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PRACTICAL ELECTRONIC CONTROL PROJECTS
Owen Bishop
Explains electronic control theory in simple, non-mathematical terms and is illustrated by 30 practical designs suitable for the student or hobbyist to build. Shows how to use sensors as input to the control system, and how to provide output to lamps, heaters, solenoids, relays and motors.

Computer based control is explained by practical examples that can be run on a PC. For stand-alone systems, the projects use microcontrollers, such as the inexpensive and easy-to-use Stamp BASIC microcontroller.

198 pages **Temporarily out of print**

PRACTICAL ELECTRONICS HANDBOOK – Fifth Edition. Ian Sinclair
Contains all of the everyday information that anyone working in electronics will need.

It provides a practical and comprehensive collection of circuits, rules of thumb and design data for professional engineers, students and enthusaists, and therefore enough background to allow the understanding and development of a range of basic circuits.

Contents: Passive components, Active discrete components, Circuits, Linear I.C.s, Energy conversion components, Digital I.C.s, Microprocessors and microprocessor systems, Transferring digital data, Digital-analogue conversions, Computer aids in electronics, Hardware components and practical work, Microcontrollers and PLCs, Digital broadcasting, Electronic security.

440 pages **Order code NE21** **£15.99**

COIL DESIGN AND CONSTRUCTIONAL MANUAL
B. B. Babani
A complete book for the home constructor on "how to make" RF, IF, audio and power coils, chokes and transformers. Practically every possible type is discussed and calculations necessary are given and explained in detail. Although this book is now twenty years old, with the exception of toroids and pulse transformers little has changed in coil design since it was written.

96 pages **Order code 160** **£4.49**

OPTOELECTRONICS CIRCUITS MANUAL
R. M. Marston
A useful single-volume guide to the optoelectronics device user, specifically aimed at the practical design engineer, technician, and the experimenter, as well as the electronics student and amateur. It deals with the subject in an easy-to-read, down-to-earth, and non-mathematical yet comprehensive manner, explaining the basic principles and characteristics of the best known devices, and presenting the reader with many practical applications and over 200 circuits. Most of the i.c.s and other devices used are inexpensive and readily available types, with universally recognised type numbers.

182 pages **Order code NE14** **£15.99**

OPERATIONAL AMPLIFIER USER'S HANDBOOK
R. A. Penfold
The first part of this book covers standard operational amplifer based "building blocks" (integrator, precision rectifier, function generator, amplifiers, etc), and considers the ways in which modern devices can be used to give superior performance in each one. The second part describes a number of practical circuits that exploit modern operational amplifiers, such as high slew-rate, ultra low noise, and low input offset devices. The projects include: Low noise tape preamplifier, low noise RIAA preamplifier, audio power amplifiers, d.c. power controllers, opto-isolator audio link, audio millivolt meter, temperature monitor, low distortion audio signal generator, simple video fader, and many more.

120 pages **Order code BP335** **£5.45**

A BEGINNERS GUIDE TO CMOS DIGITAL ICs
R. A. Penfold
Getting started with logic circuits can be difficult, since many of the fundamental concepts of digital design tend to seem rather abstract, and remote from obviously useful applications. This book covers the basic theory of digital electronics and the use of CMOS integrated circuits, but does not lose sight of the fact that digital electronics has numerous "real world" applications.

The topics covered in this book include: the basic concepts of logic circuits; the functions of gates, inverters and other logic "building blocks"; CMOS logic i.c. characteristics, and their advantages in practical circuit design; oscillators and monostables (timers); flip/flops, binary dividers and binary counters; decade counters and display drivers.

119 pages **Order code BP333** **£5.45**

AUDIO AND MUSIC

INTRODUCTION TO DIGITAL AUDIO
(Second Edition) Ian Sinclair
The compact disc (CD) was the first device to bring digital audio methods into the home.

This development has involved methods and circuits that are totally alien to the technician or keen amateur who has previously worked with audio circuits. The principles and practices of digital audio owe little or nothing to the traditional linear circuits of the past, and are much more comprehensible to today's computer engineer than the older generation of audio engineers.

This book is intended to bridge the gap of understanding for the technician and enthusiast. The principles and methods are explained, but the mathematical background and theory is avoided, other than to state the end product.

128 pages **Order code PC102** **£8.95**

PROJECTS FOR THE ELECTRIC GUITAR
J. Chatwin
This book is for anyone interested in the electric guitar. It explains how the electronic functions of the instrument work together, and includes information on the various pickups and transducers that can be fitted. There are complete circuit diagrams for the major types of instrument, as well as a selection of wiring modifications and pickup switching circuits. These can be used to help you create your own custom wiring.

Along with the electric guitar, sections are also included relating to acoustic instruments. The function of specialised piezoelectric pickups is explained and there are detailed instructions on how to make your own contact and bridge transducers. The projects range from simple preamps and tone boosters, to complete active controls and equaliser units.

92 pages **Order code BP358** **£5.45**

VALVE AMPLIFIERS
Second Edition. Morgan Jones
This book allows those with a limited knowledge of the field to understand both the theory and practice of valve audio amplifier design, such that they can analyse and modify circuits, and build or restore an amplifier. Design principles and construction techniques are provided so readers can devise and build from scratch, designs that actually work.

The second edition of this popular book builds on its main strength – exploring and illustrating theory with practical applications. Numerous new sections include: output transformer problems; heater regulators; phase splitter analysis; and component technology. In addition to the numerous amplifier and preamplifier circuits, three major new designs are included: a low-noise single-ended LP stage, and a pair of high voltage amplifiers for driving electrostatic transducers directly – one for headphones, one for loudspeakers.

488 pages **Order code NE33** **£26.99**

VALVE RADIO AND AUDIO REPAIR HANDBOOK
Chas Miller
This book is not only an essential read for every professional working with antique radio and gramophone equipment, but also dealers, collectors and valve technology enthusiasts the world over. The emphasis is firmly on the practicalities of repairing and restoring, so technical content is kept to a minimum, and always explained in a way that can be followed by readers with no background in electronics. Those who have a good grounding in electronics, but wish to learn more about the practical aspects, will benefit from the emphasis given to hands-on repair work, covering mechanical as well as electrical aspects of servicing. Repair techniques are also illustrated throughout.

A large reference section provides a range of information compiled from many contemporary sources, and includes specialist dealers for valves, components and complete receivers.

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LOUDSPEAKERS FOR MUSICIANS
Vivan Capel
This book contains all that a working musician needs to know about loudspeakers; the different types, how they work, the most suitable for different instruments, for cabaret work, and for vocals. It gives tips on constructing cabinets, wiring up, when and where to use wadding, and when not to, what fittings are available, finishing, how to ensure they travel well, how to connect multi-speaker arrays and much more.

Ten practical enclosure designs with plans and comments are given in the last chapter, but by the time you've read that far you should be able to design your own!

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★PIC Graphics L.C.D. Scope		300	£5.07
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Magfield Monitor (Sensor Board)		302	£4.91
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