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EVERYDAY

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DECEMBER 2001

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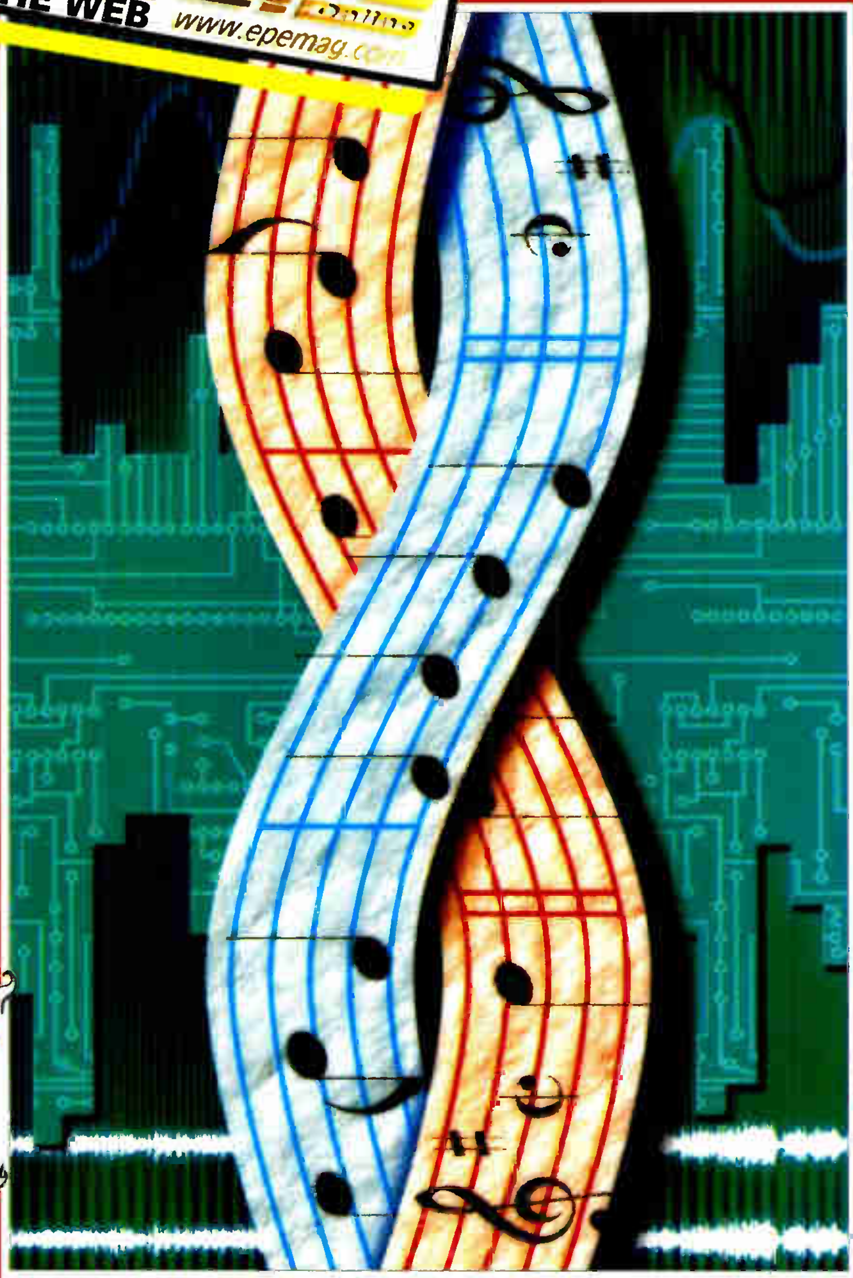

TWINKLING LIGHTS Xmas lights controller

GHOST BUSTER LF standing wave detector

MARCONI Transatlantic transmission anniversary

PLUS

TEACH-IN 2002 - Part 2

VOL 30 INDEX

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GAS MASKS RUSSIAN, new and boxed standard NATO filter, £39.
LOW COST NIGHT VISION system. Russian handheld complete with infra-red illuminator, l00m range. Runs on 2 AA batteries, just £109.95.
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ELECTRIC SCOOTERS 18kph, 24V motor, 6 hour charge time, 22kg weight, max load 90kg, running time up to 1 hour, range 15km, 8·5A motor, 24V, direct drive. Our Price £229.95. Ref ESCOOT.
VOICE CHANGERS Hold one of these units over your phone mouthpiece and you can adjust your voice using the controls on the unit. Battery operated, £15. Ref CC3.
EMMINENCE LOUDSPEAKERS 12in. dia., 50W nom, 100W peak, 16 ohm impedance. Pack of 4 just £39.95. Ref SPEAK39.
PIR SECURITY SWITCHES These brand new swivel mounting PIR units will switch up to 2 kilowatts. Adjustable sensitivity, light level and time delay (9 seconds to 10 minutes), 15m detection range, mains operated, waterproof. £5.99 Ref PIR1PACK or a pack of 5 for £22.95 Ref PIR5PACK or 10 for £39.95 Ref PIR10PACK.
12V 18Ah SEALED LEAD-ACID BATTERIES, new and boxed, unused, pack of 4 £44.95 Ref CYC7 or £15.95 each Ref CYC6.
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SEALED LEAD-ACID CHARGER AND FLOAT CHARGER. Complete unit will charge 12V lead acids and maintain them with an automatic trickle charge. Charger on its own is £15 Ref LAC or charger and a 12V 12Ah battery (all fully cased) is £25 Ref ACB.
AERIAL PHOTOGRAPHY KIT. This rocket comes with a built-in camera! It flies up to 500 feet (150m), turns over and takes an aerial photograph of the ground below. The rocket then returns with its film via its parachute. Takes 110 film. Supplied with everything including a launch pad and 3 motors (no film). £29.98 Ref Astro.
BUILD YOUR OWN WINDFARM FROM SCRAP. New publication gives step-by-step guide to building wind generators and propellors. Armed with this publication and a good local scrapyard could make you self-sufficient in electricity! £12. Ref LOT81.
MAGNETIC CREDIT CARD READERS AND ENCODING INFO, £9.95. Cased with flyleads, designed to read standard credit cards! Complete with control electronics p.c.b. and manual covering everything you could want to know about what's hidden in that magnetic strip on your card! Just £9.95 Ref BAR31.
77 KILO LIFT MAGNET. These Samarium magnets measure 57mm x 20mm and have a threaded hole (5/16th UNF) in the centre and a magnetic strength of 2·2 gauss. We have tested these on a steel beam running through the offices and found that they will take more than 170lb. (77kg) in weight before being pulled off. Supplied with keeper. £19.95 ea. Ref MAG77.
HYDROGEN FUEL CELL PLANS. Loads of information on hydrogen storage and production. Practical plans to build hydrogen fuel cell (good workshop facilities required). £8 set. Ref FCP1.
STIRLING ENGINE PLANS. Interesting information pack covering all aspects of Stirling engines, pictures of home made engines made from an aerosol can running on a candle! £12 STIR2.
12V OPERATED SMOKE BOMBS. Type 3 is a 12V trigger and 3 smoke cannisters, each cannister will fill a room in a very short space of time! £14.99. Ref SB3. Type 2 is 20 smaller cannisters (suitable for mock equipment fires etc.) and 1 trigger module for £29. Ref SB2. Type 1 is a 12V trigger and 20 large cannisters, £49. Ref SB1.
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SAVE £££££s, RCB UNITS. Inline IEC lead with fitted RC breaker. Installed in seconds. Fit to any computer, monitor, office equipment and make it safe! Pack of 10 just £9.98. Ref LOT5B.
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VIBRATING WATCHES, vibrate when your phone rings, £16.99.
PULSE WATCHES, display your pulse, £16.99.
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MINIATURE TOGGLE SWITCHES. These top quality Japanese panel mounting toggle switches measure 35mm x 13mm x 12mm, are 2-pole changeover and will switch 1A at 250V a.c., or 3A at 125V a.c. Complete with mounting washers and nuts. Supplied as a box of 100 switches for £29.95. Ref SWT35 or a bag of 15 for £4.99. Ref SWT34.
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IR LAMP KIT. Suitable for CCTV cameras, enables the camera to be used in total darkness! £6. Ref EF138.
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200 WATT INVERTERS, plugs straight into your car cigarette lighter socket and is fitted with a 13A socket so you can run your mains operated devices from your car battery. £49.95. Ref SS66.
THE TRUTH MACHINE. Tells if someone is lying by micro tremors in their voice, battery operated, works in general conversation and on the 'phone and TV as well! £42.49. Ref TD3.

AIR RIFLES FROM LESS THAN £40, CROSSBOWS, WIDE RANGE OF BB GUNS, AMMO, TARGETS, PISTOLS, REPLICA GUNS, UZI MACHINE GUN REPLICAS (BB), REPEATERS, LASER SIGHTS, ELECTRIC BB, GAS BB
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SMALL ALARMS. Mains powered, made by the famous Gent company, easy fit next to light fittings, power point. Pack of 5 £15, Ref SS23, pack of 12 £24, Ref SS24.
CCTV CAMERAS FROM £25. Check out our web site at **www.cctvstuff.co.uk** and **www.home-cctv.co.uk.**
14 WATT SOLAR PANELS. Amorphous silicon panel fitted in an anodised aluminium frame. Panel measures 3ft. by 1ft. with 3m leads for easy connection. 3ft. x 1ft. solar panel £79. Ref MAG45. Unframed 4 pack, 8-9W (3ft. x 1ft.) £99, Ref SOLX. **35 watts of solar power for just £99.** 4 panels, each one 3ft. x 1ft. and producing 8W min., 13V. Pack of four £99, Ref SOLX.
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SOLAR MOTORS. Tiny motors which run quite happily on voltages from 3-12V d.c. Works on our 6V amorphous 6in. panels and you can run them from the sun! 32mm dia., 20mm thick. £1.50 each.
MAMOD STEAM ENGINES and a full range of spare parts. Check out **www.mamodspares.co.uk.**
SUPER WIDEBAND RADAR DETECTOR. Whistler 1630. Detects both radar and laser, X, K and KA bands, speed cameras and all known speed detection systems. 360 degree coverage, front and rear waveguides, 1·1in. x 2·7in. x 4·6in., fits on visor or dash, new low price £99, Ref WH1630. Other models available at **www.radargun.co.uk.**
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FREEZER/MAINS FAIL ALARMS. Designed to fit around the mains cable on a freezer this alarm will sound if the device is unplugged from the mains supply, battery operated, cased, built-in sounder. Ideal for TVs, Hi-Fi equipment etc. £7.01, Ref FRE2.
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DC MOTOR. 12VC d.c., general purpose model motor, 70mm x 50mm, 12V d.c., permanent magnet, 4mm x 25mm shaft. £6, Ref GPM1, pack of 10 is just £40, Ref GPM2.
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VENNER TIME CONTROLS. Designed to be wired in permanently they will switch up to 16A 240V a.c. motorised with dial and pins. New and boxed. £15, Ref VTS.
GYROSCOPES. We still sell original 1917 design, hours of fun for all the family, complete with stand, string, box and info. £6, Ref EP70.
INNOVATIONS. We also sell a wide range of innovative products for the home, these are at **www.seemans.com.**
INVERTERS. Convert 12V d.c. into 240V mains (modified sine wave), 300 watt (150 watt continuous), £59.95, Ref VER3. 600 watt model (330 watt continuous), £79.97, Ref VER4.

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STICKY LABELS. Small address labels etc. are very useful and can be ordered online at **www.stickon.co.uk.**
RED L.E.D.s. Hewlett Packard red l.e.d.s, 5V operation, available in a pack of 50 for £8, Ref SS200, or 500 for £9.95, Ref SS201.
MICROSOFT TRACKBALL AND MOUSE. Called the Microsoft Ballpoint this has 4 buttons, a trackball and PS2 connector. Will work with most PCs. £5.99, Ref EP50.
MAXON WALKIE TALKIES, up to 2 mile range, UK legal, 300 channel, 2 x walkie talkies, £74.95, Ref. Maxon1. Chargers £14, Ref. Maxonc, battery packs £12, Ref. Maxonb (otherwise uses AAA batteries).
2-WAY MIRROR KIT. Contains enough material to make up to a 500mm x 2200mm mirror (excl. glass), full instructions. £19.95, Ref WF001.
.22 AIR RIFLE. Under lever type, powerful Chinese training rifle, £38.26, Ref A1047. 500 pellets, £2.68, Ref A1091.
.22 AIR RIFLE STANDARD TYPE. Chinese training rifle, on legal limit for air rifles, £29.75, Ref A1040. Pellets £2.68, Ref A1091.
SHUT THE BOX. Check out **www.bullybeef.co.uk** for a range of pub games and magic tricks.
WANT TO MAKE SOME MONEY? STUCK FOR AN IDEA? We have collated 140 business manuals that give you information on setting up different businesses, you peruse these at your leisure using the text editor on your PC. Also included is the certificate enabling you to reproduce (and sell) the manuals as much as you like! £14, Ref EP74.
ANICS CO2 GAS POWERED PISTOL. Russian handheld pistol powered by Sparklets CO2 cylinders (give approx. 70 shots), fires steel BB. Pistol £58.22, Ref AGA101, tub of 1,500 BB shot £5.10, Ref A1015, pack of 5 CO2 cartridges £3.50, Ref GAS5.
33 KILO LIFT MAGNET. Neodynium, 32mm diameter with a fixing bolt on the back for easy mounting. Each magnet will lift 33 kilos, 4 magnets bolted to a plate will lift an incredible 132 kilos! £15, Ref MAG33. Pack of 4 just £39, Ref MAG33AA.
BSA METEOR AIR RIFLE. UK made .22 rifle, top quality professional air rifle, £84.15, Ref BSAMET 500 Lazapell pellets £5, Ref LAZAPELL.
MAMOD 1313 TE1A TRACTION ENGINE. Attractive working model of traditional steam engine, £85, Ref 1313.
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MAMOD STEAM WAGON. Working model steam wagon finished in blue. £112, Ref 1318. Brown version (with barrels), £122, Ref 1450.
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KEVLAR BRITISH ARMY HATS. Broken or missing straps, hence just £8 each. Ref KEV99.
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FM BROADCAST BAND HIGH POWER TRANSMITTERS can be viewed and bought online at **www.veronica-kits.co.uk.**
TONER CARTRIDGES FOR COPIERS AND PRINTERS can be bought online at **www.nationaltoners.co.uk.**
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HYDROPONIC GROWING SYSTEMS. Complete, everything you need apart from plants and light, contains grow tank, nutrients, pump, tester etc. GT205 710mm x 390mm, NFT system, £31.45, Ref GT205. GT424 1070mm x 500mm, NFT system, £58.65, Ref GT424.
ELECTRIC BIKES, £679, Viking, built-in indicators, radio, lights, 13mph, 5 hour charge, Shimano gears, up to 50 mile range, horn, 26in. wheels, suspension, no licence needed, key operated, £679, Ref VIKING.
PIR PCBs. These contain a standard PIR detector circuit with all components, easy to wire up and use. Pack of 4 £6, Ref PIR8.
NEBULISER, WATER ATOMISER. Ultrasonic module that you place in water, atomises the water into a very fine mist, many applications from special effects to scientific. £69, Ref NEB6.
PORTABLE X-RAY MACHINE PLANS. Easy to construct plans on a simple and cheap way to build a home X-ray machine! Effective device, X-ray sealed assemblies, can be used for experimental purposes. *Not a toy or for minors!* £6/set, Ref F/XP1.
TELEKINETIC ENHANCER PLANS. Mystify and amaze your friends by creating motion with no known apparent means or cause. Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect. Excellent for science projects, magic shows, part demonstrations or serious research and development of this strange and amazing psychic phenomenon. £4/set, Ref F/TKE1.
ELECTRONIC HYPNOSIS PLANS & DATA. This data shows several ways to put subjects under your control. Included is a full volume reference text and several construction plans that when assembled can produce highly effective stimuli. This material must be used cautiously. It is for use as entertainment at parties etc only, by those experienced in its use. £15/set, Ref F/EH2.
GRAVITY GENERATOR PLANS. This unique plan demonstrates a simple electrical phenomena that produces an anti-gravity effect. You can actually build a small mock spaceship out of simple materials and without any visible means cause it to levitate. £10/set, Ref F/GRA1.
TESLA COIL/LIGHTENING DISPLAY GLOBE PLANS. Produces up to 750,000 volts of discharge, experiment with extraordinary HV effects, 'Plasma in a jar', St Elmo's fire, corona, excellent science project or conversation piece. £5/set, Ref F/BTC1/LG5.
COPPER VAPOUR LASER PLANS. Produces 100mW of visible green light. High coherency and spectral quality similar to argon laser but easier and less costly to build, yet far more efficient. This particular design was developed at the Atomic Energy Commission of NEGEV in Israel. £10/set, Ref F/CVL1.
VOICE SCRAMBLER PLANS. Miniature solid-state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit. Use on telephone to prevent third party listening and bugging. £6/set, Ref F/VS9.
PULSED TV JOKER PLANS. Little handheld device utilises pulse techniques that will completely disrupt TV picture and sound! Works on FM too! *Discretion advised.* £8/set, Ref F/TJ5.
BODYHEAT TELESCOPE PLANS. Highly directional long range device uses recent technology to detect the presence of living bodies, warm and hot spots, heat leaks etc. Intended for security, law enforcement, research and development etc. Excellent security device or very interesting science project. £8/set, Ref F/BHT1.
BURNING, CUTTING CO2 LASER PLANS. Projects an invisible beam of heat capable of burning and melting materials over a considerable distance. This laser is one of the most efficient, converting 10% input power into useful output. Not only is this device a workhorse in welding, cutting and heat processing materials, but it is also a likely candidate as an effective directed energy beam. Burning and etching wood, cutting, plastics, textiles etc. £12/set, Ref F/LC7.

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VOL. 30. No. 12 DECEMBER 2001
Cover illustration by Jonathan Robertson

EVERYDAY PRACTICAL ELECTRONICS

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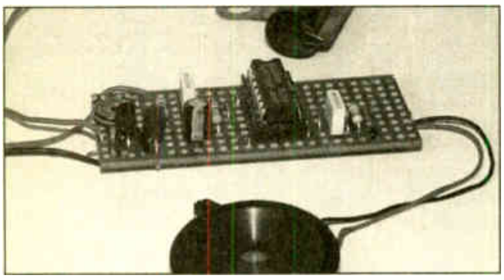
Projects and Circuits



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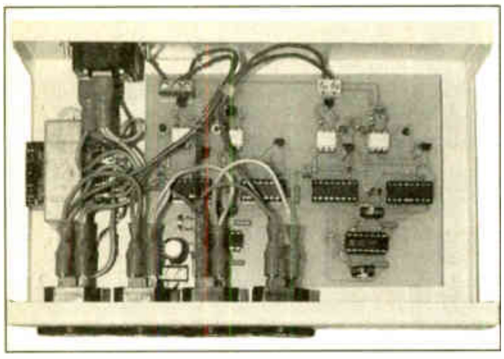
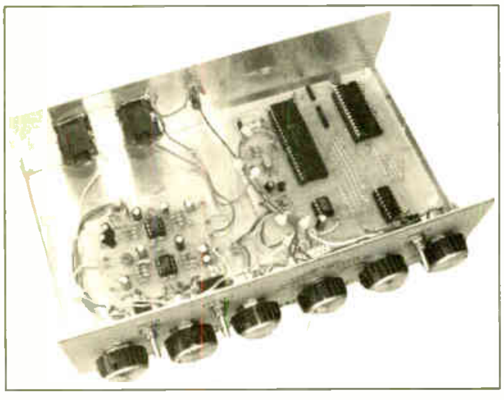


Regulars and Services



Our January 2002 issue will be published on Thursday, 13 December 2001. See page 823 for details

World Radio History

NEXT MONTH

PIC MAGICK MUSICK

Having enchanted and puzzled his intimate audience with close-up magic, the lone magician raised his hands and made a grand sweeping gesture of departure, punctuated by the downwards glissando of an ethereal harp, conjured as though from thin air.

On being questioned later about its origin, all the magician would say was "there's a magic beam"! Intrigued, the author began to puzzle about how a similar effect could be achieved as a simple hobbyist electronics project. Next month he reveals how he did it (without, we hope, triggering the wrath of the Magic Circle)!

To partly reveal the secret – he uses sleight of hand! (plus a couple of PICs and ultrasonic echo detection). The result is not only glissandos but finger-sensitive individual note triggering in mid-air (just wiggle your fingers!), and the ability to add your own remotely triggerable theme tune (via a PIC programmer). Baffle your friends as to how you did it! Spell-binding entertainment for Christmas (and beyond).

FOREVER FLASHER

A simple flashing l.e.d. micropower circuit – it uses just 10µW – that will probably run for 20 years from a 9V lithium battery. However, it can also be powered by the "free energy" from a TV or similar aerial, in which case it should continue flashing forever – or at least until TV transmissions cease.

You might even be able to power it from the electrical pick-up off your own body. A fascinating, easy-to-build project – "look no battery!"

TIME DELAY TOUCH SWITCH

Save energy and help to save the planet. A self-contained mains switch that will automatically turn off a light after a preset period. Useful where a light can often be left on, i.e. understairs cupboards, attics and cellars, or to replace those mechanical delay switches on communal stairways, etc.

PLUS: TEACH-IN 2002, Part 3
AND ALL THE REGULAR FEATURES

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INCORPORATING ELECTRONICS TODAY INTERNATIONAL

DON'T MISS AN ISSUE – PLACE YOUR ORDER NOW!
Demand is bound to be high

JANUARY 2002 ISSUE ON SALE THURSDAY, DECEMBER 13

SIMPLE PIC PROGRAMMER

INCREDIBLE LOW PRICE! **Kit 857 £12.99**

INCLUDES 1-PIC16F84 CHIP SOFTWARE DISK, LEAD CONNECTOR, PROFESSIONAL PC BOARD & INSTRUCTIONS

Power Supply £3.99

EXTRA CHIPS: PIC 16F84 £4.84

Based on February '96 EPE. Magenta designed PCB and kit. PCB with 'Reset' switch, Program switch, 5V regulator and test L.E.D.s, and connection points for access to all A and B port pins.

PIC 16C84 DISPLAY DRIVER

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

Kit 860 £19.99

Power Supply £3.99

FULL PROGRAM SOURCE CODE SUPPLIED – DEVELOP YOUR OWN APPLICATION!

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

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

- WITH PROGRAMMED 16F84 AND DISK WITH SOURCE CODE IN MPASM
- ZERO VOLT SWITCHING MULTIPLE CHASE PATTERNS
- OPTO ISOLATED 5 AMP OUTPUTS
- 12 KEYPAD CONTROL
- SPEED/DIMMING POT.
- HARD-FIRED TRIACS

Now features full 4-channel chaser software on DISK and pre-programmed PIC16F84 chip. Easily re-programmed for your own applications. Software source code is fully 'commented' so that it can be followed easily.

Kit 855 £39.95 LOTS OF OTHER APPLICATIONS

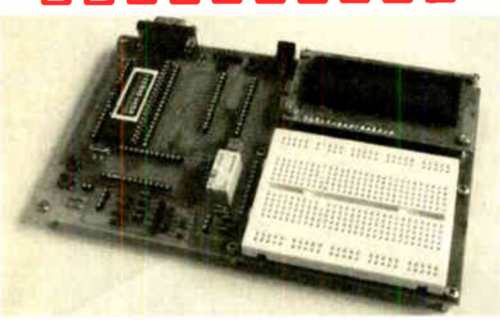
8-CHANNEL DATA LOGGER

NEW!

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

KIT 877 £49.95 inc. 8 × 256K EEPROMS

ICEBREAKER



PIC Real Time In-Circuit Emulator

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

As featured in March '00 *EPE*. Ideal for beginners AND advanced users.
Programs can be written, assembled, downloaded into the microcontroller and run at full speed (up to 20MHz), or one step at a time.
Full emulation means that all I/O ports respond exactly and immediately, reading and driving external hardware
Features include: Reset; Halt on external pulse; Set Breakpoint; Examine and Change registers, EEPROM and program memory; Load program, Single Step with display of Status, W register, Program counter, and user selected 'Watch Window' registers.

KIT 900 . . . £34.99

POWER SUPPLY £3.99 STEPPING MOTOR £5.99

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EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 30 No. 12 DECEMBER 2001

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HOW?

Most of our projects use i.c.s of one type or another and a number of our articles tell you a bit about how they work and maybe give some insight into what is inside some of them. But have you ever wondered how the chips are actually designed?

I guess that through various factory visits, seminars and articles I had some outline knowledge, but when one considers the sheer vastness and complexity of the design problems facing engineers trying to fit literally millions of components onto a single chip, to optimise the design and to make it manufacturable, then you begin to realise that some very powerful design tools indeed are needed if thousands of man hours of work are to be avoided.

We all tend to use a range of i.c.s, or the equipment they make work, without a second thought. We expect the chips to be readily available at low prices, we probably don't ever consider how technically advanced the design process is.

PLUG

My eyes were opened by a new book from one of our *EPE Online* editors, Clive (Max) Maxfield, and his co-author Kuhoo Goyal Edson, in it they explain what EDA (Electronic Design Automation) is and how chips are created using it. To quote one reviewer: "Max and Kuhoo have taken a complex world, foreign to most, full of algorithms and methodologies that make no sense to any normal person, and reduced it to a well-organized city with large, clear street signs and devoid of shifty characters and potholes."

If you have ever wondered how engineers design i.c.s in a few weeks, using millions of transistors, then this book is well worth reading – it's available from our *Direct Book Service*. And no, I'm not ashamed of plugging it – it's rather a good book titled *EDA – Where Electronics Begins*.

Mike Kenward

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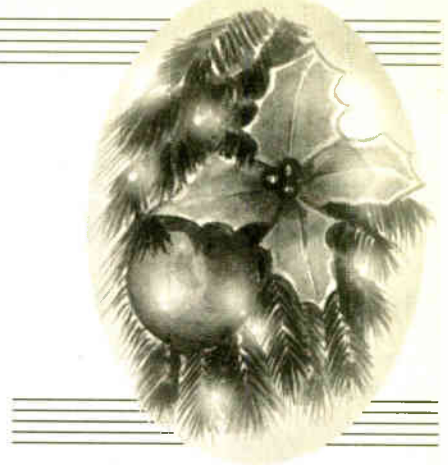
Constructional Project

TWINKLING LIGHTS



TERRY DE VAUX-BALBIRNIE

A beautiful four-channel lighting effect for your Christmas tree or festive party

LAST year, the large Christmas tree in the author's local shopping centre was decorated with hundreds of white twinkling lights. Each bulb appeared to be flashing independently of the others giving a very beautiful effect.

This led to the design of the circuit presented here, which is a smaller version of the display. It could be used for Christmas trees in the home and for other types of display in discos and so on.

CLOSE LOOK

By concentrating on how one bulb flashed, it was easy to see how the effect was produced. It gave three flashes followed by an off period equal in length to the period of flashing. The cycle then repeated at some 1 to 1·5 second intervals. Each flash appeared to have a more-or-less equal mark-space ratio (on and off for equal times). This is, perhaps, more easily understood by referring to Fig.1.

The tree was decorated with dozens of "strands" of series-connected lamps. The bulbs in each strand therefore behaved in the same way. However, each set operated at a slightly different frequency. Since the strands of bulbs were arranged to criss-cross one another at random, it gave the illusion that every bulb was flashing in its own particular way.

The circuit described here provides the same pattern of flashing as shown in Fig.1 but uses only four sets of lamps. Whilst the smaller number of sets means that the "independence" of the flashing of each bulb is not quite so pronounced as in the large display, the end result is still very attractive.

The lighting sets used are of the familiar commercial pattern used on Christmas trees ("fairy lights"). These usually have twenty or forty bulbs connected in series across the mains supply.

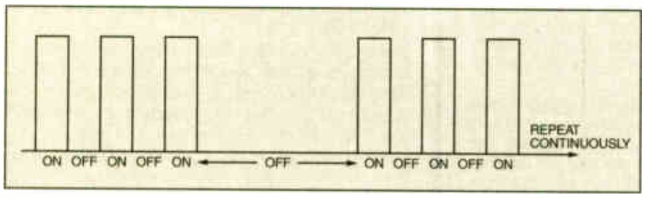
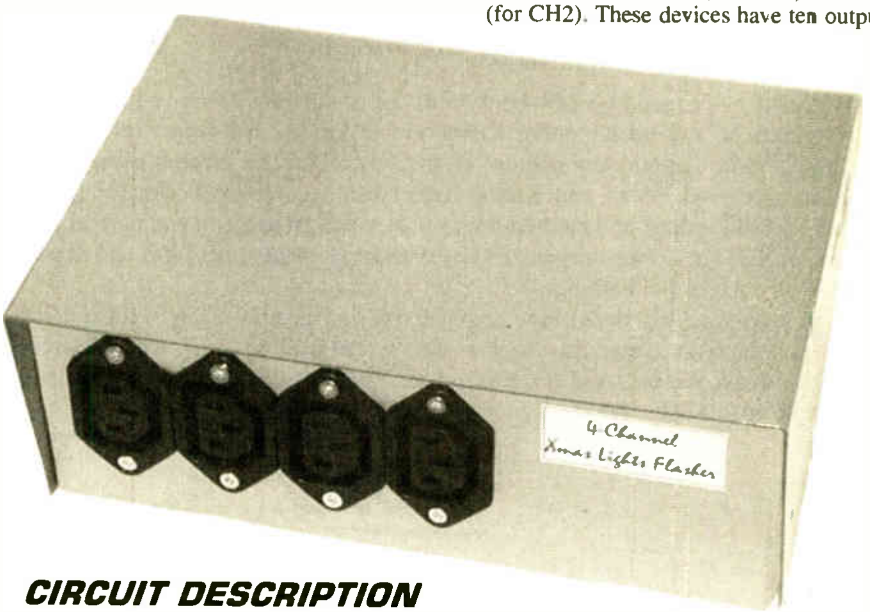


Fig.1. On/Off switching sequence for a single bulb.

The unit is built in an aluminium box having four mains outlet sockets (channels) on the front (one for each set of bulbs) plus an input plug and associated fuse on the back.



CIRCUIT DESCRIPTION

The complete circuit diagram for two channels (CH1 and CH2) of the Twinkling Lights display is shown in Fig.2. The other two, CH3 and CH4, are identical.

The operating frequency of each channel is controlled by a pair of astables centred on a dual CMOS 7556 timer, IC1, having outputs at pins 5 and 9.

The pulse repetition frequency for CH1 is dependent on the values of fixed resistors R3 and R4, preset potentiometer VR2 and capacitor C2. That for CH2 depends on R1, R2, VR1 and C1. Presets VR1 and VR2 allow adjustment of the frequency between about 1Hz and 15Hz and are set for best effect at the end of construction.

The mark-space ratio of the pulses also depends on the setting for VR1 and VR2, but this is not important here because it has no visible effect on the display.

The Reset inputs of IC1, pins 4 and 10, are connected to the positive supply rail, which causes the astables to oscillate continuously. The control voltage inputs (CV – pins 3 and 11) are not used and are left unconnected.

DECADE COUNTERS

Pulses from IC1 output pins 5 and 9 are applied to the clock inputs (pin 14) of decade counters IC2 (for CH1) and IC3 (for CH2). These devices have ten outputs and with the arrival of successive clock pulses, each goes high in turn. The cycle repeats continuously since their Inhibit and Reset pins (13 and 15) are held low.

The printed circuit board tracks connecting IC1 outputs and IC2/IC3 clock inputs are vulnerable to the pick-up of stray a.c. signals along their length. Although weak, these can cause erratic operation. Capacitors C3 and C5 bypass these signals to the 0V line and eliminate the problem.

The operation of CH1 and CH2 is identical and from hereon only CH1 is discussed.

IC2 outputs 0, 2 and 4 are OR-gated using diodes D1, D2 and D3. Thus, when any of these outputs goes high, current flows into the base of transistor TR1 via a current-limiting resistor R5. The transistor then turns on and its collector goes low.

MAINS SWITCHING

With transistor TR1 on, current flows through the light-emitting diode (l.e.d.) section of optically-coupled triac IC4 with

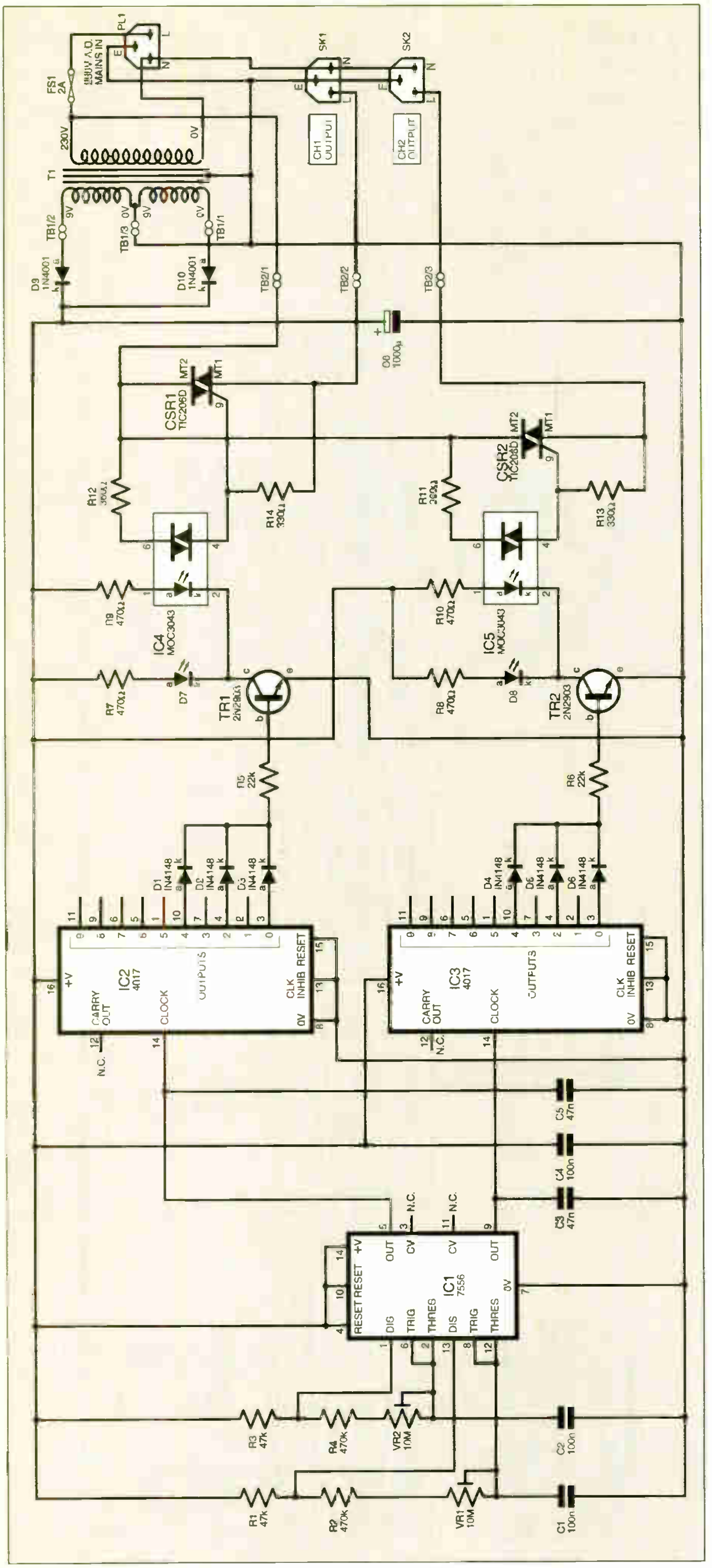


Fig.2. Circuit diagram for two channels of the Twinkling Lights; channels 3 and 4 are identical. The power supply serves all four channels.

COMPONENTS

See SHOP TALK page

Resistors

R1, R3, R21, R23	47k (4 off)
R2, R4, R22, R24	470k (4off)
R5, R6, R25, R26	22k (4 off)
R7 to R10, R27 to R210	470Ω (8 off)
R11, R12, R211, R212	360Ω (4 off)
R13, R14, R213, R214	330Ω (4 off)

All 0·25W 5% carbon film.

Potentiometers

VR1, VR2, VR21, VR22	10M min. preset, vert. (4 off)

Capacitors

C1, C2, C4, C21, C22	100n ceramic, 5mm pitch (5 off)
C3, C5, C23, C25	47n ceramic, 5mm pitch (4 off)
C6	1000µ radial elect. 25V

Semiconductors

D1 to D6, D21 to D26	1N4148 signal diode (12 off)
D7, D8, D27, D28	red l.e.d., 3mm (4 off) (see text)
CSR1, CSR2, CSR21, CSR22	TIC206D 1·5A triac (4 off)
TR1, TR2, TR21, TR22	2N3903 *npn* transistor (4 off)
IC1, IC21	7556 dual CMOS timer (2 off)
IC2, IC3, IC22, IC23	4017 decade counter (4 off)
IC4, IC5, IC24, IC25	MOC3043 opto-triac (4 off)

Miscellaneous

T1	mains transformer, 3VA, twin 9V secondary windings
TB1, TB2	3-way screw terminal block, p.c.b. mounting, 5mm spacing (2 off)
TB3	2-way screw terminal block, p.c.b. mounting, 5mm spacing
FS1	1A ceramic fuse, quick-blow, mains-type
SK1 to SK4	IEC panel mounting mains output sockets (4 off)
PL1	IEC panel mounting mains input plug with integral fuseholder

Printed circuit board, available from the *EPE PCB Service*, code 325; aluminium case, 200mm x 125mm x 75mm: panel-mounting fuseholder (if not built into the inlet plug – see text); 6-pin d.i.l. socket (4 off); 14-pin d.i.l. socket (2 off); 16-pin d.i.l. socket (4 off); 10mm (minimum) plastic stand-off insulator (3 off); plastic self-adhesive feet (4 off); IEC connectors for lamp sets (4 off); 3A mains cable; connecting wire; solder, etc.

Approx. Cost Guidance Only **£45** ***excluding case.***

current limited by resistor R9. At the same time, current flows through conventional l.e.d. D7 with current limited by R7. This l.e.d. (and its CH2 to CH4 counterparts) is only used during setting-up and flashes with the pattern shown in Fig.1.

When IC4's internal l.e.d. operates, it illuminates its triac and triggers it into conduction. The bi-directional nature of a triac allows virtually the whole of the a.c. waveform to flow through it. Since the only coupling between the l.e.d. and the triac is optical, the low voltage and mains aspects of the circuit are electrically isolated from one another.

The maximum current carrying capacity of IC4 is only 100mA, consequently it is followed by a higher power triac (1·5A), CSR1, which is capable of driving the lamps.

Since IC4 is a "zero-crossing" device, the circuit generates hardly any r.f.i. (radio frequency interference).

The power supply consists of a conventional arrangement of mains transformer T1, twin rectifier diodes D9 and D10 and smoothing capacitor C6. The rectified voltage is approximately 12V d.c. and powers all four control channels.

Fuse FS1 protects the circuit and the four light channels.

CONSTRUCTION

This is a mains operated circuit and its construction should not be attempted by those who are not suitably experienced or supervised.

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.3. This board is available from the *EPE PCB Service*, code 325.

The board holds two copies of the circuit in Fig.1, providing the control for all four channels. Note that the component numbering for CH3 and CH4 is the same as for CH1 and CH2 except that they are all prefixed "2". Thus, R5 for CH1 becomes R25 for CH3.

Assemble components in order of size, observing the correct orientation of the electrolytic capacitor, and all semiconductors. Use sockets for the dual-in-line i.c.s. but do not insert the i.c.s until you have checked the correctness of your assembly.

The i.c.s. are CMOS devices and the usual anti-static precautions must be observed (touch something which is earthed, such as a metal water tap, to remove any charge from your body immediately before handling the pins).

Adjust all preset potentiometers to approximately mid-track position.

INITIAL TESTING

The completed p.c.b. should first be tested using a *battery* supply so that any errors may be corrected without the need to connect the mains. *This is important for safety reasons.*

Place the p.c.b. on an insulating work surface. Connect a battery supply of between 9V and 12V to terminal block TB1. The positive connection should be made to either of the "9V" terminals and the negative one to the "0V/9V" terminal.

The l.e.d.s should now be seen to be operating in the pattern shown in Fig.1. Adjust the preset potentiometers so that the

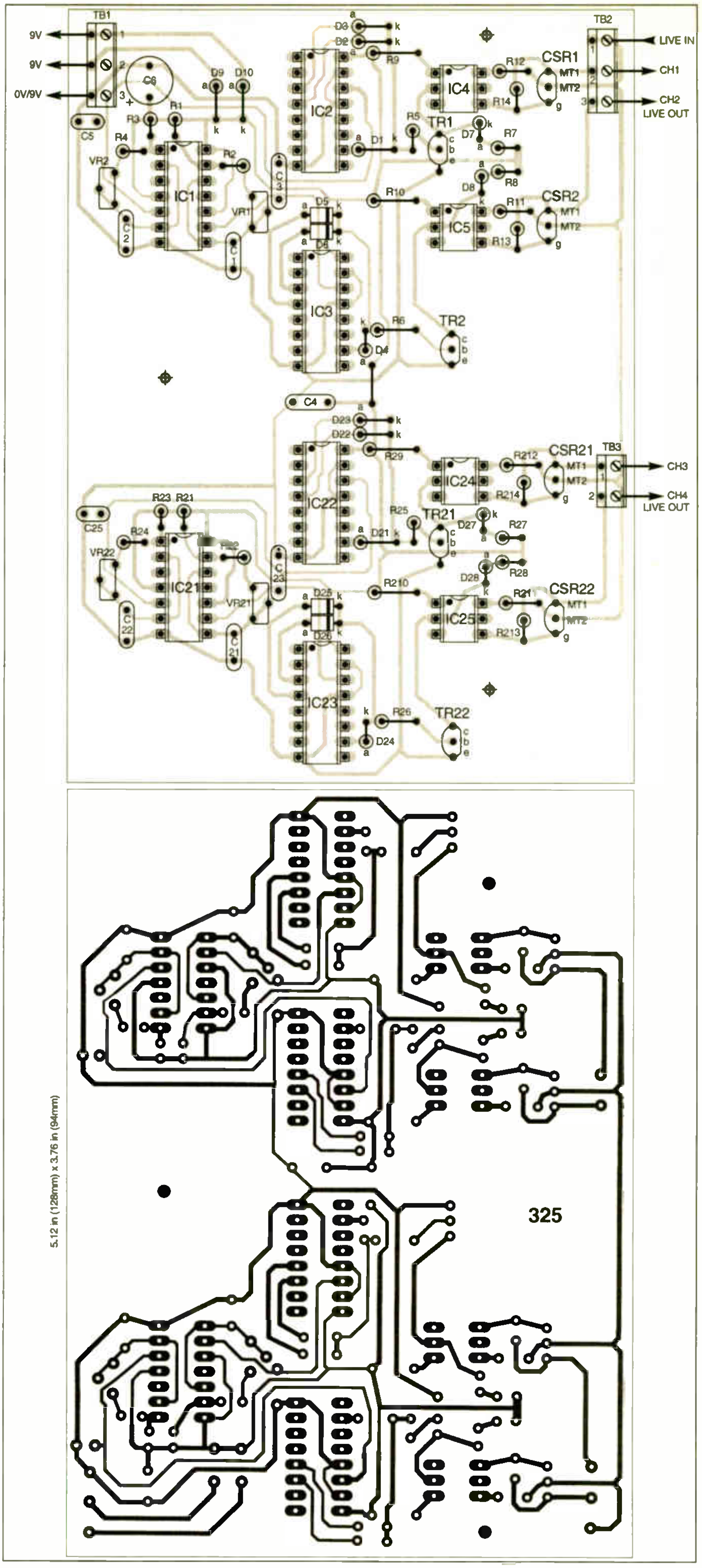


Fig.3. Twinkling Lights four-channel printed circuit board component layout and full-size copper track foil master pattern.

external l.e.d. associated with each channel performs a complete cycle in about one to 1·5 seconds. But set them so that there is a noticeable difference between the operating frequencies. This should give satisfactory operation but further adjustments may need to be made under real conditions.

It is suggested (but not essential) that you remove the l.e.d.s when setting-up has been completed so as not to load the power supply unnecessarily.

ENCLOSURE

For electrical safety reasons, ***this circuit must be built in an earthed metal case.*** All mains connections must be placed so that a gap of 5mm minimum exists between them and the circuit panel.

Note that the panel-mounting inlet plug used in the prototype had an in-built fuseholder (FS1). If an unfused unit is used, a separate panel mounting fuseholder must be fitted (see the wiring diagram in Fig.4).

The transformer should be bolted to the case, together with a solder tag on one of its fixings. Using a multitester, check that the solder tag makes good metallic contact with the case. This is used to earth the case and transformer core.

Mount the p.c.b. on 10mm (minimum) plastic stand-off insulators using nylon fixings. There are mains connections on the underside and there must be a sufficient gap between these and the case.

Refer to Fig.4 and complete the internal wiring. For all mains wiring, (including the earth connections) use mains-rated wire of 3A minimum. For the connections between TB1 and the transformer secondary, use light-duty stranded connecting wire.

Use insulated spade receptacle connectors on the inlet plug and outlet sockets or make soldered joints and fit insulating plastic shields. Fit a plastic shield on fuseholder FS1 if it is not part of the inlet plug. Insert a 2A quick-blow mains-type ceramic fuse in the fuseholder.

Attach a label to the rear of the case stating that the mains input plug must be removed before the lid may be removed. Attach self-adhesive plastic feet to the bottom of the box to prevent damage to the work surface.

Remove the existing mains plugs from the Christmas tree lighting sets and replace them with IEC connectors to suit the recommended sockets. Do not connect more than one set of lights to any output. Fit a 3A fuse to the mains connecting plug.

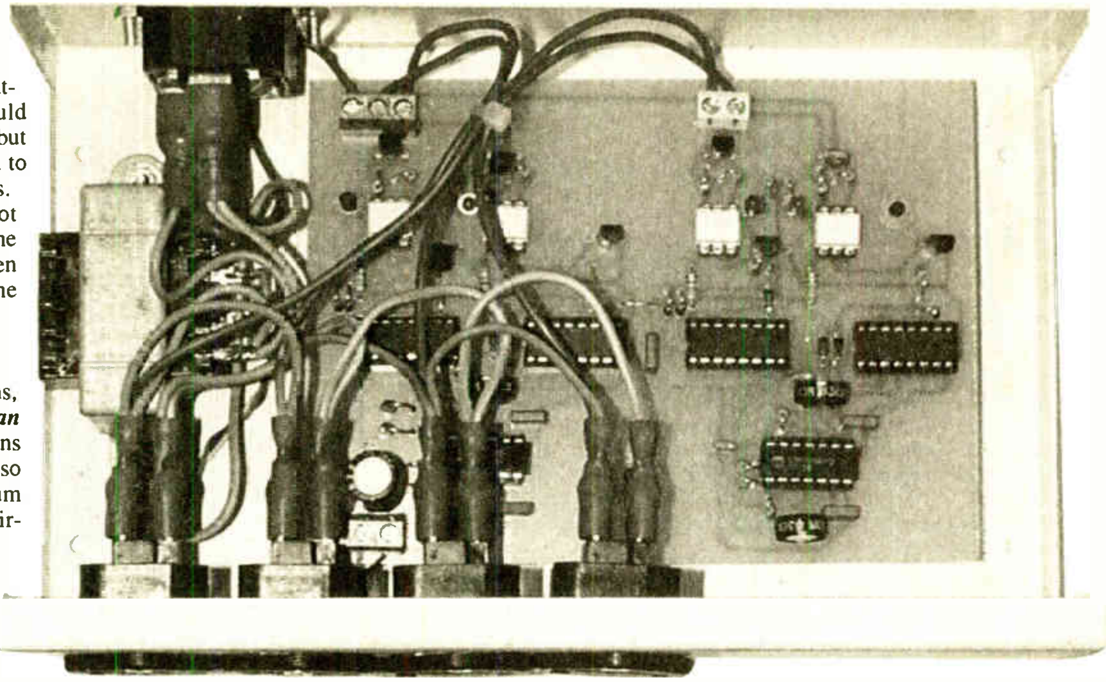
FINAL TESTING

For safety reasons the lid of the case must always be secured in position when the mains inlet plug is connected. When making adjustments to the preset potentiometers to set the desired lighting effect, do so in a series of small steps, each time replacing the lid before re-connecting the mains.

In trials on the prototype unit, it seemed that plain white lamps gave the best effect. However, this is subjective and some readers will probably wish to experiment with different colours.

If the unit is to be used for disco or similar purposes, a single coloured spot lamp (60W rating maximum) could be connected instead to each channel output.

Happy Christmas! □



Layout of components inside the prototype metal case. For all mains wiring, including earth connections, use mains-rated wire of 3A minimum. The panel mounting fuseholder is not shown in this model, being contained in the panel-mounting mains input plug.

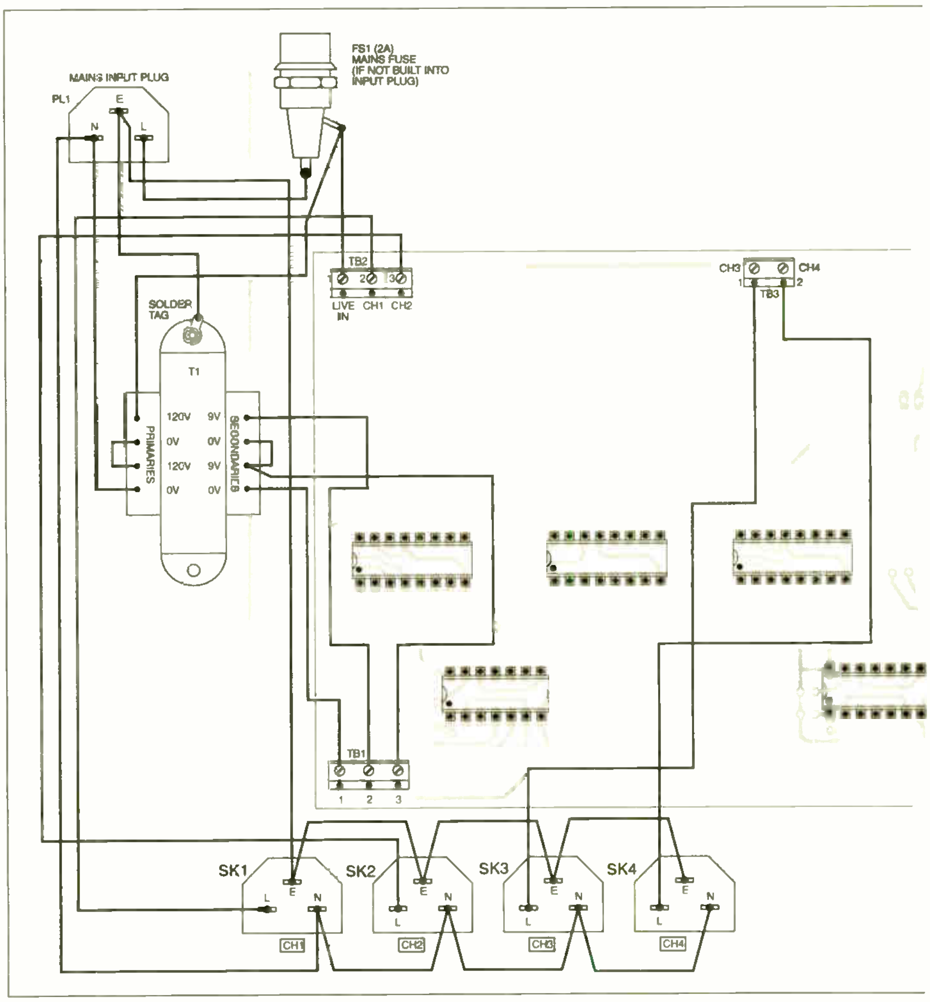


Fig.4. Interwiring between all off-board components and p.c.b.

New Technology Update

Ian Poole takes a brief look at the history of l.e.d.s and how they could replace incandescent lamps.

MANY of the limitations previously associated with light emitting diodes (l.e.d.s) are progressively being overcome. New high efficiency, high output devices have been introduced and these can be used in daylight. Additionally, a full range of colours, including blue and white, can be obtained.

These improvements have enabled l.e.d.s to be used in many new applications, including traffic lights, sign illumination and back lighting. Currently they are not available in a form that can be used for general lighting situations, but this may be a possibility in the medium term.

The developments have meant that l.e.d.s are challenging incandescent lamps in many areas. Their uptake is likely to be fairly rapid as they have several advantages. L.E.D.s typically have an operating life of over 100,000 hours, which is ten to a hundred times that of an incandescent lamp. They also offer a much higher level of efficiency, typically providing at least a five-fold improvement.

Discovery

Before looking at the latest developments, it is interesting to see how these devices were developed. Surprisingly, the effect was observed very early in the twentieth century. One of Marconi's engineers, a man named H. J. Round, who was famous for many valve and radio developments, was the first to see the effect in 1907 when he was working with Marconi on point contact crystal detectors. Although he reported his findings in *Electrical World* in 1907, little investigation was carried out for many years.

As a result, the idea lay dormant until it was again observed by O. V. Losov in 1922. Unfortunately, he lived in Leningrad and he was killed during the Second World War. He took out four patents between 1927 and 1942 but these were not discovered after his death and it is likely that they were destroyed during the hostilities.

The idea for the l.e.d. resurfaced in 1951 when a team of researchers led by K. Lehovec started to investigate the effect. The research continued with many companies and researchers, including Shockley, becoming involved. The light-emitting diode was eventually refined sufficiently and the first devices hit the market in the late 1960s.

Basis of operation

An l.e.d. is a form of *p-n* junction, but it must be fabricated using a compound semiconductor. Silicon and germanium do not provide the correct environment for light to be emitted from the junction, but compound semiconductors formed from two or more elements, such as gallium arsenide, gallium phosphide and indium phosphide, are widely used.

In the example of gallium arsenide, gallium has a valency of three and arsenic a valency of five and as such they are known as group III-V semiconductors. Other compound semiconductors are also formed from group III-V materials.

An l.e.d. operates as a diode in the normal way. When forward biassed, holes from the *p*-type region and electrons from the *n*-type region enter the junction and recombine giving a current flowing across the junction. When this occurs energy is released, and for these group III-V compounds some of the energy is in the form of light.

It is found that for a number of reasons more light is usually produced from the *p* side of the junction, and this is kept closest to the surface of the device to ensure that the minimum amount of light is absorbed in the structure.

To produce light that can be seen, the junction must be optimised and the correct materials must be chosen. Pure gallium arsenide releases energy in the infra-red portion of the spectrum. To bring the light emission into the visible red end of the spectrum, aluminium is added to the semiconductor to give aluminium gallium arsenide (AlGaAs). Phosphorus can also be added to give red light.

For other colours other materials are used. For example gallium phosphide gives green light and aluminium indium gallium phosphide is used for yellow and orange light. Most l.e.d.s are based on gallium semiconductors.

White L.E.D.s

To be able to use l.e.d.s in lighting applications from back lighting to area lighting it is necessary to be able to generate white or near-white light. Until recently this has not been possible. Now there are a number of ways in which this can be done. One method is to use an l.e.d. fabricated from indium gallium nitride. On its own this would give a bluish white light.

This can be filtered using a phosphorus filter in the lens of the l.e.d. This produces a cool white light similar to that given by a fluorescent light. Further filters can be used to give a light that is warmer, but the addition of each filter absorbs a little more light and reduces the overall efficiency. Unfortunately, this does not produce a fully white light as no red is present.

Toshiba have adopted a variation on this method. They use a white l.e.d. based on an indium doped gallium nitride emission layer. This in turn excites red, green and blue phosphors in the transparent resin of the package. The colour temperature of the device can be changed by altering the level of the phosphors in the package to give the required balance.

Another method is to fabricate three l.e.d.s in a trio close to one another. This is obviously more costly than a single l.e.d. but it gives the best control over colour. The major drawback is that l.e.d.s of different colours have different levels of light output for the same current. To overcome this the currents for the different colour l.e.d.s need to be set.

L.E.D. lighting bulbs

L.E.D.s are not usually associated with area lighting applications, but lighting bulbs are starting to become available now. Currently the market is mainly in the US and the standard Edison screw mount base is the most widely available type.

The bulbs are capable of operating at mains voltages having their own internal current limiting and rectification. Typically, they consume between one and two watts and they are equivalent to ordinary household types between 15 and 20 watts, so there is a considerable improvement in efficiency. Bulb life is also considerably improved, although they are still much more expensive than their incandescent equivalents.

These lamps are not yet suitable for room lighting as they do not have a sufficiently wide angle of illumination, but they are useful for signs, decorative lighting and similar applications.

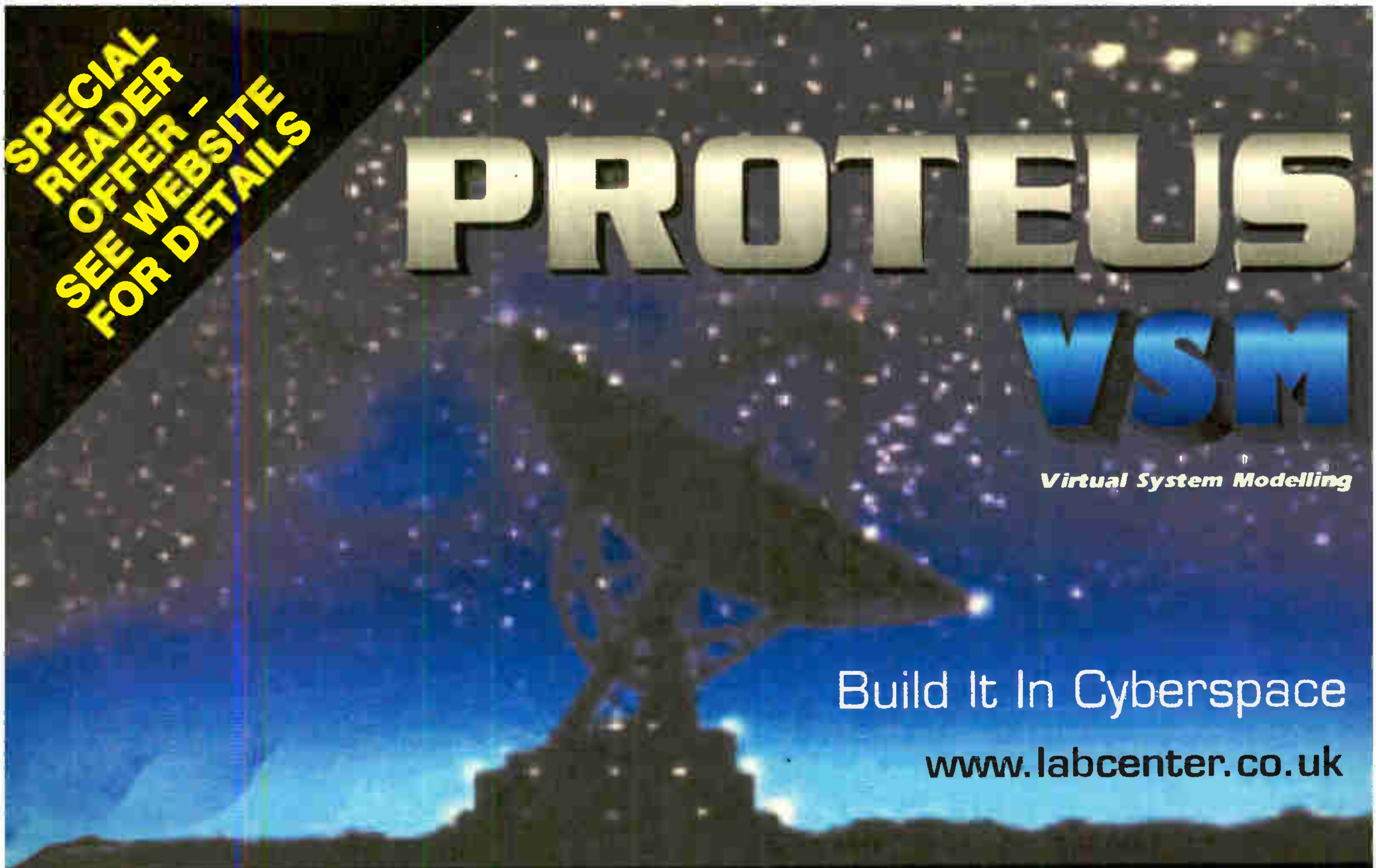
Back Lighting

Back lighting and other similar applications can now be performed by l.e.d.s. One vendor has mounted a 50 l.e.d. die onto a beryllium oxide substrate. This substrate is required to remove the heat, and the whole assembly is mounted in a TO66 package. However, for full back lighting a much larger array of l.e.d.s is required.

There are two approaches that can be adopted. One is to build up an array from surface mount devices. A number of manufacturers now produce high output SMDs. These include Agilent Technologies (formerly the test and measurement division of HP) and Philips Lighting. However, it is also possible to procure moulded modules designed to provide back lighting for liquid crystal displays. In this way the two technologies that were once rivals have come together to provide a complete solution.

For the future many more applications are likely to arise for l.e.d.s as a result of new developments. They may even start to appear for domestic lighting applications.

SPECIAL READER OFFER – SEE WEBSITE FOR DETAILS



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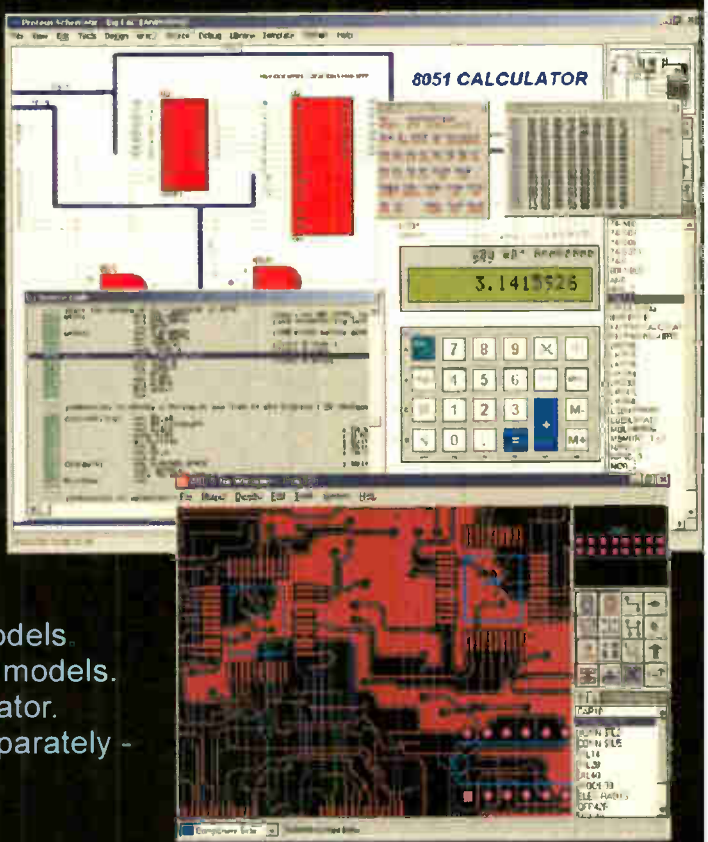

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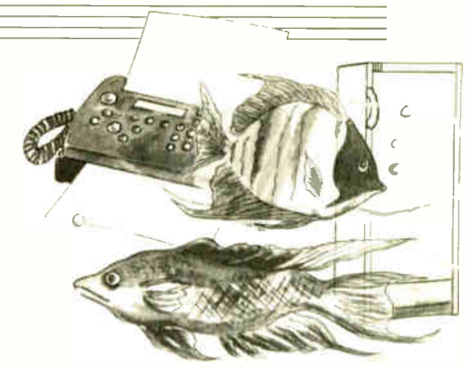
Constructional Project

MAINS FAILURE ALARM



BART TREPAK

Protect your freezer or fish tank contents, or monitor mains connections.

MAINS failure alarms are often employed in situations where the removal of the mains supply from a piece of equipment can have adverse or even disastrous consequences.

In the domestic situation, the equipment in question could be the freezer which, in the event of a mains failure, could result in tens of pounds worth of food thawing out and having to be thrown away. A tank full of expensive tropical fish may be another example, while at school or in a laboratory the failure of the mains supply may result in a long term experiment having to be repeated.

Very often, the "failure" may simply be the result of the switch on the outlet socket being operated inadvertently and this may have no immediately noticeable effect on the equipment. The results of the mistake may only become evident a few hours or even days later, when it is too late.

MONITORING OPTIONS

There have been many circuits published to perform a mains monitoring function and there are also commercial devices available for this purpose. All work on the same principle:

The mains voltage is monitored by some means – usually by using it to switch on a transistor or the light emitting diode (l.e.d.) inside an optoisolator. This signal is used to hold an oscillator/buzzer in the off condition so that no alarm is produced.

When the mains fails, the transistor or l.e.d. switch off, enabling the oscillator and activating the alarm. The device is battery powered, of course, but as the unit (hopefully) spends most of the time in the standby mode drawing little current, the battery life is virtually its shelf life.

Most commercial units come in the form of an oversized mains plug which contains a buzzer and a battery compartment and which is plugged into an adjacent socket to that used by the equipment. Home-made projects usually opt for a small box with a plug fitted via which the mains supply is monitored.

MAINS OR FUSE FAILURE

Most people would consider a mains failure to be the result of some problem in relation to the supply company, causing a "black-out" in the local neighbourhood. If this is not the case, then the fault would probably be in the consumer unit where the fuse or circuit breaker protecting the mains circuit has tripped and all mains failure alarms will signal this eventuality.

However, what if the outlet socket to which the equipment is connected is inadvertently switched off, or the equipment is simply unplugged? Worse still, what if the fuse in the plug serving the appliance itself blows? Either of these eventualities will result in a loss of power to the appliance as sure as any power cut, but will go unnoticed by the plug-in alarm in the adjacent socket to which the supply will not have been interrupted.

One answer to this is to make the alarm unit in such a way that the equipment to be monitored can be plugged into it rather than directly into a mains outlet. Then, instead of simply monitoring the mains voltage, the unit can monitor the current drawn by the equipment.

FAILURE FAILINGS

Although this sounds easy enough to do in theory, the practice is much more difficult. The current drawn by various appliances can vary from a few tens or hundreds of milliamps to ten amps or more, so that a variable trip level would be required.

Some appliances such as freezers, for example, may draw a very small or even no current at all during certain periods, and a large current at other times when the compressor motor switches on. This makes it almost impossible to select a universal current level below which the mains could be considered to have failed.

The circuit described here overcomes all of these problems at a stroke and also does away with the need for mains plugs, or indeed any connections to the mains at all. It does so by monitoring the electric field which exists around a cable connected to the a.c. supply (whether it is carrying a current or not).

By placing it on or near to the cable of the appliance to be monitored, it will also sound the alarm if the fuse in the plug blows, the outlet is switched off or the plug disconnected. It will only fail to detect the situation where the equipment itself has been switched off via its own built-in

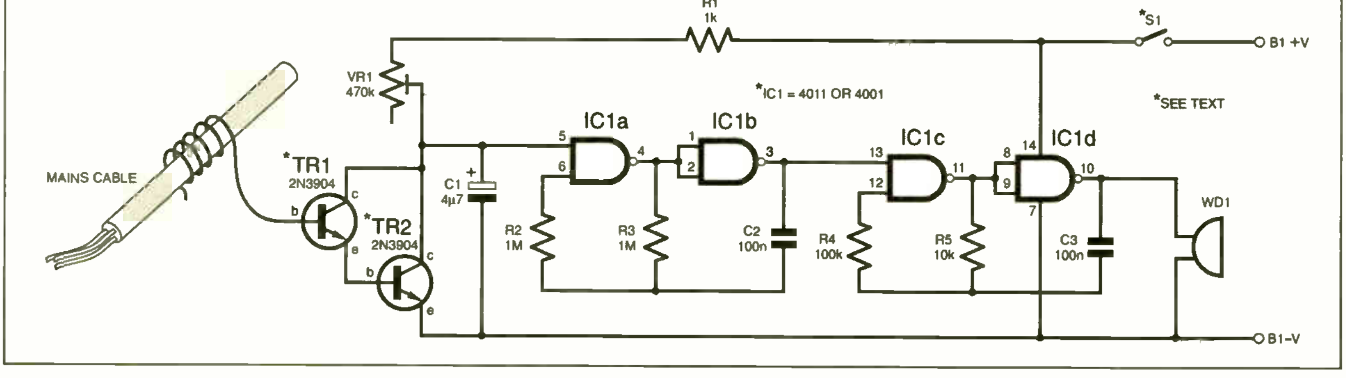


Fig.1. Complete circuit diagram for the Mains Failure Alarm.

switch. However, since many appliances such as freezers do not have on/off switches, this is not really a problem.

CIRCUIT DESCRIPTION

The circuit is extremely simple and inexpensive to build. Its simplicity and lack of any specialised components should make it attractive to many constructors who will probably already have most of the components to hand. The absence of any mains connections should make it an ideal project for a beginner.

As with many simple circuits, however, the advantages and possible uses take longer to describe than the operation of the circuit diagram which is shown in Fig.1.

The heart of the circuit is an oscillator built around two CMOS NAND gates (IC1c and IC1d) which drive a small piezo sounder, WD1. With the values specified for resistor R5 and capacitor C3, the circuit oscillates at around 200Hz, producing a fairly loud sound from WD1.

Since an intermittent sound is better at gaining attention than a louder continuous alarm, this oscillator is driven by another similar circuit built around IC1a and IC1b. Here the frequency determining components, R3 and C2, have been chosen to give a lower frequency so that when the circuit is activated, the sounder produces a tone of 200Hz in bursts at around 2Hz (i.e. two bursts per second).

MAINS FIELD

Oscillator IC1a/b is normally disabled, however, because of the action of transistors TR1 and TR2. These are switched on in the presence of the alternating electric field which exists around all cables carrying a mains potential, manifesting itself in high gain amplifier systems as "mains hum".

In this circuit, transistor TR1 is used as the high gain amplifier, providing base current for TR2. There is a combined current gain of around 10,000.

With a high value of collector load resistance (VR1 plus R1), transistor TR2 does not need to pass very much current before its collector voltage falls below the nominal logic-high level for CMOS gates (approximately half of the supply voltage).

When the input to TR1 is placed near enough to a cable carrying a mains voltage, the positive mains half-cycles are amplified and TR2's collector voltage falls, so disabling the oscillator around IC1a/b.

Capacitor C1 prevents the collector voltage from rising again during the negative half cycles.

Should the mains field cease, TR1 and TR2 will remain off and C1 will charge to the circuit's d.c. supply voltage via VR1 and R1, allowing IC1a/b to oscillate and the alarm to sound.

SENSITIVITY

The sensitivity of the circuit depends on the value of the collector load and is best determined experimentally, so it has been made variable using preset VR1. In most cases, unless the mains field is generally very high, it will probably not need to be reduced from its maximum 470kΩ value.

Resistor R1 has been included to prevent a direct short-circuit between the two power lines via TR2 should VR1 be set to zero resistance.

Because capacitor C1 takes time to charge via VR1 and R1, there will be a delay of about one second (depending on the setting of VR1) before the alarm sounds following a mains failure.

The circuit can be powered by a PP3 9V battery, or two AA cells in series providing 3V, depending on the user's preference. With the lower supply voltage, however, the sound produced will not be as loud. Since the current consumption in the stand-by mode is around 45μA (at 9V) the battery should last many months.

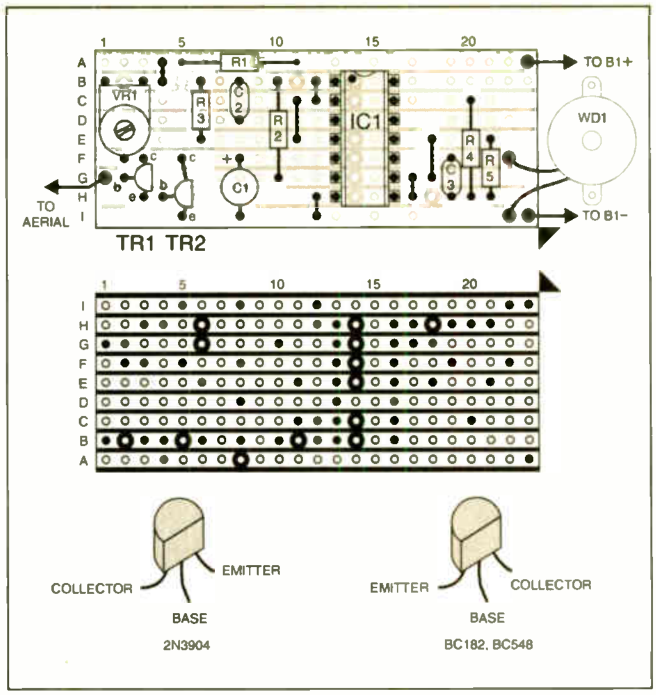


Fig.2. Stripboard component layout, details of underside copper track breaks and transistor pinout details.

Layouts of components on the completed prototype circuit board. Resistor R1 is missing from this board.

CONSTRUCTION

The circuit was constructed on a small piece of 0·1in. matrix strip board (9 tracks x 23 holes) for which the layout is shown in Fig.2. Assembly should start by cutting the tracks at the points shown, using a 2·5mm to 3mm diameter drill bit or the tool available for this purpose.

The circuit can then be assembled and soldered in the normal way. There are seven links required and these may be made from discarded component leads. The i.c. is a CMOS device so care should be taken when handling it, discharging static electricity from your body by touching an earthed item, such as a water pipe; use a socket for it.

Observe the correct polarity for capacitor C1, the transistors and IC1.

Many different types of silicon transistor may be used for TR1 as long as they are *npn* types. It should be noted, however, that the connections for the 2N3904 device specified are different from the more usual *npn* types such as the BC182 or BC548. Pinouts for these three devices are also shown in Fig.2.

The circuit has been designed for use with a *passive* piezo device as WD1. A piezo *buzzer*, which contains an internal oscillator, could be used instead. In this case, the second oscillator will not be required, consequently R4, R5 and C3 should be omitted, and IC1 pins 12 and 13 should be linked.

Do not use a loudspeaker for WD1 since it would demand more current than IC1 can provide.

COMPONENTS

See SHOP TALK page

Resistors

R1	1k
R2, R3	1M (2 off)
R4	100k
R5	10k

All 0·25W 5% carbon film.

Potentiometer

VR1	470k min. preset horiz.

Capacitors

C1	4μ7 radial elect. 16V
C2, C3	100n ceramic, 5mm pitch (2 off)

Semiconductors

TR1, TR2	2N3904 *npn* transistors (see text)
IC1	4011 CMOS quad NAND gate (see text)

Miscellaneous

S1	s.p.s.t. switch (see text)
WD1	piezo sounder, passive (see text)
B1	9V battery (PP3 or 2 x AA)

Stripboard, 9 strips x 23 holes; PP3 battery and clip (see text); plastic case, size and type to choice; connecting wire; solder, etc.

Approx. Cost Guidance Only **£8** *excluding batts.*

TESTING

For initial tests, keep the unit well away from any potential source of mains electrical field.

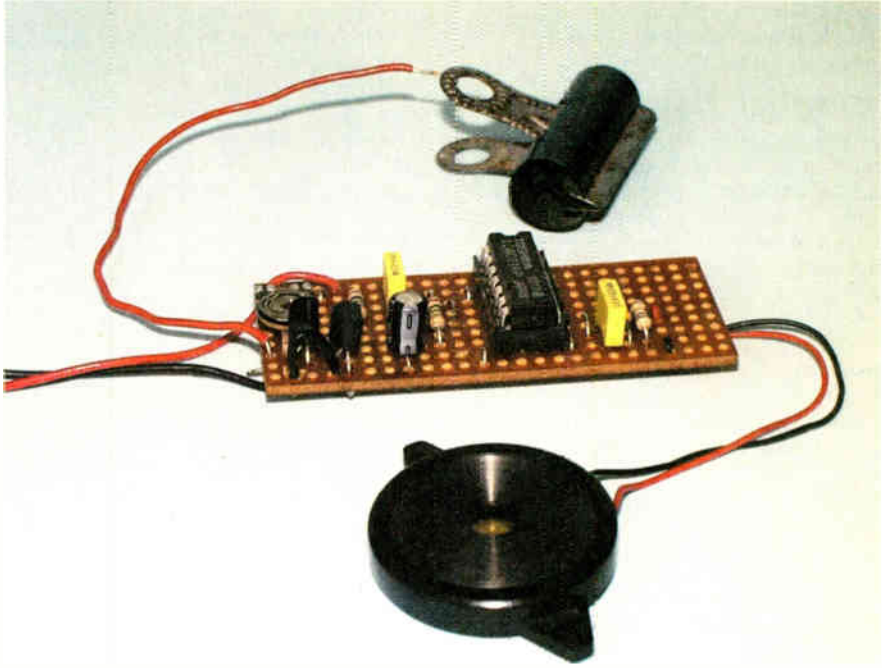
Solder a short length (say 100cm) of single core insulated wire to the base connection to TR1 to act as an "aerial". Set VR1 to its maximum resistance.

When the battery is fitted, the alarm should sound after capacitor C1 has had time to charge. If it does not sound, there may be sufficient local mains electrical radiation for the unit to pick it up undesirably. If so, reduce the resistance of VR1 to reduce the circuit's sensitivity, although the need to do this is unlikely.

Now the oscillator should only stop when you grip the aerial insulation.

Once the circuit is working correctly it should be mounted in a plastic box of a size that will accommodate it and the battery. The piezo sounder was purchased mounted in a plastic package suitable for fixing to the box but uncased elements are also available and if this type is used it should be glued to the inside of the box lid.

It may be found necessary to drill a small hole in the lid to allow the sound to be heard, although the lid will generally act as a sounding board.



Completed prototype circuit board with the piezoelectric sounder and "bulldog" clip wired to the board ready for inserting in a suitable case.

COMPLETION

The sensitivity of the unit may be high enough for the aerial wire to be left inside the box and the box simply placed alongside the mains cable. If this is not the case, the wire should be brought out and wrapped around the appliance mains lead a few times. This will not only increase the apparent sensitivity of the circuit but will also ensure that the unit remains in close proximity to the cable.

Alternately, a Bulldog type paper clip attached to the box and wired to the base of TR1 could be used as an aerial and a means of securing the device to the cable.

Once complete and in proximity to the mains cable of the appliance, or clipped to it, final testing of the circuit is very simple. Unplugging the mains lead or switching off the power at the mains socket should cause the alarm to sound. Restoring the power should mute the alarm. It is probably better to use a small appliance such as a table lamp to do this initially, rather than your freezer!

OTHER APPLICATIONS

As well as a mains failure alarm, the circuit will be found to be a useful addition to any electrician's tool box. It may be used in identifying which circuit is connected to which fuse in the main fuse box or indeed to ensure that the cable which is about to be cut is not carrying a mains voltage.

The circuit can be attached to the cable and the fuses removed in turn until the alarm sounds. Most non-contact cable testers provide only a visual indication and cannot be attached to a cable.

The circuit is also useful in finding a break in a cable or mains circuit. One application which comes to mind is the annual quest to discover which lamp in the Christmas tree lamp chain has mysteriously become disconnected during its year-long storage.

Another is checking the fuse in a mains plug without the need to undo the whole thing – only to find that the fuse is OK!

In all of these "portable" applications, an On/Off switch will be necessary to prevent the alarm from sounding continuously when the device is placed away from a mains cable or stored in your tool box. However, if in constant use for monitoring an appliance, it may be best to omit the switch since it could become accidentally switched off.

Alternatively, the 4011 quad NAND gate could be replaced by a 4001 quad NOR gate which is pin compatible and this would cause the alarm to sound only when a mains field was detected.

Indeed, this is the way most commercial mains testers operate, although in the author's view, his "fail safe" design is better as a *non*-sounding alarm in the presence of an electrical field, since a flat or disconnected battery in other designs could easily be mistaken for the absence of the mains supply, with potentially disastrous consequences. □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News . . .

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

WALLS *CAN* HAVE EARS!

New building bricks do not block 3G mobile phone signals. Barry Fox reports

TELECOMS companies staking their future on third generation mobiles may like to point the building trade in the direction of Roke Manor Research, part of the Siemens Group. Roke's laboratory in Hampshire has filed patents round the world on a smart brick which can make house and office walls transparent to fragile 3G radio signals (W0 01/45303 and GB 2 357 394).

Roke says its main priority now is developing new 3G devices and its researchers were faced with two conflicting requirements. Mobiles are no longer just phones, they are use-anywhere, do-everything devices. But the higher frequencies allocated to 3G, over 2GHz, are blocked by house and office walls.

Says Paul Smith, Roke's Director of Radio Devices, "We had a brainstorming session and asked ourselves the question –is there a better form of building material?" Roke's Walter Tuttlebee went away and came up with the "Bricksat" – a modified brick, the same size as a standard builder's brick, but hollowed out to contain a wideband radio amplifier connected to small printed circuit antennae on opposite surfaces of the brick.

The amplifier can be powered by the mains, if fitted near a power point. Or it can be fed from a rechargeable battery and solar panel that takes energy from room lighting. 3G signals picked up by the antenna on one brick surface are boosted and re-broadcast by the antenna on the opposite surface. So signals pass transparently through a solid wall. The amplifier can pass signals in both directions, or in one direction only, to relay business data, digital TV or home entertainment.

The same system can be used for very low power computer networks, like Bluetooth, which normally only work in one room. Although the patent suggests that the new smart bricks could be sold in DIY stores, for retrofitting, Paul Smith thinks the real opportunity is for the building trade. "It would be very easy to build a few bricks into a new building", he says.

MORE WAVE POWER

DURING a visit to the Isle of Islay, an established wave power centre, the Minister for Energy, Brian Wilson, committed £1.67 million to developing the world's first ever floating *mini power-station*, which turns wave power from the ocean into megawatts for the national grid.

The machine is expected to be launched next summer from a new maritime energy testing centre to be built in Orkney. This innovative technology will supply enough electricity to power 1400 homes.

For more information browse **www.dti.gov.uk**.

SHERWOOD CAT

JUST in is the latest Sherwood Electronics catalogue, the 2002 edition. In a bit over 100 A5 pages, this pocket-sized cat contains a wide variety of full specification components and equipment, with new products and increased ranges of existing stock. It costs £1.

Sherwood's range extends from batteries, through connectors, etch resist materials, passive components, semiconductors and soldering aids, to tools and transformers.

There is no minimum order value and UK p&p is just £1.50 irrespective of order quantity. Despatch is normally by return post. Moreover, Sherwood *do not* charge VAT.

For more information contact Sherwood Electronics, Dept EPE, 7 Williamson Street, Mansfield, Notts NG19 6TD. No phone etc quoted.

AUTUMNAL GREENWELD

THE Autumn Inspirations brochure from Greenweld seems ideal browsing (and enticement to purchasing) for the darkening autumn evenings. You must know by now that Greenweld always have some great bargains on offer, and again this is the case now.

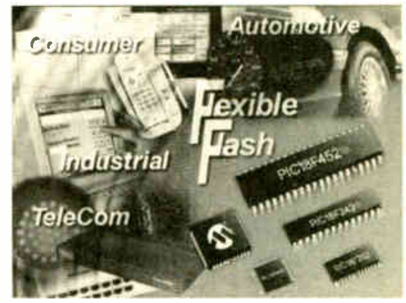
The brochure includes a small selection from Greenweld's stock of tools, components, books and materials for the home hobbyist, as well as a variety of special seasonal offers and "surplus" lines, including manufacturers' overruns and obsolete items.

Director Geoffrey Carter says "We had so many items we wanted to include, we had to produce a bumper edition. Even with 48 A4 pages we still didn't have room to include all the standard electronic components available by mail order, but our website has the full range, with over 6000 lines available for secure online ordering".

Greenweld will also be participating in the London Computer & Communication Show, which is taking place on Sat/Sun 24/25 November at the Lee Valley Leisure Centre (Pickett's Lock) in North London.

For more information contact Greenweld Ltd, Dept EPE, Unit 24 Horndon Ind. Park, West Horndon, Brentwood, Essex CM13 3XD. Tel: 01277 811042. Fax: 01277 812419. Email: service@greenweld.co.uk. Web: **www.greenweld.co.uk**.

LOTS MORE PICS



Microchip, manufacturers of the PIC microcontroller families, have advised us of several new PICs they are introducing. The first family, PIC18Fxx8, has an intelligent CAN 2.0B active interface and has a 10MIPS performance at 10MHz. It has self-programmable Flash memory which allows the device to be programmed in socket, eliminating the need for external high voltage or additional hardware.

The new PIC18Fxx2 Flash microcontrollers also provide a 10MIPS at 10MHz performance and an operating range of 2.0V to 5.5V. They are drop-in compatible with the existing PIC18Cxx2 OTP family. The devices offer up to 32K bytes of self-programmable memory.

The third arrival is the new rfPIC microcontroller family, which simplifies radio frequency designs. The 18-pin rfPIC12C509AG features an integrated 315/433MHz ASK transmitter, while the 20-pin rfPIC12C509AF features an integrated 315/433MHz FSK/ASK transmitter. Both are the first of 10 planned devices in the rfPIC family, which is aimed at RF connectivity for embedded control applications such as remote sensing, remote control, toys, security and access control.

For more information contact Arizona Microchip Technology Ltd, Microchip House, 505 Eskdale Road, Winnersh Triangle, Wokingham, Berks RG41 5TU. Tel: 0118 921 5858. Fax: 0118 921 5835. Web: **www.microchip.com**.

SKY ELECTRONICS

"MASSIVE" is the first term to come to mind with the latest Sky Electronics catalogue on the News Desk! "Beautifully produced and well-stocked" are other terms that flip off the tongue and keyboard.

When it comes to wide ranges of audio equipment, it seems that Sky have pretty much got it amplified and taped. The range includes hi-fi loudspeaker sets, headphones, TV and video accessories. CD storage, audio and video leads and switches, just to name but a few of the categories.

Not only does the cat have masses of items to appeal to you, especially with the mouth-watering colour pictures, but also has prices that are bound to tempt your pocket.

Get your copy, *now*. Just send £1.85 in stampps to Sky Electronics, Dept EPE, 40-42 Cricklewood Broadway, London NW2 3ET. Tel: 020 8450 0995. Fax: 020 8208 1441.

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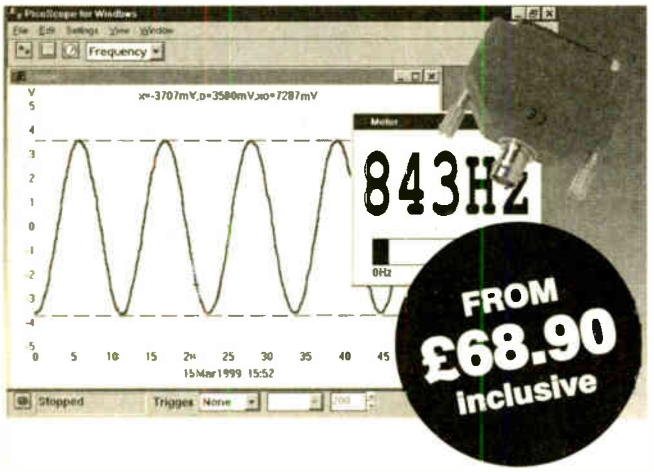

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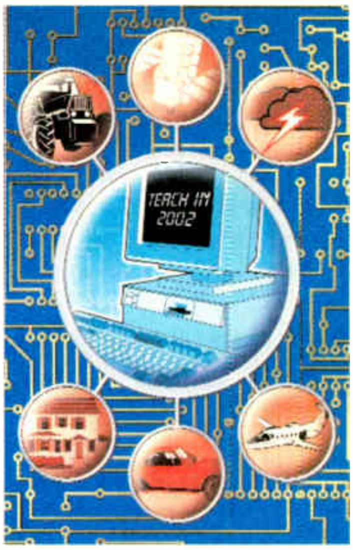
TEACH-IN 2002

Part Two – Op.amps in sensor circuits, plus light sensors



IAN BELL AND DAVE CHESMORE

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

WELCOME to Part 2 of our 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 needed to process the signals from them.

Last month we discussed heat sensing and the basic concepts of measurement such as accuracy and resolution. In order to make good quality measurements using sensors, we need to be aware of the errors and difficulties associated with the circuits we use with them.

In particular, the understanding and correct use of operational amplifiers (op.amps) is crucial to the success of any sensor circuit. A preliminary example of op.amp use was given in Part 1 Fig.1.5, and it raised a number of questions. To answer these and other related questions, it is thus the subject of op.amps that we first examine this month.

We shall then move on to discuss light sensors and offer you the chance to build a light-meter as part of the Lab Work.

OP.AMPS

Op.amps are one of the key building blocks for sensor signal processing circuits, typically being used to amplify and calibrate signals from the sensors. Such circuits often have to be accurate and precise, therefore we will look (in this and future parts) at how imperfections in the op.amp may cause difficulties in achieving this.

An op.amp is a high-gain, direct-coupled amplifier. Its symbol is shown in Fig.2.1. The term *direct-coupled* means that the inputs and internal stages are connected directly, not via coupling capacitors. This enables the op.amp to amplify d.c. and very low frequency signals – useful if we need to process slowly changing signals from a sensor, such as the temperature in a room.

An op.amp has two inputs, one *inverting* and one *non-inverting*, and an output. The inputs and outputs are usually referenced (applied or measured with respect to) ground or 0V. Op.amps usually have two power supplies, one at a positive voltage with respect to ground and the other at the same magnitude negative with respect to ground.

However, many "single supply" op.amps are also available. Suppliers' catalogues usually indicate whether an op.amp is intended for single or dual supply operation, otherwise check the data sheet. The power supply connections are not always shown on schematics.

An op.amp may also have other terminations which are used in a variety of ways, such as offset adjustment, which will be examined in a future part.

OP.AMP TERMINOLOGY

The output voltage, V_o, of an op.amp is given by the equation:

$$V_o = A_V \times (V_2 - V_1)$$

where:

A_V is the *open loop* voltage gain
V_1 is the inverting input voltage
V_2 is the non-inverting input voltage

The term *open loop* gain refers to the gain of the op.amp itself, without any *feedback* circuitry. The value is usually very large (tens of thousands or even millions) and can be found on the device's data sheet. However, op.amps are almost always used with some form of feedback, which results in a gain for the *circuit* that is different from that of the op.amp itself, usually much smaller than the actual op.amp gain, and largely independent of it.

An op.amp amplifies the *difference* in voltage between its two inputs. The equation $V_o = A_V \times (V_2 - V_1)$ always holds for the totally ideal device, but in reality is only valid for a small range of $(V_2 - V_1)$ and there are limits on the individual values of V_2 and V_1 too. The op.amp's input-output relationship is illustrated in Fig.2.2.

Saturation occurs in an op.amp when any increase in the magnitude of the differential input does not result in further increase in the output voltage magnitude. The values shown in Fig.2.2 are an example for an op.amp with a gain of 100,000 and maximum output voltage of ±15V. The gain of the op.amp is equal to the slope of the graph between the saturation points.

We have said that op.amps have very high gains. Ideally, their gain should be infinite. The gain specified on data sheets is for low frequency operation and op.amp gain is deliberately made to fall as frequency increases to prevent instability.

Gain may be specified as a number e.g. 100,000, as a ratio of voltages, e.g. 100V/mV, or in decibels, e.g. 100dB (the gains in these three examples are the same). The gain in decibels is found by taking the gain as a number, taking the logarithm and multiplying by 20, e.g. 100dB = 20log(100,000).

NEGATIVE FEEDBACK

Op.amps are often used with negative feedback in three well-known configurations, as shown in Fig.2.3. The high gain of the op.amp means that when negative feedback is used appropriately the gain of the

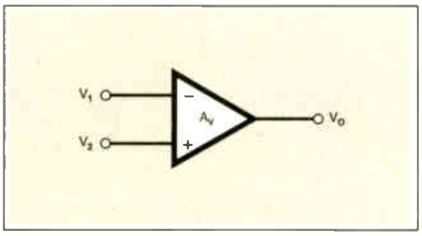


Fig.2.1. Op.amp symbol.

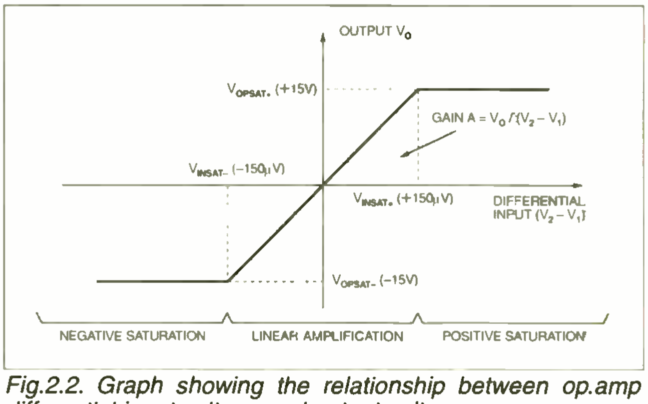


Fig.2.2. Graph showing the relationship between op.amp differential input voltage and output voltage.

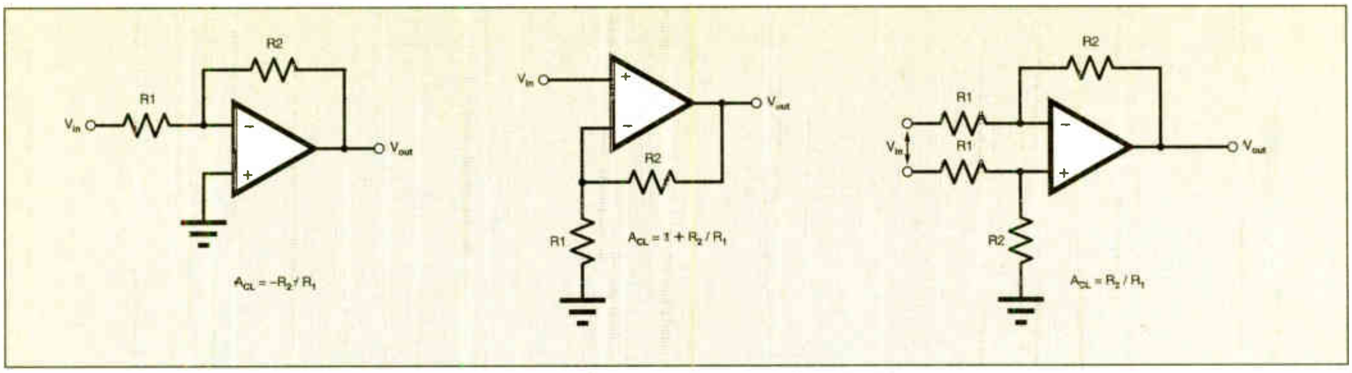


Fig.2.3. The basic op.amp amplifier circuits.

circuit depends on the component values in the feedback circuits and *not on the gain of the op.amp*.

It is a very important result because it means we can set the gain of a circuit without worrying about the variation in gain between individual op.amps. This means that the fall in gain of the op.amp with frequency mentioned does not affect the circuit until the very high frequencies at which the op.amp's gain becomes low.

VIRTUAL EARTH

The high gain of an op.amp means that if it is not saturated then the voltage between its two input terminals must be very small. This is an important property of op.amp circuits, with some very significant consequences.

As an example, using an op.amp with a gain of 500,000 and supplies of ±15V, the voltage between the op.amp's inputs will always be less than $\pm 30\mu V$ (outside saturation), while other circuit voltages will typically be volts or tens of millivolts.

Whilst the explanation is beyond the scope of *Teach-In*, it is important to note the consequence of this effect, which is that the very small voltage difference between the inputs of an op.amp during normal (non-saturated) operation means that the two inputs always try to track each other as circuit voltages change.

The idea of the virtual short-circuit can be very useful when analysing op.amp circuits because, if we can calculate the voltage at one input, we can often regard the other input as having the same voltage (although there are some cases where this may not apply).

If one of the terminals is connected to a fixed voltage, the other input will also stay at approximately this voltage. If this fixed input is 0V (earth or ground), the other terminal is said to be a *virtual earth*, or *virtual ground* (see Fig.2.4) and behaves much like an actual ground terminal.

The virtual earth is also very important because it helps isolate and simplify the interactions between multiple signal sources applied to an op.amp's input.

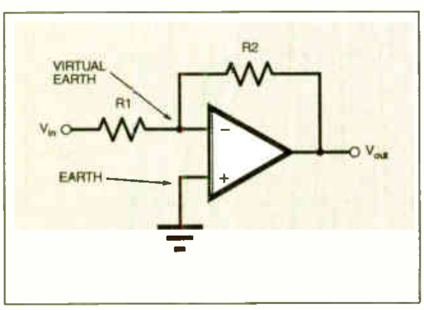


Fig.2.4. Op.amp circuit with a virtual earth.

HIGH IMPEDANCE

Another important property of the op.amp is its high input impedance. This means that we can often (but not always) ignore currents flowing into the op.amp's inputs, thus simplifying our analysis and calculations. In an *ideal* op.amp, *no* current at all would flow into its inputs!

Note, though, that the *circuits* which use op.amps may have a much lower input impedance than the op.amp itself, even if we assume infinite input impedance for the op.amp.

Referring to Fig.2.4, assuming that the op.amp's input voltages are equal and that no current flows into the inputs, the inverting input is at 0V and behaves as if it were a ground terminal.

Furthermore, all the current flowing in resistor R2 must also flow in R1. The virtual earth condition means that the voltage across R1 must be equal to Vin and the voltage across R2 must be equal to Vout. Thus, using Ohm's Law, the current in R1 is V_{in} / R1 and current in R2 is V_{out} / R2.

We have already noted that these currents are equal, so $V_{in} / R1 = V_{out} / R2$, from which we can find that the gain of the circuit (ACL – Amplification, Closed Loop) is:

$$ACL = V_{out} / V_{in} = R2 / R1$$

Use of the "equal voltage" and "zero current" assumptions gives us a very simple analysis of the circuit and a quick and easy derivation of the gain formula for this circuit. Any source connected to the input of the circuit in Fig.2.4 is connected to the virtual earth via R1 and therefore effectively "sees" a resistance of R1 connected to ground.

The input impedance of the circuit is therefore simply equal to R1 – another simple analysis helped by our two assumptions. We look at the idea of input impedance and its implications in more detail later in the series.

OP.AMP OPERATIONS

The name *operational amplifier* comes from the original use of these devices, which was to perform mathematical operations in analogue computers. Op.amp circuits can do more than just amplify and many of these "operations" are still useful today in sensor signal processing. These include a variety of *adder* and *subtractor* circuits (which can amplify as well as add).

In Fig.2.5 is shown a 2-input adder circuit. This is like an inverting amplifier with an extra input resistor. The input voltages V_1 and V_2, are connected to the virtual earth point and do not influence one another. If all the resistors are equal, the output is the (inverted) sum of the input voltages. Changing R1 or R2 scales the inputs with respect to one another and changing feedback resistor R_f alters the overall gain.

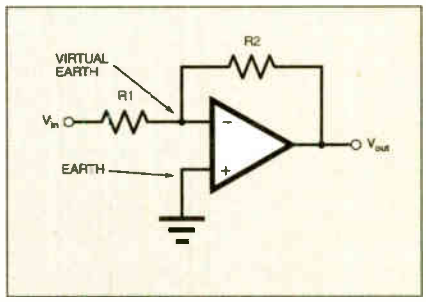


Fig.2.5. Two input adder circuit.

The circuit would be useful in a sensor application where we need to add a d.c. level to the signal from the sensor.

The non-inverting configuration can also be used to make adding circuits and two approaches can be combined to produce circuits that both add and subtract. The simplest version of this has one "add" input and one "subtract" input and is shown in Fig.2.6. This circuit is useful for scaling and offset shifting of signals.

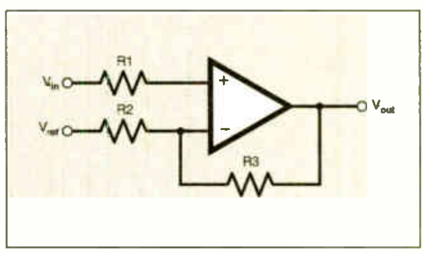


Fig.2.6. Basic add and subtract circuit.

You can also think of it as an non-inverting amplifier with respect to V_{in} and an inverting amplifier with respect to V_{ref}. For the non-inverting amplifier we have a contribution to the output of $(1 + R3 / R2) \times V_{in}$ and for the inverting amplifier $(-R3 / R2) \times V_{ref}$. So the output is

$$V_{out} = \left(1 + \frac{R_3}{R_2}\right) Vin - \frac{R_3 V_{ref}}{R_2}$$

The reason that the value of 1 is added to the gain for the non-inverting input is that even with total negative feedback, the gain for this path can never be less than 1.

By suitable choice of R2, R3 and V_{ref} you can map the output voltage range from a sensor onto a different range suitable for the rest of your circuit. The resistor values or reference voltage can be made variable if required, for example, to facilitate calibration of a sensor.

Note that the value of R1 should be equal to the parallel value of R2 and R3 (i.e. *R1 = R2//R3)* to reduce unwanted offsets. We will return to this trick when we discuss op.amp offsets in more detail in a later part.

The amplifier circuits shown in Fig.2.3 should have a gain of 1 or more for stable operation of the op.amp. The same applies to Fig.2.5.

SHIFT AND AMPLIFY

As the basic op.amp amplifier configuration can be either inverting or non-inverting, we would need to completely reconfigure the circuit if we wanted to swap from positive to negative gain.

Fortunately, we can get round these difficulties with the circuit in Fig.2.7, which has a continuously variable gain from –1 to +1. In fact the gain is given by $2k - 1$, where k is a value ranging from 0, when the wiper of VR1 is at the ground end, to +1 when it is at the input end.

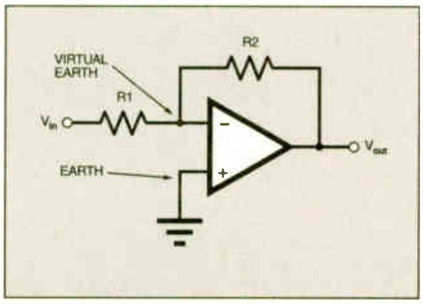


Fig.2.7. Circuit with variable gain from –1 to +1.

We can regard VR1 as two resistors having values kR for the lower resistor and $(1 - k)R$ for the upper resistor, making a total value of R. In this case R is 10kΩ and as the other resistors are also 10kΩ we can write their value as R too.

VR1 acts as a potential divider for V_{vin} so the voltage at the wiper of VR1 is kV_{in}. As we discussed earlier, the high gain of the op.amp means that its inputs are at effectively the same voltage. As the non-inverting input is connected to the wiper of VR1 we can conclude that the voltage at the op.amp inputs is also kV_{in}.

We also assume that the op.amp's inputs take no current so that the current in R1 (I_1) is the same as the current in R2 (I_2). A simple application of Ohm's Law gives us these currents. That is:

$I_1 = (V_{out} - kV_{in}) / R$ and
$I_2 = (kV_{in} - V_{in}) / R$.

As the two currents are equal we can write:

$$\frac{(V_{out} - kV_{in})}{R} = \frac{(kV_{in} - V_{in})}{R}$$

$$\text{so } V_{out} - kV_{in} = kV_{in} - V_{in}$$

$$\text{or } V_{out} = 2kV_{in} - V_{in}$$

Thus the gain, which is V_{out}/V_{in}, is $2k - 1$.

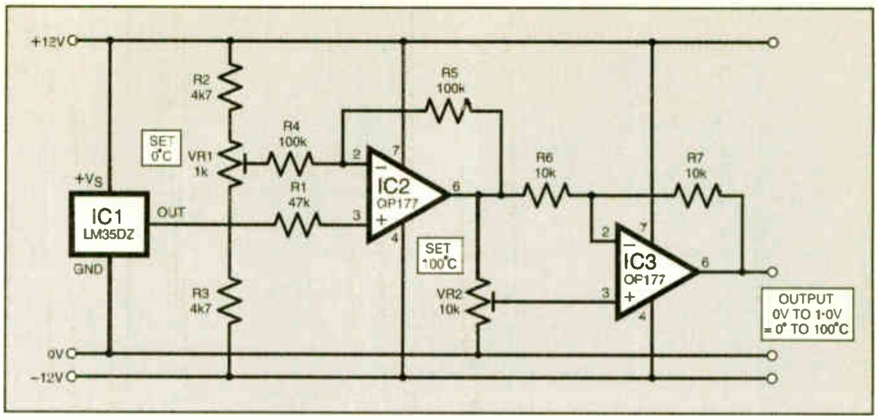


Fig.2.8. Calibrated temperature sensor using an LM35DZ.

LAB 1 REVISITED

Referring back to last month's Lab Work Fig.1.5, which is repeated here as Fig.2.8, we are now able to see that it consists of a shift and scale circuit (around IC2) based on that in Fig.2.6, and a ±1 variable gain circuit (IC3) based on that in Fig.2.7.

Resistors R4 and R5 set the gain of the first stage with respect to V_{ref} at 1 (i.e. *R5 / R4 = 100k / 100k = 1)*. With respect to the sensor's output level, the gain is 2 (i.e. *1 + (R5 / R4))*.

Resistor R1 is used to reduce bias current offsets. We will discuss such concepts in a future part.

The second stage has a gain varying from –1 to +1. We need a gain of about +0·5 to give an overall gain of +1 between the sensor and the final output. Consequently, the wiper of VR2 should be nearer the input end, at about ¾ of the way from ground to input.

The voltage reference for the shift operation is provided by the potential divider formed from R2, R3 and VR1. This is more tricky than it seems. The values shown in Fig.2.8 provide a voltage range of about ±1·15V at the wiper of VR1. This is larger than really required, which will tend to make the adjustment during calibration less easy to control.

We could use a value of 100Ω for VR1 to give a ±0·13V adjustment range, but this may give us a problem due to the 5% resistor tolerance specified in Part 1. With worse-case variation in all resistors, the range may actually be –0·71 to –0·46, which would not be able to compensate for a negative offset (remember that V_{ref} is subtracted).

PANEL 2.1 Sensor circuits

Sensors are of little use on their own – we need circuits to process the signals we get from them, amplifying and filtering, and converting to digital form for display or processing by a computer or microcontroller.

Some sensors require input signals that we need to generate, or accurate reference levels for calibration. In other cases, sensors act together with actuators, devices that put a signal into the environment which the sensor detects in order to make the measurement required (e.g. a smoke detector based on reflection of light, here we need a light source and a light sensor for the complete sensor system).

Actuator/sensor combinations need circuits to drive the actuator (e.g. we may use pulsed light to distinguish it from the background in the smoke sensor). In this series we concentrate on the basic analogue signal processing circuits associated with sensors, together with a look at analogue/digital data conversion. However, we will not look in detail at software, such a PIC programming, as this has been covered at other times in *EPE*.

- **Amplifiers:** the signals from sensors are often small (e.g. very low voltage or current) and have to be amplified before any further processing can be performed.
- **Buffers:** buffering is a form of amplification, but usually considered separately. Buffers are needed for weak signals (not necessarily very low voltage or current), that is signals which would be excessively "loaded" if we tried to use an amplifier without buffering properties.
- **Comparators:** we often need to know when a value being sensed or measured crosses a particular threshold, or strays outside a certain range. Comparator circuits provide this function.
- **Voltage and current references:** for some sensor and measurement systems we need very accurate or very steady reference levels against which we can compare or measure the sensor's signals. In other cases we need to power the sensor using an accurately controlled current or voltage. In some cases we use special voltage and current references for these purposes, in others we rely on a well regulated power supply.
- **Data converters:** to get sensor data into microcontrollers (such as a PIC) or into PCs or other computers for processing and storage, or simply to display the result on a digital meter, we need to convert analogue sensor data into digital form using an analogue-to-digital converter (ADC). If the sensor circuitry has to be controlled by the computer or microcontroller we may also need a digital-to-analogue converter (DAC).

In circuits where accuracy or control of small ranges of voltages or currents are required, it is not always possible to ignore component tolerances – another factor to take into account and challenge us when we are designing.

The simple, but not ideal, solution we use here is to make the adjustment range large enough so that the resistor tolerance variation could not make it unusable. This has the effect of making the calibration adjustment insensitive.

We could make one of the 4·7kΩ resistors variable too (using a 10kΩ trimmer) and use this as a coarse adjustment. A 100Ω value for VR1 could then be used to make a fine adjustment. This approach, of course, uses more trimmers, making the calibration more complex and the circuit more expensive.

A possible problem with the reference voltage potential divider is its power consumption. The potential divider using the values shown in Fig.2.8, takes 2·3mA from 24V, which is 55mW – enough to be of concern if we wanted to run this circuit from a battery.

PANEL 2.2 The Electromagnetic Spectrum

The electromagnetic (EM) spectrum ranges from gamma rays at very short wavelengths, to radio waves at long wavelengths. Visible light is the part of the spectrum to which our eyes are sensitive; this is from 700nm (red) to 400nm (deep blue) – 1nm (nanometre) is 10^{-9}m, i.e. one thousand millionth of a metre! Table 2.1 lists the wavelength ranges around the visible area which are of interest for environmental sensing.

Wavelengths shorter than 400nm are termed ultraviolet (UV) and are the cause of sunburn and skin cancer. Most of the shorter, more harmful UV emitted by the sun is removed by the ozone layer. Depletion of ozone in the "ozone hole" over Antarctica, and more recently over the Arctic, is leading to worries about increased skin cancer because of increased levels of ultraviolet light.

At the other end of the visible spectrum, beyond red, is infra-red (IR). Those wavelengths closer to red are known as *near-IR* and those further away (longer wavelengths) are called *middle-IR* and *far-IR*.

There is a simple relationship between wavelength (λ), frequency (f) and speed (v) of an EM wave:

$$v = f \times \lambda$$

In space, v is the speed of light, which is 3×10^8 m/s or 300 million metres per second. This relationship means that shorter wavelengths have higher frequencies.

Table 2.1

Band	Wavelength range (nm)
Ultraviolet	100 to 400
Visible	400 to 700
Near-IR	700 to 1,500

LOADING

The resistor values are relatively low in order so that the voltage provided by the divider is not *loaded* by the op.amp circuit (via R4). We could use larger value resistors in the divider, taking loading into account, but this would be more complex to do.

We could also use a more efficient low voltage reference to "power" the potential divider. We could even use very large resistor values and buffer V_{ref} using an op.amp. We will look at loading effects and buffers later in the series.

On the subject of loading, the circuit presents high input impedance to the LM35 temperature sensor. It may be argued that this is not really necessary as the LM35 can drive reasonably low resistances. However, it does give us the flexibility of controlling the load driven by the LM35 without the op.amp circuit having much influence. The LM35 datasheet addresses the issue of loading for this device.

One possible drawback of the high input impedance is susceptibility to noise pickup. Again the datasheet has advice on this and we will be looking at the problem in general later in the series.

DUAL ISSUE

Another issue concerning this circuit is: *should we have tried to use just one op.amp rather than two?* This would have made the circuit cheaper and may have reduced noise and op.amp offset problems. But the design would have been more complex, possibly "designed from scratch" rather than combining building blocks as we did.

We may also not have been able to have a high input impedance at the sensor input due to other circuit considerations. Single op.amp circuits do not always have all the properties we need so we use more op.amps to build up our circuit. We will see more examples of this later.

The circuit in Fig.2.8 has raised a lot of issues and questions, which we will continue to discuss in other contexts as the series progresses. The preceding discussion serves to illustrate the large number of factors which may have to be taken into account even with quite a simple circuit design.

In electronics and in all engineering, design is a matter of compromise between conflicting requirements. We have to consider things like accuracy, cost, ease of calibration, and power consumption. Improving one aspect may make others worse. This is part of the challenge of design.

LIGHT SENSING

Time now to move on to our next sensor discussion – about light sensing.

Sensing light has many applications, ranging from simple light level measurements to the detection of chemicals and heat. Visible light is in a small part of the electromagnetic (EM) spectrum (see Panel 2.2).

The visible spectrum is so-called because our eyes are sensitive to this range of wavelengths; other animals are sensitive to ultraviolet (UV) and infrared (IR) light. For example, many butterflies, moths and bees are sensitive to UV as well as "normal" colours, in fact bees and butterflies are thought to have the widest vision spectrum in the animal kingdom. Some predatory birds can also see in UV.

CHEMICAL MEASUREMENT

Light can be used in a variety of ways to measure chemicals in the air or in solution. Chemicals absorb light differently depending on their nature and the wavelength of the light.

There are several ways in which we can use absorption of light to determine chemical content. The most comprehensive is to shine pure white light through the chemical held in a transparent tube and measure the complete spectrum of light – this is known as *spectroscopy* and provides information about the absorption of all the different wavelengths in the light, thus acting as a form of "fingerprint".

Many chemicals also fluoresce (glow) in UV light. The "colour" of this glow is dependent on the chemical. For example, oil fluoresces in longer wavelength UV, blue or yellow depending on the chain length. The longer the chain (the heavier the oil), the longer the wavelength.

Interestingly, instruments have been designed to measure the amount of plankton in the sea at different depths using the fact that plankton contains chlorophyll. The instrument comprises a depth sensor, a xenon flash and a red-filtered photodiode mounted behind a window in a sealed container. The flash emits UV and the photodiode detects the fluorescence from any chlorophyll present.

Another way is to use one or two wavelengths which are known to be absorbed by the chemical – the amount of absorption is then proportional to the chemical concentration. This is known as *colorimetry* and instruments are available to measure, for exmple, iron and copper concentration in water (and other chemicals).

pH INDICATORS

It is also possible to use colorimetry to measure the pH (acidity) of a solution using an indicator. Litmus is the most well known and is blue in alkalines (pH greater than 7) and red in acids (pH less than 7, 7 being neutral).

We could use a red l.e.d. to shine light through the solution and use a photodiode and amplifier to measure the amount of light passing through it. If the solution is acid, the red light will pass through more easily than if the solution is alkaline. This can form the basis of a simple acid/alkali detector.

The other common indicator for pH is a chemical universal indicator that changes colour from red (acid) through green to blue (alkaline) – the colour tells us the pH.

The more adventurous amongst you could try to build a colour detector using two l.e.d.s, one red and the other blue and two photodiodes to pick up light from each l.e.d. The output from each photodiode could be input to your Picoscope ADC-40 to analyse the levels and produce a pH value.

ORGANIC DETECTORS

Chemical analysis in the infrared (IR) region is used widely for the identification of *organic* chemicals because they have lots of absorption bands in this region. There are also instruments capable of measuring gaseous chemicals in pollution clouds using IR absorption.

These LIDAR (LIght raDAR) systems operate by shining powerful IR lasers at the pollution cloud; small amounts of energy are reflected back to a telescope and the chemicals identified. It is possible to use the position of the telescope and the time of flight of the light pulse (speed of light) to measure the location of the pollution and 3D maps can be made. This is an example of remote sensing where information about objects is obtained without any physical contact.

Satellite-based remote sensing is used widely for monitoring the Earth and other planets. It is possible to make many different measurements using satellites ranging from weather patterns through geology to determining crop health.

Some of the more interesting applications are in space. Most of you will have heard of the Mars Pathfinder and the Galileo probe in orbit around Jupiter. Mars Pathfinder's small rover Sojourner could determine the chemical content of rocks and the Galileo probe uses IR cameras operating at different wavelengths to determine the chemical composition of Jupiter's atmosphere and the surfaces of its moons.

This is how we know Jupiter's moon Io has a surface consisting mainly of sulphur compounds and that it has the most active volcanoes in the solar system. Astronomers use the same ideas for finding inorganic and organic molecules in stars and gas clouds in our galaxy and even other galaxies. Truly remote sensing!

COMMUNICATIONS

Perhaps the best known use of light in electronics is for communications using fibre optic cable. The amount of information that can be sent down a fibre optic cable is huge, much higher than copper cable because of the high frequency of the light.

Some commercial systems can transmit several TV and video channels together with telephone and internet links down a single fibre. Other advantages of fibre optic cable over copper cable are its low attenuation, so increasing the communication distance, and its immunity to electromagnetic interference.

Another very common application for light is in TV and video remote controllers which use near-IR l.e.d.s to transmit digital signals from the handset to the TV or video. Near-IR is used because there is a lot of visible light present which would swamp the signal. You may have noticed that the photodiode receiver on the TV or video has a black plastic cover; this is transparent to IR and acts as a filter to prevent the photodiode being affected by visible light!

LIGHT SENSING DEVICES

There are various devices that can be used to sense light, including light dependent resistors (l.d.r.s), photodiodes and phototransistors. Some of the more advanced light sensors contain integrated amplifiers.

So how do we select the best sensor? The most important thing to consider is the wavelength range we wish to detect. An IR sensor will not necessarily work in visible light and definitely not in UV. All sensors have differing sensitivity at different wavelengths and data sheets show this as a *spectral sensitivity* curve.

The spectral sensitivity depends on the material from which the device is made. Fig.2.23 (later) shows the spectral sensitivities of a number of sensors and we use these curves to determine which sensor is best for our purpose.

As you can see, silicon photodiodes have their best sensitivity in near-IR light and respond very poorly in UV. Sensors made of MCT (mercury-cadmium-telluride) are good for near and middle IR but won't work at visible wavelengths.

RESISTIVE LIGHT SENSORS

So-called light dependent resistors (l.d.r.s) are made of light sensitive material, usually Cadmium Sulphide (CdS). The common ORP12 is an example. They are highly non-linear and have similar shaped curves to thermistors (discussed in Part 1), i.e. they have very high resistance at low light levels (megohms) and low resistance at high light levels (hundreds of ohms).

They are not particularly stable and the resistance drifts over time. They are, however, low cost and are commonly used as their spectral response is mainly in the visible region.

PHOTO DIODES

There are many different photodiodes on the market with different spectral responses. UV-enhanced devices have been specially modified to increase their sensitivity in UV and they have quartz windows because normal glass is opaque to UV. They tend to be rather expensive.

Others photodiodes have a modified spectral response to mimic the human eye, such as the BPW21 we suggest you use in this month's Lab Work. Other forms of photodiode include multiple diodes in single packages – some are quadrant devices, i.e. they have four diodes arranged in quadrants and are used for determining position. Others have arrays of photodiodes, as many as 256, and are again used for position detection.

INTEGRATED SENSORS

The photocurrent from a photodiode is very small and must be amplified. Many photosensors have integrated amplifiers which simplifies circuit design and increases signal-to-noise ratio. Others include amplifiers but produce digital outputs. Some give an output frequency directly proportional to light intensity. The output frequency can be measured by a microcontroller without having to perform analogue-to-digital conversion.

Now let Alan Winstanley take over and tell you about interesting experiments you can do with temperature and light sensors.

TEACH-IN 2002 – Lab Work 2

ALAN WINSTANLEY

Temperature Sensing continued, plus Opto-Sensors

THIS month, first we continue the topic of temperature sensing, and then delve into the world of light-dependent sensors (opto-sensors), offering some practical demonstrations of a number of different types that can be interfaced with your own projects.

Lab 2.1: Sub-Zero Temperatures

In Part 1 we described the popular LM35 integrated temperature sensor. You will recall that the LM35 outputs +10·0mV/°C but cannot directly measure sub-zero temperatures as its output cannot drop below 0V. However, it is possible to measure as low as –50°C simply by adding a resistor to a negative voltage as shown in Fig.2.9.

National Semiconductor, the manufacturer of the LM35, recommends a resistor value of $-V_{SS}$/50mA, so using a –12V rail, for example, R1 should be 240kΩ.

The output voltage will still be 10mV/°C, so a temperature of –55°C will create a potential of –550mV at the LM35 output. Try this with the LM35 and the *Teach-In 2002* power supply described last month.

A typical domestic deep freezer runs at –18°C and would be a suitable source of sub-zero temperatures – simply trap the sensor cable in the magnetic door seal and close the door. The TO92 package is rated at –60°C storage temperature.

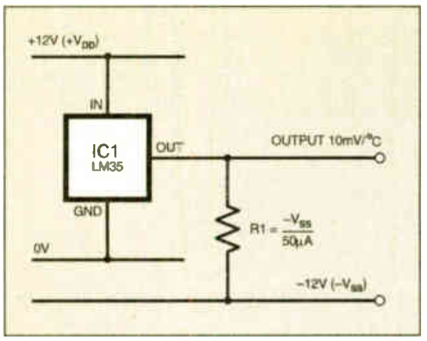


Fig.2.9. Temperature sensing above and below 0°C.

Monitor the output of the LM35 using a multimeter or the Picoscope ADC-40. **Ensure that the ADC-40 is not subjected to an input voltage below –5·0V.**

Lab 2.2: Basic Thermostat

A thermistor can be connected to an *npn*-type transistor that acts as a basic buffer/amplifier capable of doing useful things. Fig.2.10 shows a single transistor switch that we used to drive a series of three light-emitting diodes (why three? because that's how many were lying on the bench!).

Thermistor R2 is a negative-temperature coefficient (*ntc*) type with a resistance of 4.7kΩ at 25°C, and if the temperature falls its resistance will rise.

At a point determined by the variable resistor VR1, the voltage at transistor TR1's base will be enough (+0·65V more than the emitter) to cause the transistor to conduct. If the thermistor cools down to the desired "set point", TR1's base voltage rises and the l.e.d.s will illuminate. The transistor switches off again when the temperature rises beyond the set point.

This circuit can be assembled on a solderless breadboard using almost any small-signal *npn* transistor for TR1, powered from the +12V supply. Adjust VR1 until the l.e.d.s glow, then warm the thermistor between finger and thumb. Gradually the l.e.d.s will extinguish. If the thermistor warms up again, the l.e.d.s. will glow once more. Now reverse the positions of the thermistor and VR1/R1 – what happens?

Substitute the l.e.d.s for a suitable heating control circuit and this circuit has the makings of a primitive thermostat, but it has many drawbacks, some of which are described later. The circuit is re-used in the next Lab.

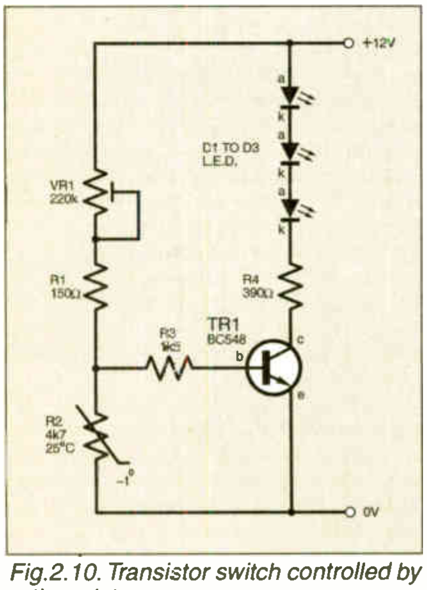


Fig.2.10. Transistor switch controlled by a thermistor.

COMPONENTS

Approx. Cost Guidance Only £20

(Excludes Lab 2.1, see Part 1 for details, although additional resistor required, see text)
N.B. some components are repeated between Lab Works

Lab 2.2/2.3

Resistors

R1	150Ω
R2	ORP12 or similar rated l.d.r. (4k7 at 25°C)
R3	1k5
R4	390Ω
R5	2k2

Potentiometer

VR1	220k and 4k7 sub-min. preset (one of each – see text)

Semiconductors

D1 to D3	red l.e.d. (3 off)
D4	1N4001 (see text)
TR1	BC548 or other similar small signal *npn* transistor

Miscellaneous

RLA	12V s.p.s.t. relay, 150 ohm coil (see text)

Lab 2.4

Resistors

R1	47Ω
R2	100k

Semiconductor

IC1	741 and OP177 (one of each – see text)

Lab 2.5

Semiconductor

D1	BPW21 eye response photodiode

Lab 2.6

Resistors

R1	3M9
R2	390k
R3	39k
R4	4k7 (see text)

Potentiometers

VR1	1M sub-min preset
VR2	220k sub-min preset
VR3	22k sub-min preset

Capacitor

C1	10μ elect. radial (see text)

Semiconductor

IC1	OP177
D1	BPW21

Lab 2.7

D1	any gen. purpose infra-red photodiode

Lab 2.8

R1	4k7 resistor
IC1	TSL25x family photosensor (e.g. TSL250)

Lab 2.3: Light-Sensitive Switch – Contact Bounce

The transistor switch of Lab 2.2 is insufficient (due to the high value of VR1) for it to drive any "really useful" loads. The next lab is a basic light-operated switch that can be used with the Picoscope to demonstrate some problems that arise with such a simple system. We can also capture waveforms and measure their duration.

Firstly, preset VR1 should be changed for a 4·7kΩ type, see Fig.2.11a. The thermistor is exchanged for a light-dependent resistor (l.d.r.), such as the popular ORP12 or any similar device, which can be inserted into the breadboard, connected between R1 and 0V. A torch (flashlight) or penlight is also needed.

The resistance of l.d.r. R2 falls when the light shining on it increases. Adjust VR1 as necessary so the l.e.d.s glow when the l.d.r. is not illuminated. Passing the flashlight over the l.d.r. should cause the l.e.d.s to extinguish.

By experimenting, the l.e.d.s. can be made to glow more brightly, or be dimmed just a little. There is often an "in-between" state where they are neither fully on nor off, a situation which is very undesirable in many applications. In due course we will describe ways in which such problems can be overcome.

As a suggestion for an optional experiment, a small 12V relay can be added in parallel with the l.e.d.s and R4, as shown in Fig.2.11b. Diode D4 clips any high reverse-voltages (back e.m.f.) generated by the

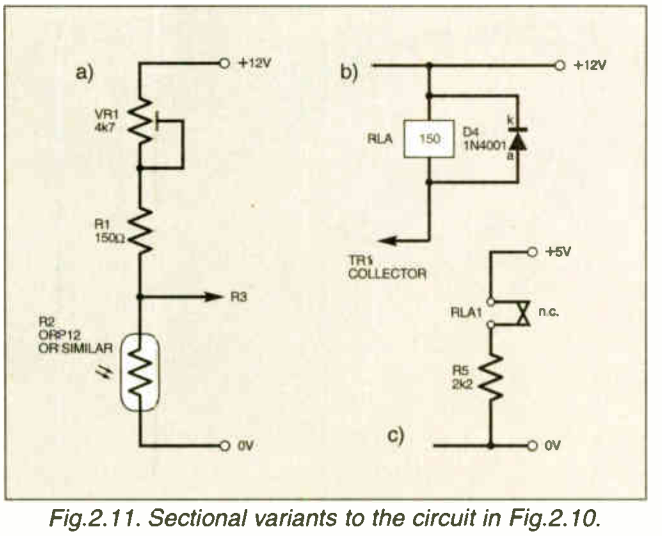
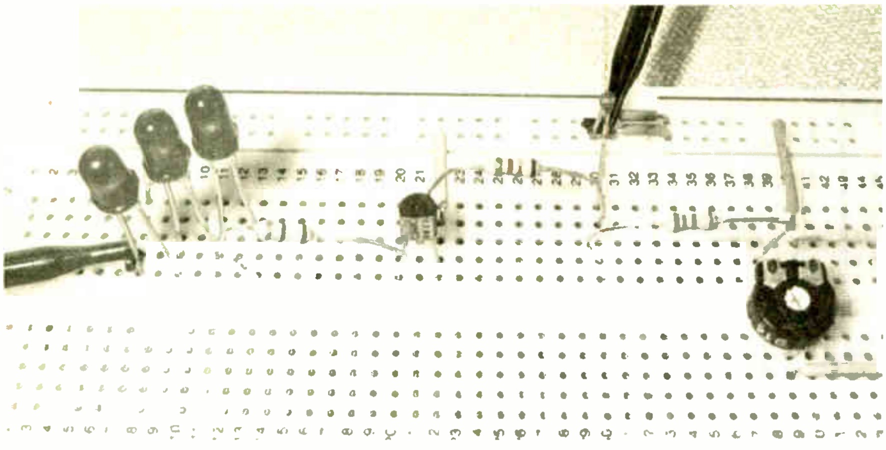


Fig.2.11. Sectional variants to the circuit in Fig.2.10.



Breadboard assembly for the circuit in Fig.2.10.

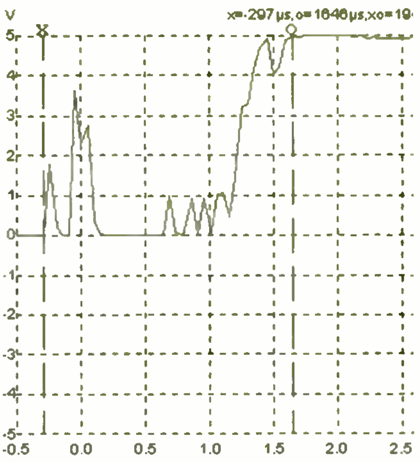


Fig.2.12. Relay contact bounce as displayed by the Picoscope ADC-40.

relay coil when it switches off – observe its polarity carefully when assembling on the breadboard. Normally-closed relay contacts RLA1 switch a load resistor, R5, connected across a separate supply, the +5V rail (Fig.2.11c).

Some experimentation reveals that the relay contacts click on and off in response to the light level on R2, but the l.e.d.s can still be forced to glow or dim much more gradually.

CONTACT BOUNCE

All switch and relay contacts suffer from undesirable "bounce". The Picoscope can be connected across R5 to practice capturing and measuring contact bounce waveforms, as follows:

Rather than leave the Picoscope in free-running mode, it can capture events on-screen using its built-in trigger function. Using the dialogue boxes at the bottom of the screen, click on Trigger and choose the Single trigger setting, select Falling to capture the waveform on the downward slope, and set a trigger voltage of 2500mV to start with (the grey diamond marker on the vertical axis also denotes this – it can be dragged).

Using the <F4> key, set the timebase for 1ms/division and choose Stop after Trigger. Set Delay After Trigger to a negative value, say 10 per cent, to show the pre-trigger portion of the waveform. Experiment with these settings as desired, using the keyboard spacebar to toggle the Picoscope on and off.

By passing a torchlight beam over the l.d.r. to switch the relay on and off, waveforms of the relay contacts switching can be captured on-screen.

Click and drag the mouse on-screen to draw a vertical ruler on the display at the start of the waveform, and a second ruler at the end of the transition. The Picoscope will then display the duration of the switch bounce – nearly two milliseconds as measured, see Fig.2.12. Rulers can be erased with the Delete key, or dragged back off the screen.

Also handy is the Notes function (<F6>) to add comments underneath the graph. Lastly, you can save the result as a graph (Edit menu) to paste elsewhere, or Save the Picograph to disk (File menu).

Lab 2.4: Monitoring Op.amp Offsets

The preceding circuits are basic and primitive, and are not suited to many practical applications. They may prove unreliable, difficult to calibrate or cause other problems such as electrical interference. There are much better ways of sensing heat or light, for example by using a number of self-contained semiconductor devices specially designed for the job.

In Lab Work 1 (last month) an op.amp circuit was built (see Fig.1.5 and Fig.2.8) which enabled us to calibrate the output from an LM35 sensor. The point was that differences in individual sensors could be compensated for by the calibration process. The accuracy of the output obtained from any sensor and associated circuitry depends on the circuit as well as the sensor itself.

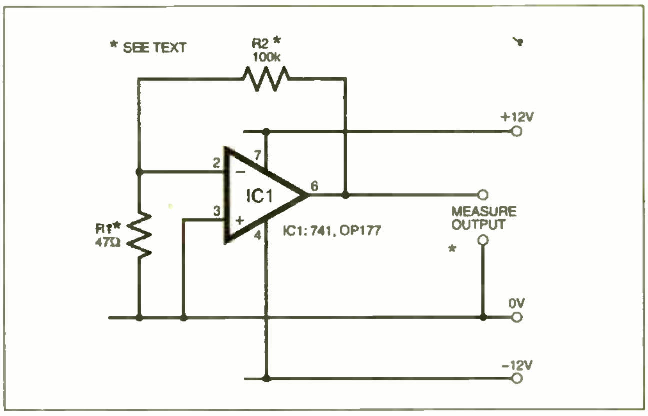


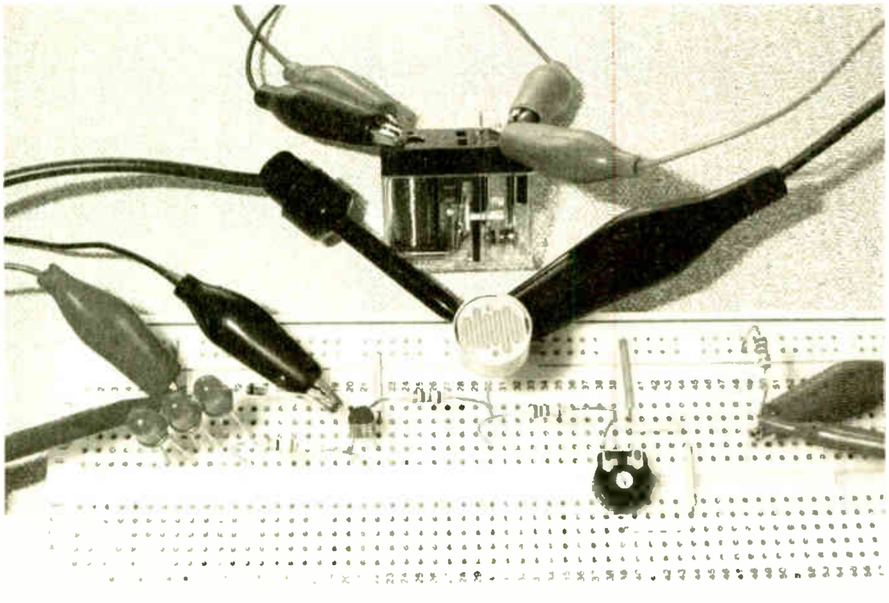
Fig.2.12. Measuring the offset voltage of an op.amp.

One of the key problems when measuring slowly changing quantities, such as environmental temperatures, are the *offset* voltages and currents which occur in all signal processing circuits. Worse still, these tend to vary quite a bit with the temperature of the circuit. Offsets are described later on in this *Teach-In* series.

When dealing with signals at audio frequencies and above, offsets can easily be removed using coupling capacitors, but for slowly-changing events this is not possible due to the large-value capacitors that would be required.

Direct-coupled amplifiers such as an op.amp can be used, but these are susceptible to offsets. However, not all op.amps are alike. In this Lab we now illustrate offsets and their variation with temperature for a couple of different op.amps.

The circuit in Fig.2.12 is used to measure the *input offset voltage* of an op.amp.



Breadboard assembly for the circuit in Fig.2.10, modified to include the components in Fig.2.11.

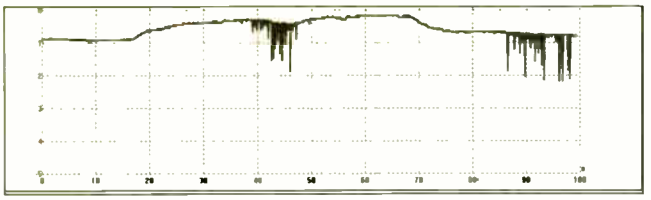


Fig.2.13. Picoscope plot of an op.amp's change in offset voltage with temperature. Timescale is in seconds.

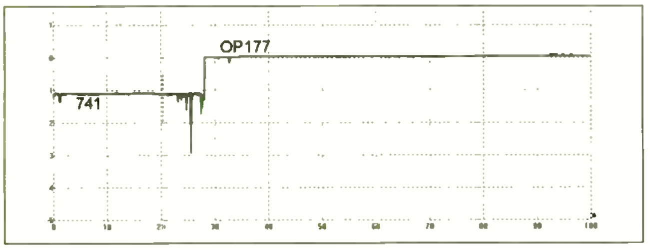


Fig.2.14. Picoscope plot showing the difference in offset voltages for 741 and OP177 op.amps.

It is simply a high-gain inverting amplifier with the input connected to 0V. Ideally, the output would be 0V as well, but this is unlikely due to the amplification of the input offset voltage.

The output of the op.amp circuit equals the gain (R2/R1) times the input offset voltage. If R2 is 100kΩ and R1 is 47Ω, the gain is about 2,000 so a 1mV op.amp offset would produce an output of 2V.

Build this simple circuit on the breadboard and use the +12V supply. Start with a type 741 op.amp and measure the output voltage with a digital meter or the Picoscope. To illustrate its temperature dependency, check the output voltage as you heat the circuit by blowing warm air onto the op.amp using a hairdryer from a distance of 15cm to 30cm.

We "chilled" a 741 op.amp with a freezer spray before plugging it into the breadboard and switching on, then warmed it with the hairdryer. We noted wide variations using different 741C samples, and the Picoscope went off-scale with some devices (the 'scope is protected to ±30V). Our "best" measurement of amplified offset voltage is shown in Fig.2.13. Those spikes may be due to power supply noise.

By using an OP177 op.amp instead, the difference in the two offset characteristics was plotted in Fig.2.14 with the Picoscope. The main thing to note is the difference in scale of the offset voltages of a 741C (0·45mV) and a low offset type such as the OP177 (we measured 15μV), and how this offset is temperature dependent.

If you have suitable facilities (such as in a school laboratory), consider controlling the temperature more accurately and plotting a graph of offset against temperature. Also try measuring longer term changes (e.g. due to room temperature variation) by using the PicoLog software to log the output voltage over say a 24-hour period.

You could also start the PicoLog running quite fast (e.g. 10 to 20 samples per second) and power up the circuit after having not used it for a while, to see if the offsets eventually settle. Think about the implication that the variations you see would have on making accurate measurements. What do you conclude about the 741 and OP177 op.amps?

Lab 2.5: Using Photodiodes

Light dependent resistors are bulky devices that are relatively slow to respond to changes in light levels. In Lab 2.5 we demonstrate a *photodiode* which can detect fast-changing light levels – even when the human eye cannot discern any visible changes.

Photodiodes are high-speed sensors which generate a tiny *photocurrent* (microamps) proportional to the amount of *incident* light (light falling on it). They are high-impedance devices which are usually reverse-biased for improved performance. Fig.2.15 shows the spectral response of a BPW21 "eye response" photodiode – one whose response is close to that of the human eye.

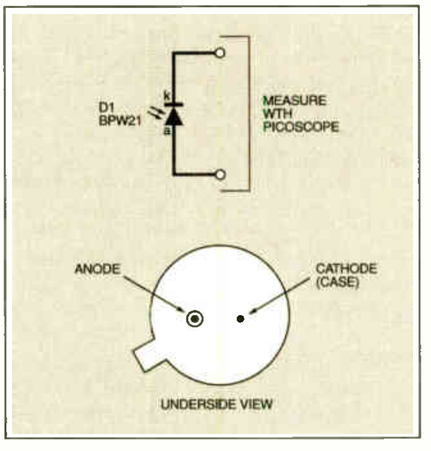


Fig.2.16. BPW21 photodiode pinouts and Picoscope connections.

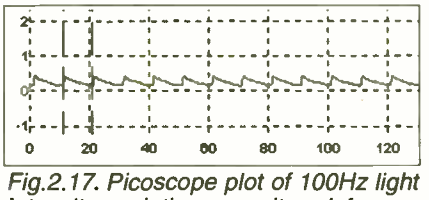


Fig.2.17. Picoscope plot of 100Hz light intensity variations monitored from a TV screen using a BPW21 photodiode. Timescale in milliseconds.

By connecting this photodiode directly to the Picoscope, Fig.2.16, its output can be observed. The screenshot in Fig.2.17 illustrates the data we recorded by placing the photodiode against a computer monitor which had been set for a vertical frequency of 100Hz. By using rulers to measure the waveform period (9,998ms), we see that the frequency detected is indeed 100Hz.

Lab 2.6: Simple Light Meter

To do anything useful, a photodiode needs amplification.

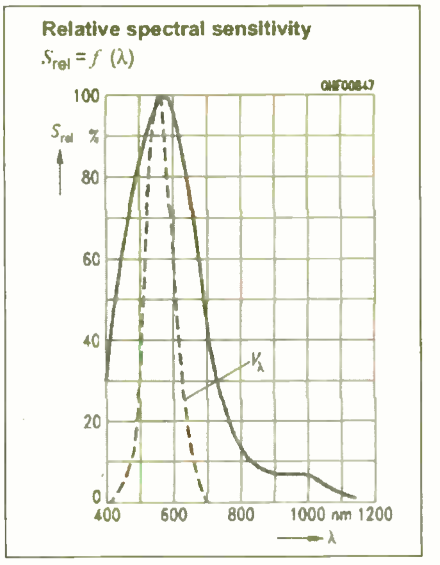


Fig.2.15. Special response of a BPW21 photodiode. Courtesy of Siemens.

The circuit diagram in Fig.2.18 shows a useful light meter which can measure light levels between 100 and 10,000 lux in three ranges. It uses the BPW21 eye response photodiode connected in a "short circuit" mode. This means the photocurrent generated by the diode is a linear function of the light intensity in *lux*.

The photodiode is connected directly across the inverting and non-inverting inputs of an OP177 op.amp and, since the non-inverting input is grounded, the photodiode is effectively short-circuited due to the presence of a virtual earth.

The op.amp acts as a *current to voltage converter*, the output voltage being produced by the feedback resistance multiplied by the photocurrent. Since the photocurrent is very small, the amplification factor must be very large.

Construct the circuit on your breadboard and hard-wire the 100 lux feedback network (R1 and VR1 – ignore R2/R3 and VR2/VR3 for the moment). Power the circuit from the +5V supply. Use the Picoscope to measure the output voltage and waveform under ambient light conditions.

By pointing the photodiode at ordinary mains lighting, the waveform shown in Fig.2.19 was detected. This has a frequency of 100Hz, even though the UK mains is 50Hz: a mains light bulb actually "flashes" once on the positive a.c. cycle and again on the negative a.c. cycle, i.e. 100 times per second.

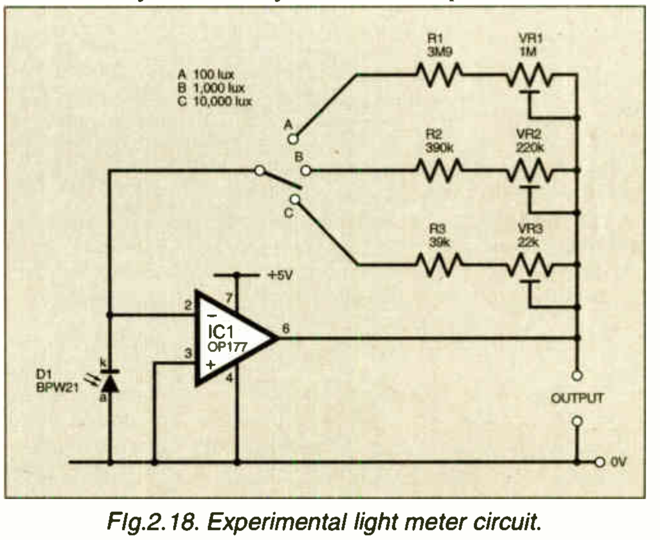
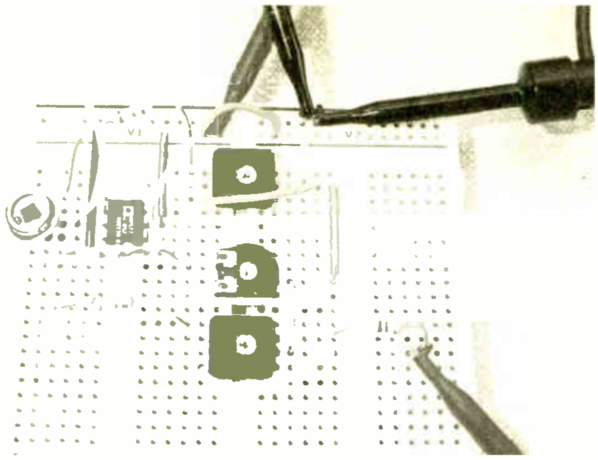
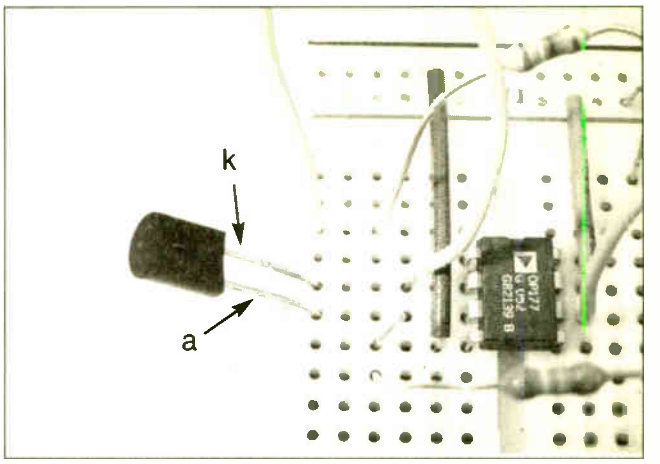


Fig.2.18. Experimental light meter circuit.



Breadboard assembly for the circuit in Fig.2.18, using a BPW21 photodiode.



Section of the breadboard assembly for the circuit in Fig.2.18 modified to use an infra-red photodiode.

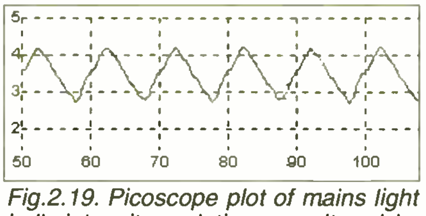


Fig.2.19. Picoscope plot of mains light bulb intensity variations monitored by the circuit in Fig.2.18.

A photodiode is easily capable of responding to very high frequencies: the BPW21 has a rise time of only 1·5ms and so it detects a 100Hz "flickering" light bulb with ease. You should get an impression of the level of interference that a TV remote control has to overcome and why infra-red is used instead of visible light!

PRACTICAL LIGHT METER

If you want to convert Lab 2.6 into an improvised light meter with three ranges, the output can be connected to your multi-meter as shown in Fig.2.20. It should be set to a range that adequately shows current up to 1mA.

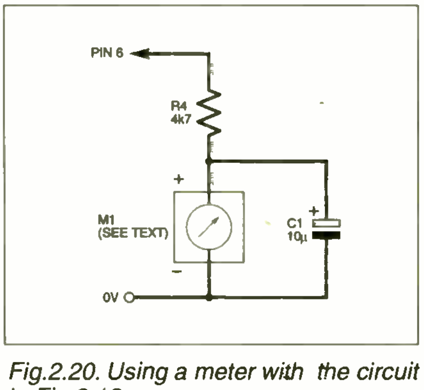


Fig.2.20. Using a meter with the circuit in Fig.2.18.

Resistor R4 and capacitor C1 provide a low pass filter to stop the meter reacting to very fast changes in light level. Omit the filter if you wish to observe the light changes on fluorescent and incandescent lamps, or use the circuit for other applications. A 9V battery can power the circuit. Use a 3-way switch to select the lux range.

For calibration, a known light level is needed for each range. A standard mains 100W pearl (frosted glass) incandescent lamp can be used with no lightshade and in a darkened room. On the 100 lux range, place the photodiode 100cm away from the lamp and adjust VR1 until the meter reads 1mA.

On the 1,000 lux range, place the photodiode 30cm from the lamp and adjust VR2 for a reading of 1mA. To calibrate the 10,000 lux range, keep the photodiode at 30cm, switch to the 10,000 lux range and adjust VR3 until the meter reads just 10 per cent of full-scale, i.e. 0·1mA. 10,000 lux is a very bright light!

If you wanted to construct a more portable light meter, a 1mA moving coil meter could be used in place of your multi-meter.

Lab 2.7: Infra-Red Photodiode

As an optional experiment, exchange the BPW21 visible light photodiode for almost any infra-red photodiode. Preferably under low lighting conditions, try aiming a TV remote control at the IR photodiode and monitor the output of the light meter. We obtained the screenshot in Fig.2.21.

Lab 2.8: TSL250 Light-to-Voltage Converters

Other useful options for the detection of light include the popular TSL25x family from Texas Instruments. These transparent 3-pin light-to-voltage converters include a photodiode and integrated amplifier, with special provision to improve the amplifier's offset voltage stability. The output voltage is directly proportional to the incident light level. Data sheets can be downloaded via **www.ti.com**.

Our final experimental circuit this month is shown in Fig.2.22 and uses a TSL250. It is powered from the +5V rail (its absolute maximum rating is +7V) with a load resistor R1.

We suggest you discover for yourself what waveforms can be displayed via your Picoscope.

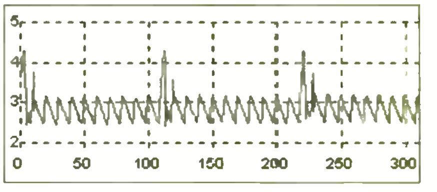


Fig.2.21. Picoscope plot created using an infra-red sensor to monitor a TV remote control.

NEXT MONTH

In Part 3 we examine humidity sensors, and offer you more Lab Work experiments.

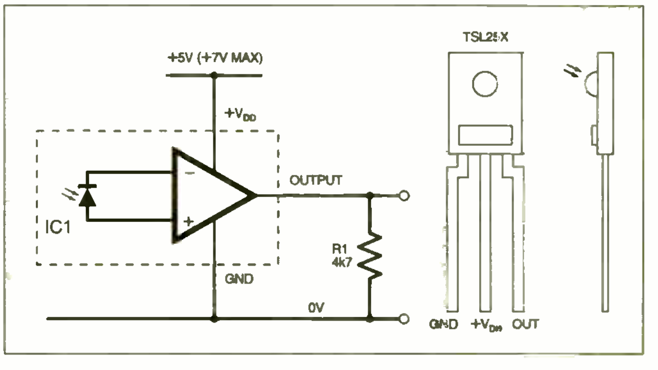


Fig.2.22. Details for using the TSL25x light to voltage converter.

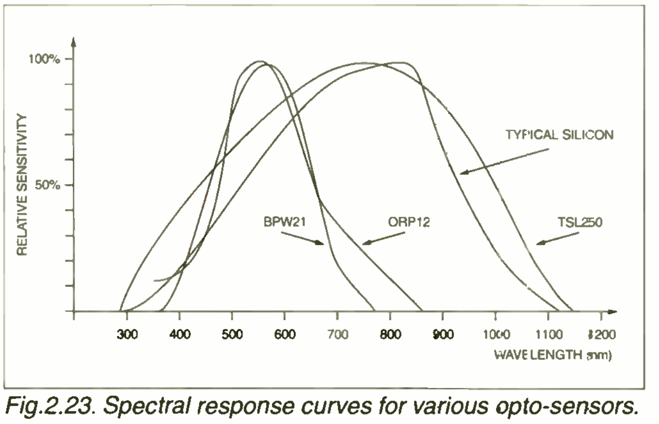


Fig.2.23. Spectral response curves for various opto-sensors.

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MARCONI – THE FATHER OF RADIO

IAN POOLE G3YWX

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

ALL transmitters around the globe were silenced for two minutes as a mark of respect on the day after Marconi died. Such was the stature of Guglielmo Marconi, often called the Father of Radio.

During his lifetime Marconi had made a phenomenal number of achievements and he did more than any other person to advance the technology of radio. As a result of his efforts he became an international celebrity and received many honours world wide. In Britain he received the Knight Grand Cross of the Royal Victorian Order, which was bestowed on him by King George V. In his native Italy he served as a senator and represented his country as a diplomat.

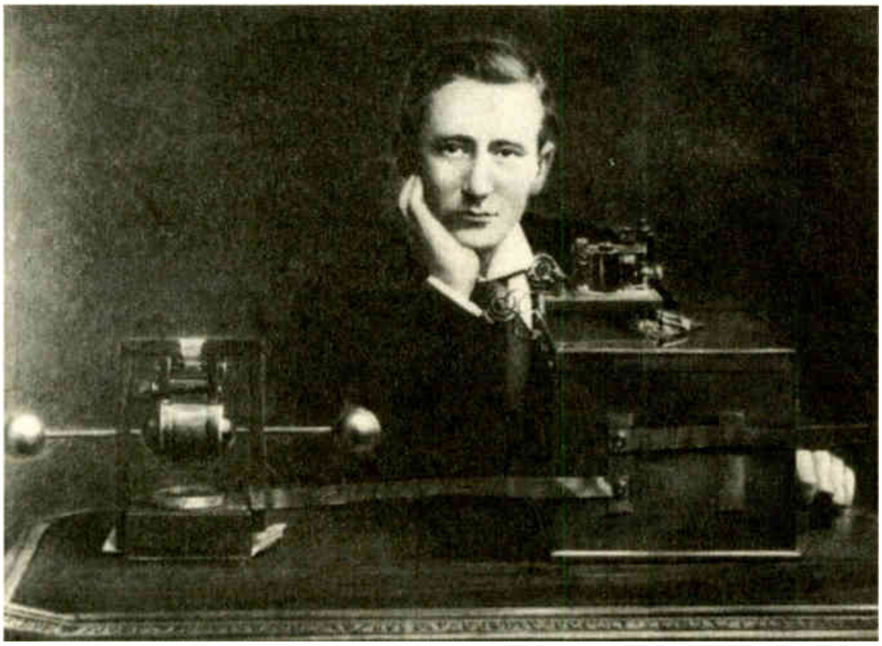
In fact his whole life was full. Although he was not a theoretical scientist he had a very inventive mind. He also never let the obstacles that stopped others prevent him from reaching his goal. It was these qualities that enabled him to achieve greatness, and receive his rightful place in history.

CHILDHOOD

Guglielmo Marconi was born on 25th April 1874 in Bologna in Northern Italy. His father, Guiseppe, was a wealthy Italian whilst his mother, who was much younger than her husband, came from a family drawn from Scottish and Irish roots. She had run away from home to marry Guiseppe, a widower.

Marconi's mother loved to travel and the young Guglielmo accompanied her on many of her travels. As a result his education suffered. First he received private tuition, and later he attended a school in Florence. He found his work difficult, but he still managed to progress to the Technical Institute of Leghorn where he was more successful, and developed an interest in physics.

As a result of this liking, his mother arranged some extra tuition for him, and this gave him further insight into some of the fundamental concepts he would require later.



Guglielmo Marconi and his radio equipment, 1896. Courtesy Marconi PLC.

Unfortunately, Marconi left the Institute without any formal qualifications. This displeased his father, but despite this he returned home and continued to perform various scientific experiments.

Marconi's mother was very loyal to her son, and she arranged that one of their neighbours, a noted physicist named Professor Righi acted as an adviser. It was through this contact that Marconi's interest became focused on the newly discovered radio or Hertzian Waves.

WIRELESS EXPERIMENTS

With Marconi's interest fired with ideas of Hertzian Waves, he started by repeating the experiments of Heinrich Hertz who had discovered their existence. These experiments used a spark in a transmitting circuit to induce a second but smaller spark in a receiving circuit placed a short distance away

Like Hertz he only managed to achieve ranges of a few metres. Later he managed to improve the distance over which the spark could be detected by using a device called a coherer in the receiver. A Frenchman named Edouard Branly was the first to observe the effect behind the coherer and this was later improved and popularised by Oliver Lodge in its use for detecting Hertzian Wave transmissions.

Marconi realised that the sensitivity of the coherer was crucial to the range that could be achieved. As a result he set about trying to improve its sensitivity. At this time, the way in which the coherer operated was not understood, and so Marconi set about improving it by trial and error. His experiments led to a much improved device which used 95 per cent nickel filings and five per cent silver filings in an evacuated tube (see Fig.1).

Marconi made other discoveries and improvements. He discovered that by using an antenna consisting of a combination of an earth and a vertical conductor, significant improvements in the signal strength could be made. This enabled him to increase the range of his transmissions even further. In one experiment he operated the transmitter in the house whilst the receiver was taken into the fields.

Confirmation of a signal was indicated by the operator waving a white handkerchief. However, when the receiver was taken over a hill the report from a hunting rifle had to be used.

Eventually Marconi was able to detect signals at distances up to about two kilometres. Realising the possibilities this offered for communications, he offered the idea to the Italian authorities. Unfortunately, they were not impressed and they dismissed the idea.

MOVES

Marconi was not deterred by his rejection, but in order to be able to exploit his idea he moved to England in February 1896 accompanied by his mother.

They were met by Marconi's cousin, Henry Jameson-Davies. He was an engineer himself, and gave the young Marconi an introduction to the influential electrical engineer A. A. Campbell Swinton. In turn this led to an introduction to William Preece, the Chief Engineer of the Post Office. Preece was keenly interested in wire-less forms of communications and had performed a number of experiments.

The first of Marconi's demonstrations was set up on the rooftops of two buildings in London in July of that year. Communication was successfully made over a distance of a few hundred yards. This impressed all that were present, especially because there were buildings in the line of transmission.

As a result of the success of the first demonstration, a further test was requested on Salisbury Plain at the beginning of September. This time representatives from the War Office and the Admiralty were also present. In view of the additional observers, Marconi used parabolic reflectors at the transmitter and receiver to show the directional properties of the waves. This was important to show that secrecy could be maintained during transmissions.

The use of this technology limited the range to about two and a half kilometres. Further tests six months later used balloons to raise the height of more conventional antennas. This time a range of over seven kilometres was achieved.

The next demonstration was made to the press. This was very successful, partly because of the novelty of being able to communicate electrically without any intervening wires. The effect was also enhanced by the showmanship used in the performance as both transmitter and receiver were housed in black boxes. As a result Marconi became an instant celebrity.

Up until this time the new Hertzian or radio waves used by Marconi had not been put to any real use. Then in 1897 it was decided to test the new system and see if it could provide a reliable link across various stretches of water. If this were successful it would save on the installation of expensive submarine cables. In some of the first of these tests across the Bristol Channel, Marconi's system proved to be very successful, further enhancing his image.

BUSINESS STARTS

With the success of these tests, interest in the possible uses of radio grew, and in July 1897 Marconi decided that he had to launch his own company. Named the Wireless Telegraph and Signal Company Limited, its foundation allowed him to borrow money to allow further tests and development to be performed.

The company rented wireless equipment primarily to ships so that they could commuicate with the shore. It supplied a service – not only did it rent the equipment but it also supplied an operator. In this way the company gained over a much longer period of time.

In late 1897 he erected masts over 40 metres high outside the Needles Hotel on the Isle of Wight. From here he made transmissions which he received on a boat which steamed up and down the Solent to test reception over the sea. From this site he managed to achieve a range of over 30 kilometres. In fact, for anyone visiting the Needles today there is a plaque in the car park commemorating the site of these transmissions.

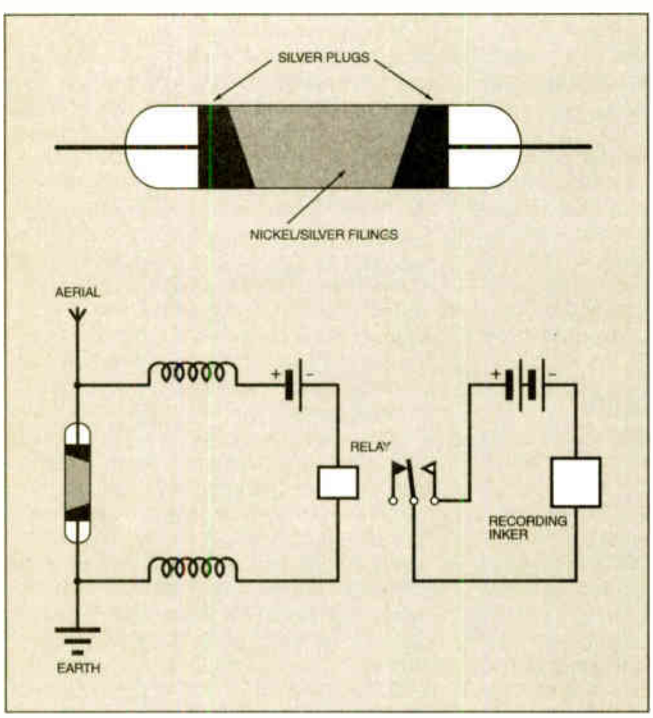


Fig.1. Coherers were one of the most popular ways of detecting radio signals around the end of the 19th Century.

With these further increases in range, in 1899 it was decided to attempt to make the first international radio link by transmitting across the English Channel. To achieve this, masts were set up at South Foreland and at Wimereux near Boulogne. In view of its importance this test received a large amount of press coverage, and was very successful.

However, it also enabled new discoveries to be made because the transmissions were picked up over 130 kilometres away in Chelmsford, where Marconi's company was located. This discovery was very significant because until this time it was only thought that transmissions could be made over line of sight paths.

The same year brought another success for Marconi. He received his first order from the British Navy. Up until this time he had spent large sums of money on research, but had received very few orders. If his company was to survive, then he needed more orders.

NEXT CHALLENGE

Despite the fact that finance was becoming tight, Marconi saw that he still needed to break new ground. He knew that he had to look to the areas that were most likely to offer new business. He thought this was likely to be in maritime communications, because there was no other method they could employ for communicating over the long distances necessary.

However, he still had to prove that radio could be used over the vast distances on the shipping lanes between Europe and North America. To prove this he decided the only way was to show that it was possible to establish a contact across the Atlantic.

After his successes with transmissions across the Channel and to Chelmsford, he thought it was quite possible that this could be achieved. He had a tough battle, though, to convince the fellow directors of his company in view of the financial situation. Eventually Marconi was given the go-ahead and work started on this massive project.

Sites were selected at Poldhu in Cornwall and Cape Cod in Massachusetts. The Poldhu station was the first to be set up. A massive antenna consisting of a ring of twenty masts over sixty metres high was erected. This supported a cone of wires that formed the actual antenna.

One of Marconi's assistants, a man named Vyvyan expressed concern over the design of the antenna. His reservations were brushed aside, but unfortunately he was proved to be right as the whole structure came crashing to the ground in a gale.

The antenna at Cape Cod was of the same design, and even became distorted in a strong breeze. Later it suffered the same fate as the one at Poldhu and by a strange quirk of fate one of the masts narrowly missed Vyvyan.

REBUILDING

Marconi did not let this setback defeat him. With typical resilience he set about the task of rebuilding. This time he made the Poldhu antenna smaller and more robust. He also decided to move the site of the American station to Newfoundland to shorten the distance of the path.

At this location he decided the antenna would have to be kept as simple as possible, consisting of a wire supported by kites or balloons – this was no doubt in some degree due to the cost of rebuilding a full antenna system. It also meant that a transmission could only be made in one direction, from England to Newfoundland.

Tests commenced in December 1901 with the Poldu station transmitting the Morse code for the letter "S", consisting of three dots, for three hours every day. This letter was chosen for two reasons. The first was that it would be easy to recognise. The

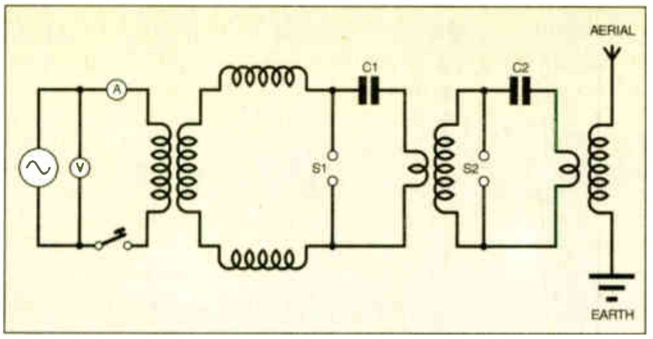


Fig.2. Schematic diagram of the transmitter used in Marconi's 1901 transatlantic transmission.

second was probably more important. The transmitter was a very new design and it could not be trusted to transmit dashes without the risk of a breakdown!

The weather in Newfoundland was bad for these tests. On the first two days kites were lost because of the strength of the wind. A third kite was tried, but this moved rapidly in the wind causing the resonance of the antenna to alter, and the receiver tuning to vary.

In order to be able to detect the signals under these difficult conditions, Marconi reverted to an untuned circuit and what was called a self-restoring coherer. Despite its name this was not a coherer at all, but an early example of a detector that operated by rectifying the signal as modern AM (amplitude modulation) detectors do. This was used with a sensitive telephone earpiece to enable Marconi to listen to the signals. Despite these difficulties, Marconi heard these long-wave transmissions from Cornwall at 12.30 p.m. on 12th December 1901.

Elated by the success, Marconi released the information to the press, despite the fact that he had no independent witness, nor any instrumental record. This news was received enthusiastically by the press, although the scientific community was more sceptical. They thought he might have mistaken static cracks for the Poldhu transmissions.

FURTHER TRANSMISSIONS

While Marconi genuinely believed that he had heard the signals from Poldu, the signals were so weak that it would not have been possible to send a message. Unfortunately, Marconi was not allowed to repeat the experiment because the local telegraph company exerted its rights to a monopoly and forced him to close his station there.

Again he had to move, and this time he set up a station on Cape Breton Island. When the station entered service it was difficult to assess its performance because propagation conditions were varying so widely. However, it was found that increasing the wavelength improved the performance. As the wavelengths were already of the order of 2000 metres, this meant that even larger antennas were necessary.

The transatlantic project was costing the company vast sums of money, and despite the problems it was decided that it was necessary to use it to bring in some finance. To achieve this, a news transmission service, using Morse code, was introduced, in conjunction with the *Times* newspaper. Again the size of the antennas meant that the one at Glace Bay in Nova Scotia collapsed.

Even with the replacement antenna the service proved to be difficult and Marconi resorted to testing new antennas at Poldhu. Whilst he was doing this he noticed that a wire on the ground pointing towards Glace Bay gave a stronger signal than his other antennas. Further development resulted in the inverted L antenna used to this day.

Now it was possible for the two stations to maintain a far better level of service.

MARINE BUSINESS GROWS

The main area of business for Marconi's company was in providing communications for ships. With the transatlantic link established, more ships took the Marconi system on board. The first commercial installation on a merchant ship was completed in 1900, and by 1902 seventy ships had Marconi systems on board.

Marconi's company did not sell its equipment. Instead it charged a rental fee for which it provided the equipment and a trained operator. This enabled Marconi to overcome the monopoly that the Post Office had on communications because no charge was made for each message. It also meant that they could restrict the use of Marconi shore stations to those ships carrying Marconi apparatus. The only exception was in cases of distress.

Business grew steadily but the company still remained in a poor financial state. Marconi put in all his money and when Vyvyan visited South Africa to search for new business it was on the arrangement that he paid his own expenses unless he came back with new orders. Fortunately for all he brought in some new work.

Despite this, financial problems remained with the company for a number of years. They were only resolved when a new managing director named Isaacs joined the company. He was very successful in turning the company's fortunes around, and within two years of him joining, the company saw much better times. By 1910 over 250 ships had been fitted with Marconi systems.

OTHER SYSTEMS

Although Marconi was the leading light in his company, the field of radio was advancing very rapidly, and it was no longer possible for one person to dominate in all areas of research. Marconi employed a number of other engineers who were leading the field in their own right.

Professor Ambrose Fleming was one notable example. He was the first professor of electrical engineering in Britain, and inventor of the diode valve. This was an invention he made whilst working for Marconi.

Another was H. J. Round. He is credited with a number of innovative valve radio sets. In addition to this, he made a number of significant developments in valve technology. One of these included a low capacitance valve known as the V24 that was introduced in 1916. This was a major step forward, as one of the major problems with valves of the day was the inter-electrode capacitance limiting their frequency response and causing the circuits to break into oscillation.

RADIO SYSTEM DEVELOPMENTS

In the early 1920s, the shortwave bands were starting to be exploited. Many of the first discoveries had been made by radio amateurs, who made the first short-wave transatlantic contact in 1923.

Many professionals including Marconi started to experiment with these bands. In 1923 he built a parabolic reflector antenna at Poldhu and used his yacht *Elettra* to investigate the signal strength as it sailed away from Britain. He found that the signal strength fell at first and then started to rise. At a distance of 4000km he found that the shortwave transmissions were stronger than the very high power longwave transmissions.

With proof that the shortwave bands could provide reliable communication over long distances, the British Government decided that it needed to install an Imperial Wireless Network. The Marconi Company approached the Government and offered to link up the Empire with shortwave stations in England, Canada, India, South Africa and Australia.

As the technology was very new and there was a high risk of failure, the Government insisted that Marconi bore all the risk of failure. This the company did, but it set to work very quickly. Once installed the system was very successful, and very reliable. The equipment was so good that it was still in operation over forty years later.

Not content with investigating the properties of the shortwave bands, Marconi also devoted some of his time to discoveries about wavelengths below a metre. This was made easier by the fact that valves were beginning to become available for these frequencies. One application was for a VHF radio link between the Vatican and the Pope's summer residence at Castel Gandolfo.

FINAL YEARS

In later life Marconi became more involved with politics and the interests of his native Italy. He had been appointed to the Italian Senate in 1914, but in later life he undertook diplomatic missions for his country. In view of his position he was obliged to join the Fascist Party in 1923, but he was never happy about this.

His last years were very troubled with the increasing tension of the 1930s. He found himself having to represent his country under increasingly difficult circumstances. To add to this his health started to fail and he suffered a number of heart attacks.

He died on 20 July 1937 at the age of 63. This was the end to a brilliant career of true pioneering work in the field of radio, and of service to the country he loved. □

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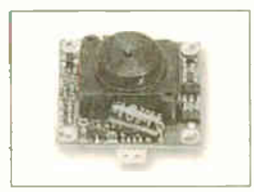

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Constructional Project

GHOST BUSTER

ANDY FLIND

Spooky feelings all around you? Track down their source!

SOME time ago, an interesting manuscript was received at the *EPE* Editorial office. The author, Vic Tandy, had apparently heard that his workplace was haunted, but as a confirmed sceptic in ghostly matters had dismissed it as colleagues' imagination. Until that is, he had occasion to work late one night.

Suddenly he experienced all the phenomena associated with the supposed haunting: the hair standing on the back of the neck, a feeling of being watched by another "presence", a deep sense of unease . . .

Some time later, quite by accident, he discovered the presence of strong sub-audio "standing waves" in the air of the affected premises. The source of these was subsequently traced to an extractor fan. Modifications were made to prevent the formation of the standing waves from this fan and the apparent "haunting" promptly ceased.

The obvious conclusion was that serious ghost hunting enthusiasts should include a test for such standing waves to the "armory" of physical checks they already use in order to establish that the "ghost" they are investigating is not due to some simple physical effects generated on this earthly plane.

A copy of this manuscript was sent to Andy Flind, the author of this article, with a suggestion that perhaps some suitable equipment might be designed and presented for enthusiasts to construct.

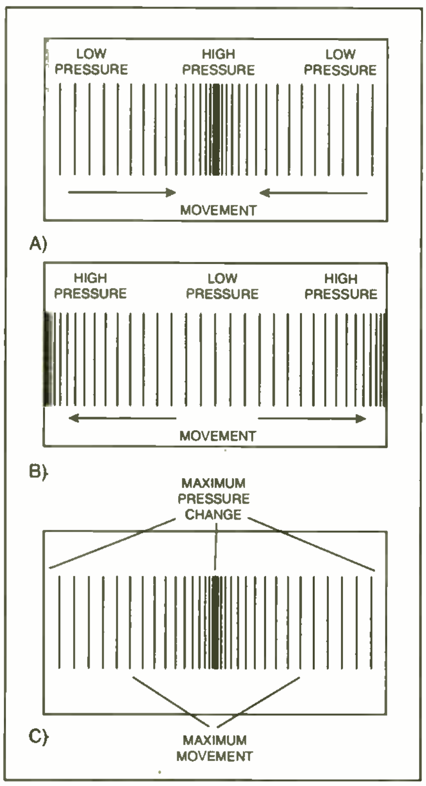


Fig.1. Simplified explanation of standing wave effect.

STANDING WAVES

A brief explanation of the "standing wave" effect is appropriate before continuing. Any hollow space filled with air will have at least one, and often several, resonant frequencies. Usually we're not aware of this because the spaces we occupy are often relatively small, not well-shaped for efficient resonance and contain carpets, curtains and other soft furnishings, which tend to damp down any oscillation of the air contained in them.

Rooms without such furnishings often demonstrate some resonance though, which explains why bathrooms have always been so popular with would-be opera stars! Larger rooms, such as concert halls, often suffer from resonance to the point where it causes serious problems, and there is a whole science devoted to the control of its effects in such places.

Here though, we are describing resonance at audio frequency. Some sizes and shapes of space will have resonances below the audio range. Such low frequencies cannot be heard, but may have other undesirable manifestations, such as the ghostly effects described earlier.

BAD VIBRATIONS

The author recalls hearing some years ago of a case where the staff of a large office building suffered endless headaches and nausea, leading to high sickness rates which caused their employer much difficulty. The cause was eventually traced to a strong vibration in the building structure at just seven hertz, which was duly fixed, curing the sickness problems.

A "standing wave" consists of a body of air literally expanding and contracting, bouncing back and forth at a resonant frequency determined by its elasticity and the physical dimensions of the space in which it is confined. It follows that at some points within the space it will be moving a great deal, whilst at others it will be more or less still, but experiencing pressure changes.

FUNDAMENTAL WAVEFORM

There will be a fundamental frequency, but other, higher "harmonic" frequencies may also be present. Fig.1 shows one possible form of this effect.

In Fig.1a the air is moving towards the centre, leading to high pressure here and low pressure at the walls. In Fig.1b it is bouncing back again, causing low pressure at the centre and high pressure at the walls. It can readily be seen that there are points where there will be large movements of the air but little pressure change, and other points where there will be less movement but large pressure changes.

There would have to be some motivating cause for the oscillation, which could take almost any form. Extractor fans, resonant vibrations of the building structure, perhaps some effect due to wind, might all serve as prime movers. Logic suggests that in all cases, an area of little movement but high pressure change should be found close to at least one of the boundaries, or walls of the space.

"MIC"-ING THE BOWL

In constructing a device to detect such waves, three problems had to be tackled. The first concerned the microphone. An ordinary electret or similar microphone cannot be used as most of these do not operate much below 100Hz. In fact it would be a disadvantage for a microphone intended for audio use to operate below the audio frequency range, so even the best professional microphones would be unlikely to do so.

A suitable microphone had to be designed and constructed for the job. It seemed, too, that it should be simple and inexpensive to make, as well as being very sensitive at low frequencies.

After numerous experiments with various techniques the design shown in Fig.2 was arrived at. This consists of a 7-inch (18cm) diameter Pyrex glass mixing bowl with some wadding glued inside it for damping, and a cling-film (yes, cling-film) diaphragm stretched across the top. Cling-film sticks quite well to glass, but plastic insulation tape was added to secure it, see photograph opposite.

A "bridge" of stout iron wire from a coat-hanger was bent to fit across the top above the cling film and taped into place on the bowl. Some single-core insulated wire was shaped to form a "nib" pointing down into the centre of the diaphragm. This was taped to the bridge, slipping a piezo disc sounder beneath it to act as a transducer to sense vibrations picked up by the film diaphragm. These transducers make excellent microphones, with a high output and good sensitivity well into the audio range.

A pinhole was pierced in the cling-film close to the edge of the bowl to allow air pressure inside to equalise slowly with the general atmospheric pressure outside. This arrangement detects pressure change rather than movement, as variations in air pressure cause changes in the volume of air behind the diaphragm, moving the diaphragm as they do so.

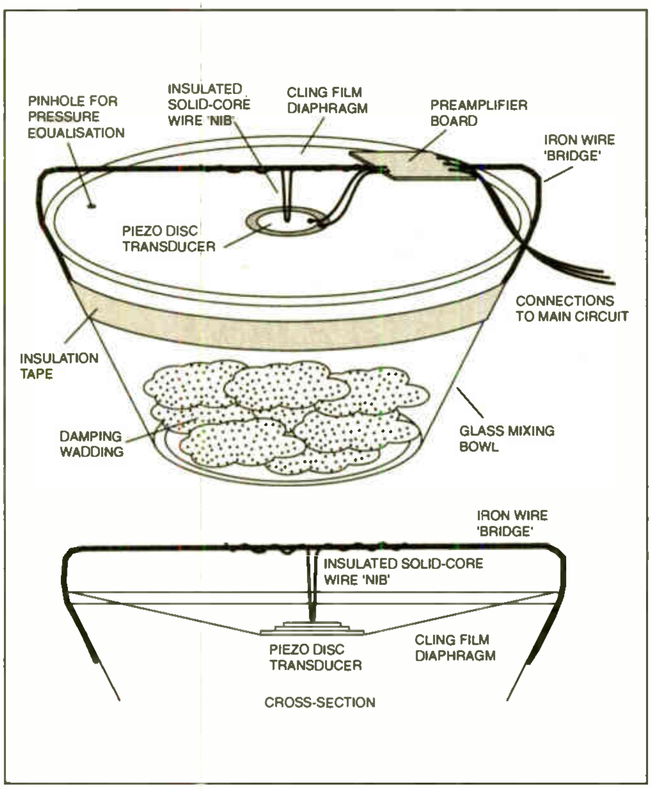


Fig.2. Suggested method of construction for a simple, low-frequency microphone using a piezoelectric disc transducer, a coat-hanger and a glass mixing bowl.

COMPONENTS

Resistors

R1 to R4	1M (4 off)
R5, R6	10k (2 off)
R7, R10, R11, R14, R18, R19, R24	10k (7 off)
R8	100k
R9	47k
R12	1k
R13	27k
R15, R17	2k2 (2 off)
R16, R25	1k2 (2 off)
R20	560Ω
R21	82k (2 off – see text)
R22	22k
R23	33k
R26	390Ω

All 0·6W 1% metal film.

See SHOP TALK page

Potentiometers

VR1	10k 22-turn cermet preset, vertical
VR2, VR3	10k rotary carbon, lin (2 off)
VR4	10k rotary carbon, log

Capacitors

C1, C3, C5, C6, C8, C9	100n ceramic, resin-dipped (6 off)
C2	22n ceramic, resin-dipped
C4	10µ radial elect. 16V
C7	470µ radial elect. 16V

Semiconductors

TR1	BC184L *npn* transistor
IC1, IC2	TL082 f.e.t. dual op.amp (2 off)
IC3	LP2950 micropower +5V voltage regulator
IC4	3914 linear bargraph display driver
IC5	OP296 CMOS dual op.amp
IC6	7556 CMOS dual timer
IC7	LM358 dual op.amp

Miscellaneous

S1	s.p.s.t. toggle switch
S2	s.p.d.t. toggle switch
X1	10-segment l.e.d. bargraph display
MIC1	piezo disc sounder, 27mm 1·8kHz resonance (see text)

Printed circuit boards, available as pair from the *EPE PCB Service*, code 326 (Mic.) and 327 (Main); 8-pin d.i.l. socket (4 off); 14-pin d.i.l. socket; 18-pin d.i.l. socket; 20-pin d.i.l. socket; 7-inch (18cm) diameter glass mixing bowl, cling film etc.; 9V battery, battery holder and connector; plastic case (see text); control knob (3 off); connecting wire; solder, etc.

Approx. Cost Guidance Only **£30** *excl. case, bowl & hanger*

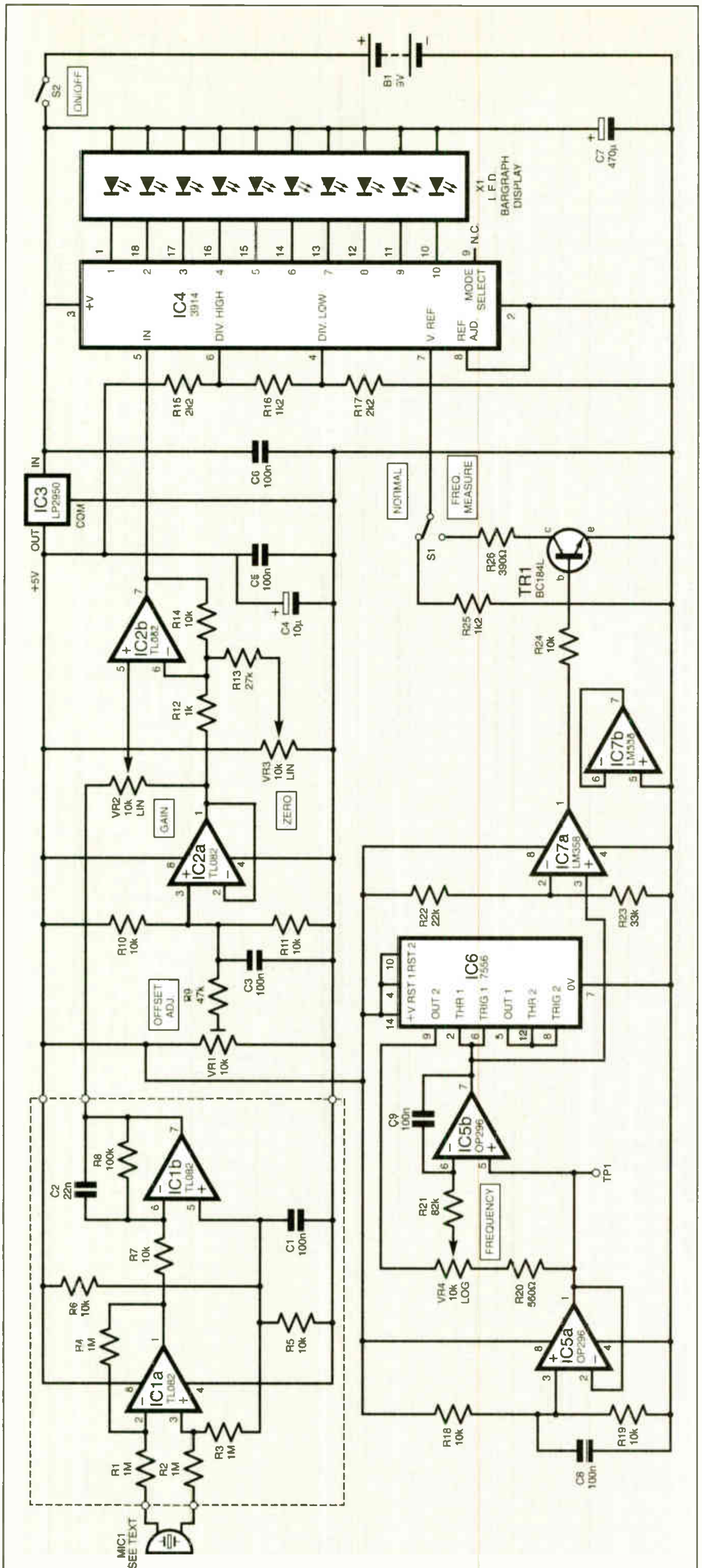


Fig.3. Complete circuit diagram for the Ghost Buster.

HIGH IMPEDANCE

Although the piezo disc makes a fine microphone, it has a very high impedance. Because of this the first stage of any circuit must also have a very high input impedance, plus some ability to cancel out mains "hum" which may be induced into the wires leading from it.

To achieve this, the first part of the circuit, shown in a dotted box in the full circuit diagram of Fig.3, is a differential amplifier with an input impedance of about two megohms, built around op.amp IC1a. IC1b provides a gain of about ten, and capacitor C2 provides frequency attenuation above about 100Hz. Without this capacitor the "microphone" was found to operate up to 4kHz, but we're not really interested in such frequencies with this project.

The output from IC1b has a low impedance and a relatively high level so it can be connected to the rest of the circuit through ordinary unscreened cable. This part of the circuit is constructed on a separate printed circuit board and mounted directly on the "microphone" for two reasons.

First, although the differential input cancels out most of the mains "hum", it is still advantageous to keep the leads to the piezo disc MIC1 as short as possible. Second, it may be desirable to place the rest of the electronics a short distance away from the "microphone" so the ability to connect it through a length of ordinary wiring is useful.

This "microphone" assembly is extremely sensitive and operates well at frequencies extending to below 1Hz, detecting the sub-audio frequencies required by this project with no difficulties whatsoever.

DISPLAY SOLUTION

The next challenge was to find a simple and inexpensive way of displaying sub-audio frequencies detected by it since they cannot be heard. An oscilloscope can be used, but not every ghost hunter is going to possess one of these, and even those that do may be unwilling to lug it to the investigation site and find a suitable power supply.

The solution adopted is the use of a 10-segment bargraph display (X1) with a 3914 linear driver (IC4). The illuminated segment is adjusted to be approximately central when there is no input, and to move up and down when a signal is applied.

Op.amp IC2a generates a low-impedance voltage of about half the supply. A small offset adjustment through preset VR1 allows it to be set to exactly the same value as the average d.c. voltage from the output of IC1b. This allows adjustment of the gain control VR2 without affecting the average value at the output.

Op.amp IC2b provides further voltage gain of just over ten, with a user-adjustable "zero" control, VR3, and the output is applied to the bargraph driver IC4. This is configured with resistors R15, R16 and R17 to have a full-scale span of about 1V, centred around 2·5V.

Leaving pin 9 (mode select) unconnected invokes "dot" mode, where only one segment is illuminated at a time. Connecting pin 7, V_{ref}, to ground via resistor R25 causes the l.e.d. segment current to be set to about 10mA.

IC4 and the bargraph X1 are powered directly from the 9V battery supply voltage. Everything else is powered with a regulated 5V supply from IC3, which is an LP2950 low drop-out, micropower voltage regulator, much better suited to battery operation than the standard 78L05 type.

SPECTRE

The last problem to be overcome was the provision of some way of determining the frequency of signals detected. Their waveform and level might be unsuitable for squaring and feeding into some sort of frequency measuring circuit, and in any case it is difficult to measure really low frequencies in real time.

Again, a requirement was that the method used should be simple and inexpensive. The technique adopted is to flash the illuminated segments of the bargraph, with a fairly short duty cycle, at a frequency that can be manually adjusted by the user. If the flashing is at a rate similar to the detected frequency, the illuminated segment will appear to stand still or travel very slowly up and down the display. This method isn't perfect but it works and with care will usually give a good idea of the detected frequency.

The oscillator is a type used by the author in several previous designs because its output can be directly proportional to the position of the variable resistor used to control it. It is constructed around IC5 and IC6.

Op.amp IC5a provides a low-impedance voltage of half the supply. IC5b is configured as an integrator, where the rate of change of output is directly proportional to the input voltage applied to resistor R21 from frequency control VR4.

The output from IC5b is connected to the inputs of the first half of the 7556 dual timer IC6, so that the output of this goes high when the input falls below a third of the supply voltage, and low when it rises above two thirds of it. The output from the timer, at pin 5, is of opposite polarity to the feedback needed by the integrator to form an oscillator, so it is applied to the inputs of the second timer which simply inverts it, providing the required feedback from output pin 9.

An OP296 precision op.amp is used for IC5 as this was found to produce a much more linear output than other types, especially at low frequency. The output from IC5b is an almost perfect triangle wave. With the values shown the frequency range extends from around 5Hz to 75Hz. The reasoning for this range being that higher frequencies will be audible and lower ones can be simply counted as the illuminated bargraph segment travels up and down!

A logarithmic (log) potentiometer is used for frequency control VR4 as this type provides some useful expansion of the low frequency end.

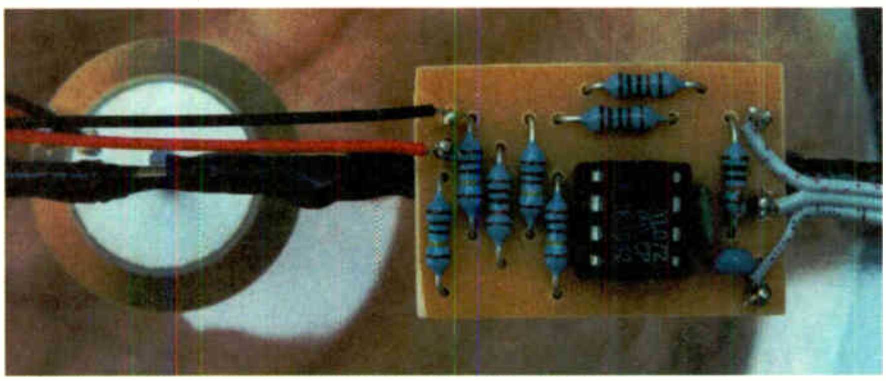
A comparator, IC7a, is used for picking off the positive tops of the triangle waveform to give drive pulses of around a seventh of the total cycle time to transistor TR1. This controls the l.e.d. current-setting input, V_{ref}, of IC4 through resistor R26, which has a lower value than R25 and gives a higher l.e.d. current so that the short pulses do not result in the l.e.d.s appearing too dim.

MICROPHONE BOARD

There are two printed circuit boards for this design, which are available as a pair from the *EPE PCB Service*, codes 326 and 327.

The physical construction of the microphone has been described earlier. Its electronic circuit is assembled on the p.c.b. whose layout details are shown in Fig.4.

Construction should begin with the fitting of the five solder pins for external connections, followed by the resistors, capacitors and IC1. As usual, the author recommends the use of d.i.l. (dual-in-line) sockets for all integrated circuits wherever possible.



The completed preamplifier circuit board suspended above the "microphone".

For testing this circuit, IC1 should be inserted and the board powered with a supply of 5V. The drain from the supply should be in the region of 3mA. The voltage at the output should be around 2·5V d.c., half the supply.

The piezo disc can be connected, and if the centre of this is pressed with an insulated object it will be possible to observe the change of output voltage with a meter as the pressure is applied and released. If the test works, this p.c.b. is ready for use and can be fitted to the "microphone" to complete it.

Various means can be used to fix it in position, such as a drop of glue, double-sided adhesive foam etc. The author is particularly fond of Blu-Tack for such tasks.

MAIN BOARD ASSEMBLY

Construction should now proceed with the main p.c.b., whose layout details are shown in Fig.5. Before describing this, it should be pointed out that the frequency-determining part of the circuit is entirely optional. If this feature is not required then resistor R18 and everything else physically

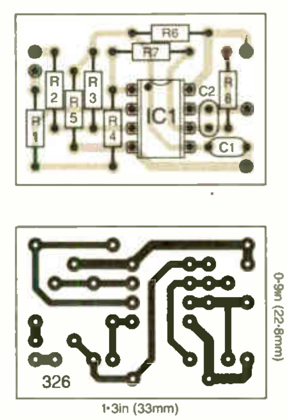
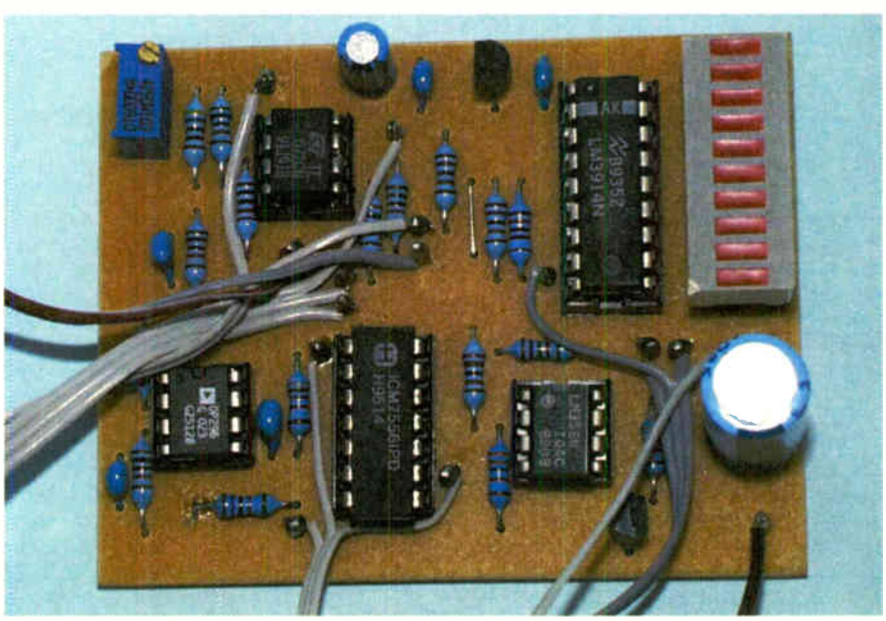


Fig.4. Microphone preamplifier printed circuit board component layout and full-size copper foil master.

beneath this level on the board (as viewed in Fig.5) can be omitted, with the exception of R25 and capacitor C7.

The suggested assembly procedure is to fit the single link, followed by the solder pins for external connections, there are



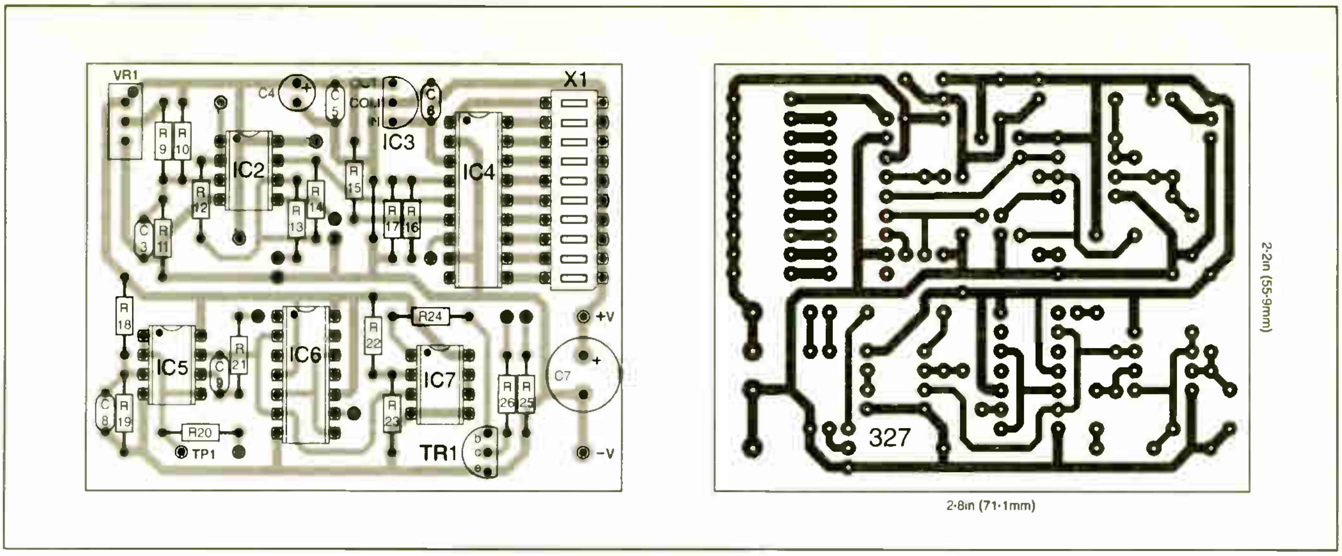


Fig.5. Main printed circuit board topside component layout and full-size underside copper foil master pattern.

fifteen of these. Next all the resistors should be fitted, followed by d.i.l. sockets for IC2 and IC4 to IC7. A 20-pin d.i.l. socket is also recommended for the bargraph l.e.d. display X1.

The five 100n ceramic capacitors should now be fitted, followed by the two electrolytics C4 and C7, observing their correct polarity. Finally, preset VR1, transistor TR1 and the regulator IC3 should be fitted, after which the p.c.b. is ready for testing.

FIRST CHECKS

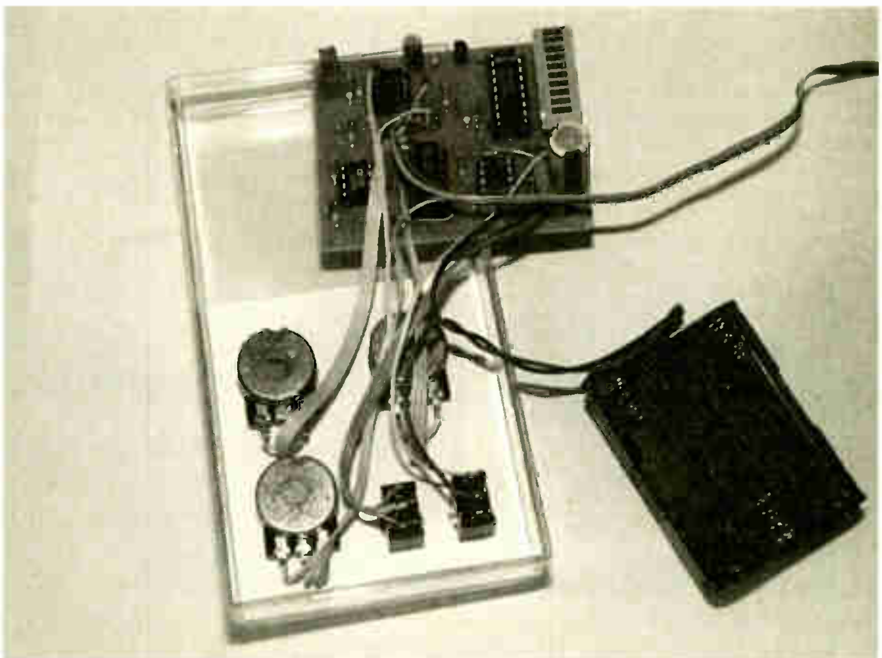
A check without any of the i.c.s inserted (except regulator IC3) should be made. When the board is connected to a 9V supply, there should be a brief surge as capacitor C7 charges, after which the current drain should settle to about 2mA. If so, the 5V regulated output can be checked, this should appear at pin 8 of the sockets for IC2, IC5 and IC7, and at pin 14 of the socket for IC6. These are the top-right pins as shown in Fig.5.

The 9V supply should appear at pin 3 of the socket for IC4, and of course at all the right-hand side pins of the socket for the bargraph display. If this checks out, VR2 should be temporarily connected, just two wires from the wiper and the bottom, or counter-clockwise end, to the board, and IC2 inserted.

This should take the supply current to 4mA or 5mA, and the voltage at both outputs of IC2, pins 1 and 7, should be in the region of 2.5V d.c. Adjusting preset VR1 should cause a small variation of this.

Next IC4 and the bargraph display X1 should be fitted. The bargraph used in the prototype has a small bevel on one corner and the product markings, on the right-hand side when fitted to the p.c.b. (as shown in Fig.5), denotes the anodes of the l.e.d.s.

If there is any doubt regarding polarity, though, it would be wise to check this before fitting it. A temporary wire link can be used to connect the solder pin adjacent to pin 8 of IC4 (from pin 7) to the pin above resistor R25. When powered, one or two segments of the display should illuminate and the supply current will be somewhere around 25mA to 35mA.



ALIGNMENT SETTING

The three leads of the microphone p.c.b. can now be connected, two (power supply) to the main board, the third to the top (clockwise) connection of VR2. The piezo transducer should be disconnected for this test, as it will make reading of the d.c. voltages to be checked difficult.

A digital voltmeter should be connected across VR2 top and bottom (not the wiper) and preset VR1 carefully adjusted for a reading as close to zero as possible. The purpose of this is to cancel out any d.c. voltage discrepancy here, so that the average output will be unaffected by gain adjustment with control VR2.

Following this, the Zero control VR3 should be temporarily connected. This control should adjust the illuminated segment of the bargraph up and down its range. The centre should correspond roughly to the centre of the range of VR3.

It may prove easier to check this with VR2 turned to minimum as stray noise may cause the display to jump about a bit with the gain turned up. Variation of VR2 should not cause any change in the average position of the display set with VR3, though. If it does, the adjustment of VR1 should be re-checked.

It is now possible to connect up the piezo transducer and try out the complete amplifier section. This is a very experimental project, and some care may be needed to operate it. It has been found helpful to stand the microphone on a piece of foam plastic to insulate it from vibrations in the surface it is placed on. It may take some time to settle following large changes in air pressure due to wind, extractor fans etc.

Another factor that has been found to affect it is shining an incandescent light directly on it, the cause of this is not fully understood but is likely to be a change in the tension of the cling-film caused by heat. Sunlight would presumably have a similar effect, but wind would usually make outdoor use difficult anyway, and the unit is not intended for this.

Apart from these limitations, the prototype usually settles reasonably quickly and works well. Finding a source of low frequency sound can be difficult, though, since loudspeakers are not very effective at the low frequencies this project is designed to detect, and ghosts are notoriously difficult to find!

Meanwhile, the author has found that in a small room, the door can be held slightly ajar and pulled back-and-forth at four or five hertz, and the project responds to this very well. Waving a hand up and down over the diaphragm will also generate an output, indicating that it is operating correctly and with good sensitivity.

FREQUENCY GENERATOR

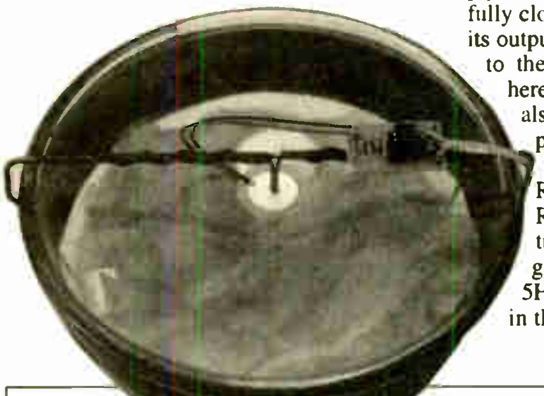
Moving on now to testing the frequency generator section, it is suggested that IC4 should be removed first, to allow the supply current to be checked more readily. This should leave an overall drain of about 9mA before any of the i.c.s of this section are fitted.

Frequency control VR4 should be connected first. This is a log type, to provide some expansion of the scale at lower frequencies. IC5 and IC6 should be fitted next. These are both micropower types and will make almost no difference to the power consumption.

Control VR4 should be turned fully clockwise (highest frequency) and the average d.c. voltage at the clockwise end of VR4 and pin 3 of the socket for IC7 should both read about 2·5V. If VR4 is turned fully anti-clockwise (lowest frequency) these voltages should show a slight flicker on an analogue meter. If an oscilloscope is available, the waveforms can be checked visually, square wave from VR4 and triangle wave at IC5 pin 7.

Fitting IC7 should now increase the supply current by about 1mA, and with VR4 fully clockwise, the average d.c. voltage at its output pin 1 should be around 0·5V due to the duty cycle of the output pulses here, which is about 7:1. These can also be observed on a 'scope as short positive-going pulses.

If the lead from the pin above R25 is now moved to the one above R26 and IC4 is refitted, and VR4 turned fully anti-clockwise, the bargraph display should flash at about 5Hz with an average supply current in the region of 20mA.



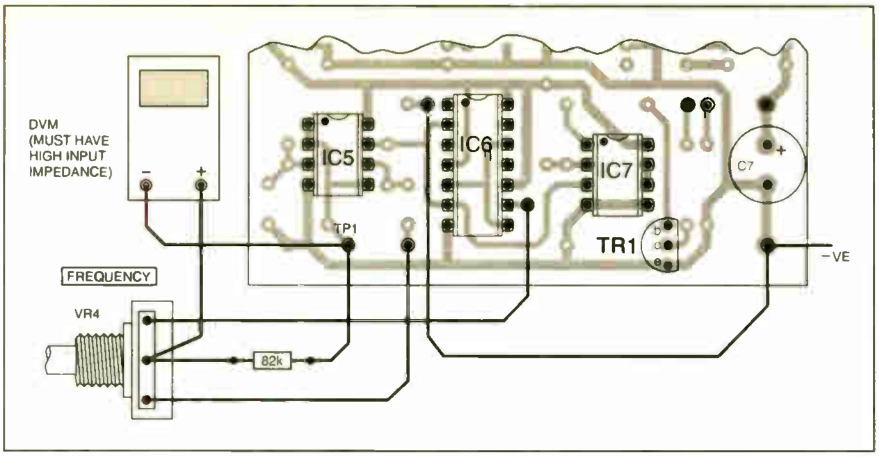


Fig.6. Interwiring connections for frequency calibration using a digital voltmeter (DVM).

PHANTOM DISPLAY

This completes the testing of the frequency checking part of the circuit. It should be possible to try it out by placing a finger on one input to inject some 50Hz "hum", adjusting Gain control VR2 for a suitable "spread" on the bargraph, then carefully adjusting VR4 around 3/4 travel.

A point should be found where the bargraph display keeps "moving" slowly from a single point at one end through the "spread" to a single point at the other end and back again. This is the frequency indication for 50Hz.

Calibration of the frequency checker is most easily carried out with a frequency meter hooked up to the top of VR4, but it is appreciated that not every constructor will have such an instrument. Another way is to temporarily connect the circuit as shown in Fig.6.

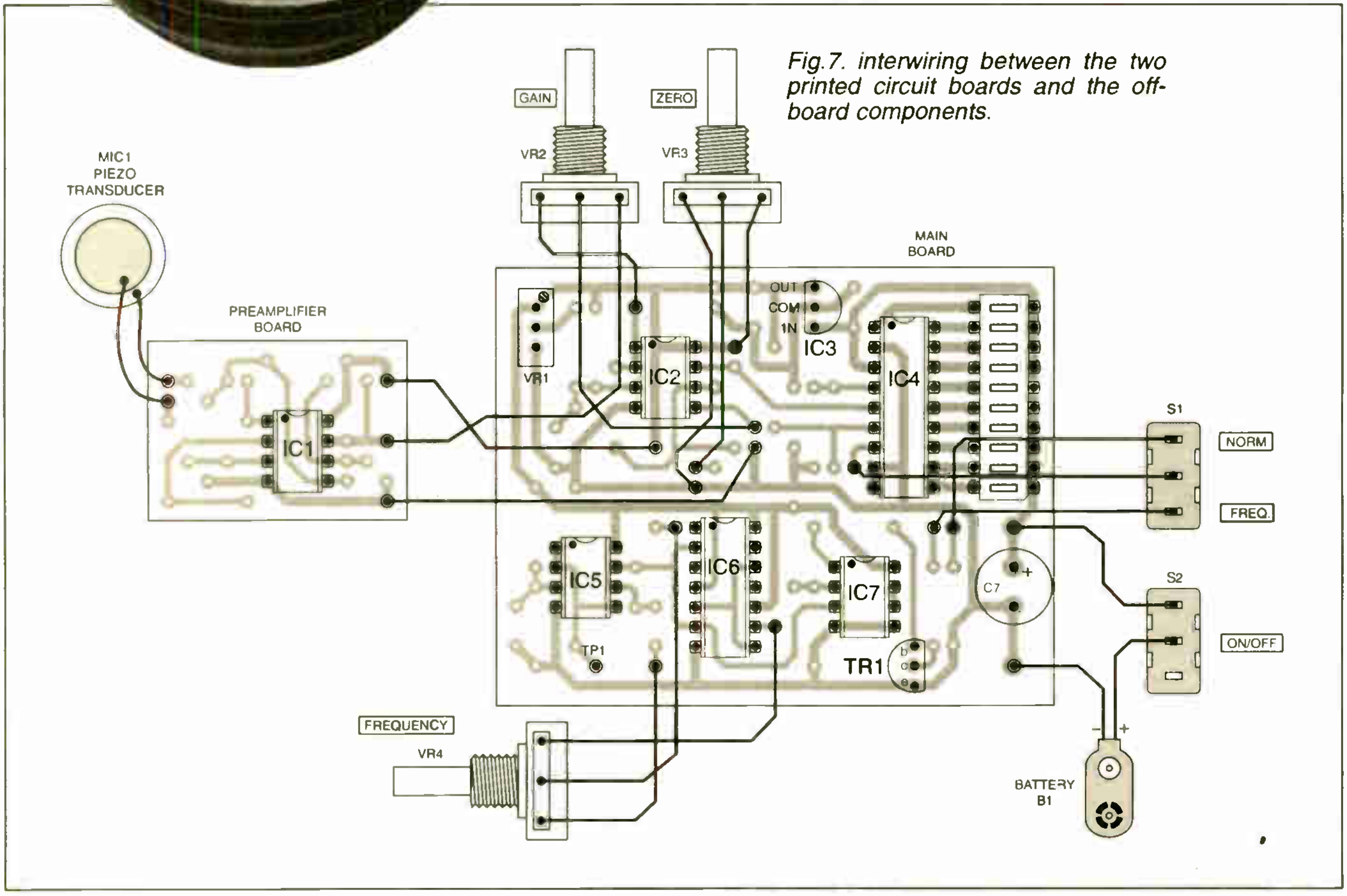


Fig.7. interwiring between the two printed circuit boards and the off-board components.

Pin 7 of IC4 should now be connected to resistor R25 or left open for this procedure, to avoid overloading IC4 and the bargraph display.

As shown in Fig.6, connecting resistor R21 to the battery negative causes IC6 output pin 9 to go high and remain there. The extra 82kΩ resistor between VR4 and test point TP1 simulates the load of R21 on VR4.

The voltage from VR4 can now be measured with a high impedance meter such as a DVM, allowing this control to be calibrated using the values shown in Table 1. Although not as accurate as a frequency meter due to component tolerances, when this procedure was tried on the prototype the errors were surprisingly low, within two per cent.

HOUSING PREFERENCE

The unit can be housed in any manner preferred. The connections between the two boards and the controls are shown in Fig.7. As this is an experimental project, there was no attempt to make it look "commercial" in a smart housing. Using a mixing bowl from the kitchen to make the "microphone" would make this difficult in any case!

The main p.c.b. must be visible since the bargraph is mounted directly onto it, so the prototype is housed in the transparent plastic case which the author had in his "spares box". An alternative approach would be to cut a window in one of the more common grey plastic boxes.

An alkaline PP3 battery could be used as the power supply, but where long periods of surveillance are to be undertaken a pack of six AA cells would be better due to the current consumption of the display. The "microphone" stands on a piece of plastic foam, but could be suspended on elastic for greater isolation from surface vibration. It is unlikely this will be necessary in most situations, however.

A small plug and socket arrangement could be used to connect the microphone assembly to the main section if this is thought more convenient.

Table 1. Frequency Calibration

FREQUENCY	*VOLTAGE*
5	0·14
10	0·27
15	0·41
20	0·55
25	0·68
30	0·82
35	0·96
40	1·09
45	1·23
50	1·37
55	1·50
60	1·64
65	1·78
70	1·91
75	2·05

Remember to disconnect IC4 Pin 7 from resistor R26 when using this calibration procedure.

TRACING APPARITIONS

A final interesting option would be to use John Becker's *Micro-PICscope* (April 2000) for displaying the output, but it must be pointed out that this will only be suitable for displaying steady standing wave frequencies.

Unlike a conventional oscilloscope, *PICscope* works by storing the incoming waveform as a series of digital values, then outputting these to the display. As such, it is not a "real-time" instrument, and will miss many of the transients picked up by the microphone and readily displayed by a normal scope or the bargraph display.

It is likely that most of the commercial miniature l.c.d. scopes work in a similar manner. However, where a steady standing wave frequency is thought to be the source of the effects being investigated, the *PICscope* could prove to be a useful tool if used in conjunction with this project.

HAUNTING REFRAIN

So "Who Ya Gonna Call"? Now you know - happy ghost hunting! □

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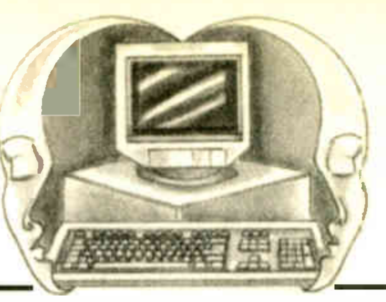
INTERFACE



Robert Penfold

SIMPLE ANALOGUE-TO-DIGITAL CONVERTER USING A 12-BIT CHIP

ELECTRONICS has always moved on at a fair pace, which means that there are always new things coming along for the electronics hobbyist to try. There is a downside to progress though, which is that parts that were once readily available eventually become obsolete, as do any designs that use them.

There has been a succession of "here today, gone tomorrow" devices over the years, most of which disappeared simply because they never achieved high enough sales. Recently it has tended to be the "golden oldies" that have disappeared from the market. In some instances this is due to manufacturers or retailers rationalising their ranges, while in others it is just a matter of the parts concerned being out of date.

It is worth repeating the advice that is often given to readers of this magazine. Make sure that you can obtain any unusual components before buying any of the others. With most obsolete parts there are still supplies of them available somewhere, but there is no guarantee that the particular component you require will still be available.

Stocks of all obsolete parts will "dry up" eventually. Also, where a stock of obsolete components is available, the prices are often quite high. These stocks are mainly held as spare parts rather than for use in new units, and they sell at spare part prices.

Defunct A/D

The TLC548IP has been used in a number of *Interface* circuits over the years. It has also been used in a few *EPE* projects, although none of these are particularly recent designs. This device seems to have been added to the list of components that are no longer available from the usual component retailers.

Fortunately, there are potential "get out clauses" with this device. The TLC548CP is currently available from RS outlets, and this is a slightly inferior version of the device. Its electrical characteristics seem to be the same as the "IP" version, but it has a more restricted operating temperature range of 0 to 70 degrees Celsius. The "IP" version will operate over a very wide temperature range of –40 to 85 degrees Celsius. The temperature range of the TLC548CP seems to be perfectly adequate for most purposes.

Another possibility is to use the TLC549IP, which seems to be almost identical to the TLC548IP. Obviously there is no guarantee that the TLC549IP will be available for years to come, but it is currently available and listed by several suppliers including Farnell, RS, and ESR Electronic Components. There should be no supply problems in the immediate future. A factor in favour of this option is that this chip is available at quite low prices.

Common Bond

The TLC548IP and TLC549IP seem to be essentially the same chip. They are pin for pin compatible and are covered by a common data sheet. Most of the parameters for the two chips are the same, including the accuracy of 0·5 LSB. The typical conversion time for the TLC548IP is somewhat faster at 8 microseconds, which compares to 12 microseconds for the TLC549IP. However, the maximum conversion time is the same for both devices at some 17 microseconds.

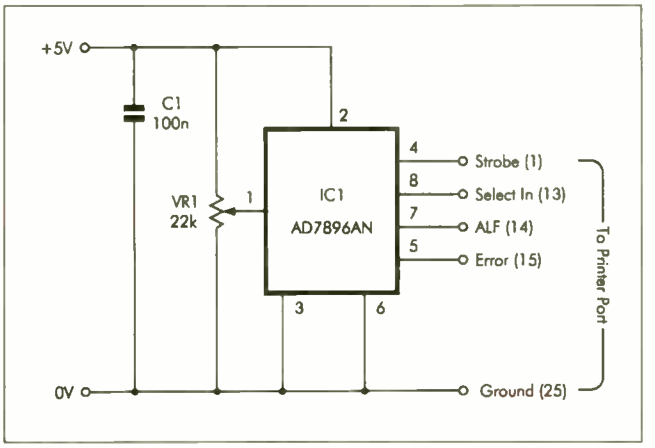


Fig.1. Circuit diagram for the simple 12-bit Analogue-to-Digital Converter.

The main difference seems to be in the speed of the interface circuitry. The TLC548IP is able to operate at almost twice the speed of the TLC549IP in this respect. This permits the latter to provide up to 40,000 conversions per second, whereas the former can provide 45,000 conversions per second.

The author has not yet had an opportunity to try the TLC549IP, but it should work well in the circuits featured in previous issues of *EPE*. These circuits use relatively long control pulses and do not attempt to achieve anything approaching 40000 conversions per second. The slower interface logic circuitry should therefore be of no consequence.

If you use the TLC549IP to do your own thing, it will be necessary to bear in mind that the maximum frequency on the IO Clock input is 1·1MHz. The equivalent figure for the TLC548IP is 2·048MHz.

There has been a certain amount of confusion over the TLC548IP type number, which has produced several queries from readers. The type number was actually shown incorrectly in some component catalogues, but the TLC548IP and TLC549IP type numbers are both shown correctly here. The seventh digit is definitely a capital "I" and not a figure one.

12-Bit A/D

Of course, there are many other analogue-to-digital converter chips that can be used with a PC printer port. Some of these are serial types that, like the TLC548IP and TLC549IP, will interface to the port using a small number of lines.

The AD7896AN is one that has been covered before, and it is perhaps worth considering it again here. It is available from Farnell and RS outlets incidentally, so there should be no supply problems. Like the TLC548IP, it has a built-in sample and hold circuit. It offers superior resolution of up to 12-bits, which gives the potential for far better accuracy than 8-bit chips. The raw readings run from 0 to 4095, which compares to a range of 0 to 255 for an 8-bit converter.

The AD7896AN has one more control line than the TLC548IP, but it still requires just four lines plus the ground connection to interface properly to a PC printer port. One of the lines is optional, so the interfacing can be simplified to a simple three wire plus earth connection.

A simple analogue-to-digital converter circuit using this chip is shown in Fig.1. The full-scale value is equal to the supply voltage, so this should be a highly stable and well smoothed 5V supply. In this simple test circuit a variable input voltage is provided by potentiometer VR1. Note that with a "real world" potentiometer something slightly less than the full range of input values might be provided.

In order to start a conversion, pin 7 of IC1 is pulsed low. Pin 8 is then monitored, and the conversion has been completed when this output returns to the low state.

Alternatively, the software can provide a hold-off for at least eight microseconds to enable the conversion to be completed. Pin 8 can then be left unconnected. The first bit (the most significant bit) can then be read from pin 5.

In order to read the next bit a clock pulse is first supplied to pin 4, and the new bit of data can then be read from pin 5. Another pulse is supplied to pin 4, pin 5 is read again, and so on until all 16 bits have been read. Note though, that the first four bits are always at zero, and that the converter only provides 12 valid bits of data. Some simple software is all that is needed in order to reassemble the 12-bits of data and produce the reading from the converter.

Noise Abatement

Noise is not usually a problem with 8-bit converters, as they do not have very high resolution. It is much more likely to be a problem with a 12-bit converter, which has some 16 times the resolution of an 8-bit equivalent. With 12-bit resolution and a full-scale value of 5V, in voltage terms the resolution is only about 1·2 millivolts.

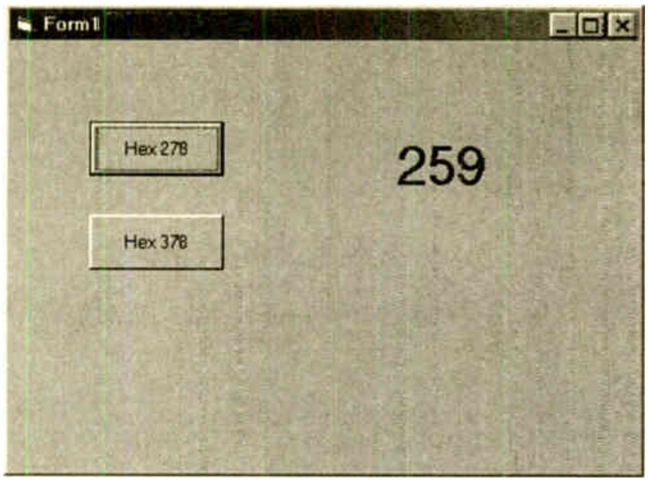


Fig.2. Screen view of the 10-bit A/D converter program in operation.

While this may not seem to be particularly high, in an environment that has a lot of digital noise from the PC, etc., it can give problems with slightly unstable readings. Placing your hand near to the converter chip is usually sufficient to produce some wayward readings. Those who can remember the *BBC Model B* computer will no doubt recall the problems with its 12-bit analogue-to-digital converter.

In order to keep noise problems to a minimum keep digital signals well separated from the analogue circuitry and the converter chip itself. Obviously the cable to the PC must connect to the converter chip, but avoid having the cable pass over the top of the chip or the input circuitry.

Having an excessively long cable curled up inside the interface's case is definitely inviting problems. Monitors tend to produce substantial amounts of electrical noise, so try to position the interface well away from the monitor or any likely source of electrical noise.

Using a mains power supply unit for the interface circuit can introduce problems with "hum" loops. Ideally, the interface should be powered from the PC or from a battery. Connecting the interface to the PC via a high-speed opto-isolator circuit is one of the best ways of avoiding noise problems, but it can be awkward and expensive to implement in practice.

Powering the interface from a "battery eliminator" that has a regulated 5V output is likely to be the easiest solution. Power supplies of this type invariably use double insulation and no mains earth connection, which eliminates the possibility of earth loops.

Reduced Resolution

Bear in mind that it is not mandatory to use the full 12-bit resolution. Using 10-bit operation gives a rough equivalent to a conventional three and a half digit readout, as used on most digital multimeters. Therefore, 10-bit resolution is perfectly adequate for most purposes, and is much less likely to give problems with wobbly readings.

The effective resolution is governed by the software. Part of the listing for a program that has been modified to provide 10-bit operation is shown in Listing 1. The program operates in the same basic fashion as the converter programs featured in previous *Interface* articles, so an explanation of the complete program will not be provided here.

This section of the program reads in the first bit and increments the variable Reading by 512 if it is high, or by 0 if it is low. Normally a value of 2048 would be added if this bit was high. The lower value used here reflects the fact that this bit is effectively bit 9 rather than bit 11.

Next another clock pulse is generated and the next bit is read. This time the variable is incremented by 256 or 0 depending on whether the bit is high or low. This process continues until all 10 bits have been read. The final two bits are then clocked out of the chip, but 0 is added to Reading whether these bits are high or low, effectively removing them.

This method reduces the resolution to 10 bits, but leaves the full-scale value at 5V. Note that removing the two most significant bits would reduce the full-scale value to 1·25 volts and would not ease any noise problems. With any digital system there will be "jitter" when the input is close to the changeover level from one reading to the next. If a reading alternates between (say) 768 and 769, this is just the result of a random element in the system and is not a noise problem.

The program's buttons (Fig.2) enable the appropriate base address for the printer port to be selected. The program will not start to take readings until one of the buttons has been operated. As usual, the compiled version of the program plus all the support files are available in the *Interface* folder on the *EPE* ftp site:

ftp://ftp.epemag.wimborne.co.uk.

LISTING 1

```
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = 512 Else
  Reading = 0
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading +
  256
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading +
  128
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 64
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 32
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 16
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 8
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 4
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 2
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 1
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 0
Out Port3, 0
Call Delay
Out Port3, 1
Call Delay
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 0
Label1.Caption = Reading
```

Constructional Project

PIC POLYWHATSIT

JOHN BECKER

A novel compendium of musical effects to delight the creative musician!

WHAT'S in a name? Well, in this case, *Polywhatsit* was the title given by the author to a similar musical multi-effects unit published in *Practical Electronics* in May-June 1987. As he commented at that time, the effects are so unusual and varied that there really is no other descriptive name that could be given!

So, what *does* a PIC Polywhatsit do? Well, using just seven integrated circuits instead of the previous 17, it provides a compendium of some of the typical delay-based musical effects that amateur musicians have delighted in employing across many decades:

- ***Echo***
- ***Reverberation***
- ***Delay***
- ***Double-tracking***
- ***Phasing***
- ***Flanging***
- ***Chorus***
- ***Vibrato***
- ***Pitch multiplying***
- ***Pitch halving***
- ***Reverse tracking***

Despite the sophistication of modern musical instruments available from major manufacturers such as Korg, Roland, Yamaha and their likes, amateur musicians continue to enjoy enhancing their instrument playing and vocalisations with all the first eight functions, especially as they can be realised comparatively simply 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 PIC-microcontrolled design described here.

Whilst the design cannot be termed hi-fi in the purist sense, it is remarkably good with its quality considering that it is software controlled, although pitch changing and reverse tracking should only be regarded as novelties.

CONCEPTS

The majority of delay-based musical effects rely on splitting the original signal into two paths. One path remains unmodified, while the second path is subjected to varying degrees of delay and proportional feedback. The processed signal is usually, but not always, recombined with the unprocessed path to produce a composite output signal.

When the author first entered the musical effects field in the early 1970's, delays were introduced by the use of spring line reverberation units, but were typically of only a few milliseconds duration. The subsequent introduction of charge-coupled devices (CCDs) allowed delays of several hundredths of a second to be created using integrated circuits.

The advent of inexpensive analogue-digital-analogue converters (ADCs and DACs) and memory chips extended the delays that could be introduced to a few tenths of a second, limited only by the size of memory and the rate of conversion. Until the ready availability of microprocessors, though, the entire control of the sampling, storing and recall had to rely purely on standard digital logic devices, resulting in a high chip count.

The introduction of microcontrollers, such as PICs, has changed that situation. Indeed, the basic control of the PIC Polywhatsit could in principle be accomplished just by a single PIC16F877, using its internal ADC and memory, plus a separate DAC device.

However, none of the current PIC family have sufficient memory to allow delays of any respectable length to be created. Consequently, a larger external memory chip is used as well. Delays from practically zero up to about 0·9 seconds are available with a sampling rate of around 18kHz.

The full circuit diagram for the delay creating stage is shown in Fig.1.

CONTROL ASPECTS

In Fig.1, the PIC16F877 is notated as IC1. It is operated at its maximum possible rate of 20MHz, as set by crystal X1.

The signal to be processed is fed to the first of the PIC's ADC inputs, at RA0. The signal is repeatedly sampled, and its digital conversion value is output via Port D to the 32K (kilobyte) memory IC2, at addresses set by Ports B and C. Port D data lines are also fed to the latching DAC device, IC3.

During data storage, memory chip IC2 is set for input mode with its Output Enable ($\overline{OE}$) pin set high and its Write Enable ($\overline{WE}$) pin set low, controlled respectively by PIC pins RA5 and RA4. The latter, being an open-collector output, is normally biassed high via resistor R3. On completion of the data-write, $\overline{WE}$ is returned high.

While memory data is being written, DAC IC3 is held in latched output mode via its Write pin ($\overline{WR}$), controlled by RC7, and ignores the Port D data on its inputs. The data output from IC3 pin 15 is that previously latched into the DAC.

On completion of each individual data storage action, a memory-write counter within the PIC is incremented and Port D is set into high-impedance mode. The PIC then selects a memory-recall address counter value and sets that on the memory's address lines. The $\overline{OE}$ pin is then taken low so that the memory outputs the data stored at that address.

Port D is unaffected by the data, but DAC IC3 responds to it immediately the

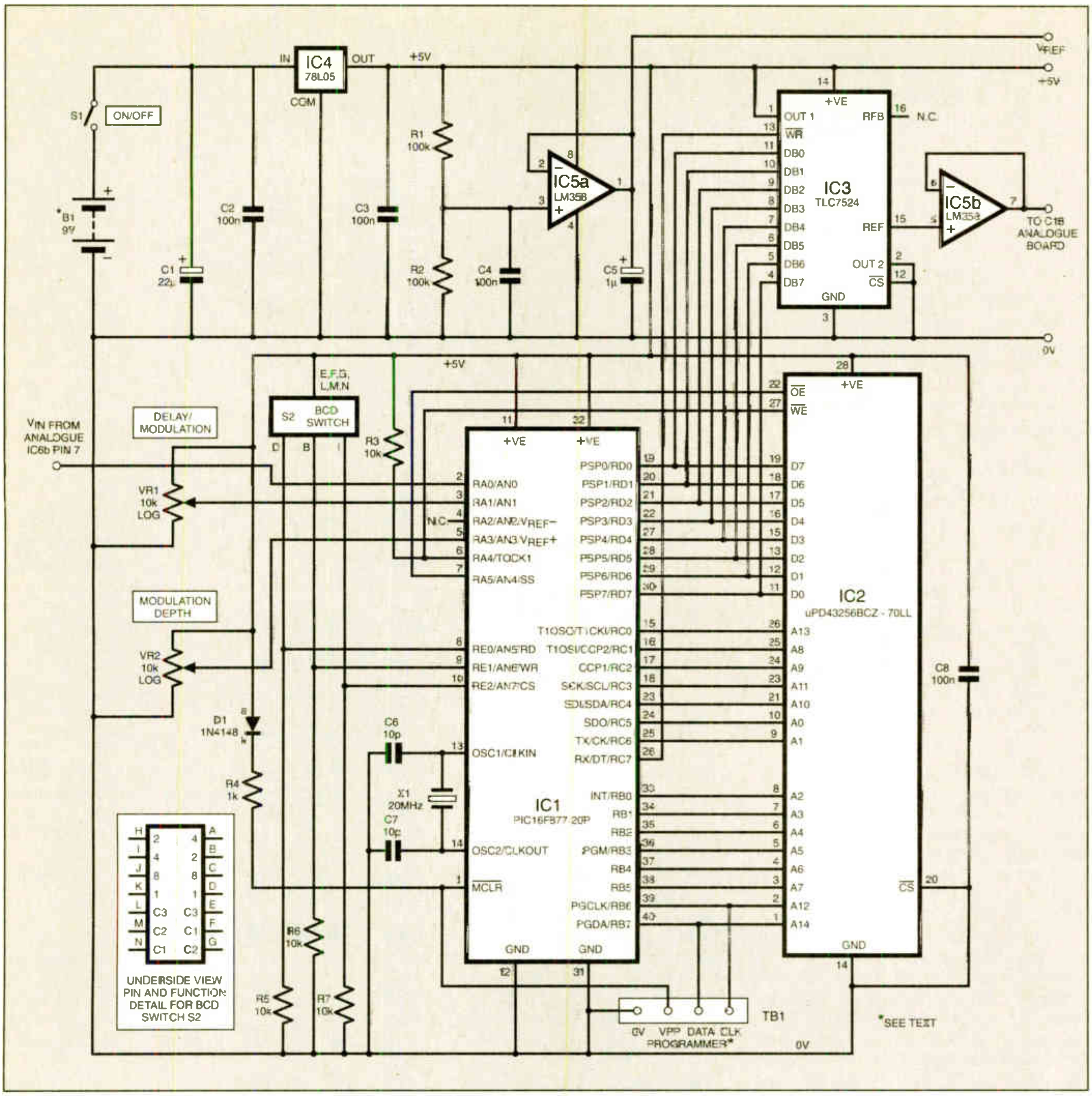


Fig.1. Complete circuit diagram for the PIC Polywhatsit controller.

PIC takes the $\overline{WR}$ pin low. This action latches the memory data into the DAC, which outputs the analogue equivalent via pin 15 to the op.amp buffer IC5b (pin 5).

The memory-recall address counter is then updated to an address that depends on the mode in which the PIC is operating, after which the PIC reverts to ADC sampling mode and the cycle repeats.

PIC MODES

There are seven sampling/recall modes that the PIC can be set to control, selected by binary-coded-decimal (BCD) switch S2. The selected 3-bit BCD value is monitored via PIC Port E, with its inputs biassed normally-low via resistors R5 to R7. The pole of switch S2 is biassed to the positive rail.

Any value between 0 and 7 can be selected via S2, representing Modes 1 to 8, as follows:

1. Echo/reverb/double-tracking
2. Phasing/flanging
3. Chorus/vibrato
4. Pitch halving
5. Reverse tracking
6. Pitch doubling
7. Pitch tripling
8. Same as Mode 1

Note that the photograph of the prototype shows only seven switch positions notated. The pitch tripling was added only as an afterthought following case completion.

Two panel mounted potentiometers also control the PIC's behaviour. VR1 sets the delay between a sample being stored and its subsequent recall. It also controls the rate of delay modulation when the mode requires it. It is not used during pitch variation and reverse tracking. VR2 sets the depth of modulation when required, but otherwise has no function.

The PIC monitors both pots in respect of the voltage set on their wipers, as detected by pins RA1 and RA3 operating in ADC input mode.

In the prototype the processed signal frequency range is from about 200Hz to in excess of 6kHz. The non-processed signal frequency maximum is around 18kHz. In Mode 1, the delay range is changeable between about 0·15ms and 900ms.

POWER SUPPLY

The design is intended to be run from a 9V d.c. supply, such as a battery. It may, though, be operated from any d.c. supply between about 7V and 15V. Regulator IC4 reduces the input supply to a well-stabilised 5V d.c., the maximum acceptable to IC1, IC2 and IC3.

Op.amp IC5a is used in buffer mode, outputting a mid-rail (2·5V d.c.) bias voltage, set by resistors R1 and R2, as required by the analogue processing stage to be described next.

ANALOGUE CIRCUIT

The circuit diagram for the analogue pre- and post-processing stages is shown

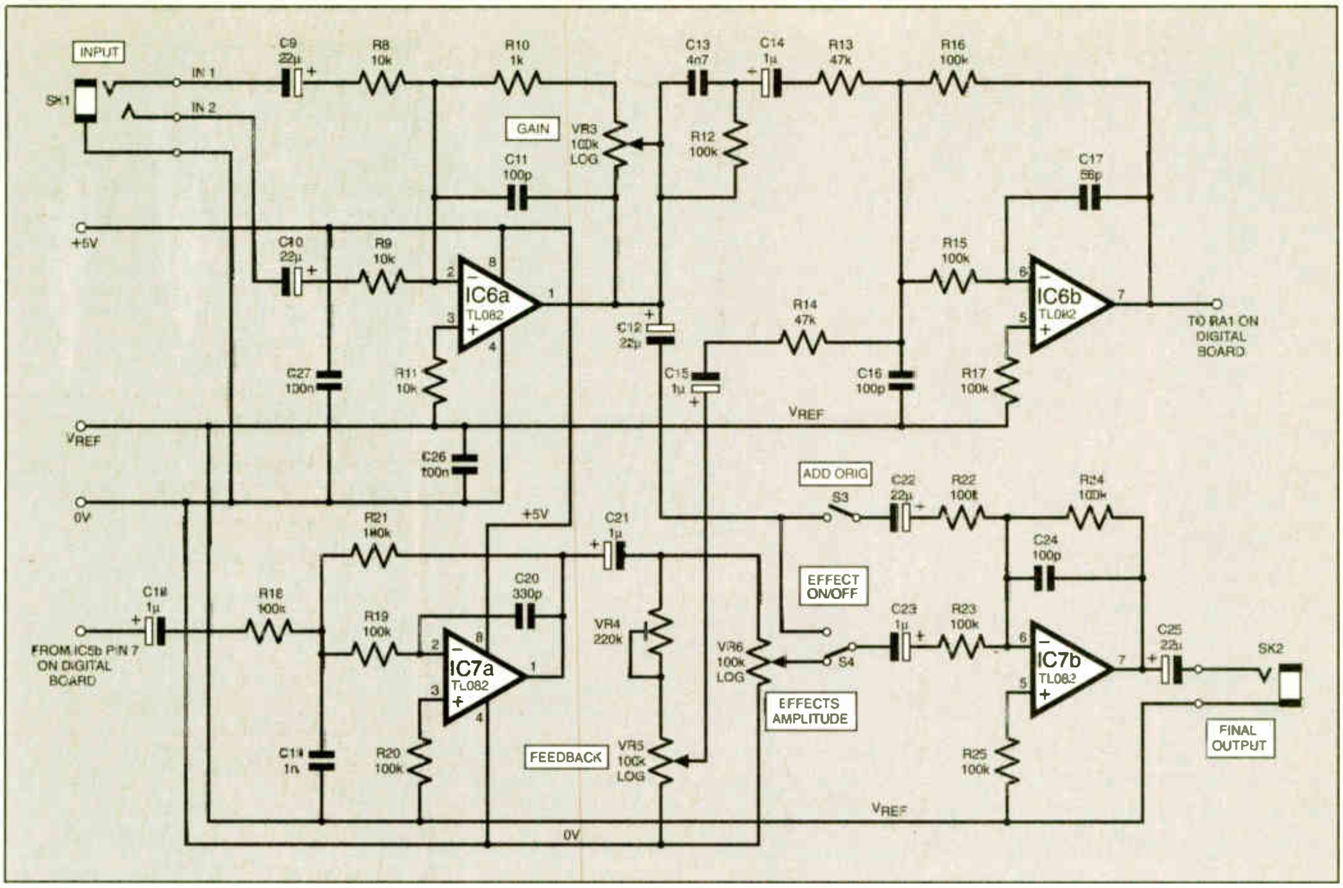


Fig.2. Analogue circuits that control signal amplitude, feedback and mixing.

in Fig.2. These stages are concerned with controlling the level of the basic input signal, its output to the digital processing stage in Fig.1, positive feedback to the delay stage following the processing, and final mixing of the signals prior to outputting to any normal preamplifier or power amplifier.

Two signal inputs have been included, allowing for stereo input signals if required, although the prototype only uses a mono input. The signals are input via capacitors C9/C10 and resistors R8/R9 to the mixer and gain setting stage around IC6a. Here the signal gain can be set by potentiometer VR3 to between ×0·1 and ×10.

From IC6a pin 1, the signal is routed in two directions. One path takes it via capacitor C12 and switch S3 to the mixer and unity-gain output stage around IC7b. This path allows the unprocessed aspect of the signal to be switched on or off by S3 according to the effect you wish to achieve.

The other path prepares the input signal for processing via the digital circuit in Fig.1. Upper input frequencies are given a slight amount of pre-emphasis by the combination of resistor R12 and capacitor C13. This helps to partly compensate for later low-pass filtering after the digital processing.

The stage around IC6b prepares the signal for entry to the digital sampling stage via IC1 pin RA0 (Fig.1). Capacitors C16 and C17 limiting the upper frequencies that can be processed.

IC6b is also configured to mix pre- and post-processed signals, allowing the positive signal feedback required for some of the effects.

Following sample processing, the output from the DAC buffer IC5b (Fig.1) is returned to the analogue board and the filter stage around IC7a. This stage helps to "smooth" the inevitable steps generated during sampling.

This processed signal is itself routed in two directions. One path is via the potentiometer chain VR4 and VR5, which sets the amount of processed signal which is to be fed back to the sampling stage via mixer IC6b. Preset VR4 sets the maximum signal level that can be fed back without "howl" occurring. Potentiometer VR5 is a panel mounted control that varies the feedback from nil to the maximum set by VR4.

The second path is via potentiometer VR6, which varies the level of processed signal sent to the output mixer IC7b via switch S4. This switch ensures that IC7b always receives a signal, either the "original" or the processed one. Capacitor C24 provides a final amount of upper frequency limiting to help smooth the sampled waveform.

PROGRAMMING AND SOFTWARE

In common with all the author's recent PIC designs, the ability to program the PIC from within the circuit is provided by pin-header connector TB1 (connections as shown in Fig.1). The pins are in the author's usual order and are suited for use with *EPE* PIC programmers *Toolkit Mk2* and *Mk3 (TK3)*.

Diode D1 and resistor R4 permit correct functioning of the PIC's $\overline{\text{MCLR}}$ pin during programming and operational modes.

The software is available as stated on the *EPE PCB Service* page. Three files are provided, the original source code (ASM – written in TASM), and a choice of assembled code in OBJ (TASM) and HEX (MPASM) formats.

Configuration settings needed are WDT off, POR on, HS crystal. This is embedded in the MPASM HEX code (h'3F32'), but TASM OBJ users must set it separately in the usual way.

Pre-programmed PICs are available as stated on this month's *Shoptalk* page.

CONSTRUCTION

The Polywhatsit circuit is assembled on two printed circuit boards (p.c.b.s), one for the digital circuit, the other for the main analogue stages. These boards are available as a set from the *EPE PCB Service*, codes 328 (Digital) and 329 (Analogue).

Component layout and tracking details for the boards are shown in Fig.3 and Fig.4.

Assemble the boards in order of component size, starting with the link wires. These are best made using 22 s.w.g. tinned copper wire. Providing the links are kept reasonably straight and taut, they do not need insulating.

Sockets should be used for all d.i.l. (dual-in-line) i.c.s, but do not insert these i.c.s until the correctness of the power supply has been established. Ensure the correct orientation of the electrolytic capacitors and semiconductors.

The prototype is housed in a metal case measuring approximately 230mm × 133mm × 64mm. Signal input and output jack sockets (SK1 and SK2) are mounted on the rear. The panel mounting potentiometers and BCD switch S2 are spaced at 35mm centres and the toggle switches are mounted between the controls at about 15mm above them.

Sockets SK1 and SK2 in the prototype are 6·35mm types but may be changed to suit the equipment with which Polywhatsit is to be used.

COMPONENTS

Resistors

R1, R2, R12, R15 to R25	100k (14 off)	See SHOP TALK page
R3, R5 to R9, R11	10k (7 off)	
R4, R10	1k (2 off)	
R13, R14	47k (2 off)	

Potentiometers

VR1, VR2	10k log, rotary (2 off)
VR3, VR5, VR6	100k log, rotary (3 off)
VR4	220k min. preset, round

Capacitors

C1, C9, C10, C12, C22, C25	22µ radial elect. 16V (6 off)
C2 to C4, C8	100n ceramic, 5mm pitch (4 off)
C5, C14, C15, C18, C21, C23	1µ radial elect. 16V (6 off)
C6, C7	10p ceramic, 5mm pitch (2 off)
C11, C16, C24	100p ceramic, 5mm pitch (3 off)
C13	4n7 ceramic, 5mm pitch
C17	56p ceramic, 5mm pitch
C19	1n ceramic, 5mm pitch
C20	330p ceramic, 5mm pitch

Semiconductors

D1	1N4148 signal diode
IC1	PIC16F877-20 microcontroller, pre-programmed (see text)
IC2	µPD43256BCZ-70LL 32-kilobyte memory (SRAM)
IC3	TLC7524 latching digital-to-analogue converter
IC4	78L05 +5V 100mA voltage regulator
IC5	LM358 dual bipolar op.amp.
IC6, IC7	TL082 dual FET op.amp (2 off)

Miscellaneous

S1, S3	min. s.p.s.t. (or s.p.d.t.) toggle switch (2 off)
S2	BCD rotary switch
S4	min. s.p.d.t. toggle switch
SK1	mono or stereo jack socket, 6·35mm (see text)
SK2	mono jack socket, 6·35mm (see text)
X1	20MHz crystal
TB1	4-way pin-header (see text)

Printed circuit boards, available from the *EPE PCB Service*, codes 328 (Digital) and 329 (Analogue); metal case 230mm x 133mm x 64mm; knobs (6 off); p.c.b. self adhesive supports (8 off); 8-pin d.i.l. socket (3 off); 16-pin d.i.l. socket; 28-pin d.i.l socket; 40-pin d.i.l. socket; self adhesive case feet; 9V battery clip or external power input socket (see text); connecting wire; solder, etc.

Approx. Cost Guidance Only **£39** *excluding case*

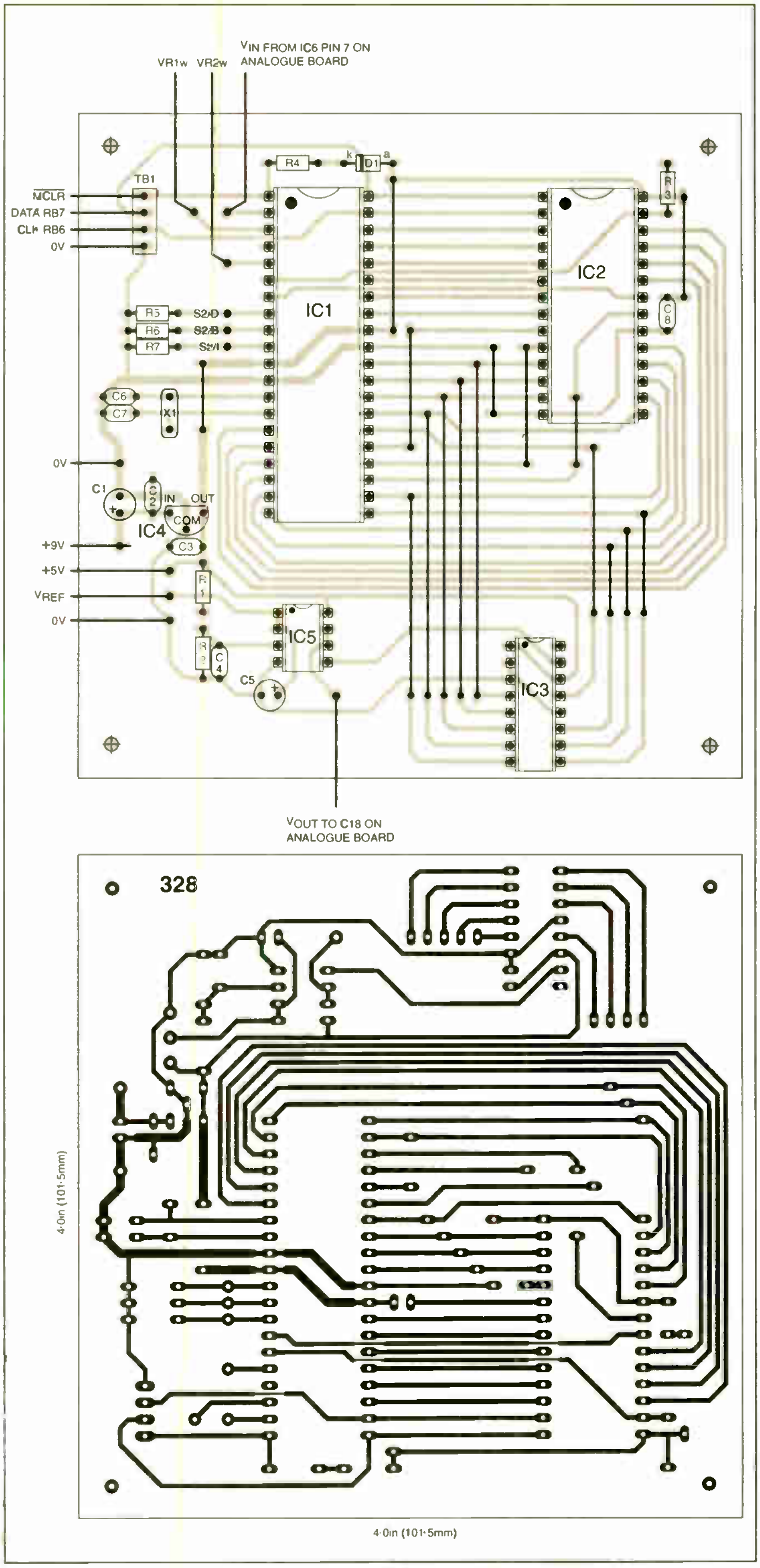


Fig.3. Component layout and full-size underside copper foil track master pattern for the digital board.

If the unit is to be used with an external d.c. power supply rather than an internal battery, a suitable input connector will be required.

The p.c.b.s were secured to the base using self-adhesive p.c.b. supports.

Interwiring details are shown in Fig.5. Following assembly and full checking for its accuracy and satisfactory soldering, connect power to the unit and check that +5V appears at the output of regulator IC4. Only once this has been established should

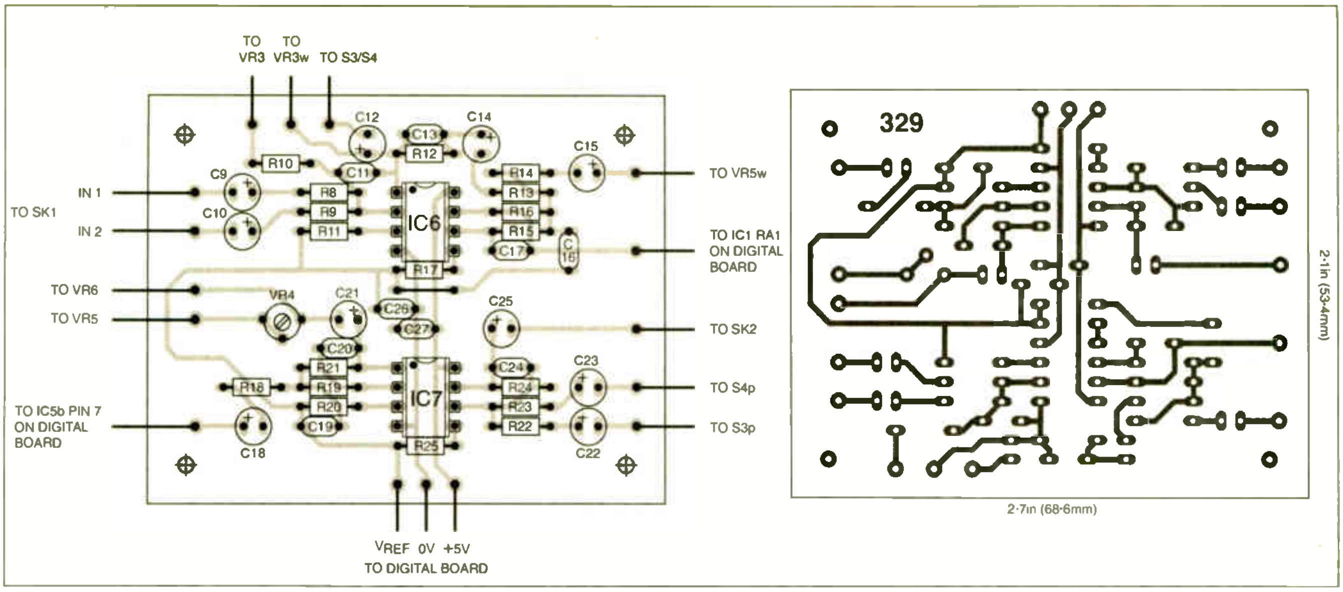


Fig.4. Component layout and full-size underside copper foil track master pattern for the analogue board.

the d.i.l. i.c.s be inserted (observe usual anti-static precautions), and the unit put to musical use.

The only setting-up required is adjustment of preset VR4 to prevent signal howl when the feedback potentiometer, VR5, is set for maximum level. This adjustment can be done by trial and error while the unit is in "active service". Start off with VR4 and VR5 set for maximum signal level.

If howl occurs, sharply reduce VR5 and start again. Aim for the closest possible to the howl point. Howl is more likely to occur with strong bass notes.

SAMPLE RECALL TECHNIQUES

The storing of each digitised sample is done in strictly consecutive numerical order from 0 to 32767, then rolling over to 0 and repeating indefinitely.

There are several ways in which the stored digital samples are recalled from memory and converted back to an analogue signal, depending on the mode selected by switch S2:

● Static Delay

In the static delay modes (echo, reverb and double-tracking), sample recall is in the same order as stored, but with a displacement value subtracted from the current store address. Thus by subtracting a value of one from the storage count would result, for example, in storing at 128 and recalling from 127 to give a delay to the signal of one sample period.

At the other extreme, subtracting 32767 from the storage count would result in storage at 127 and recall from 128, the latter being the storage address 32767 samples ago.

In static delay modes the 10-bit ADC value of the voltage at the wiper of potentiometer VR1 is multiplied by 32 ($(2^{10} = 1K) \times 32 = 32K$) and subtracted from the storage address counter value to become the recall displacement.

● Modulation Effects

In modulation effects such as chorus, vibrato, phasing and flanging, the relationship between the sample and recall addresses is constantly and smoothly varied by software between short and long displacements.

The basic rate at which the displacement is changed is slow for phasing and flanging, but faster for chorus and vibrato. Variation of the rate of change is set by VR1. The range of displacement (modulation depth) depends on the setting of VR2.

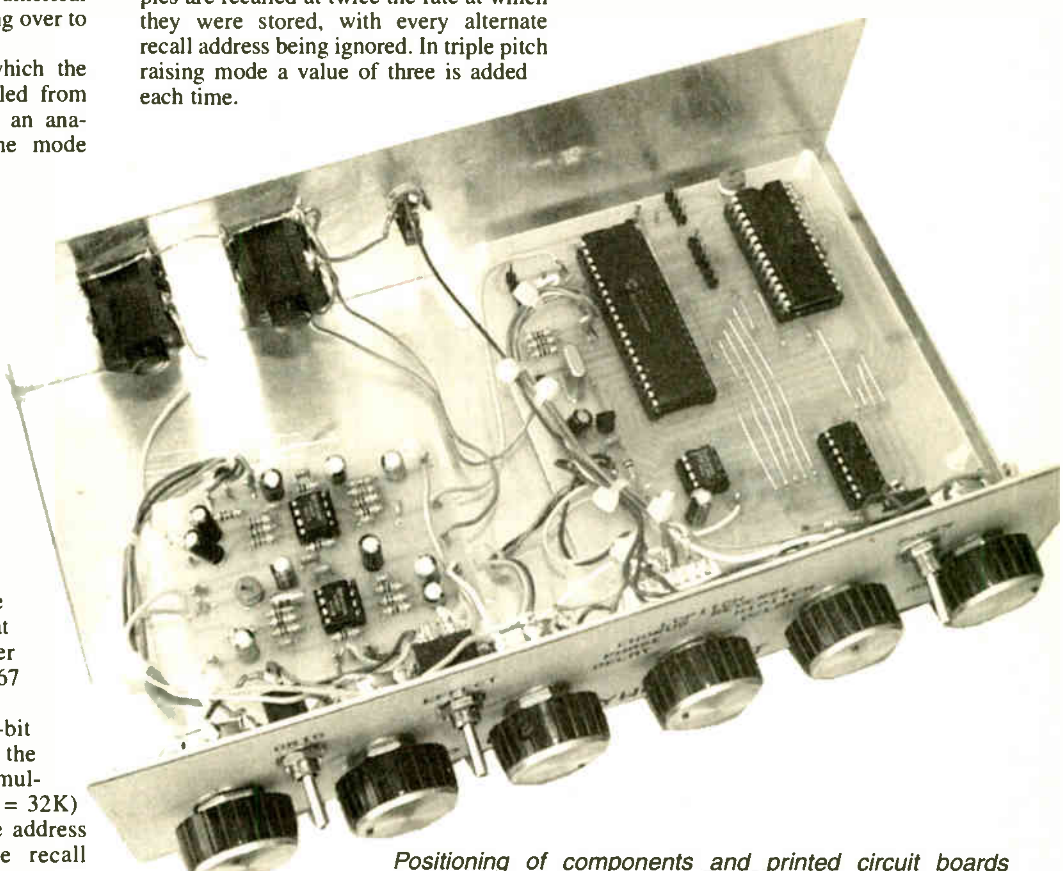
● Octave Raising

In octave raising, recall addresses are increased by two for each increment of the storage counter, which means that the samples are recalled at twice the rate at which they were stored, with every alternate recall address being ignored. In triple pitch raising mode a value of three is added each time.

Eventually, of course, the recall counter catches up and passes the storage counter, at which point the previous set of samples is again recalled. Whilst in deluxe hi-fi situations this technique would be limited in its appeal, in many less-conventional music making applications it can be extremely effective in thoroughly changing the pitch of an instrument or voice (Donald Duck and scuba divers on helium come to mind!).

● Pitch Halving

In octave halving, the recall address counter is incremented once for every two increments of the storage counter. As with pitch increasing, the technique



Positioning of components and printed circuit boards inside the prototype model of the PIC Polywhatsit.

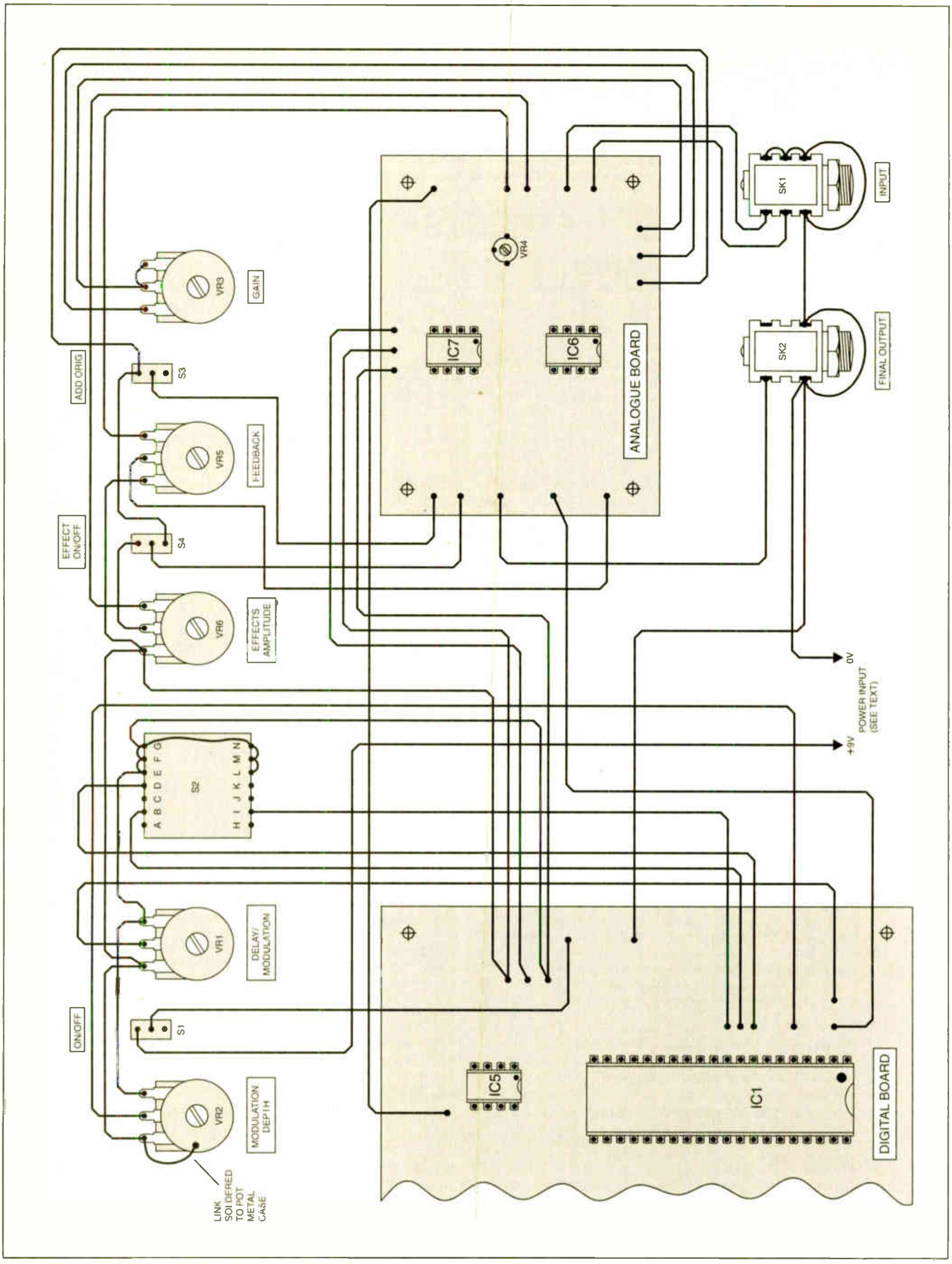


Fig.5. Interwiring details for the PIC Polywhatsit.

also means that storage and recall addresses overtake each other with consequent sample loss. But again the result can have its applications when novelty music or vocal effects are felt to be appropriate!

● **Reverse Tracking**

The previous comment also applies to reverse tracking, in trumps for vocals! The effect is achieved by *decrementing* the replay counter each time the storage counter is incremented. Once more storage and recall addresses periodically pass each other with consequential sample loss.

Whilst instrumental music does not necessarily always show that reverse tracking is in use, the effect is particularly pronounced (and humorous) with speech!

DELAY OSCILLOGRAMS

The varying delay relationships of the Polywhatsit can be easily seen on an oscilloscope. Those shown in Fig.6 were created using the author's *PIC Dual-Channel Virtual Scope* of October 2000. In each case the upper trace shows the original signal and the lower shows the processed one.

IN USE

There are no restrictions to the type of signal fed into Polywhatsit provided that the music lends itself to enhancement within the factors discussed.

A variety of signal sources can be used, from high-output microphones and electric guitars, to line output signals from preamps and synthesizers. Polywhatsit is well-suited for use with amplifiers having echo-send-return facilities.

Ideally, to make reasonable use of the PIC's ADC range, the signal amplitude reaching it (IC1 pin RA0) should be at around 1V to 2V peak-to-peak, although levels well to either side of this produce very acceptable results. The maximum output swings for both the processed and final mixed signals are about 3V peak-to-peak.

PANEL 1. EFFECTS GLOSSARY

REVERBERATION AND ECHO

Artificial reverberation is an extremely useful sound effect that can be used to compensate for the loss of natural reverberation brought about by the use of close-microphone recording techniques. It can be used to restore the spacious quality that is characteristic of concert hall performances, and to give extra dimensions to the sounds produced by electronic instruments.

Echo is a similar effect to reverb but the term really refers to the successive attenuating repetition of a particular sound by reflection, as when shouting across a courtyard or valley, for instance.

In electronic units both effects are created using preset fixed delays, unlike several other effects in which the delay is kept constantly changing. Reverb delays are normally short, typically just milliseconds, whereas echo uses much longer delays, measured in hundredths or tenths of a second.

With both effects a proportion of the delayed signal is always fed back on itself so that sound phrases repeat, but at successively lower levels until they decay away. Too much signal feedback can cause the circuit to go into oscillation, resulting in the "howl" typical of incautious use of microphones with public address systems.

Electronic reverb units have largely replaced mechanical spring line units which, although useful, suffer from susceptibility to external sounds and vibration.

DOUBLE TRACKING

For double-tracking, feedback is not used. The processed path is simply given a short delay and then mixed with the original. The effect is more apparent with staccato sounds rather than mellow drawn-out notes.

PHASING

The phasing effect can be loosely described as an "atmospheric whooshing" sound. The delay within the processing channel is subjected to a constant slow variation between short and long. The delayed signal is then mixed with the original.

During the mixing, at certain signal frequencies depending on the delay introduced, when two equal amplitude signals are in anti-phase they cancel each other, but when they are in phase the total output amplitude is doubled. As the delay period changes so does the phase relationship, and the phasing effect heard.

The most noticeable change is apparent with signals having a high harmonic content. Slightly clipped signals can produce good phasing effects as the "corners" of the clipped waveforms "slide over" each other. In more sophisticated units, modulated voltage controlled filters can be used to emphasise the effect at selected signal frequencies (Polywhatsit does not have this facility).

In most instances a slowly changing delay rate, possibly over several seconds, normally produces the most noticeable phasing effect.

FLANGING

Essentially, flanging is phasing with reverb. It has similar feedback qualities to straight reverb, though with greater resonance, and at the same time consists of a slowly modulated phase change relationship both to itself and to the original signal. It produces a strong tunnel-like effect with an accentuated upper frequency pitch change and under some conditions of speech or singing, this can sound like an eerie additional background voice accompanying the performer.

The amount of feedback is critical. If too much is given, the signal level will increase each time round the loop, resulting in perpetual howl. If too little feedback is given, the flanging effect does not develop. The correct amount lies within a narrow band, so that the maximum enhancement results without howl.

At the correct settings, the phase and pitch changes of the feedback loop result in repeated emphasis and de-emphasis of particular frequencies and their harmonics.

The most noticeable flanging effect is created with higher frequencies having a high harmonic content, with short delay times modulated at a slow rate. Although the effect is still produced with purer or lower frequency tones, it is less noticeable to the ear.

Paradoxically, a very pronounced different effect is produced by fast modulation with deep sweeping delay changes. Music then loses its tonal qualities and takes on a very deep whooshing effect which, although unmusical, can be used for dramatic sound changes.

CHORUS

Basically, chorus is the sound produced by two or more performers singing or playing identical music. Naturally none of the performers, however professional, will be precisely in identical pitch, amplitude or synchronisation with the others, and consequently the sound will be characteristically fuller.

Electronic simulation of the chorus effect is done here by again splitting the music into two channels, with a variable time delay on one of them. By varying the amount of delay at a moderately fast rate, the relationship of the delayed signal to the original can be kept constantly shifting.

In addition to the delay changes, pitch changes also occur. Normally, the time of each cycle within a musical tone remains constant. If the time between the cycles is varied by introducing a changing delay then by definition the note is no longer the same. In effect the doppler shift principle often associated with approaching or receding sirens is being introduced.

As the distance between the cycles shortens so the pitch increases, and vice versa. Thus in a modulated chorus unit not only is the synchronisation between the original and processed sounds changing, but also the frequency relationship, just as occurs with natural chorus. It will also be apparent that if pitch is being constantly varied, then vibrato is also occurring.

When the processed and original signals are recombined, an enhanced and fuller sound is created.

VIBRATO

Only the processed signal is used to create vibrato effects. The signal is fed back upon itself and subjected to moderately fast changing delay rates. This results in modulated shifts in the signal frequency.

Vibrato is not the same as tremolo, in which it is the signal *amplitude* level that is modulated, not its frequency.

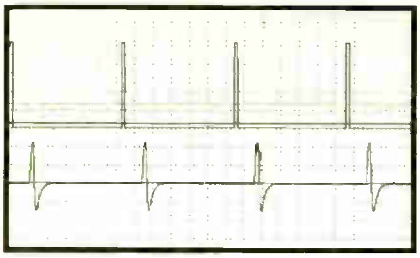
MODULATION VALUES

There is an optimum chorus and vibrato modulation rate that produces the most interesting and satisfying results. If too slow a rate is given, the effects tend to sound similar to a wowing record deck due to the pitch change. Too fast a modulation rate will either produce delay changes too fast to be noticed or, at its worst, will have a frequency that is within the audio spectrum, and which will be heard as a low hum.

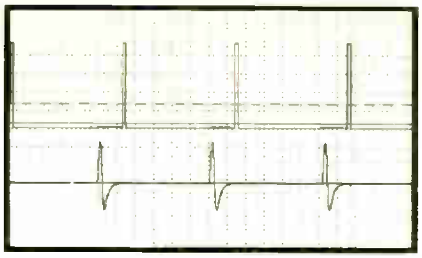
The generally accepted ideal modulation rate for chorus and vibrato is about 6·5Hz. Furthermore, analysis of the recordings of professional musicians shows a strong tendency towards a maximum *depth* of pitch change of about a quarter to half a tone of the original frequency.

Using electronic delay techniques, the degree of pitch change will only be the same for identical frequencies. Other frequencies present at the same time will be subjected to greater or lesser degrees of pitch change. Thus for a composite signal passing through a simple electronic unit, true vibrato can only be approximated.

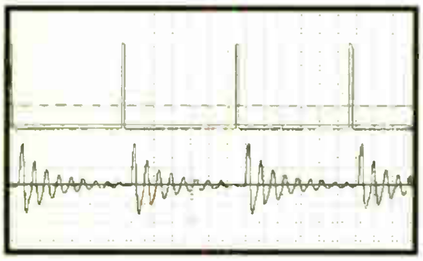
Fig.6. A selection of screen dumps recorded using PIC Polywhatsit, a signal generator. PIC Dual-Chan Virtual Scope (Oct '00) and a PC. Upper trace is original, lower trace is waveform after processing.



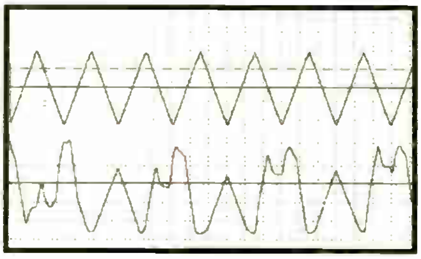
Short delay.



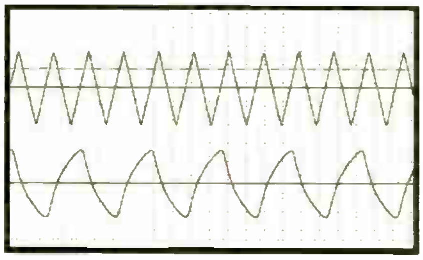
Long delay.



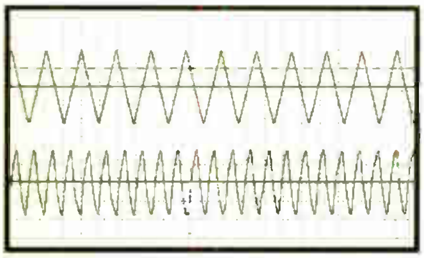
Short delay with a little reverb.



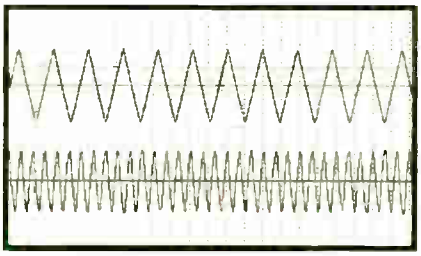
Chorus.



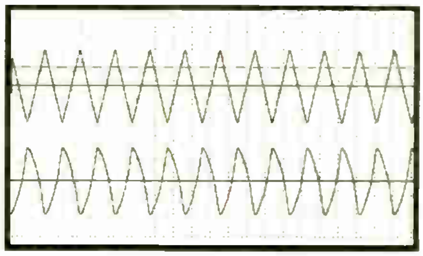
Pitch halving.



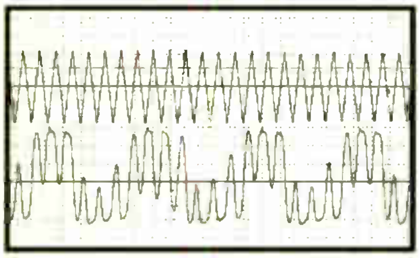
Pitch doubling.



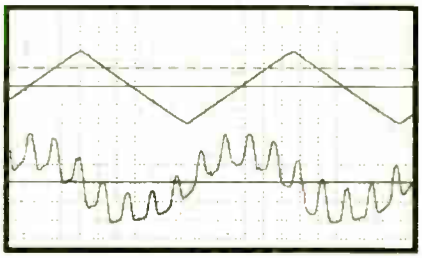
Pitch tripling.



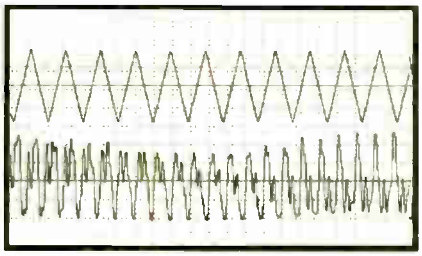
Reverse tracking.



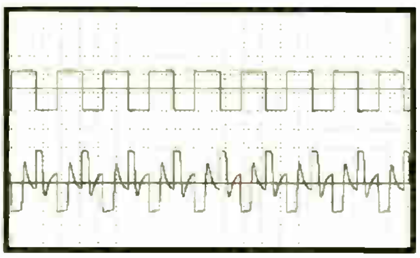
Reverb, short delay.



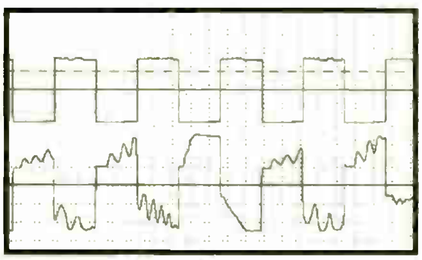
Heavy reverb.



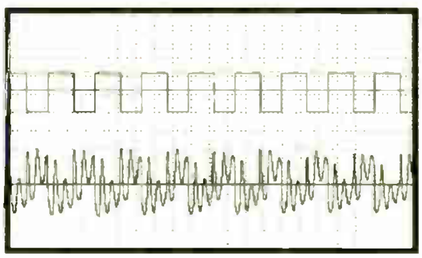
Pitch doubling with reverb.



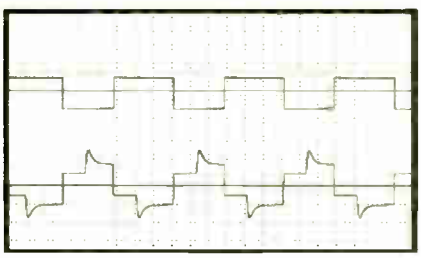
Phasing.



Phasing with reverb.



Flanging.



During double-tracking.

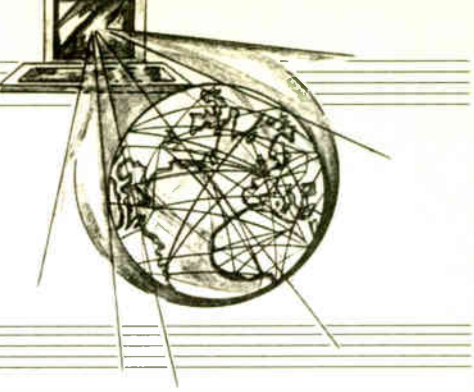
When inputting signals remember that the processed and unprocessed signals have their amplitudes added when mixed,

It will soon become obvious which type of music requires which particular control setting for the best effect. This is a matter of personal preference, but the author feels that as with any effects unit, *moderation* is the keyword. Certainly overemphasis of an effect is dramatic, but it is easier to become tired of an over-dramatic effect than one which produces a discrete change.

In general terms, music having a high harmonic content, but otherwise of a simple nature, will benefit most. Mellow or full orchestral sounds will not show the same degree of change. In the first case there is insufficient harmonic information available in the signal for the effect to fully develop. In the second case, the sound is already so full that the effect will probably be lost unless the original sound is full of spiky waveforms.

The harsher sounds of voices, drums, synthesizers and organs can produce good effects. Pure sine tones and muted waveforms, especially in the lower octaves, will be less affected by processing. □

SURFING THE INTERNET



NET WORK

ALAN WINSTANLEY

Anyone for Shopping?

ONE of the author's customers tells the story of his friend, an Internet neophyte who found a web site for a car import/sales business apparently based in Ireland. The company claimed to offer discounts on cars imported from Europe. His friend was tempted enough to pay £10,000 ($14,500) as a deposit on a new BMW saloon. Needless to say, the web site closed down a few days later and there has been no trace of the car trader – or the £10,000.

Fortunately for the rest of us, online shopping is usually less traumatic and involves more modest sums of money! Used sensibly and with some experience, Internet access can prove a boon when you are feeling "shoppy" (as Google's online store dubs the process of retail therapy).

Indeed, over the past few weeks, online ordering really came into its own from the author's point of view: for starters, the author needed a replacement CD writer – a wonderful Plextor unit bought online from a small specialist company with a modest Internet presence (**www.121cdr.co.uk**). Other recommendations I received meant I felt confident about placing an order online.

Bedtime Shopping

Then the author's flatbed scanner had to be replaced suddenly – his second HP Scanjet to fail – so the time was ripe to shop around. Before taking a decision, it's wise to check manufacturers' web sites to compare current models, specifications and dimensions, then draw up a short list. Read any FAQ and Support pages to assess potential problems before you buy.

Some confident users may also scan through Usenet archives – search Google Groups to see whether any real-life users have voiced any complaints. Look for independent online reviews of products as well. Check the ratings at **www.dooyoo.co.uk** for general consumer feedback.

Locating a supplier on the Internet is relatively easy once you know where to look, and whether it's coffee or computers you need, it becomes a habit to buy online from your preferred supplier. Suggested suppliers of computers and accessories include Simply Computers, (**www.simply.co.uk**), Dabs Direct (**www.dabs.com**) and Inmac (**www.inmac.co.uk**), all of whom have online shopping cart systems.

Using Internet Explorer, it is easy to compare prices amongst online sellers – simply find the price on a particular supplier, then hit CTRL+N to open a new window. Enter the URL of your next supplier, and repeat until you have several prices available simultaneously. Just click between the windows to compare prices. Check postage rates and returns policies as well.

Timeout

Having selected the likeliest supplier, hopefully the order will be processed trouble-free but there is still scope for things to go wrong: in the author's case, having finally settled on a transparency scanner, Simply Computer's shopping cart system indicated that three units were in stock. As the author's financial year-end was fast approaching, prompt delivery was critical to get the capital purchase into the accounts before the cut-off date. Time was of the essence.

With that in mind, the order was telephoned through to Simply Computers in London, when it was learned that actually, none were in stock as they were supplied to order. The telesales agent also confirmed that the invoice (£800 worth) could be dated so it would go through the accounts in time to claim the allowances. On that basis, the order was placed.

You guessed it, the delivery was made a few days after the year-end. The accounts section could not change the invoice date either, so I lost out. Simply's spokeswoman was very apologetic; I could have argued the case but I needed the scanner anyway. Exactly the same happened the previous year when a Dell PC was purchased online.

Net-centric

More shopping cart woes followed: over a hundred pounds' worth of consumables arrived from another online vendor, Dabs.Com. No invoices ever arrived, hence no proof of purchase or warranty.

This company claims to be "net-centric" in its approach to business – but there was no reply to my E-mail, nor one sent to its webmaster either. To the telephones then, only to be confronted by one of the most frustrating phone stacking systems I have ever had to endure.

After 20 minutes of mindless queuing, an agent curtly fed me back into the system again, where I was stacked to speak to someone else who didn't know the answer either: they fed me back into the queue yet again, after which I hung up. Of course, I accept that things can go wrong from time to time – all I ask is that the means are there to put it right promptly and efficiently.

After a bad week something had to go right, I hoped – my compliments then to the helpful agent at Inmac: when I ordered a replacement tape drive at 5.30 p.m. Friday evening, it was delivered on Monday, just in time to salvage my backup tapes. Although a vendor's hours of business may stretch into the evening, there is usually a deadline for getting goods onto that day's transport, so it does sometimes pay to ignore a shopping cart altogether and speak to a real human being if time is tight.

On Time

Onwards then to the next "online experience" the author undertook recently – when trying to buy electronic components, especially when co-writing *Teach-In 2002* to tight deadlines, online ordering can be a boon. Without doubt, the web site of RS Components (**http://rswww.com**) is a masterpiece – so it should be, at a reported cost of over £2 million. Non-account holders can pay by credit card but will be clobbered for P&P costs, which will have an impact on small orders. I am happy to say that RS Components' online ordering process is very slick, and the requisite parts for *Teach-In 2002* duly arrived next day.

What did I think of the online ordering system of their main competitor, Farnell Components (**www.farnell.com**)? Find out next month in Net Work! You can E-mail me at **alan@epemag.co.uk**

RS Components (rswww.com) – the industry giant's web site has a slick interface and a powerful order processing system.

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!**

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- 50MSPS Dual Channel Storage Oscilloscope
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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.

Squash Switch – Press On

A CAPACITOR is usually conceived of as two fixed metalised plates separated by a dielectric. However, some interesting possibilities arise when these plates are no longer fixed in relation to one another.

The primary purpose of the Squash Switch circuit (see Fig.1) is to produce a logic high at IC1c output (pin 10) when a copper-clad "sandwich" is pressed or squashed. This sandwich is an extremely durable device which can even be stamped on without damage *(if using copper clad fibreglass board – ARW).*

The logic high produced may be taken to a monostable trigger, a flip-flop, a relay, or virtually any logic circuit.

In the prototype, two copper-clad boards, each measuring 5cm × 7cm, were sandwiched together (see Fig.2a), with the copper sides facing inward, and separated by a 7mm thick sheet of foam rubber. This forms the "sandwich" capacitor C2 and when it is squeezed, l.e.d. D3 is illuminated.

Oscillator IC1a clocks decade counter IC2, while oscillator IC1b, when correctly adjusted, resets decade counter IC2 just after its output Q9 (pin 11) has gone high. When the two plates of C2 are squeezed together, oscillator IC1a slows, so that output Q9 no longer has the time to go high – and this is easily detected.

The purpose of capacitor C4 is to bridge the pulses from IC2 output Q9. Light-emitting diode D1 serves to give a precise indication of the pulses at IC2 output Q9, and may be removed after testing. If, during testing, l.e.d. D3 is off all the time, regardless of the setting of preset VR1, then reduce the value of capacitor C3. If it is always on, increase the value of C3.

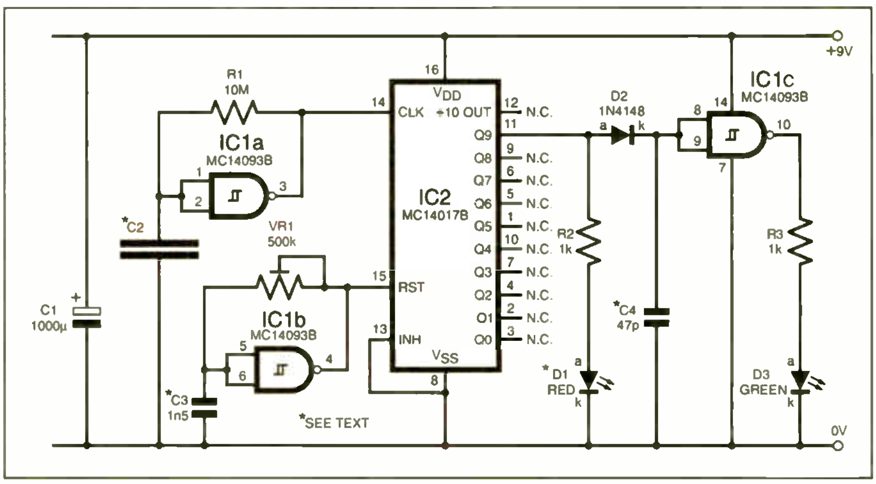

Fig.1. Complete circuit diagram for the Squash Switch.

Good Potential

There are many potential applications for the Squash Switch. It may be inserted in a fluffy toy, or under the leg of a bed, to toggle from a ceiling light to a bedside light when getting into bed. It could also be used in security applications.

The foam rubber may be removed from the sandwich, retaining the thickness of just one copper-clad board between the two layers of

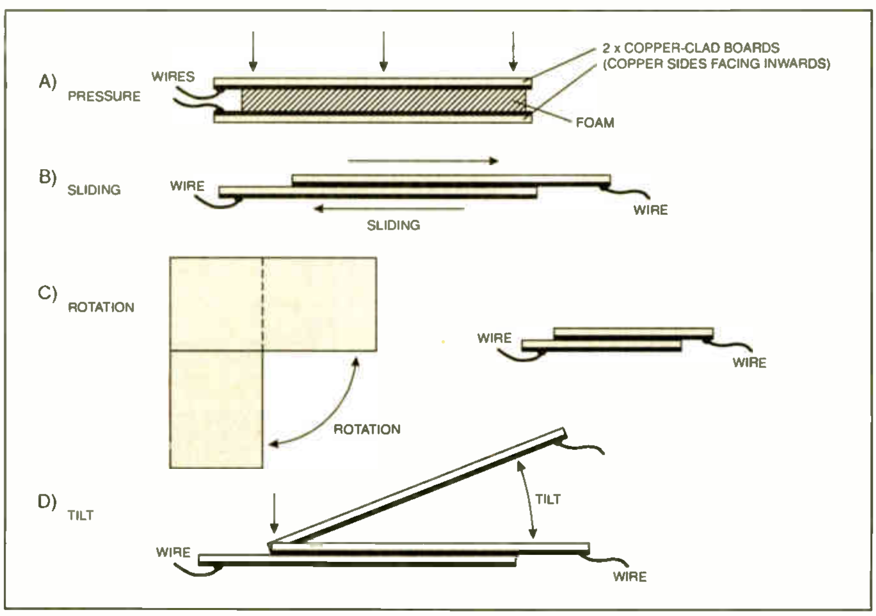

Fig.2. Various combinations of the Touch Switch assembly.

copper (See Fig.2b). The capacitance of C2 then increases significantly, so C3 should be increased to about 22nF and C4 to 470pF, since the bridge between pulses now needs to reach further.

The circuit may now serve as an accurate motion sensor, triggering on a specific measure of horizontal or vertical "slide", rotation, or tilt as shown in Fig. 2b to Fig.2d. It will detect a fraction of a millimetre's slide, or a fraction of a degree of tilt.

The circuit draws approximately 3mA which can be reduced to about 700µA using the spare gate IC1d (see Fig.3) to strobe the oscillators IC1a and IC1b through their input pins 1 and 5. Trimmer preset VR2 adjusts oscillator IC1d to allow sufficient time for pulses from IC1a to reach IC2 output 9. Also capacitor C4 may need to be increased further in value.

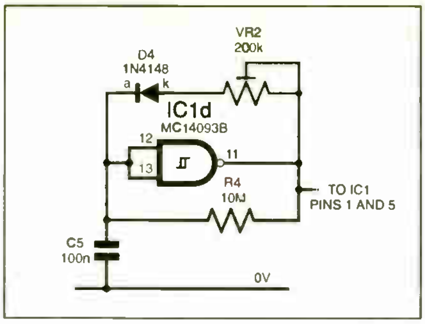

Fig.3. Power saving feature using the unused gate (IC1d).

Whilst the circuit has good stability, body capacitance may affect its operation. This can be minimised by adjusting preset VR1 (and VR2) but in some applications it may be necessary to compensate for this.

Thomas Scarborough, Fresnaye, South Africa

WHY NOT SEND US YOUR CIRCUIT IDEA?
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Fine Tuning Aid For AM Receivers – Tone Control

The circuit diagram of Fig.4 causes an audio tone to appear in an AM receiver when off-tune. The tone disappears when tuning is exactly right. It can be added to any AM receiver including synchrodynes and other direct-conversion types, but it is necessary that the incoming signal is complete with carrier.

The circuit shows how the tuning aid can be combined with a fine-tuning arrangement using varicap diodes D1 and D2. Both coil L1 and tuning capacitor VC1 are signal-tuning components in an existing receiver.

Identical varicaps D1 and D2 are in series and add a small amount of capacitance equal to half that of a single varicap. Fine tuning is adjusted by VR1 whilst resistor R1 and capacitor C1 keep audio and hum away.

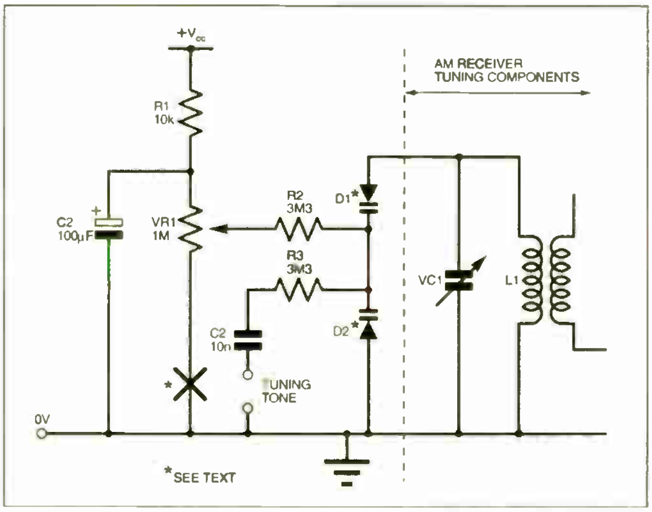


Fig.4. Circuit for the Fine Tuning Aid for AM Receivers.

An audio signal from an external source is introduced via capacitor C2 and resistor R3; tones around 500Hz tend to be pleasant to the ear. The audio level (typically 100mV at C2) should be adjusted to be the minimum consistent with getting a clear tuning indication.

The effect of the audio is to swing the tuning periodically this way and that. If the manual tuning is exact, both half cycles of the audio wave mistune the *LC* circuit equally but in opposite directions. The effect is to produce at the receiver output an audio signal at twice the input frequency. When the audio level is correctly adjusted this double-frequency output is virtually inaudible. If the receiver is mistuned a tone appears, getting louder as the mistuning increases.

The carrier level at the varicaps must not be so large as to cause them to conduct. If the *LC* circuit is at a low-signal-level point such as an aerial (antenna) tuned circuit then this is unlikely to happen. If however the *LC* circuit is part of an oscillator it may be necessary to ensure that the d.c. bias on the varicaps is always higher than the peak oscillating voltage: do this by inserting a resistance at point "X" in Fig.4 to keep the minimum bias large enough.

The amount of capacitance change needed to produce the tuning tone is very small. Therefore, makeshift varicaps such as ordinary silicon diodes or l.e.d.s can be used. L.E.D.s have the advantage that they do not conduct until forward biased by over 1·5V, which gives added protection against their being accidentally forced into conduction by the signal voltage; avoid red l.e.d.s as these can have a relatively large capacitance.

In receivers with ganged tuned circuits the l.e.d. capacitance should be low enough to be offset by adjustment of the trimmer which is usually present across VC1. If the receiver already uses varicap tuning then the only components to be added are C2 and R3, the values of which are not critical. Many diodes are sensitive to light so they should be shielded from ambient light.

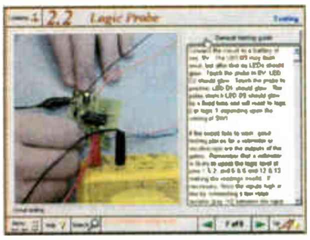
Tuning-In

The basic arrangement could also provide automatic tuning correction. This is made theoretically possible by the fact that, as tuning moves through the exactly-correct point, the tuning tone reverses phase. Comparison with the input tone in a phase-sensitive detector could yield a d.c. correction voltage.

Fine-tuning indication is particularly useful in shortwave receivers. If the receiver employs reaction (regeneration) the arrangement continues to work even when the circuit is set to cause gentle oscillation locked to the signal frequency (homodyne reception). It then functions by phase-modulating the local oscillation.

ELECTRONICS CD-ROMS

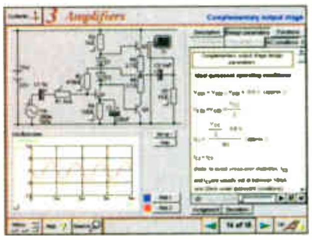
ELECTRONICS PROJECTS



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.

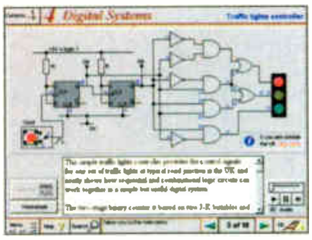
ANALOGUE ELECTRONICS



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.

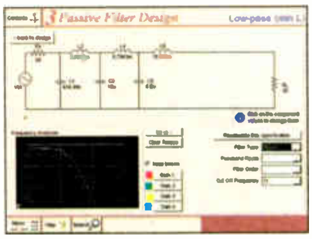
DIGITAL ELECTRONICS



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.

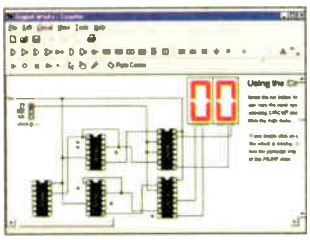
FILTERS



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

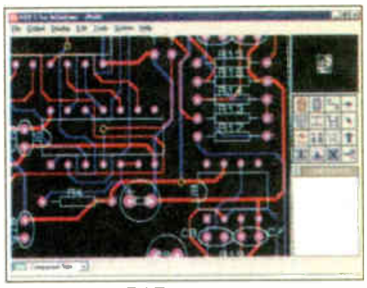


Counter project

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

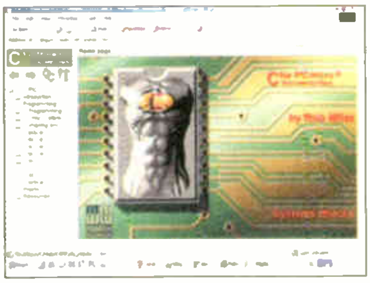
ELECTRONICS CAD PACK



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:

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

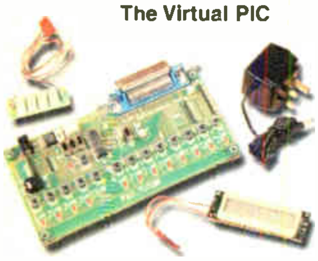
(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

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.



Deluxe PICtutor Hardware

PICtutor CD-ROM
Hobbyist/Student . . . .£45 inc. VAT
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HARDWARE
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ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 JPG images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).
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ELECTRONIC CIRCUITS & COMPONENTS V2.0

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

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

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

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Single User £19.95 inc. VAT. Multiple User £34 *plus* VAT
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Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98/NT/2000/ME, mouse, sound card, web browser.

CD-ROM ORDER FORM

B3

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- ☐ Electronic Projects
- ☐ Analogue Electronics
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- ☐ Digital Works 3.0
- ☐ Electronics CAD Pack
- ☐ C For PICmicro Microcontrollers
- ☐ PICtutor
- ☐ Electronic Circuits & Components V2.0

Version required:
- ☐ Hobbyist/Student
- ☐ Institutional
- ☐ Institutional 10 user
- ☐ Institutional site licence

Note: The software on each version is the same (unless stated otherwise above), only the licence for use varies.

- ☐ PICtutor Development Kit – Standard
- ☐ PICtutor Development Kit – Deluxe
- ☐ Deluxe Export

Note: The CD-ROM is not included in the Development Kit prices.

- ☐ Electronic Components Photos
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SHOP TALK
with David Barrington

Twinkling Lights

Most of the components listed for the *Twinkling Lights* project should be readily available. As the mains transformer is not required to mount directly on the printed circuit board, most of our components advertisers should be able to offer a suitably rated one. It can be greater than the 3VA type mentioned.

The IEC Euro-style connectors used in the model are of Bulgin manufacture and our components advertisers should be able to supply these or their equivalents. **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***) list a snap-in, fused mains chassis mounting "plug" as code MK18U or a bolt-in type, code FT37S. An insulating cover for the rear tags is listed as code JK67X.

The specified opto-triac MOC3043 requires only 5mA max. l.e.d. current to trigger the internal triac. However, the circuit is capable of supplying more current than this so the MOC3042 (10mA) or MOC3041 (15mA) could also be used. All these devices are listed by **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***), codes 885-710 (MOC3043), 885-708 (MOC3042) and 327-074 (MOC3041). The MOC3041 is also listed by **Rapid** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 58-0892.

Some readers may experience problems finding the 10 megohm preset potentiometer. The one in the model came from RS Components and can be ordered from any *bona-fide* RS stockist, or directly (credit card only) from **RS** (☎ ***01536 444079*** or ***rswww.com***), code 387-048. There is a minimum order of 5 off for these presets.

The printed circuit board is available from the *EPE PCB Service*, code 325 (see page 897).

Ghost Buster

No ghostly problems should be encountered when shopping for parts of the *Ghost Buster* project.

The LP2950 micropower regulator (code AV35), the 3914 linear bargraph driver i.c. (code WQ41U) and the 10-segment l.e.d. bargraph display (code BY65V) all came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***). They also list the OP296 CMOS dual op.amp, code NP22Y. It is also carried by **RS** (☎ ***01536 444079*** or ***rswww.com***), code 234-6881.

The two printed circuit boards are available as a set from the *EPE PCB Service*, codes 326 (Mic.) and 327 (Main) – see page 897.

PIC Polywhatsit

Fortunately, all the "special" components used in the *PIC Polywhatsit* project are RS parts and can be ordered through any *bona-fide* stockist, including some of our advertisers. Using your credit card, you can order direct from **RS** on ***01536 444079*** or by web at **rswww.com**.

The µPD43256BCZ-70LL 32-kilobyte memory (code 265-465) and the TLC7524 latching DAC both came from them. They also supplied the rotary BCD switch, code 327-939.

For those readers unable to program their own PICs, a ready-programmed PIC16F877-20 microcontroller can be obtained from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £10 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (*EPE* Disk 4) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas see page 897). It is also available Free from the EPE web site:

ftp://ftp.epemag.wimborne.co.uk/pub/PICS/polywhatsit.

The two printed circuit boards are obtainable as a set from the *EPE PCB Service*, codes 328 (Digital) and 329 (Analogue), see page 897.

Mains Failure Alarm

All parts required to build the *Mains Failure Alarm* should be obtainable from your usual component stockist.

The passive piezoelectric sounder is widely stocked and comes in a low-profile plastic disc or just the bare element, with connecting wires attached. If an uncased element is purchased it should be glued to the inside of the plastic case containing the circuit board. A small "sound" hole will need to be drilled in the case above the sounder element.

Teach-In 2002 – Lab Work

Some items needed for this month's instalment of the *Teach-In 2002 – Lab Work* may prove difficult to locate locally.

The TSL250 photosensor came from Farnell (☎ ***0113 263 6311*** or ***www.farnell.com***), code 460-898. They also supplied the BPW21 photodiode, code 327-440. It is also listed by **RS** (☎ ***01536 444079*** or ***rswww.com***), code 303-719. Two sources came to light for the precision low off-set op.amp type OP177 and can be ordered from **RS** (see above), code 127-2868 or **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code NP16S. The latter have limited stocks.

The ORP12 light-dependent resistor (l.d.r.) has been around now for many years and should not be hard to find.

PLEASE TAKE NOTE

Teach-In 2002 Power Supply *(Nov '01)*

Page 771, Fig.3. It has been pointed out by several readers that as the metal case is also being used as a heatsink – the plastic insulating bush should be inserted from the top (through the mounting tab) to isolate the mounting bolts from the regulators – see this month's *Circuit Surgery*.

Capacitance Meter *(Nov '01)*

Page 764, Fig.6. As shown, the interconnecting topside "ground plain" pads/holes (top left and right) on the Main printed circuit board do not align with the underside foil pattern (Fig.7) and you will need to correct Fig.6 ground plain foil pattern if you intend making your own double-sided p.c.b.s. The boards available from the *EPE PCB Service* are correct.

Also note that capacitor C12 in Fig.4 (page 763) should be connected across the pads just below and to the left of IC3 pin 16 and *not* as shown.

Pitch Switch *(Nov '01)*

It appears that supplies of the 4063 4-bit comparator have "dried up". However, since the *Pitch Switch* is powered off 5V, the author suggests that the 7485 chip is a pin-for-pin match and could possibly be used in its place. It has ***not*** been tried in the model. At least four versions of the 7485 are listed in the latest RS catalogue under 74xx/Arithmetic Function.

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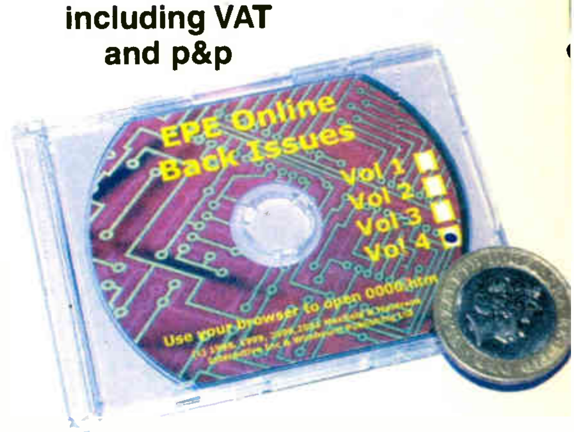

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★ LETTER OF THE MONTH ★

FUSE RATINGS

Dear EPE,

I am concerned to see in the Oct '01 issue two cases where quite small mains transformers are "protected" by 1A mains fuses (*Camcorder Power Supply* and *Three-way Lighting*). 230V at 1A results in 230W – very many times the power rating of the transformers, and 1A is the "carrying" capacity, not the fusing current! The primary resistances may well be more than 230 ohms, so that even 1A cannot be drawn with a short-circuit on the secondary winding.

You need to have a fuse in the primary circuit of a mains transformer so that it protects against a fault in the transformer. Many times I see circuits like this with a 1A fuse in the primary. It's quite safe – everything else will burn up before the fuse goes!

Working, as an example, through a 12V/500mA d.c. supply, assuming it uses a bridge rectifier, the r.m.s. secondary current will be around 800mA (but measure it with a true-r.m.s. meter), and will not be anywhere near a sinewave – hence the need for a true r.m.s. measurement.

So the output is 9·6VA. The input VA will be about 110% of that, i.e. 10·6VA. With 220V input, that means the primary current is 20·8mA. We need to add about 10mA for magnetizing current, but that is in quadrature, so the total is only 23mA. A 32mA fuse would do, then? *Wrong!*

When you switch on, the reservoir capacitor in the supply is fully discharged and initially looks like a short-circuit. In addition, when the transformer was last switched off, the core may have been left magnetized. (Although it's made of magnetically "soft" material, the magnetic circuit is closed, especially if the core is a toroid, so it can stay magnetized.) Both of these effects cause an "inrush current", which depends on the exact point on the supply voltage waveform at which the switch contacts close.

This current is typically five to ten times the full-load current, but it only lasts for a few cycles, and the highest value only lasts for one half-cycle. So the 32mA fuse is going to zap, maybe not the first time you switch on, but soon. To determine the fuse rating, you need to arrange to display the inrush current waveform on a storage scope and do the switch-on at least 25 times, to get a fair measure of the highest values. Because there are two causes of inrush – the capacitor and the transformer core – you get some weird current waveforms. Don't forget to discharge the reservoir capacitor before switching on again.

Then you should compare your worst-case inrush with the fusing-current/time curves of likely fuses. You will probably find that a 100mA time-lag ("anti-surge") type is the best choice.

That fuse should also be a high-breaking capacity type, too. Ordinary fuses are rated only for prospective short-circuit currents of a few tens of amps, and the prospective current from the mains supply is in the order of hundreds of amps. Glass-tube fuses often explode if used in mains circuits.

If you don't have a storage scope, a peak-reading a.c. ammeter with a long discharge time-constant will do. You can't buy one, as far as I know, but you can use an audio-type PPM or an EMC-type quasi-peak voltmeter to measure the peak voltage across a 0·1 ohm resistor in the mains neutral lead to the transformer. You MUST feed the unit under test from an isolation transformer in this case.

Another way is to build a dedicated instrument, which is not difficult. In principle, you feed the voltage across the 0·1 ohm resistor into a precision full-wave rectifier (a dual op-amp and four diodes), arranged to have a short charge time-constant and a long discharge time-constant. You feed the resulting d.c. into either an op-amp driver for a pointer meter or a digital meter module.

John Woodgate, Hon. Secretary, Institute of Sound and Communications Engineers, via the Net

Your clarification is much appreciated John, thank you.

MEASURING TICKS

Dear EPE,

While recognising that *EPE* does not do "commissions", a clock enthusiast friend asked me to investigate some sort of timer to adjust clock tick-length after repair. At its simplest, something which will state whether a tick-tock length is longer or shorter than before adjustment, ideally by a known amount. Even better if it has some means of calibration, it's possible to predict what the timing should be by counting cogs and teeth!

Ant Astley GWOAJA, Pen-y-Bont Fawr, via the Net

My Versatile Event Counter *of April '99 was designed partly for checking Editor Mike's antique clock for its correct timing adjustment. Perhaps it might help you too.*

EGG TIMER

Dear EPE,

I am a pupil of Thornhill College in Derry, N. Ireland. I am doing a GCSE project for Technology and Design on electronic egg timers. I would be very grateful if you could send me any information on them.

Anonymous Pupil, via the Net

To my surprise, the master record of projects that goes back to 1990 does not show any egg-timers! All you need, though, is a simple variable timer, a switch and an l.e.d. or buzzer. A type 555 timer i.c. could be the simple heart of the design and many examples of 555 use have appeared in our pages. Also, our Direct Book Service *stocks the book* IC555 Projects *which you should find helpful.*

KEYPAD ENTRY

Dear EPE,

Great magazine – I'm so very glad I found you!

I would be most interested in an article detailing the construction of a PIC-based, keypad (or fingerprint) activated, wireless, outdoor, door security project, that would open a house door when the kids come home from school and enter the appropriate numeric sequence or press on the fingerprint recognition pad. Does this sound like a project one of your more adventurous and intense developers may be interested in designing?

I've also been following the discussion on programming languages, and I would offer that in order for a language be versatile, it should be able to be ported to a variety of platforms and operating environments. Because there is more than one customer environment, perhaps there's more than one best application language, given there are more than two types of consumer platform. In any event, the final product should be self-contained and not need additional run files. Wasn't that supposed to be JAVA?

Dave Mynatt, Manchaca, Texas, via the Net

What a fortuitous moment to make your "entry" request! In fact, in response to a suggestion made by Editor Mike, I am currently working on a versatile and sophisticated PIC-based intruder alarm design. Your request arrived in time for me to add a second keypad which can be used externally to the unit (i.e. in a door porchway). On keying the correct code a power transistor is activated which could be used to drive a solenoid bolt or similar.

On your other point – agreed!

PICS AND MEMORY

Dear EPE,

I am an AS Level Technology student developing a project where it would be possible to transfer small amounts of data from an IBM-Compatible PC to a chip of some sort. I am told I would need to use RAM chips for this, as regular PIC chips wouldn't suffice for the space I need (roughly 20KB). Would you be able to recommend any literature I should read, or point me to a website I could visit?

Adam Collyer, via the Net

The most efficient way to get data into an external memory is via the PC's expansion bus, although it is conceded that this may seem daunting unless you've already done it! Until EPE *readers got to know how to use PC parallel ports for external interfacing to projects (thanks to Robert Penfold), the use of the expansion sockets and associated decoding chips was essential, and common-place.*

It's actually quite easy to interface a PC via its printer port to a PIC, and it's further quite easy to interface PICs to external SRAM (Static Random Access Memory). Several of my PIC projects that interface to PCs show a combination of both techniques.

There is an example of PIC-to-memory interfacing in this issue – my PIC Polywhatsit!

CHEATS SHIFTED

Dear EPE,

I am writing to say thanks to Peter Hemsley both for the excellent divide routine and for the lesson (*Readout* Oct '01)!

Yes, I am one of those "cheats" who had to resort to multiple subtractions in order to effect a division. It never struck me before that by successively shifting right the dividend into another register and comparing the new register with the divisor, you are doing exactly what you do with paper and pencil during long division of decimals. Well I never!

I used the cheat method in ignorance of any other solution. But it has the advantage that it can save time.

For example, I needed a division routine to convert the binary A-to-D result in a PIC16F877 to decimal in order to display it on an l.c.d. The only way I knew to do this was to successively divide by 10, each time taking the remainder as the next digit up and using the integer quotient as the next number to divide.

With 10 bits and a maximum number of 1023, I would need 102 iterations of the subtract routine first time, 10 for the second, and one each for the third and fourth. With seven instructions in my main loop, not counting the underflow section, this would total 798 cycles. As I see it, using Peter's routine, you would need 16 iterations to extract each digit resulting in 4 × 16 × 23 = 1472 cycles. I fully accept that the shifting method is much more capable especially if using 16-bit numbers, but if your application is regulated by TMR0 interrupts, this saving in time could be crucial.

Unless of course there is a quicker way of converting binary to decimal?

Gerard Galvin,
via the Net

Interesting comment, Gerard, but did you miss all the discussion in several editions of Readout *about binary-to-decimal conversion? The nub of it is in the PICTRICKS folder on our ftp site.*

TOOLKIT TK3 AND WINDOWS

Dear EPE,

Firstly, congratulations on John Becker's *Toolkit TK3*. I am reasonably new to PIC programming and this program appears very stable in comparison to some that I have used, especially in the timing area.

I have shown this program to a couple of members in the South Australian PIC Users Group. The most common comment has been that because it runs in 800 × 600 mode it would most probably not be used. They, like myself, use or only have older computers that can only run 640 × 480 mode for programming.

Would it be possible to modify the program such that the interface was divided into say three separate menus, for instance: assembly, programming and readback? I don't have enough VB programming experience to attempt this yet.

Also, as you have mentioned, it may be possible to program other 14-bit devices, such as the 16F628 (a great 16F84 replacement). My suggestion here is, could the device selection menu be changed to a drop down menu with the ability to modify an .ini file or such to add extra devices? This would make it a truly universal PIC programming environment.

Again, congratulations and thank you for your time put into these projects.

You also might like to know that I am using your *Toolkit TK3* software with a modified Microchip AN589 programmer, works fine although at this stage it doesn't verify. Will fix that problem shortly.

Terry Mowles,
via the Net

Thanks for your appreciation and comments Terry.

I think you may have missed my statement about having designed the main screen area so that the essential information can be seen even if run with a 640 × 480 format. In one of my workshops I do occasionally use TK3 on a machine that only has 640 × 480 and am not troubled by the slight cutoff. Besides which, all the main editing, assembly and programming is done via the top left area and I would be reluctant to split the main screen at all. In due course, I shall add to the list of PICs that I know can be programmed by TK3 and modify the program accordingly (if necessary). Those shown at present are those that I use regularly. Readers might care to let me know which other PICs they use with TK3.

Congrats on your AN589 ingenuity!

ANOTHER PIC TRICK

Dear EPE,

The following is a "PIC Trick" that can be used where a system requires a lot of timers that are not available in hardware. The timer requirements can also be made to vary from a few tens of μs to several minutes!

The trick is to use a file for each timer required. TMR0 is used as the master clock source. The prescaler is set to provide a convenient base interval for the chain of timers.

Two methods of timing may be used: overflow, where code execution waits for TMR0 to elapse before running through its cycle, and interrupt, where normal foreground execution is interrupted by TMR0 overflowing to 0. Which ever method is employed the basic timer chain is the same. For convenience only overflow is used in the following example (written in MPASM):

```
init: movlw              ; get base
  tmr0_count_val          timer count value
movwf tmr0              ; initialise tmr0
movlw 100               ; set up file timer 1 value
movfw tmr1              ; with start value of 100
movlw 180               ; set up file timer 2 value
movwf tmr2              ; with start value of 180

;after rest of init has executed:
wait: btfss tmr0,7      ; if tmr0 is less than 128
goto wait               ; then wait until it is 128
movlw tmr0_             ; re-start
  count_val               10ms timer
movfw tmr0              ; enter it in the base
                          timer to restart it

;this code is run every 10ms:
call test_inputs        ; do some real process-
                          ing here
decfsz tmr1             ; if tmr1 has not expired
goto wait               ; do nothing until 10ms
                          has passed

;this code is run every 1 second:
movlw 100               ; re-start the timer
movfw tmr1              ; with start value of 100
                          as above
call 1_sec_code         ; do processing less often
                          here
decfsz tmr2             ; if tmr2 has not expired
goto wait               ; do nothing until next
                          10mS has elapsed

;this code is run every 3 minutes:
movlw 180               ; re-start the 3 minute
                          timer
movfw tmr2              ; with start value of 180
                          as above
call 3_minute_code      ; do processing here
                          least often
goto wait               ; wait for 10ms timer to
                          elapse
```

Be aware that it is possible for all timers in the chain to elapse within the same 10ms interval (or whatever your base timer is set for), thus all the processing in all branches must be able to be completed in less than this time if absolute accuracy is required.

Additionally, TMR0 counts up, whereas all the file timers count down, therefore some arithmetic is needed to set the value of **tmr0_count_val** so that the correct interval is derived. The file timers do not require this, and if you require 100 times the previous interval you just set it to 100!

The numbers in the code are for illustration only, I recommend that these values are set as either equates or definitions at the head of the source file. This will ensure that if they are used in several places in the code then all values will be altered by changing only the equate value. Useful for testing.

This routine is expandable to incorporate re-triggerable and one-shot timers that may be used to provide delayed responses and reaction time-outs etc.

Harry Purves,
Newcastle-upon-Tyne, via the Net

Thank you Harry. Whilst such techniques may seem "old-hat" to experienced programmers, we must not overlook those who are just entering the PIC scene.

Anyone got more short tricks to offer (they also go up on our ftp site, in the PICTRICKS folder – as has Harry's)?

JIM'S RIGHT!

Dear EPE,

Regarding the letter sent in by Jim from Derby: I am an electronics engineer recently made redundant at the age of 49. I applied for a job with a local firm servicing their SMD production line and doing Quality Control. The work was very involved and interesting, I interviewed well and was later offered the job. I turned it down when I realised I was being offered less than my daughter was earning as a barmaid in our Local – £4.00 an hour.

I am currently working as a carer in a rehabilitation centre for the brain-damaged.

Jim's letter struck a very deep chord with me, having had similar experiences to him in the early Seventies. His observation on UK management and employment agencies is sadly correct in my opinion.

I know you asked for a more positive response, perhaps you'll get one or two from readers abroad.

Congrats again to Jim, and yourselves for a fine column in a great mag.

Pat Walton, via the Net

Disturbing, Pat. How is it that so many priorities seem to be turning upside down? Is it really more important that a barmaid should serve the social needs of a small community than an electronics engineer should perform quality control for the presumed benefit of society at large?

Shall we indeed find that readers abroad report a different attitude towards electronics and related disciplines in their country?

PIC SERIAL COMMS

Dear EPE,

I am trying to learn how to use the PIC16F877 serial communication abilities with my PC, but am having trouble finding any information telling me how this can be done. I can find plenty of pieces of sample code for performing RS232 comms on PICs, but nothing that explains what the code is doing or how it is doing it. Also I cannot find any information at all explaining how I to get my PC to communicate with the PIC.

Stephen Smith,
via the Net

I wish I could help, Stephen. Although I looked into serial comms some time ago and came across many seemingly useful websites, some suggested by Chat Zone *readers, none enabled me to find code that would let me to do what I wanted.*

For my PIC Data Logger *(Aug/Sep '99), I eventually established a technique that worked in that application, but I could not claim that the solution is ideal.*

I suggest that you ask your question via our Chat Zone *and see what response you might get.*

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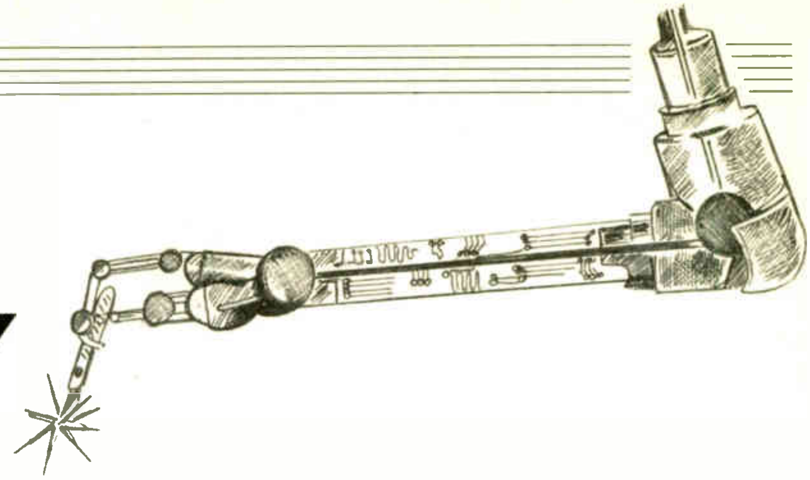

CIRCUIT SURGERY

ALAN WINSTANLEY and IAN BELL

This month we examine OTAs – operational transconductance amplifiers – and we get hot and bothered over heatsink mounting kits

Transconductance Amplifiers

Our thanks to **Graham Hunter** who E-mailed to ask: *"What is a transconductance op.amp? I found one in the Maplin CD application sheets called the LM13700. I noted its symbol was similar to that of the LM3900. Both of these are to me a little confusing, what are the advantages of using either of these op.amps over a standard bi-polar or FET type op.amp?"*

Let's take it from the top. A voltage amplifier has a voltage input and a voltage output. The output signal voltage divided by the input signal voltage gives the gain. This "voltage over voltage" formula gives us a gain value which is just a pure number.

However, if an amplifier has an input consisting of a voltage, but an output consisting of a *current*, then the gain is given by the output signal current divided by the input signal voltage. This gain formula is basically "current over voltage", which if you compare it with Ohm's Law ($R=V/I$) is in the form of "one over resistance" – i.e. the reciprocal of resistance or **conductance**.

Thus the gain is not a pure number as it would be with a voltage amplifier – it is actually a conductance. To prevent confusion with ordinary conductance, and to highlight the input-to-output nature of amplifier gain, we call this property **transconductance**. We can of course also have current amplifiers and transresistance amplifiers. This is illustrated in Table 1.

Transistors are basically transconductors. This is most obvious with a MOSFET where the insulated gate takes no current, but the voltage on it controls the current flowing in the device's source to drain channel. Thus the gate voltage is the input and the drain current is the output, and so the MOSFET's gain is specified as a transconductance, symbol g_m. For bipolar transistors the base-emitter voltage controls the collector current, but we also get a base current so we can express the gain as either a current gain (called ß (beta) or h_{fe}) or as a transconductance (g_m).

The op.amps with which most readers will be familiar are *differential voltage amplifiers*, that is, they amplify the difference in voltage between their two inputs. Almost every issue of *EPE* carries a project using differential op.amps of one type or another. The output is a voltage and the gain is expressed as a pure number.

However, we can also design op.amp-like circuits which take a differential voltage input but provide an output *current*. These are referred to as **operational transconductance amplifiers** (OTAs for short). They are used extensively in the analogue sections of complex VLSI chips, though they are also available as discrete components such as the LM13700 (for pinout details see Fig.1) and hence are available for *EPE* readers to experiment with. That "LM" prefix points to the manufacturer National Semiconductor.

An Odd Fellow

The circuit symbol for the OTAs in the LM13700 may look a little odd. The diode symbols near the inputs represent the

Table 1:

Output: / Input:	Voltage	Current
Voltage	Voltage amplifier Gain = V_{OUT}/V_{IN} (pure number value)	Transconductance amplifier Gain = I_{OUT}/V_{IN} measured in siemens or Amps per Volt (AV^{-1})
Current	Transresistance or transimpedance amplifier Gain = V_{OUT}/I_{IN} in Ohms or Volts per Amp (VA^{-1})	Current amplifier Gain = I_{OUT}/I_{IN} (pure number value)

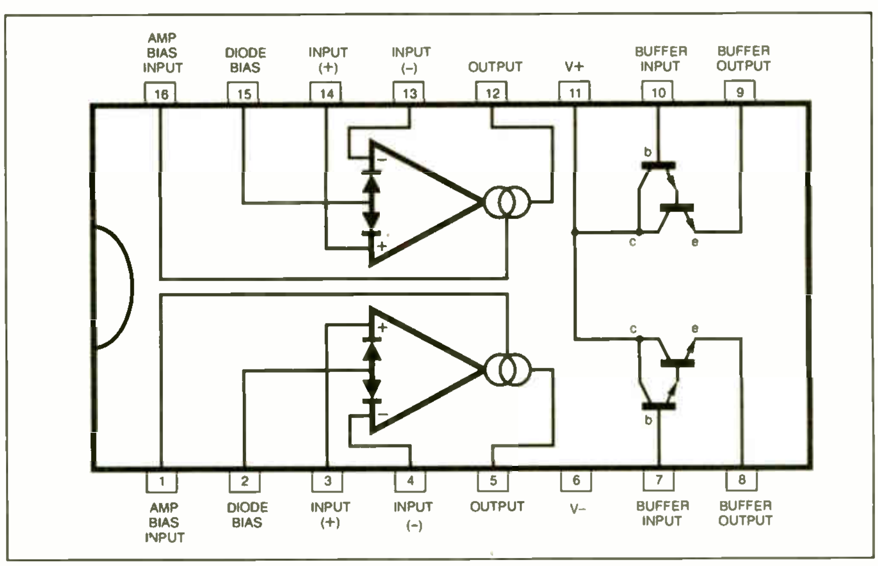

Fig.1. Pinout connection details for the LM13700 dual transconductance op.amp.

linearising diodes, which are included in the *internal* circuitry to improve the performance of the amplifier with relatively large differential input voltages. The diodes compensate for distortions of the signal which would otherwise be caused by the input transistors.

The other "oddity" of the circuit schematic is the current source symbol at the output. This should not seem so odd really for a current output device, but note the "extra" connection labelled "amp bias input" which is available at pins 1 and 16.

These inputs control the basic current levels in the OTAs' output circuits and hence their gain (i.e. transconductance). Thus, a key use of the LM13700 and similar devices is in voltage-controlled amplifiers (as an input voltage can be used to control the gain).

Applications such as voltage controlled volume controls, voltage controlled filters, signal modulators, automatic gain controlled (AGC) amplifiers, voltage controlled oscillators (VCOs), and voltage multipliers can make use of this feature. Many of these circuits are harder to design using standard op.amps (one advantage of OTAs that Graham asked about).

Darlington Buffer

The transistors included in the LM13700 (via pins 7 to 11) are wired as Darlington pairs and are provided for use as buffers in the conversion of the OTA outputs to a voltage.

If the OTA output is connected to a resistor, this will develop a voltage across it in proportion to the OTA's output current. This voltage is then buffered by the Darlington pair wired in an emitter follower configuration. The buffering prevents other circuitry from loading the voltage obtained from the OTA's current output.

In Fig.2, which is extracted from National Semiconductor's datasheet for the LM13700, a voltage controlled stereo volume control is shown. In additional to the basic features of the OTAs discussed above, it makes use of the fact that the two OTAs on the LM13700 chip are closely matched, so the behaviour of the two stereo channels will be very similar.

Note the use of R_L to develop an output voltage and the use of the transistor buffers.

Resistor R_D and others are chosen to correctly bias the OTA's input stage and to present the signal to it.

For more details on the LM13700 go to **www.national.com** and download the datasheet. It contains a number of application circuits – but why not design your own novel OTA application and send it to *EPE's Ingenuity Unlimited! IMB.*

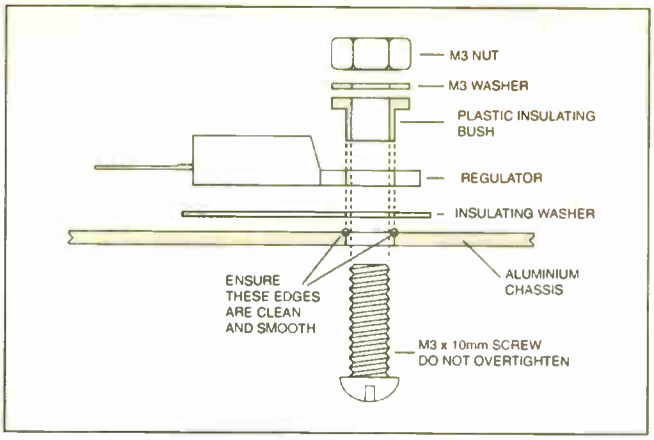

Fig.3. Preferred insulating kit assembly.

Heatsinks Revisited

In the October 2001 column we outlined the simple process of calculating heatsink values. Heatsinks are heat-dissipating metal radiators which are used to ensure that the temperature of the semiconductor junction does not exceed the maximum operating limits of the device. If a heatsink gets hot, it's just a sign that it's doing its job properly, as hopefully its thermal resistance will be sufficiently low to ensure that heat is carried away from the junction to prevent an undue temperature rise.

My *Teach-In 2002 Power Supply* in the November issue uses three regulators, bolted to the floor of the aluminium chassis, which acts as a heatsink. The question of how to actually **mount** a power device onto a heatsink has now arisen. **Bryon Epps** writes via E-mail:

"First I must tell you that I have earned my living in the electronics industry for the last 45 years but I still get a lot of enjoyment (and learn) from reading EPE.

You have probably received a thousand E-mails on the subject but just in case: on the Teach-In 2002 Power Supply *(Nov. '01* EPE*), the fixing screws and insulating bush for the regulators are arranged in such a way as to leave the screw heads external to the box at an unregulated d.c. voltage, just waiting for some gremlin to push a screwdriver underneath and short the screw heads to the chassis or to each other.*

I also noted the subject cropped up in Practically Doing It *in the same issue and both articles showed the same configuration. From the thermal efficiency viewpoint, the* Teach-In 2002 *method is preferred because of the additional heat conduction by thermal contact of the screw to the collector tab, but nevertheless . . !"*

You are perfectly correct, Bryon – and the configuration published in last month's constructional article (P. 771, Fig.3) was not the best one. The problem is that the tabs of the positive regulators are at 0V, but the negative regulator tab is at the negative d.c. input voltage of –17V. Accidentally shorting the 7912 screw to either of the other screws will short out the raw negative rail, doing the power supply no good at all! Note however that there should be no harm done shorting a screwhead to the chassis as the latter is not directly connected to 0V, provided that the transformer insulation holds up.

In my defence I must add that some gremlin sneaked in, when I wasn't looking, and my originally intended version is shown in Fig.3 above. The plastic bush should be fitted in from the top.

I like to see the tab fully isolated from all surrounding hardware as shown, which means the bush has to be inserted directly into the device's mounting hole. I needed the screwheads to be on the outside, underneath the box so that the screws can't scratch the tabletop. Opinions vary but some qualified engineers I know, nod in agreement with the arrangement illustrated.

Plastic bushes also vary: there are short and long ones. My layout uses a long insulator that passes all the way through the aluminium floor. I also prefer to use a flat washer to spread the load on the mounting bush, and a shakeproof washer (not shown) to provide grip. I am sorry if the misunderstanding caused readers any problems. *ARW.*

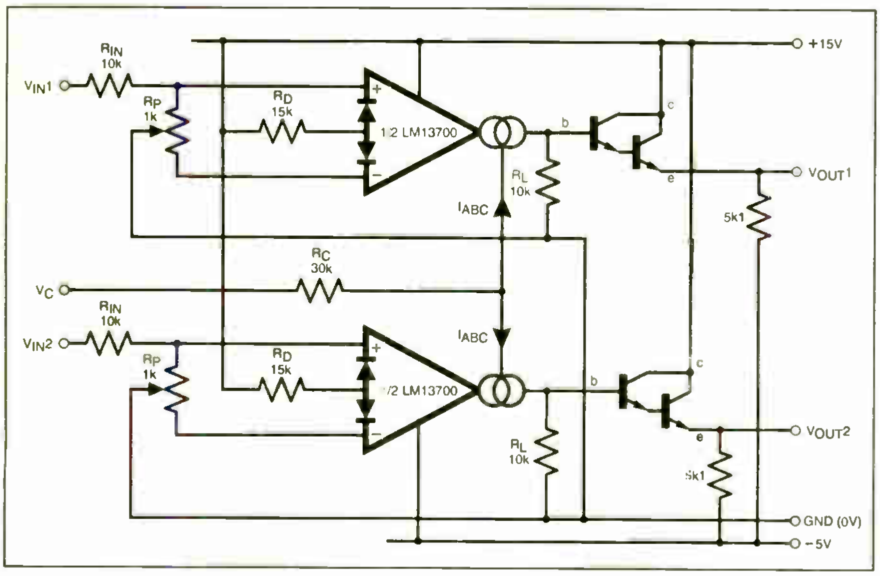

Fig.2. A Voltage Controlled Stereo Volume Control using the LM13700. (From National Semiconductor datasheet).

CIRCUIT THERAPY

Circuit Surgery is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset, BH22 9ND. E-mail (no attachments) **alan@epemag.co.uk**. Please indicate if your query is not for publication. A personal reply cannot be guaranteed but we will try to publish representative answers in this column.

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If you are, or soon will be, involved in the use of microprocessors, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors. assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern microprocessors.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages **Order code NE31** £18.99

Testing, Theory and Reference

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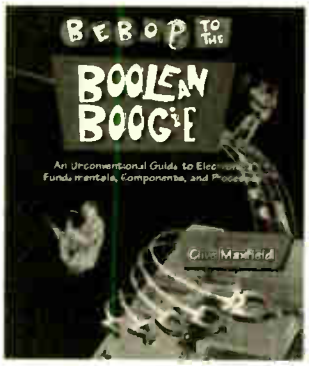

An Unconventional Guide to Electronics Fundamentals, Components and Processes

This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!).

Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day. . . .

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DIGITAL ELECTRONICS – A PRACTICAL APPROACH
With FREE Software: Number One Systems – EASY-PC Professional XM and Pulsar (Limited Functionality)
Richard Monk

FREE SOFTWARE

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchronous and synchronous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer-aided design including the FREE software.

There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

Those who prefer the 'Teach-In' approach or would rather experiment with some simple circuits should find the book's final chapters on printed circuit board production and project ideas especially useful.

250 pages **Order code NE28** **£17.99**

DIGITAL GATES AND FLIP-FLOPS
Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explainend, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.

No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic

200 pages **Order code PC106** **£9.95**

EDA – WHERE ELECTRONICS BEGINS **NEW**
By Clive "Max" Maxfield and Kuhoo Goyal Edson

EDA, which stands for *electronic design automation*, refers to the software tools (computer programs) used to design electronic products. EDA actually encompasses a tremendous variety of tools and concepts. The aim of this book is to take a 30,000-foot view of the EDA world. To paint a "big picture" that introduces some of the most important EDA tools and describes how they are used to create integrated circuits, circuit boards and electronic systems. To show you how everything fits together without making you want to bang your head against the nearest wall.

"Did you ever wonder how the circuit boards and silicon chips inside your personal computer or cell phone were designed? This book walks you through the process of designing a city on an alien planet and compares it to designing an electronic system. The result is a fun, light-hearted and entertaining way to learn about one of the most important – and least understood – industries on this planet."
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UNDERSTANDING ELECTRONIC CONTROL SYSTEMS
Owen Bishop

Owen Bishop has produced a concise, readable text to introduce a wide range of students, technicians and professionals to an important area of electronics. Control is a highly mathematical subject, but here maths is kept to a minimum, with flow charts to illustrate principles and techniques instead of equations.

Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.

The text is supported by questions under the headings Keeping Up and Test Your Knowledge so that the reader can develop a sound understanding and the ability to apply the techniques they are learning.

228 pages **Order code NE35** **£17.99**

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Robert Goodman

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394 pages **Order code MGH3** **£18.99**

The books listed have been selected by *Everyday Practical Electonics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

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Audio and Music

AN INTRODUCTION TO LOUDSPEAKERS AND ENCLOSURE DESIGN
V. Capel

This book explores the various features, good points and snags of speaker designs. It examines the whys and wherefores so that the reader can understand the principles involved and so make an informed choice of design, or even design loudspeaker enclosures for him – or herself. Crossover units are also explained, the various types, how they work, the distortions they produce and how to avoid them. Finally there is a step-by-step description of the construction of the *Kapellmeister* loudspeaker enclosure.

148 pages Temporarily out of print

PREAMPLIFIER AND FILTER CIRCUITS
R. A. Penfold

This book provides circuits and background information for a range of preamplifiers, plus tone controls, filters, mixers, etc. The use of modern low noise operational amplifiers and a specialist high performance audio preamplifier i.c. results in circuits that have excellent performance, but which are still quite simple. All the circuits featured can be built at quite low cost (just a few pounds in most cases). The preamplifier circuits featured include: Microphone preamplifiers (low impedance, high impedance, and crystal). Magnetic cartridge pick-up preamplifiers with R.I.A.A. equalisation. Crystal/ceramic pick-up preamplifier. Guitar pick-up preamplifier. Tape head preamplifier (for use with compact cassette systems).

Other circuits include: Audio limiter to prevent overloading of power amplifiers. Passive tone controls. Active tone controls. PA filters (highpass and lowpass). Scratch and rumble filters. Loudness filter. Audio mixers. Volume and balance controls.

92 pages **Order code BP309** **£4.49**

HIGH POWER AUDIO AMPLIFIER CONSTRUCTION
R. A. Penfold

Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs

96 pages **Order code BP277** **£4.49**

ELECTRONIC MUSIC AND MIDI PROJECTS
R. A. Penfold

Whether you wish to save money, boldly go where no musician has gone before, rekindle the pioneering spirit, or simply have fun building some electronic music gadgets, the designs featured in this book should suit your needs. The projects are all easy to build, and some are so simple that even complete beginners at electronic project construction can tackle them with ease. Stripboard layouts are provided for every project, together with a wiring diagram. The mechanical side of construction has largely been left to the individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing in this respect.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

138 pages **Order code PC116** **£10.95**

Testing, Theory, Data and Reference

SCROGGIE'S FOUNDATIONS OF WIRELESS AND ELECTRONICS – ELEVENTH EDITION
S. W. Amos and Roger Amos
Scroggie's Foundations is a classic text for anyone working with electronics, who needs to know the art and craft of the subject. It covers both the theory and practical aspects of a huge range of topics from valve and tube technology, and the application of cathode ray tubes to radar, to digital tape systems and optical recording techniques.

Since *Foundations of Wireless* was first published over 60 years ago, it has helped many thousands of readers to become familiar with the principles of radio and electronics. The original author Sowerby was succeeded by Scroggie in the 1940s, whose name became synonymous with this classic primer for practitioners and students alike. Stan Amos, one of the fathers of modern electronics and the author of many well-known books in the area, took over the revision of this book in the 1980s and it is he, with his son, who have produced this latest version.

400 pages **Order code NE27** £21.99

ELECTRONICS MADE SIMPLE
Ian Sinclair
Assuming no prior knowledge, *Electronics Made Simple* presents an outline of modern electronics with an emphasis on understanding how systems work rather than on details of circuit diagrams and calculations. It is ideal for students on a range of courses in electronics, including GCSE, C&G and GNVQ, and for students of other subjects who will be using electronic instruments and methods.

Contents: waves and pulses, passive components, active components and ICs, linear circuits, block and circuit diagrams, how radio works, disc and tape recording, elements of TV and radar, digital signals, gating and logic circuits, counting and correcting, microprocessors, calculators and computers, miscellaneous systems.

199 pages (large format) **Order code NE23** £13.99

TRANSISTOR DATA TABLES
Hans-Günther Steidle
The tables in this book contain information about the package shape, pin connections and basic electrical data for each of the many thousands of transistors listed. The data includes maximum reverse voltage, forward current and power dissipation, current gain and forward transadmittance and resistance, cut-off frequency and details of applications.

A book of this size is of necessity restricted in its scope, and the individual transistor types cannot therefore be described in the sort of detail that maybe found in some larger and considerably more expensive data books. However, the list of manufacturers' addresses will make it easier for the prospective user to obtain further information, if necessary.

Lists over 8,000 different transistors, including f.e.t.s.

200 pages **Order code BP401** £6.45

ELECTRONIC TEST EQUIPMENT HANDBOOK
Steve Money
The principles of operation of the various types of test instrument are explained in simple terms with a minimum of mathematical analysis. The book covers analogue and digital meters, bridges, oscilloscopes, signal generators, counters, timers and frequency measurement. The practical uses of the instruments are also examined.

Everything from Oscillators, through R, C & L measurements (and much more) to Waveform Generators and testing Zeners.

206 pages **Order code PC109** £9.95

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** £3.45

NEWNES ELECTRONICS TOOLKIT – SECOND EDITION
Geoff Phillips
The author has used his 30 years experience in industry to draw together the basic information that is constantly demanded. Facts, formulae, data and charts are presented to help the engineer when designing, developing, evaluating, fault finding and repairing electronic circuits. The result is this handy workmate volume: a memory aid, tutor and reference source which is recommended to all electronics engineers, students and technicians.

Have you ever wished for a concise and comprehensive guide to electronics concepts and rules of thumb? Have you ever been unable to source a component, or choose between two alternatives for a particular application? How much time do you spend searching for basic facts or manufacturer's specifications? This book is the answer, it covers resistors, capacitors, inductors, semiconductors, logic circuits, EMC, audio, electronics and music, telephones, electronics in lighting, thermal considerations, connections, reference data.

158 pages **Order code NE20** £15.99

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain
This is not a book of theory. It is a book of practical tips, hints, and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialized.

The book covers: **Basics** – Voltage, current and resistance; Capacitance, inductance and impedance; Diodes and transistors; Op-amps and negative feedback; **Fault finding** – Analogue fault finding, Digital fault finding; Memory; Binary and hexadecimal; Addressing; Discrete logic; Microprocessor action; I/O control; CRT control; Dynamic RAM; Fault finding digital systems; Dual trace oscilloscope; IC replacement.

274 pages **Order code NE22** £20.99

AN INTRODUCTION TO LIGHT IN ELECTRONICS
F. A. Wilson
This book is not for the expert but neither is it for the completely uninitiated. It is assumed the reader has some basic knowledge of electronics. After dealing with subjects like Fundamentals, Waves and Particles and The Nature of Light such things as Emitters, Detectors and Displays are discussed. Chapter 7 details four different types of Lasers before concluding with a chapter on Fibre Optics.

161 pages **Order code BP359** £5.45

UNDERSTANDING DIGITAL TECHNOLOGY
F. A. Wilson C.G.I.A., C.Eng., F.I.E.E., F.I. Mgt.
This book examines what digital technology has to offer and then considers its arithmetic and how it can be arranged for making decisions in so many processes. It then looks at the part digital has to play in the ever expanding Information Technology, especially in modern transmission systems and television. It avoids getting deeply involved in mathematics.

Various chapters cover: Digital Arithmetic, Electronic Logic, Conversions between Analogue and Digital Structures, Transmission Systems. Several Appendices explain some of the concepts more fully and a glossary of terms is included.

183 pages **Order code BP376** £5.45

Project Building

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R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including:

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In fact everything you need to know in order to get started in this absorbing and creative hobby.

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R. Bebbington
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Most of the projects can be simply screwed together, by following the layout diagrams, in a matter of minutes and readily unscrewed if desired to make new circuits. A theoretical circuit diagram is also included with each project to help broaden the constructor's knowledge.

The projects included in this book cover a wide range of interests under the chapter headings: Connections and Components, Sound and Music, Entertainment, Security Devices, Communication, Test and Measuring.

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R. A. Penfold
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IC555 PROJECTS
E. A. Parr
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Included in this book are over 70 circuit diagrams and descriptions covering basic and general circuits, motor car and model railway circuits, alarms and noise makers as well as a section on 556, 558 and 559 timers. (Note. No construction details are given.)

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The No 1 Magazine for Electronics & Computer Projects

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Software programs for *EPE* projects marked with a single asterisk ★ are available on 3.5 inch PC-compatible disks or ***free*** from our Internet site. The following disks are available. **PIC Tutorial** (Mar-May '98); **PIC Toolkit Mk2 V2·4d** (May-Jun '99); ***EPE* Disk 1** (Apr '95-Dec '98); ***EPE* Disk 2** (Jan-Dec '99); ***EPE* Disk 3** (Jan-Dec '00); ***EPE* Disk 4** (Jan '01 issue to current cover date); ***EPE* Teach-In 2000; *EPE* Interface Disk 1** (October '00 issue to current cover date). **★★PIC Toolkit TK3** software (Nov '01) is on CD-ROM. The 3·5 inch disks are £3.00 each (UK), the CD-ROM is £6.95 (UK). Add 50p each for overseas surface mail, and £1 each for airmail. All are available from the *EPE PCB Service*. All files can be downloaded *free* from our Internet FTP site: **ftp://ftp.epemag.wimborne.co.uk.**

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You can also enter the FTP site via the link at the top of the main page of our home site at: **http://www.epemag.wimborne.co.uk**

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