THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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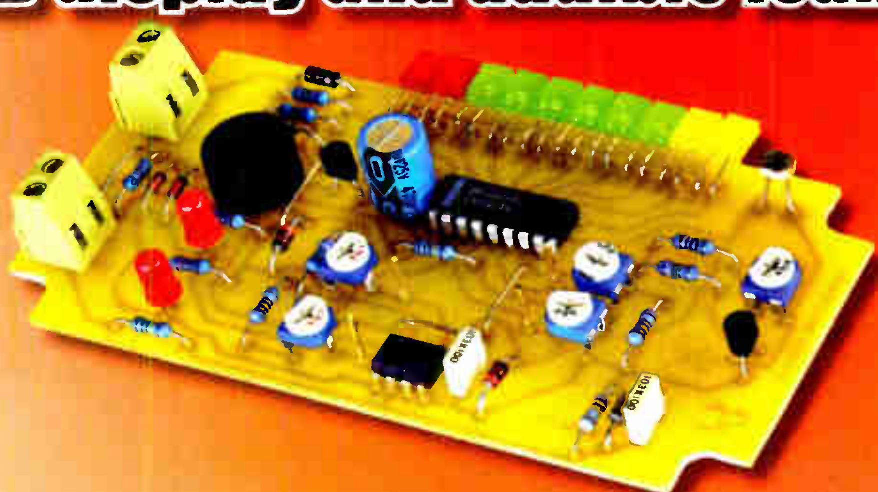

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NEW ELECTRONIC CONSTRUCTION KITS

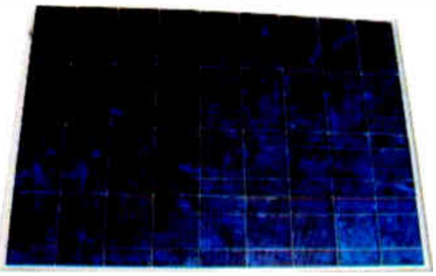
This 30 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides components that can be used to make a variety of experiments including Timers and Burglar Alarms. Requires: 3 x AA batteries. £15.00 ref BET1803

AM/FM Radio This kit enables you to learn about electronics and also put this knowledge into practice so you can see and hear the effects. Includes manual with explanations about the components and the electronic principles. Req's: 3 x AA batts. £13 ref BET1801

This 40 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides components that can be used in making basic digital logic circuits, then progresses to using Integrated circuits to make and test a variety of digital circuits, including Flip Flops and Counters. Req's: 4 x AA batteries. £17 ref BET1804

The 75 in 1 electronic kit includes an nintroduction to electrical and electronic technology. It provides conponents that can be used to make and test a wide variety of experiments including Water Sensors, Logic Circuits and Oscillators. The kit then progresses to the use of an intergrated circuit to produce digital voice and sound recording experiments such as Morning Call and Burglar Alarm. Requires: 3 x AA batteries. £20 ref BET1806

SOLAR PANELS



We stock a range of solar photovoltaic panels. These are polycrystalline panels made from wafers of silicon laminated between an impact-resistant transparent cover and an EVA rear mounting plate. They are constructed with a lightweight anodised aluminium frame which is predrilled for linking to other frames/roof mounting structure, and contain waterproof electrical terminal box on the rear. 5 watt panel £29 ref 5wnav 20 watt panel £99 ref 20wnav 60 watt panel £249 ref 60wnav. Suitable regulator for up to 60 watt panel £20 ref REGNAV

EVACUATED TUBE SOLAR HOT WATER PANELS

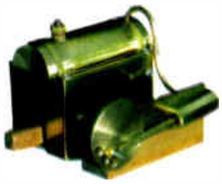
(20 tube shown) These top-of-the-range solar panel heat collectors are suitable for heating domestic hot water, swimming pools etc - even in the winter! One unit is adequate for an average household (3-4people), and it is modular, so you can add more if required. A single panel is sufficient for a 200 litre cylinder, but you can fit 2 or more for high water usage, or for heating swimming pools or underfloor heating. Some types of renewable energy are only available in certain locations, however free solar heating is potentially available to almost every house in the UK! Every house should have one -really! And with an overall efficiency of almost 80%, they are much more efficient than electric photovoltaic solar panels (efficiency of 7-15%). Available in 10, 20 and 30 tube versions. 10 tube £199, 20 tube £369, 30 tube £549. Roof mounting kits (10/20 tubes) £12.50, 30 tube mounting kit £15

2kW WIND TURBINE KIT

The 2kW wind turbine is supplied as the following kit: turbine generator 48v three taper/ twisted fibreglass blades & hub 8m tower (four x 2m sections) guylines / anchors / tensioners / clamps foundation steel rectifier 2kW inverter heavy-duty pivot tower. £1,499

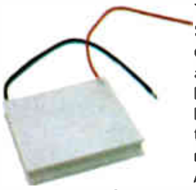
Other sizes available from 200 watts (£299) up to 20kW (£13,999) The 200w system is complete apart from 2x12v batteries and concrete for the tower. These low cost systems can provide substantial amounts of power, even in average wind conditions.

STEAM ENGINE KIT



The material in this pack enables you to build a fully functional model steam engine. The main material is brass and the finished machine demonstrates the principle of oscillation. The boiler, uses solid fuel tablets, and is quite safe. All critical parts (boiler, end caps, safety vent etc.) are ready finished to ensure success. The very detailed instruction booklet (25 pages) makes completion of this project possible in a step by step manner. Among the techniques experienced are silver soldering, folding, drilling, fitting and testing. £29.70 ref STEAMKIT Silver solder/flux pack £3.50 ref SSK

HOT AIR MOTOR (Stirling motor) This is an interesting metal based project for pupils aged 15 plus. The material pack will enable them to make a fully functional hot air motor. All the critical parts (piston, working cylinder, flywheel and coolers) have been pre-made and are ready for use. The detailed plans show all the important stages for the required metal working (Measuring with a vernier, sawing, silver soldering, drilling, marking out,thread making, silver soldering, sawing and filing, etc) At the same time the principles of the hot air motor are described in the wide ranging instructions. Technical data : Working cylinder stroke ø 12 x 10 mm Pressure cylinder stroke ø 13 x 11 mm Unloaded speed approx. 800 rpm Size: Flywheel dia. 55mm Base 130 x130 mm With sinter smooth bearings and ready shaped cooler. £29.70 ref STEAMKIT2 Silversolder pack £3.50 ref SSK



Thermo **Peltier element**, large Size: 40 x 40 x 4,7 mmTechnical data of the Thermo element:Use as a Peltier element to cool or heat: will provide 33 Watts of heating or cooling, max temp difference between sides of 67ºC, maximum output 15V 3,9 Ampere 150ºC 3,5 Ohm 250 mW/K 22 g, 49 mV/K £14 ref TEL1

Die cast illuminated microscope set in plastic carry case Includes a handy carry case with a 1200x magnification microscope. Contents include test tubes, magnifier glass and probe. Requires 2 x AA batteries (not included). ultra-compact, lightweight, easy to use and comfortable to hold. An ideal microscope for the beginner offering a good magnification range. £25.99 ref MAG1200

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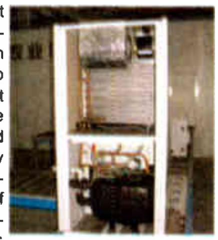
BENCH PSU 0-15V 0-2a Output and voltage are both smooth and can be regulated according to work, Input 230V, 21/2-number LCD display for voltage and current, Robust PC-grey housing Size 13x15x21cm, Weight 3,2kg £48 REF trans2

STIRLING ENGINES

HB10 One of our range of Stirling engines The Bohm HB10 Stirling engine is available in both ready built and kit form. The power comes from a small spirit burner, once lit just watch this amazing Stirling engine run. HB10 in kit form is £97.95 or £101.99 built. Many other models in stock. Order online at www.mamodspares.co.uk

Rapidos Mobile networking digital surveillance system. Plugs into USB port on computer, takes 4 cameras, NSTC or PAL, 352*288 res, 1-30 f/s MPEG4 & MJPEG, motion detection, pre and post recording, watermark, date, time and location markings, alarm notice via FAX, FTP or email, Modes- continuous record, motion detection record, sheduled record, time lapse record, dynamic IP, can send live images to your mobile phone. £109 ref RAPIDOS

HEAT PUMPS



A heat pump is a system that uses a refrigeration-style compressor to transfer heat from outside to inside, in order to heat offices or homes. Heat pumps can take heat from the air, water or ground. Ground source heat pumps are very efficient – in fact you will get 3-4 units of heat for every unit of electricity supplied to the heat-pump. Basic component parts of a GSHP:

1 A heat pump packaged unit: Water-Water type. (approx. the size of a small fridge) containing two cold water connections and two heated water connections.

2. The heat source which is usually a closed loop of plastic pipe containing water with glycol or common salt to prevent the water from freezing. This pipe is buried in the ground in vertical bore holes or horizontal trenches. The trenches take either straight pipe or coiled (Slinky) pipe, buried about 1.5 to 2m below the surface. A large area is needed for this.

3. The heat distribution system. This is either underfloor heating pipes or conventional radiators of large area connected via normal water pipes.

4. Electrical input and controls. The system will be require an electrical input energy, single phase is perfectly adequate for smaller systems. A specialised controller will be incorporated to provide temperature and timing functions of the system.

This type of installation offers many advantages.

a) The water-water heat pump unit is a sealed and reliable self contained unit.

b) There are no corrosion or degradation issues with buried plastic pipes.

c) The system will continue to provide the same output even during extremely cold spells.

d) The installation is fairly invisible. i.e. no tanks or outside unit to see.

e) No regular maintenance required.

Some tips

The efficiency of any system will be greatly improved if the heated water is kept as low as possible. For this reason, underfloor heating is preferred to radiators. It is vital to ensure that the underfloor layout is designed to use low water temperatures. i.e. plenty of pipe and high flow-rates. If radiators are to be used, they must be large enough. Double the normal sizing (as used with a boiler) is a good starting point.

5Kw (output) ground to air heat pump £1,099 ref HP5

9kw (output) ground to water heat pump £1,999 ref HP9

ISSN 0262 3617

PROJECTS . . . THEORY . . .
NEWS . . . COMMENT . . .
POPULAR FEATURES . . .

VOL. 35. No. 9 SEPTEMBER 2006

EVERYDAY PRACTICAL ELECTRONICS

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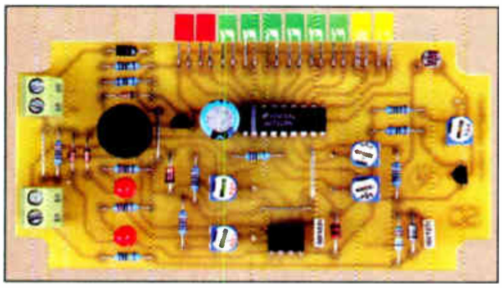
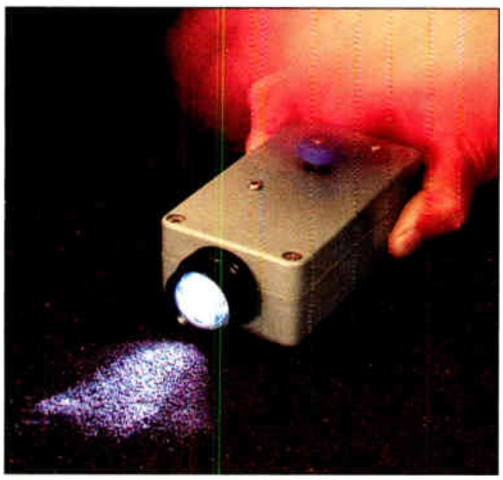
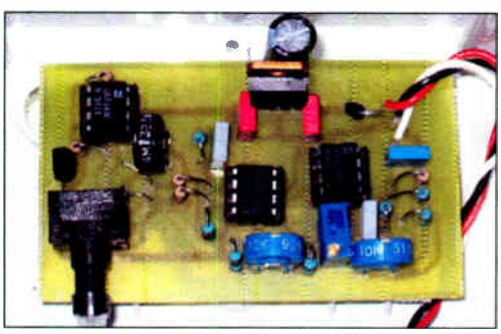






Projects and Circuits

Series and Features

Regulars and Services

Our October 2006 issue will be published on Thursday, 14 September 2006. See page 80 for details

Hot New Kits This Summer!

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

EPE Ultrasonic Wind Speed Meter

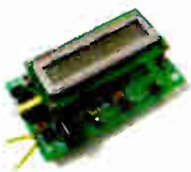
Solid-state design wind speed meter (anemometer) that uses ultrasonic techniques and has no moving parts and does not need calibrating. It is intended for sports-type activities, such as track events, sailing, hang-gliding, kites and model aircraft flying, to name but a few. It can even be used to monitor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

Specifications

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

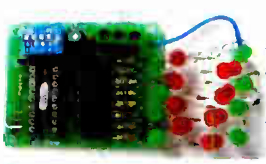
Based on the project published in Everyday Practical Electronics, Jan 2003. We have made a few minor design changes (see website for full details). Power: 9Vdc (PP3 battery). Main PCB: 50x83mm.
Kit Order Code: 3168KT - **£36.95**

Audio DTMF Decoder and Display



Detects DTMF tones via an onboard electret microphone or direct from the phone lines through an audio transformer. The numbers are displayed on a 16 character, single line display as they are received. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC via the serial port. The unit will not detect numbers dialled using pulse dialling. Circuit is microcontroller based. Supply 9-12V DC (Order Code PSU445). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£20.95**
Assembled Order Code: AS3153 - **£29.95**

EPE PIC Controlled LED Flasher



This versatile PIC based LED or filament bulb flasher can be used to flash from 1 to 176 LEDs. The user arranges the LEDs in any pattern they wish. The kit comes with 8 super bright red LEDs and 8 green LEDs. Based on the Versatile PIC Flasher, EPE Magazine Dec 02. See website for full details. Board Supply: 9-12Vdc. LED supply: 9-45Vdc (depending on number of LED used). PCB: 43x54mm.
Kit Order Code: 3169KT - **£11.95**

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

FM Bugs & Transmitters

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

MMTX' Micro-Miniature 9V FM Room Bug

Our best selling bug! Good performance. Just 25x15mm. Sold to detective agencies worldwide. Small enough to hide just about anywhere. Operates at the 'less busy' top end of the commercial FM waveband and also up into the more private Air band. Range: 500m. Supply: PP3 battery.
Kit Order Code: 3051KT - **£8.95**
Assembled Order Code: AS3051 - **£14.95**

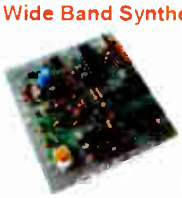
HPTX' High Power FM Room Bug

Our most powerful room bug. Very impressive performance. Clear and stable output signal thanks to the extra circuitry employed. Range: 1000m @ 9V. Supply: 6-12V DC (9V PP3 battery clip supplied). 70x15mm.
Kit Order Code: 3032KT - **£9.95**
Assembled Order Code: AS3032 - **£17.95**

MTTX' Miniature Telephone Transmitter

Attach anywhere along phone line. Tune a radio into the signal and hear exactly what both parties are saying. Transmits only when phone is used. Clear, stable signal. Powered from phone line so completely maintenance free once installed. Requires no aerial wire - uses phone line as antenna. Suitable for any phone system worldwide. Range: 300m. 20x45mm.
Kit Order Code: 3016KT - **£7.95**
Assembled Order Code: AS3016 - **£13.95**

Wide Band Synthesised FM Transmitter



PLL based crystal-locked wide band FM transmitter delivering a high quality, stable 10mW output. Accepts both MIC audio signal (10mV) and LINE input (1v p-p) for example hi-fi, CD, audio mixer (like our kit 1052) or computer sound card. Supply: 9-15Vdc.
Kit Order Code: 3172KT - **£14.95**
Assembled Order Code: AS3172 - **£32.95**

3 Watt FM Transmitter

Small, powerful FM transmitter. Audio preamp stage and three RF stages deliver 3 watts of RF power. Use with the electret microphone supplied or any line level audio source (e.g. CD or tape OUT, mixer, sound card, etc). Aerial can be an open dipole or Ground Plane. Ideal project for the novice wishing to get started in the fascinating world of FM broadcasting. 45x145mm.
Kit Order Code: 1028KT - **£23.95**
Assembled Order Code: AS1028 - **£31.95**

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Electronic Project Labs

Great introduction to the world of electronics. Ideal gift for budding electronics expert!

500-in-1 Electronic Project Lab

Top of the range complete electronics course taking you from beginner to 'A' Level standard and beyond! Contains all the hardware and manuals to assemble 500 projects. You get 3 comprehensive course books (total 368 pages) - *Hardware Entry Course*, *Hardware Advanced Course* and a microprocessor based *Software Programming Course*. Each book has individual circuit explanations, schematic and connection diagrams. Suitable for age 12+.
Order Code EPL500 - **£149.95**
Also available - 30-in-1 **£14.95** 130-in-1 **£37.95** & 300-in-1 **£59.95** (details on website)

Number 1 for Kits!

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

1046KT—25W Stereo Car Booster £29.95
3087KT—1W Stereo Amplifier £8.95
3105KT—18W BTL Mono Amplifier £10.95
3106KT—50W Mono Hi-fi Amplifier £23.95
3143KT—10W Stereo Amplifier £12.95
1011KT—Motorbike Alarm £12.95
1019KT—Car Alarm System £11.95
1048KT—Electronic Thermostat £9.95
1080KT—Liquid Level Sensor £6.95
3003KT—LED Dice with Box £8.95
3006KT—LED Roulette Wheel £10.95
3074KT—8-Ch PC Relay Board £24.95
3082KT—2-Ch UHF Relay £24.95
3126KT—Sound Activated Relay £8.95
3063KT—One Chip AM Radio £11.95
3102KT—4-Ch Servo Motor Driver £15.95
3163KT—12V DC Xenon Flasher £13.95
1096KT—3-30V, 5A Stabilised PSU £32.95
3029KT—Combination Lock £9.95
3049KT—Ultrasonic Detector £15.95
3130KT—Infrared Security Beam £14.95
SG01MKT—Train Sounds £6.95
SG10MKT—Animal Sounds £5.95
1131KT—Robot Voice Effect £9.95
3007KT—3V FM Room Bug £7.95
3028KT—Voice Activated FM Bug £12.95
3033KT—Telephone Recording Adpt £8.95
3112KT—PC Data Logger/sampler £20.95
3118KT—12-bit Data Acquisition Unit £49.95

No.1 KITS

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Secure Online Ordering Facilities • Full Product Listing, Descriptions & Photos • Kit Documentation & Software Downloads

PCB Production - Development
0.1" Copper Stripboard

Size	Tracks/Holes	
25 x 64mm	9T / 25H	£0.24
64 x 95mm	24T / 37H	£0.87
95 × 127mm	36T / 50H	£1.41
95 × 432mm	36T / 170H	£4.39
100 × 100mm	39T / 38H	£1.40
100 × 500mm	39T / 199H	£6.20
119 × 455mm	46T / 179H	£5.40
Stripboard track cutter		£1.99

Solderless Breadboard

Tie Points & Size		Power Rails	
390	81 x 60mm	2	£2.75
840	175 x 67mm	2	£4.86
740	175 x 55mm	1	£4.03
640	175 x 42mm	0	£3.08

Many other sizes available, also jump wires & matrix board.

PCB Production - Drafting Materials
A4 Artwork Film (per 10 sheets)

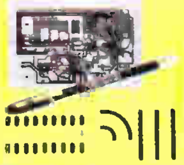
Clear Manual Film	£1.20
Clear Laser Film	£1.75
White HQ Laser Film	£4.62

Etch Resist Pens

"Dalo" Pen	£2.98
"Staedtler" Fine Pen	£0.88

Etch Resist Transfers

Seno mixed DIL pads	£2.24
Seno mixed Rnd pads	£2.24
Alfac mixed pads	£1.84
Transfer Spatular	£1.25



We carry the full range of Seno & Alfac PCB transfers, see our catalogue for full details.

Soldering Irons
We carry in stock a wide range of soldering iron and soldering accessories. Irons from 12 to 100 Watts.

20W 240V Basic	£3.74
25W 240V Ceramic	£7.14
30W 240V Basic	£4.68

Desolder Pumps

Basic 165 x 18mmØ	£2.85
Antistatic 195mm	£3.92
Antex Mini 198mm	£6.02
Antex Pro 210mm	£10.26

Soldering Station
A 48W adjustable temperature soldering station with a rotary dial, LED Temperature metering, on-off switch, iron holder and tip cleaning sponge. This station features accurate heat sensing for instant compensation & stable temperatures. Adjustable temperature range of 150 - 420°C, Low voltage iron with Silicone cable.
Supply: 240V, Iron: 24V 48W

Model 167-540 £49.00

Soldering Station
A 48W adjustable temperature soldering station with a rotary dial, Digital Temperature Indication, on-off switch, iron holder and tip cleaning sponge. This station features accurate heat sensing for instant compensation & stable temperatures. Adjustable temperature range of 150 - 480°C, Low voltage iron with Silicone cable.
Supply: 240V, Iron: 24V 48W

Model 167-570 £64.40

Digital Multimeter
Model: 121-120
Price: £11.47
A highly featured digital multitester for professional use. Offers 30 ranges and 8 functions including temperature, capacitance, diode, continuity and hFE measurement. Large 3.5 digit LCD display with automatic polarity indicator. Supplied with shrouded test leads, K type temperature probe and shock proof rubber holster.

Technical Specifications
DC voltage 200mV - 1000V (±0.5%)
AC volts 2V - 700V (±0.8%)
DC current 2mA - 20A (±1.2%)
AC current 200mA - 20A (±1.8%)
Resistance 200 Ohms - 20M Ohms (±0.8%)
Capacitance 2000pF - 20μF (±2.5%)
Temperature 0°C - 1000°C (±1.5%)
Frequency 20kHz (±1%)
Max display 1999
Power supply 9V (PP3 battery)
Dimensions 88 x 173 x 40 mm

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PCB Production - Processing Equipment
We carry a large range of the photographic & chemical processing equipment for PCB production, a full list with full technical specifications is available in our catalogue or visit our web site.

UV Exposure units
2 x 8W Tubes, 6 min timer
229 x 159mm working area
Model 332-002 £98.75
4 x 15W Tubes, 7½ min timer
330 x 260mm working area
Model 332-004 £209.48

Chemical Processing
Low cost plastic tray £1.80
Process tanks feature electrically operated pumps and/or heaters with thermostat control, suitable for boards upto 320 x 260mm.
Universal Tank with heater
Model 333-007 £169.58
Bubble etch Tank with heater & bubble pump.
Model 333-004 £208.48

Any of these items, carriage £5.50

PCB Production - Tools
Drill Bits
HSS parallel shank bits available in sizes from 0.3mm to 2.0mm

0.3-0.95mm in 0.05mm steps	£0.60ea £4.00/10
1.0-2.0mm in 0.1mm steps	£0.40ea £3.60/10

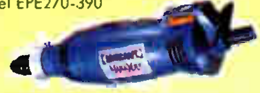
HSS Reduced shank (2.35mm) bit available in sizes from 0.6mm to 1.7mm in 0.1mm steps £0.84ea £7.60/10

Reground Tungsten carbide reduced shank available in sizes from 0.6 to 1.6mm in 0.1mm steps £1.90

Drilling Machines
Expo Reliant 12V drill, 3.8mm capacity, 8400rpm £12.78
Expo Zircon 12V drill, 3.8mm capacity, 11900rpm £14.20

Minicraft MX1 230V, 8000 - 21000rpm with chuck & collet. Model EPE270-390
Normal price £48.51

SPECIAL PRICE £31.02



Servisol Products
Aerosols

200ml	Switch Cleaner	£1.96
200ml	Freezer	£3.97
400ml	Foam Cleanser	£2.13
400ml	Cleaner / lubricant	£2.79
75ml	Vide Head Cleaner	£1.94
200ml	Aero Klene	£2.85
200ml	Aero Duster	£4.66
250ml	Cold Clean	£3.14
200ml	Label remover	£3.52
400ml	Isopropyl alcohol	£3.36

Tubes

10g	Heatsink Compound	£1.66
25g	Heatsink Compound	£2.60
50g	Silicone grease	£3.16

Educational Kits
These kits are an ideal way to start you interset in electronics. They freature re-useable components which are attached via springs & wires and easy step by step guides to make a range of exciting projects. The 300-in-1 features a breadboard for more complex circuits.

30-in-1	£13.18
50-in-1	£16.80
130-in-1	£32.29
300-in-1	£55.20

Panel Meters
High quality analogue panel meters, class 2, zero point correction, mirror scale and prewired for panel illumination. Meter size 46 x 60mm, Cutout size: 38mmØ.

Range	Int Ω
0-50uA	6k5
0-100uA	1k0
0-500uA	430Ω
0-1mA	200Ω
0-10mA	2Ω6
0-50mA	1Ω2
0-100mA	0Ω65
0-1A	60mΩ
0-3A	20mΩ
0-5A	12mΩ
0-15A	4mΩ
0-10V	10k
0-15V	15k
0-30V	30k
±50uA	1k9

All meters £5.89 each
6V Lamps £1.23 /pair

Magnifying Desk Lamp
A high quality scratch resistant magnifying glass fitted to a balanced swivel arm and desk mount. An integral flourescent tube provides illumination.
Magnification: 3x Lens: 120mmØ
Tube: 22W Daylight simulation.

Model: 028-205 £28.80

PCB Production - Laminates
Copper clad - paper
Single sided low cost paper composite board

100 × 160mm Board	£0.44
100 × 220mm Board	£0.62
160 x 233mm Board	£1.02
220 x 233mm Board	£1.40
8" x 12" Board	£1.70

Copper clad - glass fibre
Single & Double 1.6mm 305g/m²

100 × 160mm Single	£0.85
100 × 220mm Single	£1.49
160 x 233mm Single	£2.29
220 x 233mm Single	£2.88
8" x 12" Single	£3.44
100 × 160mm Double	£0.88
100 × 220mm Double	£1.25
160 x 233mm Double	£2.30
220 x 233mm Double	£2.90
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233 x 220mm			£6.83	£7.70

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250g	Ferric Chloride Pellets, makes 500ml	£1.68
500g	Ferric Chloride Pellets, makes 1lt	£3.04
2.5kg	Ferric Chloride Pellets, makes 5lt	£9.84
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90g	Tin Plating Powder, makes 1lt	£11.58
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110ml	Aerosol PCB Laquer spray	£3.63

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EVERYDAY PRACTICAL ELECTRONICS

THE UK's No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 35 No. 9 SEPTEMBER 2006

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL
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Phone: (01202) 873872. Fax: (01202) 874562.
Email: enquiries@epemag.wimborne.co.uk
Web Site: www.epemag.co.uk
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EPE Online Shop: www.epemag.wimborne.co.uk/shopdoor.htm
See notes on **Readers' Technical Enquiries** below – we regret technical enquiries cannot be answered over the telephone.
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Buying and Selling Your "Junk"

If you want it it's probably on eBay. Take a look – everything from high quality test equipment to design software to wire, including components of all descriptions and various kits etc.

A recent search for test equipment brought up items ranging in price from a few pounds to over £600. If you want amateur radio or audio equipment it's also all there from vintage stuff through to expensive modern equipment at prices which seem to vary wildly – some are absolute bargains others highly priced, but the value is, of course, determined by the buyers.

It seems like a great way to buy and the few things we have purchased (not necessarily electronics items) have all been exactly as advertised and supplied without problem. No doubt many readers will be well aware of the above and also how to sell all those unwanted bits and pieces – even if it is not you who is pushing to move the "junk"!

Watching the sale of the wide range of electronic items on offer will provide an insight into just what you might expect to get for your prized possessions – remember your "junk" might be just what someone is searching for and some old ICs or valves, for instance, can fetch good money.

Searching

Searching on eBay can be a bit hit and miss – put in "electronic test equipment" and very little comes up, but try "test equipment" and you get a whole range of items. Try "valves" and you get plenty of thermionic valves plus water valves, valves for car engines etc. You can always be more specific and search for say "multimeters" or "power supplies" if you are looking for something in particular. It is fascinating to see what is on offer and to track items to see exactly what they fetch.

You will also find recent back issues of *EPE* for sale at more than our back issue price, so do be aware that not everything on eBay is a bargain; you can get carried away and pay over the odds!

One final word of warning, please use the PayPal system to pay, don't ever send cash or use Western Union etc., as you will surely say goodbye to your money – anyone who asks for payment in this way should not be trusted.

Mike Kenward

AVAILABILITY

Copies of *EPE* are available on subscription anywhere in the world (see opposite), from all UK newsagents (distributed by SEYMOUR) and from the following electronic component retailers: Omni Electronics and Yebo Electronics (S. Africa). *EPE* can also be purchased from retail magazine outlets around the world. An Internet on-line version can be purchased and downloaded for just $15.99US (approx £9.50) per year available from **www.epemag.com**

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Cheques or bank drafts (in **£ sterling only**) payable to *Everyday Practical Electronics* and sent to EPE Subs. Dept., Wimborne Publishing Ltd. 408 Wimborne Road East, Ferndown, Dorset BH22 9ND. Tel: 01202 873872. Fax: 01202 874562. **Email:** subs@epemag.wimborne.co.uk. Also via the **Web** at: **http://www.epemag.wimborne.co.uk**. Subscriptions start with the next available issue. We accept MasterCard, Amex, Diners Club, Maestro or Visa. (For past issues see the *Back Issues* page.)

BINDERS

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READERS' TECHNICAL ENQUIRIES

E-mail: techdept@epemag.wimborne.co.uk

We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply *must* be accompanied by a **stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.**

PROJECTS AND CIRCUITS

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in *EPE* employ voltages than can be lethal. **You should not build, test, modify or renovate any item of mains powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.**

COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

News . . .

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

NO MOBILE TV SINGLE STANDARD

Where are standards when we need them, wonders Barry Fox?

THERE is now no hope of a single standard for mobile TV, admits Microtune, the Texas company which makes the chips used in most of the new generation of the USB sticks which receive Digital TV. Similar chips are now being used in pocket receivers and cellphones. There is already an unstoppable proliferation of mobile TV standards, including DVD-Terrestrial and DVB-Handheld for cellphones in Europe, ATSC and Qualcomm MediaFlo in the US, ISDB in Japan, and DMB (DAB-based) satellite and terrestrial. More systems are expected from China.

No Winner

Says James Fontaine, President and CEO of Microtune: "We are not now predicting any real winner."

He was in Europe for the World Cup and launch of a Mobile TV service in Italy where Hutchison 3 is promoting football viewing on the move. Microtune is supplying the MT 2260 DVB-H tuners inside the LG U900 handsets being used for the Italian service. The demodulator is made by Dibcom of France. The 10:1 time-slicing cycle used by DVB-H reduces power consumption from 300mW for DVB-T to 30mW.

"There are a lot of claims but we know of only two companies actually shipping DVD-H tuners", says Fontaine, "Freescale and Microtune. We now know we must provide a multistandard chip. It's not so much about travellers being able to tune in when they arrive in different countries, it's because manufacturers want to produce one design. We think DVB-H has the largest share of the world market. It's the most widely adopted standard. This is not based on shipments yet, it's about commitments".

Dual Standard Tuner

Microtune's next tuner chip, the MT 2266, will be dual standard, handling DVB-T and DVB-H. "We are shipping product now. But initially manufacturers of USB sticks will probably just not use the DVB-H option". All-standard chips will follow. The only outsider is Qualcomm's proprietary system MediaFlo. "We are not discounting Qualcomm. They are very powerful in the US. They will do what they want to do. It would be foolish to discount them. But MediaFlo is a closed monopoly market. They have created a Forum but we are not sure it is a real Forum. We think the best option is to compete with an open system. TI is an arch rival to Qualcomm."

Too Lax

Fontaine also warns that the standards for interference to mobile TV reception set by MBRAI, the Mobile Portable DVB-T/H Radio Access Interface Specification, are too lax. "It's not just that TV channels are side by side, it's that the cellphone has its own very powerful transmitter. At the recent 3-GSM show we went by demonstrations of Mobile TV and made a call. Their screens went blank". Microtune claims its inbuilt filter called ClearTune solves the problem by pre-filtering the incoming TV signal, making it possible to talk and watch TV at the same time.

Lite-On IT Plans BD Launch

Lite-On IT, one of the world's largest optical disc drive manufacturers, has announced production of BD (Blu-ray Disc) compatible drives. The first Lite-On branded drive incorporating Blu-ray technology will be the LH-2B1S due to be available in August 2006 in the UK market. As with other Lite-On products this drive will also be compatible with DVD+/R(W) media and CD-R(W) media.

The Blu-ray format provides more than 5x the storage capacity of traditional DVDs and thus can hold up to 50GB of data on a double-layer BD disc or 25GB on a single layer disc. By using the new blue-violet laser users can record, rewrite and playback high definition video (HD) as well as storing exceptionally large amounts of data.

Lite-On IT is capable of producing high quality, optical disc drives in considerable volume from Guangzhou Science Park plant (China) with a current production capacity of over five million drives per month. The Lite-On IT Corporation is part of the Taiwanese Lite-On Group, which consists of nine consolidated companies.

Lite-On has also announced the launch of its new Euoropean website, available through the main website. This offers a greatly improved customer support interface, including clear navigation for productions and company information, easy downloads and fast technical support.

The company was founded in 1995 and has grown since to become the world's 2nd largest optical disc drive manufacturer. In 2002, recognizing the convergence between the computer and consumer worlds, Lite-On expanded its portfolio and formed a Consumer Electronics Division, focusing on the development of Digital Audio-Video Appliances. Browse **www.liteonit.com** for further information.

High-performance PC Scopes

Pico Technology have introduced the PicoScope 2104 and 2105, the lightweight, high-performance PC Oscilloscopes designed to fit in your hand. These cost-effective instruments give you all the capabilities of a conventional oscilloscope in a compact probe that you can carry anywhere.

When used with the software supplied, the PicoScope 2105 converts any laptop or desktop PC with USB support into a powerful oscilloscope, without the need for additional probes or power supplies. An entry-level version, the PicoScope 2104, is also available to suit less demanding applications.

The PicoScope 2105 is suitable for a wide range of troubleshooting tasks on analogue and digital circuits. It has high performance, with a 100-megasample per second real-time sampling rate, a repetitive-signal sampling rate of 2-gigasamples per second provided by digital equivalent-time sampling, and a 25MHz analogue bandwidth. The instrument has eight input voltage ranges from ±100mV to ±20V. The USB interface and plug-and-play software make installation easy, and the user can set up, start and stop the unit by pressing a single pushbutton. A beam of light from the probe tip illuminates the area under test.

Both PC Oscilloscopes are supplied with the PicoScope oscilloscope software and PicoLog data logging software, a 32-bit driver with fully documented programming interface, and example programs in C, Visual Basic, Delphi, LabVIEW and VEE. The software is compatible with Windows 98SE, ME, 2000 and XP.

The PicoScope 2104 and 2105 PC Oscilloscopes are available from Pico Technology or one of its authorised distributors, at £125 and £199 + VAT respectively. Browse **www.picotech.com**, or contact Pico Technology Ltd, Dept *EPE*, Mill House, Cambridge Street, St Neots PE19 1QB. Tel: +44 (0)1480 396 395. Fax: +44 (0)1480 396 296.

TEST PRODUCTS CAT

Pomona Electronics, leading manufacturer of cable assemblies, connectors and test accessories, tell us that their latest test and measurement products catalogue is now available. Visit their website at **www.pomona.cc** to order a copy.

WINDOWS VIEWING

Shop windows are becoming interactive video screens, thanks to two new technologies. Barry Fox reports.

British company Visual Planet of Cambridge (**www.visualplanet.biz/news/display.php?id=20**) has developed a system called ViP Interactive that turns a patch of ordinary shop window glass into a touch sensitive display. Across the Channel and up in the mountains overlooking Cannes at hi-tech centre Sophia Antipolis, research company Accenture has come up with a system for much larger areas of glass.

Roll-up Screen

ViP Interactive is a touch and stick sheet of 100 micron transparent plastics material that can be rolled up when not in use. An embedded mesh of fine wires provides touch capacitance sensing through up to 16mm of glass. The wires connect to a PC, and work like a mouse by capacitively sensing the presence of a finger on glass over the plastics. So the sheet can be stuck to the inside of a shop window.

A projector inside the shop beams a reverse picture onto the sheet, either by direct throw or by bouncing off a mirror. Anyone outside the shop sees a video image in the middle of the window, with no apparent source. Software calibrates the system to align the projected picture with the wire grid and give touch accuracy of around 1mm. A customer in the street can touch parts of the screen to call up more information on displayed items, for instance houses for sale or flats to let. Sales started in June 2005 and are now into 17 countries; a 100-inch version has just been developed.

A 40-inch screen costs £760 and the 100-inch version is £3200. As the screen is stuck to the glass by non-permanent adhesives it can be rolled up in a cardboard tube and moved around different locations, for instance for a mobile exhibition.

Larger Version

Accenture's system is on a much larger scale. It was first used publicly for a three month trial in New York at the Virgin Megastore in Union Square. A Barco HDTV projector inside the store beamed a video and graphics image on the entire inside of the shop window, which passers-by could see from the street. Video cameras at the top left and right of the window sense the position at which someone outside touches the window. Accenture's software uses the position for mouse-like control of graphics and to change the image being projected.

The aim was to try and tell casual onlookers what they would find inside. "Did you know we sell clothing?", was one message. "Touch here to find out more".

"The only difficulty was persuading people that they really were allowed to touch", says Accenture engineering designer Robert Hasson. A recent demonstration at Accenture's labs used a mosaic of six separate 42-inch rear projection screens, closely spaced to form one big picture. Overall resolution is six Megapixels, with 1MP contributed by each of six PAL/NTSC displays. In this case the touch sensing is by two cameras on the floor at the bottom left and right corners of the screen array. Touching an item on a displayed menu, such as the trailer for a movie, makes the movie clip zoom up in size to fill a large area of screen. Touching elsewhere creates a confetti of popcorn effect.

Accenture also demonstrated the system working as a "big board" war game for the military, with a changing mix of terrain pictures and satellite maps. This system is currently being used in a Rome art museum to let visitors touch on a menu of pictures to get information on paintings and artists. A new trial is due to start soon at two airports in the US.

PSU and Battery Charger Circuits

Microchip has announced a simulation tool for power management applications. Known as the "Mindi" simulation tool, the new software enables designers to quickly generate detailed circuit diagrams and specify passive components for a variety of power supply and battery charger applications.

The software is free via **www.microchip.com/Mindi**.

WEBSITE FOR SURPLUS

SurplusTraders.Net could well be the place to find bargains of surplus equipment, and to sell them. They have also sent us an interesting 80-page catalogue of the current product selection. We won't elucidate – just browse the site! We'll be amazed if you don't find something to interest you.

JAL Becomes More Powerful

The Beta Team have announced the release of JAL version 2.0, a high-level language for PICs. JAL (Just Another Language) was originally written as a high level language better suited to PIC architecture yet understandable by new users. Sharing similarities with PASCAL, it has evolved into a solid language with an enthusiastic user base.

JAL V2 is complete rewrite by Kyle York, author of PICbsc (**www.casadeyork.com/robot/picbsc/**), building upon this proven core, producing highly optimized code while embracing JAL's simplicity, syntax and style. It now introduces many new powerful features enhancing the already strong suite.

The software is free, via **www.casadeyork.com/jalv2.zip**. Support is available via the Yahoo JAL users group at **www.groups.yahoo.com/group/jallist**.

RAPID PRODUCTS FOCUS

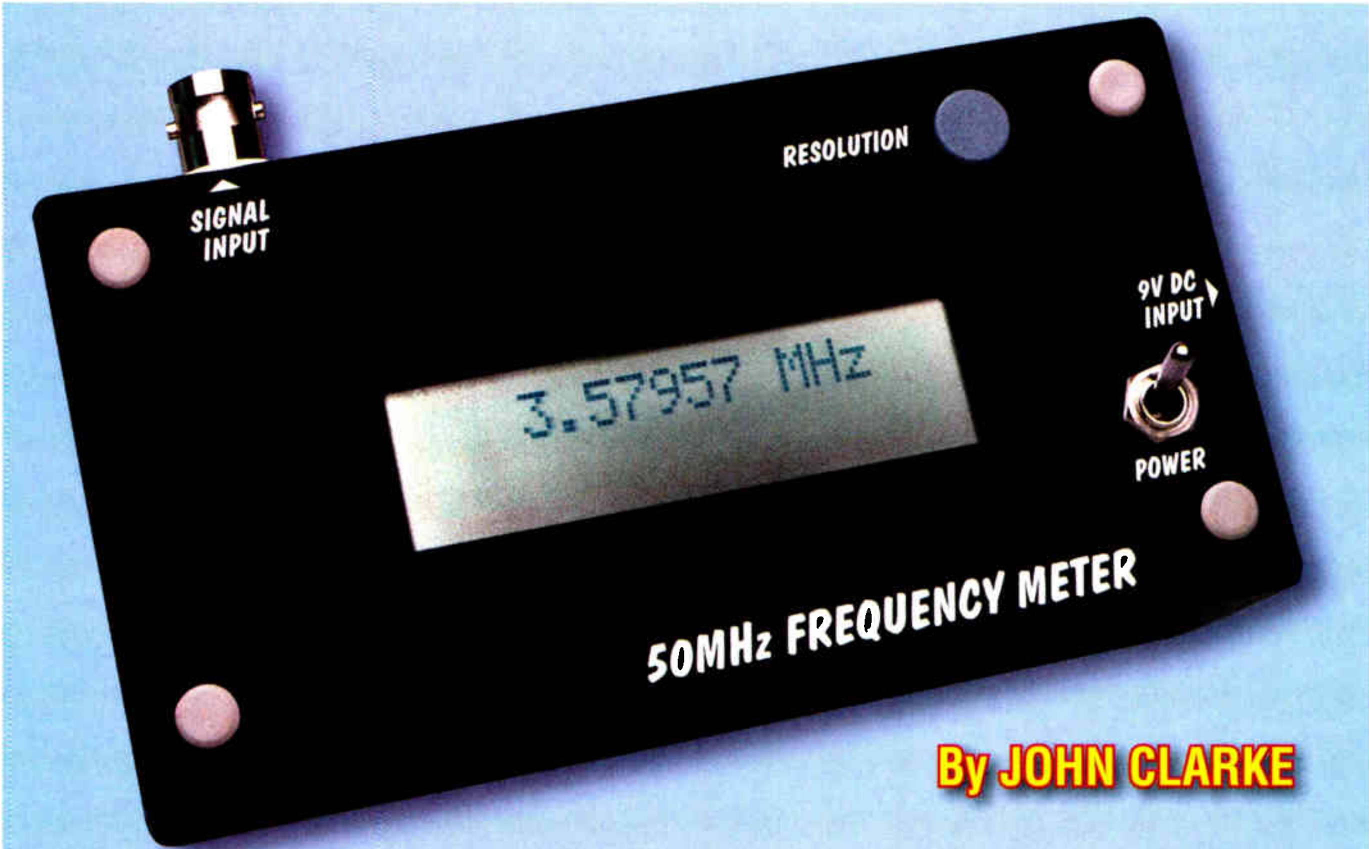
Rapid Electronics have sent the latest issue of their *New Products Focus* publication having 80+ pages of articles about, and itemised details for, a variety of new products now stocked.

Highlighted in this issue is the RSA WEEE Man – a splendidly complex-looking humanoid robot, which is part of an environmental awareness initiative from the RSA (Royal Society for the encouragement of Arts, Manufacture and Commerce), Canon and Reco-Vic Recycling. The assembly has been on display recently around the UK and emphasises the problems of waste.

Rapid can be contacted via tel: 01206 751166, fax: 01206 751188. web: **www.rapidonline.com**, email: **sales@rapidelect.co.uk**.

PLEASE TAKE NOTE

Mike Hibbett has updated the PIC files for the *Halloween Howler* (Oct '05) and the latest version is now on our Downloads site.



By JOHN CLARKE

A Low-Cost 50MHz Frequency Meter

Featuring a 16-character LCD readout, this compact 50MHz Frequency Meter can be either battery-operated or run from a DC plugpack supply. It's very accurate and includes auto-ranging and two different resolution modes.

FREQUENCY METERS are used in virtually all areas of electronics and are invaluable for servicing and diagnostics. Among other things, they are ideal for checking the operation of oscillators, counters and signal generators. They can also be used for servicing RF equipment or to simply provide an accurate frequency readout for a function generator.

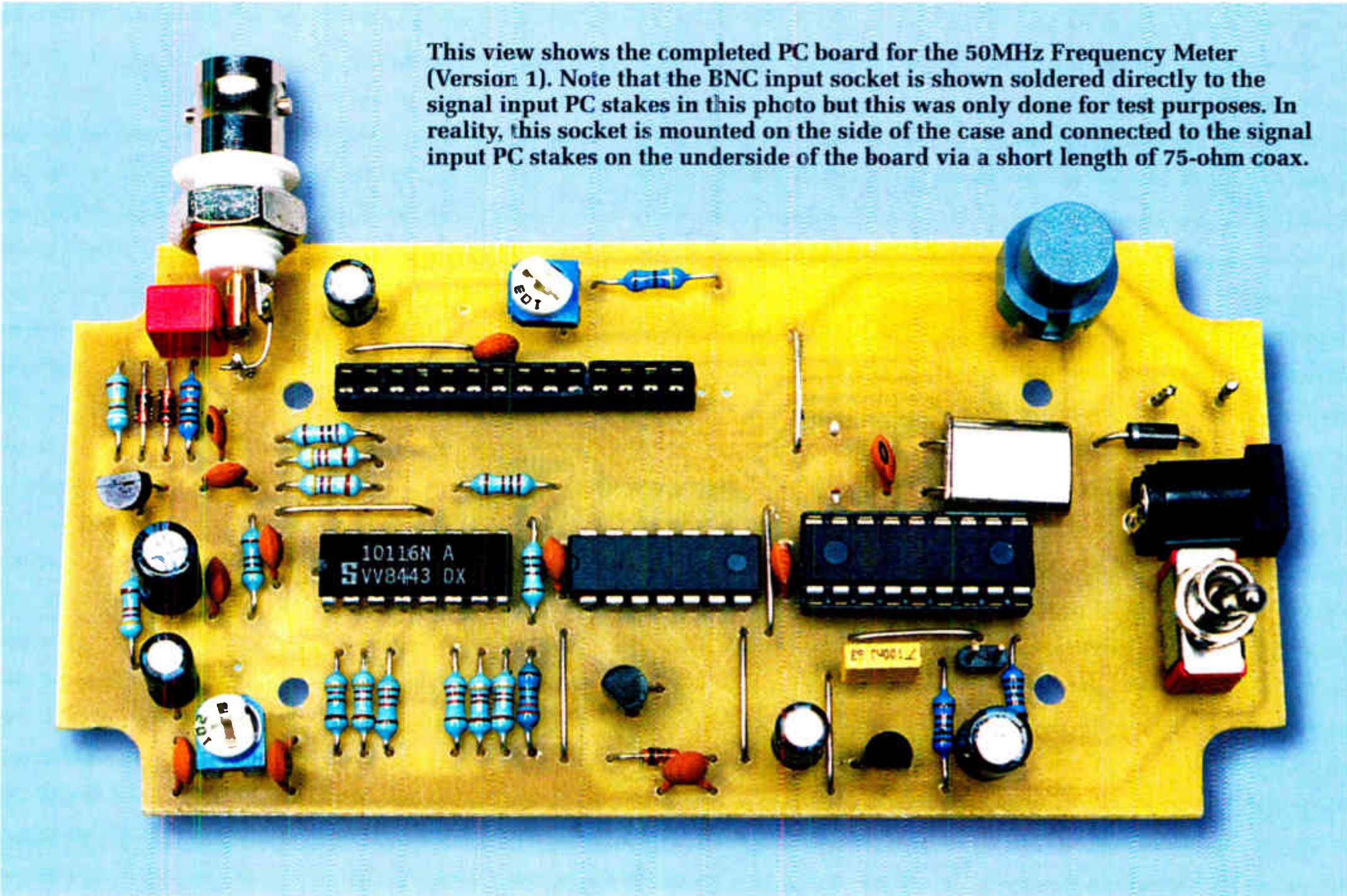
This 50MHz Frequency Meter is autoranging and displays the frequency in either Hz, kHz or MHz. This makes the unit easy to read, as it automatically selects the correct range for any frequency between 0·1Hz and 50MHz and inserts the decimal point in the correct place for each reading.

The design is easy to build too, since it uses a programmed PIC microcontroller to do all the clever stuff. Apart from that, there's an LCD readout, a couple of low-cost ICs, two transistors, a 3-terminal regulator and a few sundry bits and pieces to complete the design.

Note that although we have specified this Frequency Meter at 50MHz maximum, most units will be capable of measuring frequencies somewhat higher than this. In fact, the prototype meter was capable of making frequency measurements to above 64MHz.

LCD readout

A feature of this unit is the use of a 2-line 16-character Liquid Crystal Display (LCD) to show the frequency



This view shows the completed PC board for the 50MHz Frequency Meter (Version 1). Note that the BNC input socket is shown soldered directly to the signal input PC stakes in this photo but this was only done for test purposes. In reality, this socket is mounted on the side of the case and connected to the signal input PC stakes on the underside of the board via a short length of 75-ohm coax.

reading. This has several advantages over LED displays, including much lower current consumption. This allows the unit to be operated from batteries if required.

In addition, the LCD can show all the units without resorting to the use of separate annunciators, as would be required with an LED display.

Resolution modes

Two resolution modes are available: (1) a low-resolution mode which has fast updates and is suitable for most measurements; and (2) a high-resolution mode which can be selected when greater precision is required.

In the low-resolution mode, the resolution is 1Hz for frequencies from 1-999Hz and 10Hz for frequencies above this. The corresponding display updates time are 1s from 1-999Hz and 200ms from 1kHz-50MHz.

By contrast, the high-resolution mode provides 1Hz resolution for frequencies from 150Hz-16MHz. Above 16MHz, the resolution reverts to 10Hz. The display update time is 1s.

Below 150Hz in the high-resolution mode, the display has 0·1Hz resolution and a nominal 1s update time for frequencies above 10Hz. This 0·1Hz resolution makes the unit ideal for testing loudspeakers, where the resonance frequency needs to be accurately measured.

Note, however, that the update time takes longer than 1s for frequencies below 10Hz.

The two resolution modes are toggled from one to the other by pressing the Resolution switch. The meter then displays either "Resolution LOW" or "Resolution HIGH" to indicate which mode is currently selected. In addition, the selected resolution mode is stored in memory and is automatically selected if the meter is switched off and on again.

In the low-resolution mode, the display will show 0Hz if the frequency is below 1Hz. By contrast, in the high-resolution mode, the display will show "No Signal" for frequencies below 0·1Hz.

If the frequency is below 0·5Hz, the display will initially show an "Await Signal" indication before displaying the frequency. If there is no signal, the display will then show "No Signal" after about 16·6s.

The 0·1Hz resolution mode for frequencies below 150Hz operates in a different manner to those measurements made at 1Hz and 10Hz resolution. Obtaining 0·1Hz resolution in a conventional frequency meter normally means measuring the test frequency over a 10s period. And that means that the update time is slightly longer than 10s.

Main Features

- Compact size (130 x 67 x 44mm)
- 8-digit display (LCD)
- Automatic Hz, kHz or MHz indicator units
- Two resolution modes
- 0·1Hz resolution up to 150Hz
- 1Hz resolution maximum up to 16MHz
- 10Hz resolution above 16MHz
- Battery or DC plugpack supply

Parts List – 50MHz Frequency Meter

1 PC board, code 581 for Version 1, 582 for Version 2, 583 for Version 3. All available from the *EPE* PCB Service.
1 plastic case, 130 x 67 x 44mm
1 front panel label to suit version, 125 x 64mm (see Figs 6 & 7)
1 2-line 16-character (per line) alphanumeric LCD module – see text
1 SPST toggle switch (S2)
1 pushbutton momentary contact switch (S1)
1 panel-mount BNC socket
1 low-drift 4MHz crystal (Hy-Q HC49/U 4000.00kHz) (X1)
1 PC-mount 2·5mm DC socket
1 18-pin dual-wipe contact DIP socket (for IC3)
1 28-pin dual-wipe contact DIP socket (for Versions 1 and 2 LCD modules; see text); or
1 14-pin dual-wipe contact DIP socket (for Version 3 LCD module)
4 M3 x 10mm countersunk screws
4 M3 nuts
4 M3 x 6mm cheesehead screws
4 M3 x 10mm tapped Nylon spacers
10 PC stakes
1 300mm length of 0·7mm tinned copper wire
1 60mm length of 75Ω coax
1 1kΩ horizontal trimpot (code 102) (VR1)
1 10kΩ horizontal trimpot (code 103) (VR2)

Semiconductors
1 MC10116N triple ECL differential line receiver (IC1)
1 74HC132 quad Schmitt trigger (IC2)
1 PIC16F84-04/P microcontroller (IC3) programmed with freqency.hex, available for download from the *EPE* Website at **www.epemag.com Pre-programmed PICs and available from Magenta Electronics**
1 78L05 regulator (REG1)
1 2N5485 N-channel VHF JFET (Q1)
1 BF450 PNP transistor (Q2)
3 BAW62 diodes (D1-D3)
1 1N4004 1A diode (D4)

Capacitors
2 100µF 16V PC electrolytic
3 10µF 16V PC electrolytic
1 470nF MKT polyester
1 100nF MKT polyester
8 10nF ceramic
1 470pF ceramic
1 33pF NP0 ceramic
1 22pF ceramic
1 10-60pF trimmer (VC1)

Resistors (1%, 0·25W)

1 910kΩ	2 2·2kΩ
1 100kΩ	7 470Ω
1 47kΩ	1 330Ω
2 10kΩ	4 100Ω

This 10s update time is a very long time to wait if you are adjusting a signal generator to a precise frequency. However, in this frequency meter, the display update period is 1s for frequencies above 10·0Hz, increasing gradually to 10s for frequencies down to 0·1Hz. So for normal audio frequencies, the display will update at 1s intervals. Just how this is achieved is explained below, when we describe the block diagrams for the unit.

Presentation

As shown in the photos, the 50MHz Frequency Meter is presented as a "standalone" unit that's housed in a small plastic case. As mentioned, it can be powered using either a 9-12V DC plugpack or a 9V battery.

There are just two controls on the front panel: an on/off switch and the "Resolution" pushbutton. In addition, a DC input socket is mounted at one end of the box, while the signal input connects to a panel-mounted BNC socket on one side.

Alternatively, the unit could be added to an existing piece of equipment to provide accurate frequency readout. Its low current requirements mean that it can usually be connected to an existing supply rail inside the equipment.

Block diagrams

Fig.1 shows the general arrangement of the frequency meter. It's based mainly on the microcontroller (IC3).

In operation, the input signal is processed and applied directly to a divide-by-256 prescaler that's internal to IC3. The divided signal then clocks timer TMR0 which counts up to 256 before clocking Register A.

Register A is an 8-bit register which counts up to 256 before returning to zero. Combining all three counters (the prescaler, TMR0 and register A) allows the circuit to count up to 24 bits, or a total of 16,777,216 counts.

By counting over a 1s period, it follows that the unit can make readings up to about 16·7MHz. However, if the frequency is counted over a 100ms period, the theoretical maximum that can be measured is just over 167MHz.

As shown in Fig.1, the input signal is first boosted using an amplifier to a level sufficient to drive gating stage IC2a. This, in turn, drives clocking stage IC2b which is controlled by IC3's RA3 output. Normally, IC2b allows the signal to pass through to the prescaler at IC3's RA4 input.

IC3's RB2 output controls gating stage IC2a so that the signal passes through for either a 100ms period or a 1s period. During the selected period, the signal frequency is counted using the prescaler, timer TMR0 and register A. Initially, the prescaler, the timer and register A are all cleared to 0 and the RB2 output is then set to allow the input signal to pass through to the prescaler for the gating period (ie, for 100ms or 1s).

During this period, the prescaler counts the incoming signal applied to RA4. Each time its count overflows from 255 to 0, it automatically clocks timer TMR0 by one count. Similarly, whenever the timer output overflows from 255 to 0, it sets a Timer Overflow Interrupt Flag (TOIF) which in turn clocks Register A.

At the end of the gating period, IC3's RB2 output is cleared, thus stopping any further signal from passing through to the prescaler. The value of the count in TMR0 is now transferred to Register B. Unfortunately, the value in the prescaler cannot be directly read by IC3 and so we need to derive the value.

This is done by first presetting register C with a count of 255. That done, the RA3 output is taken low to clock the prescaler and timer TMR0 checked to see if its count has changed. If TMR0 hasn't changed, the prescaler is clocked again with RA3.

During this process, register C is decreased by 1 each time the prescaler is

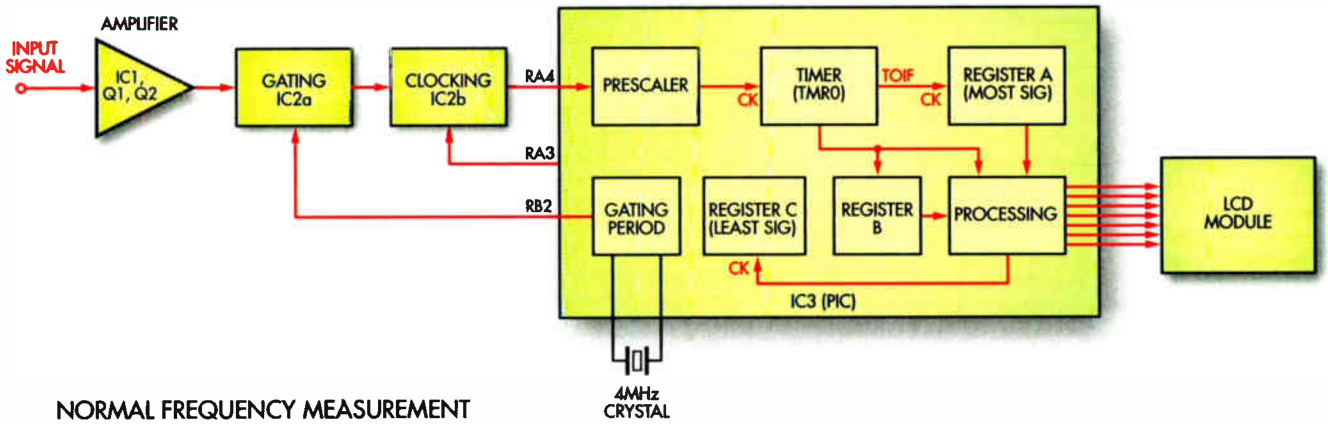


Fig.1: the block diagram of the 50MHz Frequency Meter for "normal" frequency measurements. The incoming signal is first amplified, then fed through a gating circuit to clocking stage IC2b. This then drives a divide-by-256 prescaler inside PIC microcontroller IC3. (ie, at the RA4 input).

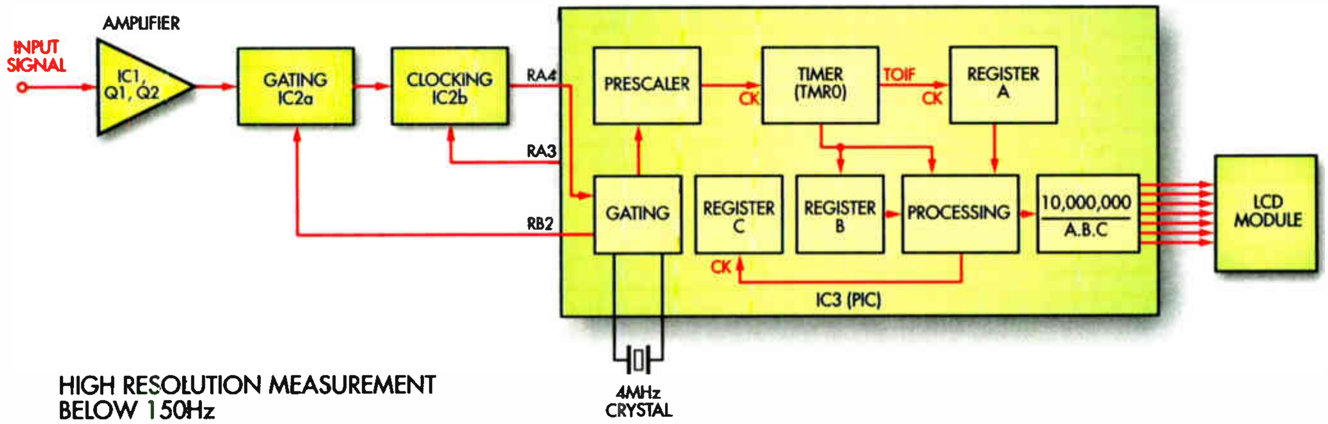


Fig.2: this is the alternative configuration for making high-resolution (ie, to 0·1Hz) measurements below 150Hz. In this case, the input signal is applied to the RA4 input as before. However, the prescaler is no longer clocked by the RA4 input but by an internal 1MHz clock instead.

clocked. The process continues, with RA3 clocking the prescaler until timer TMR0 changes by one count. When this happens, it indicates that the prescaler has reached its maximum count. The value in Register C will now be the value that was in the prescaler at the end of the counting period.

The processing block now reads the values in registers A, B and C. Based on this information, it then decides where to place the decimal point and whether to show Hz, kHz or MHz. The required value is then written to the LCD via the data and control lines (RB4-RB7 and (RA0-RA2).

Alternative configuration

If the input signal frequency is greater than 16MHz and the gating period is 1s, register A will initially have overflowed. In this case, the gating period is automatically changed to 100ms.

+Alternatively, if the high-resolution mode is selected and the frequency is below 150Hz, the frequency meter changes its configuration to that shown in Fig.2.

In this case, the input signal is applied to the RA4 input as before. However, the prescaler is no longer clocked by the RA4 input but by an internal 1MHz clock instead.

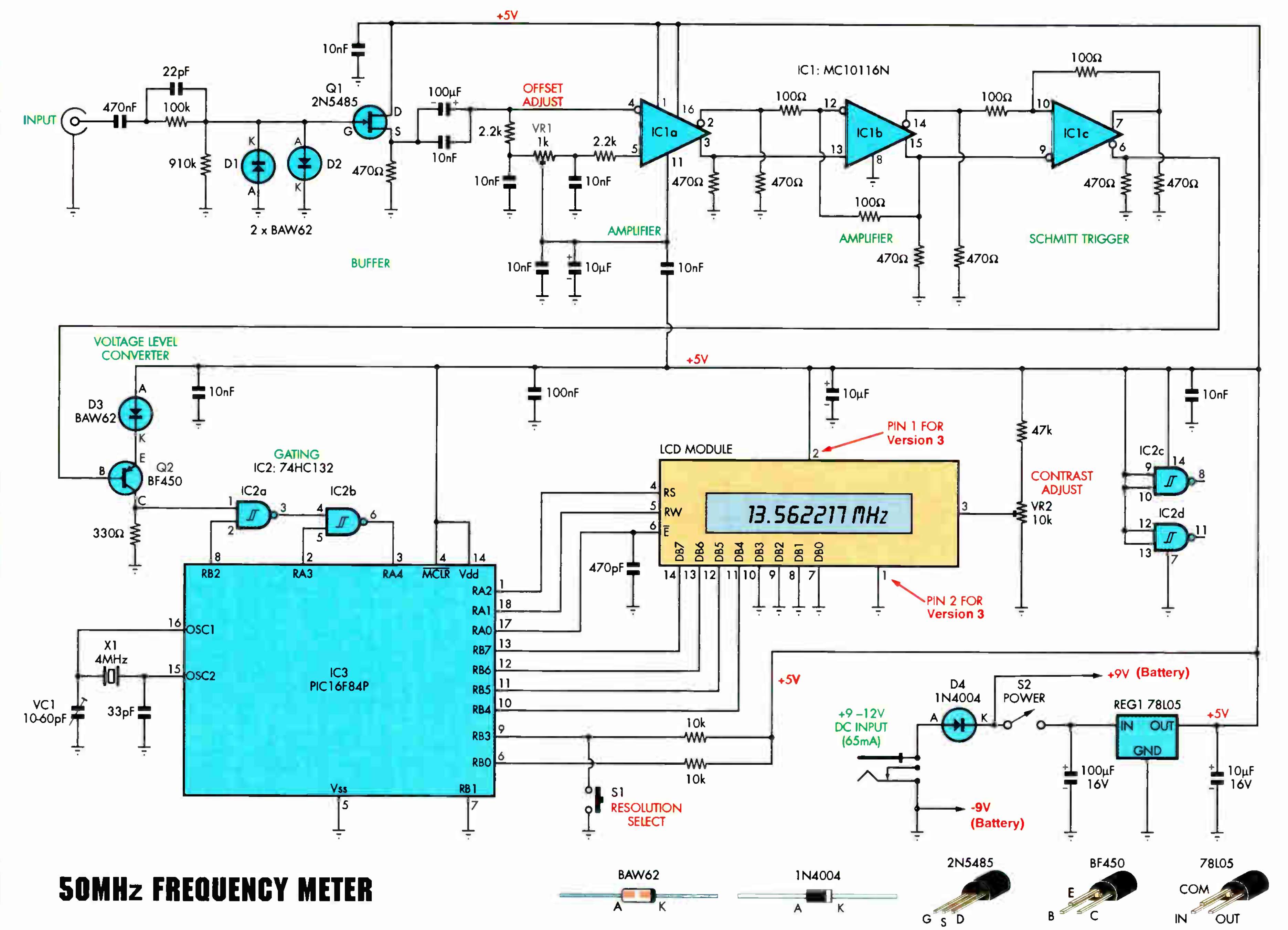
Basically, what happens is that the RA4 input is monitored for a change in state – ie, from a low voltage to a high voltage – which indicates a signal at the input. When this happens, the prescaler is cleared and begins counting the 1MHz internal clock signal. The overflows from the prescaler and timer TMR0 are carried to Register A as before.

Counting continues until the input signal goes low and then high again, at which point counting stops. If the counting causes register A to overflow, then the display will show no signal (this will happen after 16·7s if the signal does not go low and high again). Conversely, if the counting is within range, the prescaler value is determined by clocking IC2b using the RA3 output as before.

From this, it follows that if the input frequency is 1Hz (ie, a 1s period), the value in the A, B and C registers will be 1,000,000. That's because the prescaler is clocked at 1MHz for 1s. Similarly, the count will be 100,000 for a 10Hz signal and 10,000 for a 100Hz input signal.

Finally, the value in the registers is divided into 10,000,000 and the decimal point placed immediately to the left of the righthand digit. This gives a direct readout in Hz with 0·1Hz resolution on the LCD.

Note, however, that this technique cannot be used for measuring very high



50MHz FREQUENCY METER

Fig.3: the circuit is based on microcontroller IC3. This processes the signals from the preceding amplifier stages and drives the LCD. Power comes either from a 9-12V DC plugpack or from a 9V battery.

frequencies. That's because the value in the counter becomes smaller as the frequency increases and so we begin to lose accuracy. For example, at 500Hz, the counted value would be 2000 and at 500·1Hz the counted value would be 1999. The result of the division of 1999 into 10,000,000 would be 500·2 instead of the 500·1 required.

The 0·1Hz resolution has therefore been restricted to a maximum of 150Hz to ensure accuracy of the calculation.

Specifications

Input sensitivity: Typically less than 20mV rms from 1Hz to 100kHz rising to 50mV at 20MHz and 85mV at 50MHz.

Input Impedance: 1·1MΩ in parallel with about 10pF

Frequency range: 0·1Hz to 50MHz

Untrimmed accuracy: ±20ppm equivalent to 1000Hz at 50MHz

Trimmed accuracy: ±10ppm from -20°C to 70°C

Resolution: High Resolution Mode – 0.1Hz from 0.1-150Hz; 1Hz from 150Hz-16MHz; and 10Hz from 16-50MHz. Low Resolution Mode –1Hz from 1-999Hz; 10Hz from 1kHz-50MHz

Update time (approx.): 200ms for 10Hz resolution; 1s for 1Hz resolution; 1s for 0.1Hz resolution down to 10Hz, increasing to 10s at 0.1Hz

Display Units: Hz from 0.1-999Hz; kHz from 1-999.999kHz; MHz from 1-50MHz

Current consumption: 65mA with 9-12V input

Circuit details

Refer now to Fig.3 for the full circuit details. As shown, the input signal is AC-coupled to the unit via a 470nF capacitor to remove any DC component. This signal is then clipped to about 0·6V peak-to-peak using diodes D1 and D2, with current limiting provided by the 100kΩ series resistor. The 22pF capacitor across the 100kΩ resistor compensates for the capacitive load of the diodes.

From there, the signal is fed to the gate of Q1, a 2N5485 JFET. This transistor provides a high input impedance, which is necessary to ensure a wide frequency response.

Q1 is self-biased using a 910kΩ resistor from gate to ground (0V) and a 470Ω source resistor. It operates with a voltage gain of about 0·7, which means that the signal is slightly attenuated at the source. This loss is more than compensated for in the following amplifier stages.

Next, the signal is AC-coupled to pin 4 of amplifier stage IC1a via a 100µF electrolytic capacitor and a parallel 10nF capacitor. The 100µF capacitor is sufficiently large to allow for a low frequency response of less than 1Hz. However, this capacitor loses its effectiveness at higher frequencies due to its high internal inductance and the signal is coupled via the 10nF capacitor instead.

IC1a is one of three differential line receivers in an MC10116N IC package. It's biased via the DC output at pin 11 and this is decoupled using a 10µF electrolytic capacitor and a paralleled 10nF ceramic capacitor. The voltage is then applied to the wiper of trimpot VR1 (Offset Adjust) and this allows adjustment of the input bias voltage.

In operation, IC1a is run open loop (ie, without feedback) so that it provides as much gain as possible. Even so, it only operates with a voltage gain of about seven times. It's differential output signals appear at pins 2 & 3 – ie, one output is opposite in phase to the other. These outputs are in turn applied to the differential inputs (pins 12 & 13) of IC1b.

Note that the differential outputs have 470Ω pulldown resistors, as they are open emitters. In fact, the MC10116 IC is an emitter-coupled logic (ECL) device.

Unlike IC1a, IC1b has negative feedback and this is provided by the two associated 100Ω resistors. This reduces the gain of this stage to just under two.

The third stage using IC1c differs in that it employs positive feedback and so it functions as a Schmitt trigger rather than as an amplifier. Its hysteresis is around 450mV which means that the signal swing on its differential inputs must be greater than this in order for this stage to provide an output.

In operation, the output swing at pins 6 & 7 is from 4.3V when high to 3.4V when low. This needs to be level-shifted to provide for normal CMOS input levels to the gating circuit (IC2a) and this is done using PNP transistor Q2.

It works like this: when pin 6 is high at 4·3V, Q2's base is also at 4·3V, which is just 0·7V below the +5V supply rail. However, Q2 must have a base voltage that's at least 1·2V below the +5V rail in order to switch on – ie, to overcome the 0·6V "diode-drop" across D3 plus a 0·6V base-emitter voltage. As a result, when pin 6 if IC1c is high, Q2 is off and the 330Ω resistor at Q2's collector holds the output low.

Conversely, when pin 6 of IC1c goes low (3·4V), transistor Q2 turns on and pulls pin 1 of IC2a high.

IC2a is a Schmitt NAND gate. It inverts the signal on its pin 1 input when pin 2 is held at +5V by IC3's RB2 output (ie, the signal passes through to the pin 3 output but is inverted). Conversely, when RB2 is at 0V, IC2a's pin 3 output remains high and the input signal is blocked.

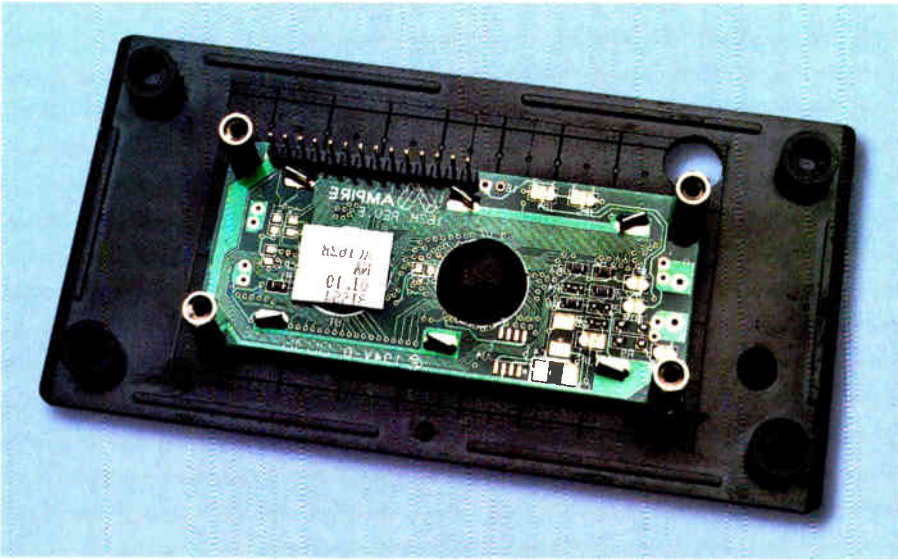
So, in summary, the signal is allowed through to IC2b when RB2 is high and is blocked when RB2 is low, as described previously.

IC2b normally has its pin 5 input held high via IC3's RA3 output, so that the signal from IC2a is again inverted at pin 6. When RB2 is brought low, pin 3 of IC2a remains high and so pin 4 of IC2b is also high. This allows RA3 to clock the RA4 input via IC2b.

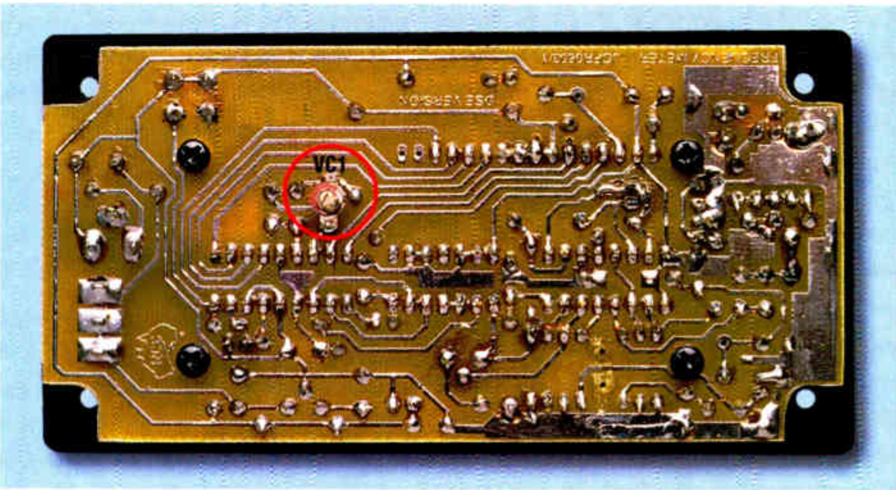
Driving the LCD

IC3's RA0-RA2 outputs drive the control inputs to the LCD module and select the line and the position of the character to be displayed. Similarly, RB4-RB7 drive the data inputs (DB4-DB7) on the LCD module. A 470pF capacitor on the $\overline{E}$ (enable control line) is included to slow down the rise and fall times of the square wave from IC3, which are nominally too fast for the LCD module to handle – particularly when the ambient temperature is well below 25°C.

A 4MHz crystal connected between pins 15 & 16 of IC3 provides the clock



The LCD module is secured to the lid of the case using four M3 x 6mm cheesehead screws, four M3 nuts and four M3 x 10mm tapped Nylon spacers.



The PC board is secured by plugging it into the matching header pins on the LCD module and installing four screws to fasten it to the spacers. Note the mounting method for VC1 (circled in red).

signals for IC3. The recommended crystal has low drift but a standard 4MHz crystal could be used if accuracy is not critical. The capacitors at pins 15 & 16 provide the necessary loading for the crystal so that it runs at the correct frequency, while trimmer VC1 also allows the clock frequency to be "tweaked" slightly to provide calibration.

Power supply

Power for the circuit is derived from either a 9-12V DC plugpack or a 9V battery (but not both). Diode D4 protects the circuit against reverse polarity protection when using a plugpack supply, while regulator REG1 provides a +5V supply rail to power the circuit.

If a 9V battery is used, it connects to the cathode side of D4; ie, it bypasses the reverse polarity protection. This means that D4 can be left out of circuit (along with the DC socket) if the unit is to be battery powered.

Construction

The 50MHz Frequency Meter can be made in one of three versions, depending on what display module you buy. That's because the different suppliers sell different LCD modules so a different PC board has been designed to suit each module. These boards are coded 581 Version 1, 582 Version 2, 583 Version 3. (All available from the *EPE PCB Service.*)

Each LCD module plugs directly into its intended PC board, which means that there are no external wiring connections except to the BNC input socket. And in case you are wondering, there are no performance differences between the three versions.

The unit is housed in a plastic case measuring 130 x 67 x 44mm, with the LCD module protruding through a cutout in the front panel. The Version 1 has the power switch on the righthand side and the signal input applied to the socket at the top left of the box. By contrast, Versions 2 and 3 have the power switch at the top left, while the input socket is mounted on the lower right of the box.

This difference comes about because the display readout for Version 1 module is upside down compared to the

Table 1: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	910kΩ	white brown yellow brown	white brown black orange brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	2	2·2kΩ	red red red brown	red red black brown brown
❑	7	470Ω	yellow violet brown brown	yellow violet black black brown
❑	1	330Ω	orange orange brown brown	orange orange black black brown
❑	4	100Ω	brown black brown brown	brown black black black brown

Table 2: Capacitor Codes

Value	µF Code	EIA Code	IEC Code
470nF	0·47µF	474	470n
100nF	0·1µF	104	100n
10nF	0·01µF	103	10n
470pF	-	471	470p
33pF	-	33	33p
22pF	-	22	22p

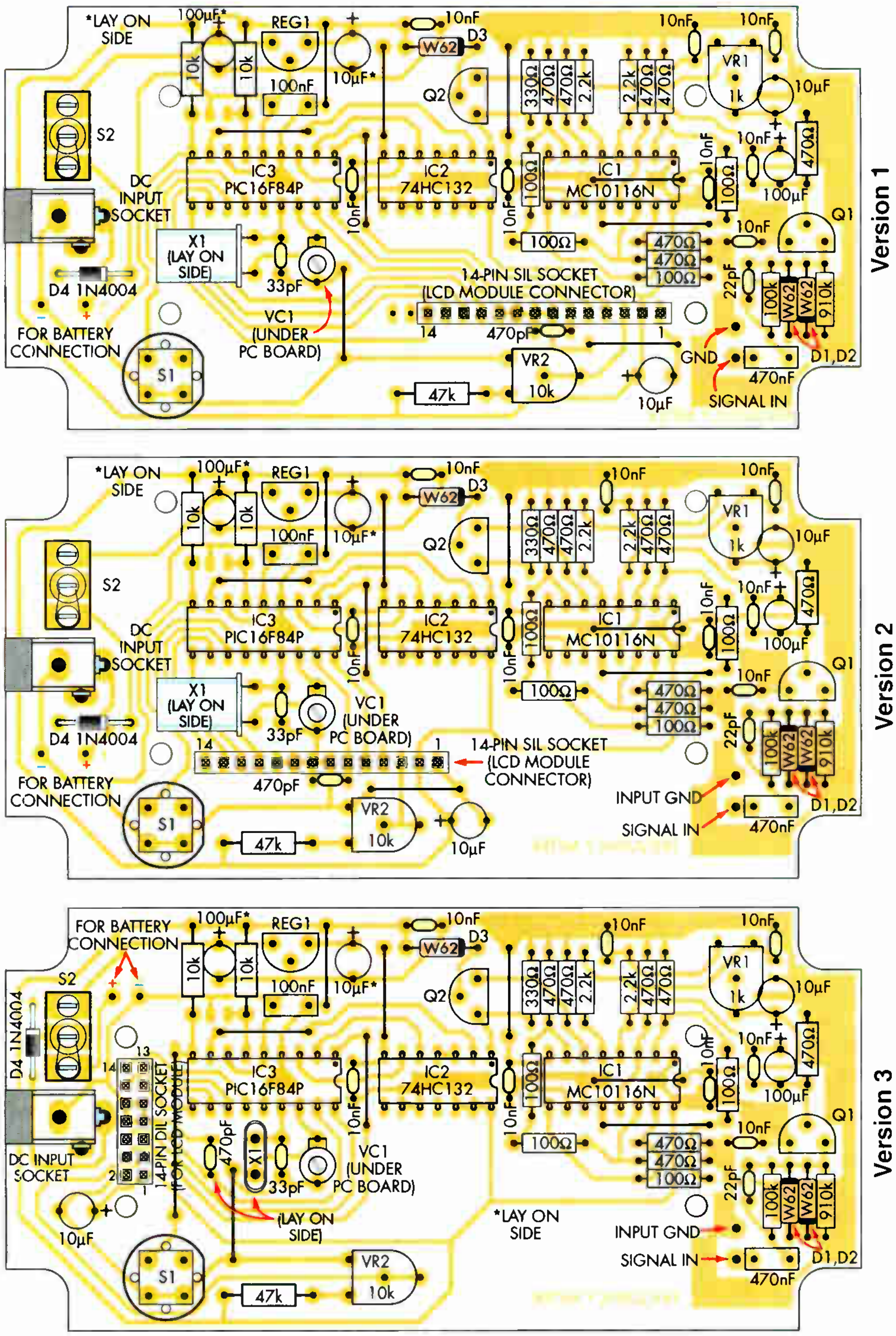


Fig.4: three different PC boards have been designed to suit the different LCD modules that are available. Just follow the parts layout that's applicable to your version.

other two modules in relation to the input terminals. The unit shown in the photos is for Version 1.

Fig.4 shows the PC board layout for each of the three versions. Begin by checking that you have the correct PC board for the LCD module you are using. (This can be done by checking the pin layout and pin numbering against the PC board layouts (Fig.4) and the circuit diagram (Fig.3)). That done, check the mounting holes for the LCD module against those on the PC board (the holes must be 3mm in diameter). Check also that holes are large enough to mount switch S2 and the DC input socket.

Next, install all the wire links and resistors, using the accompanying resistor colour code table as a guide to selecting each value. It's also a good idea to check the resistors with a digital multimeter just to make sure.

IC1 and IC2 can go in next, taking care to ensure that they are correctly oriented. Next, install a socket for IC3 but don't install the microcontroller just yet.

The diodes and capacitors can now all be installed, followed by REG1 and transistors Q1 & Q2. Note that the 100µF and 10µF capacitors in Version 2 must be installed with their bodies parallel to the PC board, so that they don't later foul the LCD module. It's just a matter of bending their leads at right angles before installing them on the board.

Similarly, the top of transistor Q2 must be no higher than 10mm above the PC board to prevent it from interfering with the LCD module (all versions).

The next step is to install the socket for the LCD module. Both Versions 1 and 2 use a 28-pin DIL IC socket which is cut in half to obtain a 14-way strip socket which is then soldered in place. By contrast, Version 3 uses a 14-pin IC socket which is cut into two 7-way strips which are then installed side-by-side.

Once the sockets are in, install PC stakes for the "+" and "-" supply connections (near D4) and for the signal input and GND connections. These PC stakes should all be installed from the copper side of the board.

PC stakes are also used to mount switch S1. These should be trimmed so that when the switch is mounted, its top face is 20mm above the top surface of the PC board. Be sure to orient S1 with its flat section facing towards the right, as shown in Fig.4.

The remaining parts can now be installed on the board. These parts include switch S2, the DC socket, trimpots VR1 & VR2, crystal X1 and trimmer capacitor VC1.

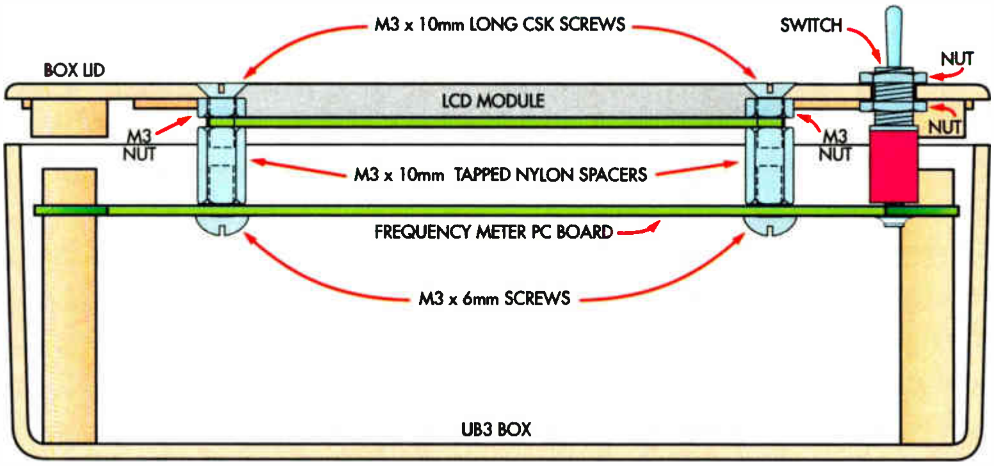


Fig.5: this diagram shows how the unit is installed inside the case. Be sure to use Nylon spacers where indicated,

Note that VC1 is mounted on the underside of the PC board, so that it can be adjusted without having to remove the LCD module.

Front panel

The front panel (ie, the case lid) must be drilled and a cutout made to accommodate the two switches and the display.

You can use one of the front panel artworks as a drilling template (see Figs.6 & 7). You can make the display cutout by first drilling a series of small holes around the inside perimeter of the rectangle, then knocking out the centre piece and filing the edges to a smooth finish.

It will also be necessary to drill the mounting holes for the LCD module. Note that these should be countersunk so that the intended screws sit flush with the surface of the lid – see Fig.5. That done, the label can be attached to the panel and the cutouts made using a utility knife

Checkout time

Now for an initial smoke test – ie, before IC3 or the LCD are plugged in.

First, apply power and check that there is +5V on pin 16 of IC1, pin 14 of IC2 and pins 4 & 14 of IC3. If this is correct, disconnect power and install IC3 in its socket, taking care to ensure it goes in the right way around. That done, plug the LCD module into its matching socket and temporarily fit a couple of 10mm tapped Nylon spacers to support it on the PC board.

Next, reapply the power again and check that the display shows either 1Hz or 0Hz. If not, adjust trimpot VR1 so that the display shows 0Hz when the signal input terminals are shorted. VR2 can then be adjust for best display contrast.

Now press the Resolution switch – the display should show "Resolution HIGH". It should then show "Await Signal" when the switch is released. If the switch is then pressed again, the display should show "Resolution LOW".

Note that, in some cases, it may be necessary to increase the value of the 470pF capacitor between pin 6 of the LCD module and ground to get the display to operate. In fact, a value as high as 2·2nF may be required but note that this may cause the character preceding the word "HIGH" when the Resolution switch is pressed to display a couple of bars instead of a blank space. The display will be perfectly normal when the switch is released.

Final assembly

Refer to Fig.5 for the final assembly details. As shown, the LCD module, is secured to the case lid using four M3 x 10mm CSK screws, four M3 nuts (used as spacers) and four 10mm-long tapped Nylon spacers. The PC board is then secured to the bottom ends of the four spacers.

You will have to drill a 9mm-diameter hole in one side of the box to provide access to the DC socket if you are powering the unit from a plugpack. This hole should be positioned midway along one side and about 6mm down from the top edge of the case.

Conversely, if the unit is to be battery powered, you will need to solder a battery clip lead to the supply PC stakes on the underside of the board. The battery can be secured to the bottom of the case by mounting it in a suitable holder. Alternatively, you could simply wrap the battery in some insulating material and wedge it between the PC board and the bottom of the case.

The BNC input socket is mounted on one side of the case towards the base and wired using 75Ω coax cable to the two signal input PC stakes on the underside of the PC board.

Calibration

The completed 50MHz Frequency Meter can be calibrated against the 15·625kHz line oscillator frequency in a colour TV set. Fortunately, you don't need to remove the back of the set to do this. Instead, all you have to do is connect a long insulated wire lead to the input socket and dangle it near the back of the TV set.

It's then just a matter or adjusting trimmer VC1 so that the meter reads 15·625kHz when the resolution is set to "High" mode.

Note: the TV must be showing a PAL program, not NTSC (15·750kHz).

If there is insufficient adjustment on VC1 to allow calibration, the 33pF capacitor at pin 15 of IC3 can be altered. Use a smaller value if the frequency reading is too high and a larger value if the frequency reading is too low.

Usually, the next value up or down from 33pF will be sufficient – ie, use either 27pF or 39pF.

If you require greater accuracy, the unit can be calibrated against the standard 4·43MHz colour burst frequency that's transmitted with TV signals. The best place to access this frequency is right at the colour burst crystal inside a colour TV set. This crystal will usually operate at 8·8672375MHz (ie, twice the colour burst frequency), although some sets use a 4·43361875MHz crystal.

BE WARNED though: the inside of a colour TV set is dangerous, so don't attempt to do this unless you are an experienced technician. There are lots of high voltages floating around inside a colour TV set and you could easily electrocute yourself if you don't know what you are doing.

In particular, note that much of the circuitry in a switchmode power supply circuit (as used in virtually all late-model TV sets) operates at mains potential (ie, many of the parts operate at 240V AC). In addition, the line output stages in some TV sets also operate at mains potential – and that's in addition to the lethal EHT voltages that are always present in such stages.

Note too that some TV sets (particularly older models) even have a "live" chassis, in which all the circuitry (including the chassis itself) operates at mains potential. Usually, there will be a label on the back of the set advising of this but don't take it for granted. Don't even think of messing about with this type of set.

In short, don't attempt the following calibration procedure unless you are experienced and know exactly what you are doing.

OK, assuming that you know what you are doing (and the set has a grounded chassis), you will need to make up an insulated probe with a 10MΩ resistor in series with the input plus a ground lead. This probe can then be connected to one side of the colour burst crystal and VC1 adjusted so that the meter reads either 8·867237MHz or 4·433618MHz (resolution set to high mode).

Make sure that the probe has no affect on the colour on the TV screen when it is connected to the colour burst crystal. If it does, it means that the probe is loading the crystal and altering its frequency. In that case, try connecting the probe to the other terminal of the crystal.

That's it – your new 50MHz frequency Meter is now calibrated and ready for action. *EPE*

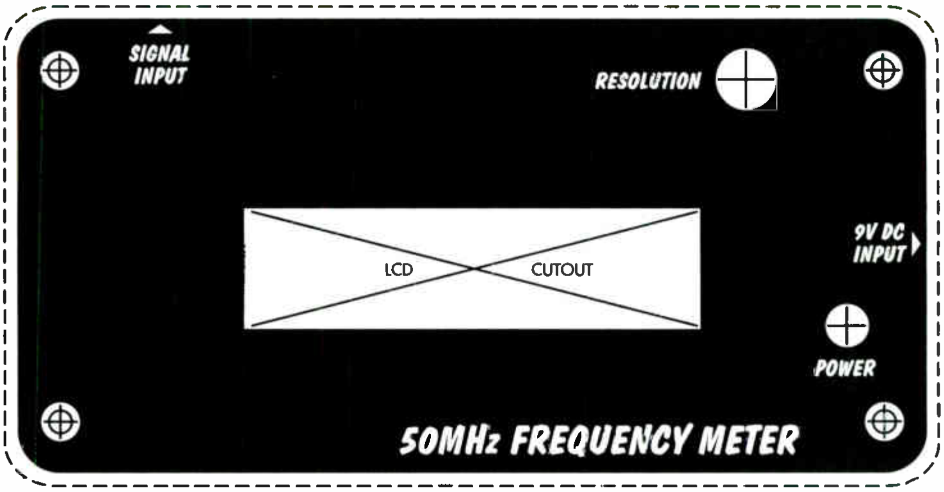


Fig.6: this is the full-size front-panel artwork for Version 1.

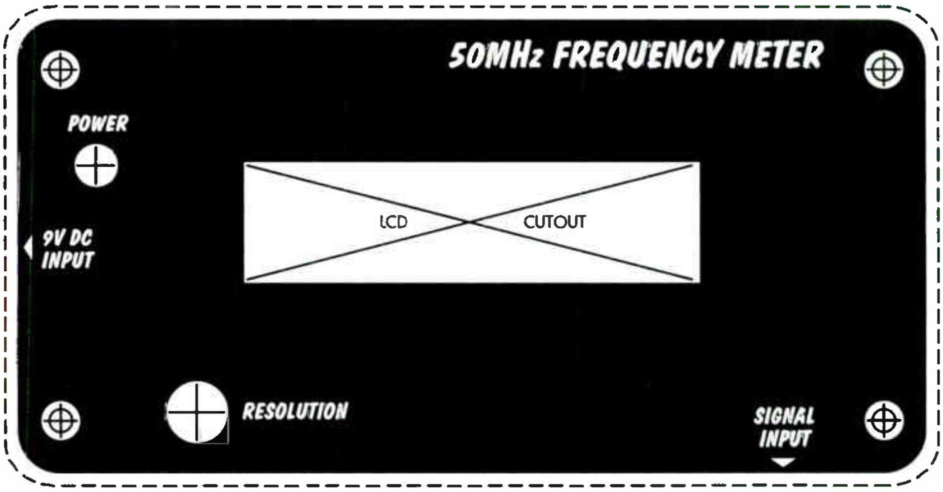


Fig.7: Versions 2 and 3 both use this front panel artwork.

This photo clearly shows the location of the access hole for the DC input socket for Version 1. It's located on the opposite side of the case for Versions 2 and 3.

TECHNO-TALK MARK NELSON

SIMPLY CONFUSED? OR NOT SO SURE?

If the future's fibre, why is copper cable refusing to coil up and die? And if it's fibre, then will it be based on silica glass or plastics? Mark Nelson wrestles with decisions that make the choice between "Daddy or Chips?" look like child's play.

NARROWCASTING needs broadband but broadcasting doesn't need narrowband. Confusing as that may sound, it's not really. Broadband cables into the home, regardless of whether they are made of copper or fibre, offer the wide frequency bandwidth to deliver full "over the air" quality television and radio. You may remember the "Negroponte Switch" prediction that tasks traditionally performed by radio waves (such as broadcast television and radio) would turn increasingly to cable, whilst a wirefree future beckoned for communication functions previously handled exclusively by wired means.

Technology guru Nicholas Negroponte argued that wires and wireless would change place and whether his forecast comes true or not, it's clear that an increasing number of households are already getting their "broadcast" television and radio by broadband delivered either by phone company wireline or by dedicated NTL or Telewest cable.

Feeding Frenzy

In this feeding frenzy of new media delivery mechanisms, what's sauce for the goose is sauce for the gander too. So it's not just BBC and ITV programmes that come down the wire but all manner of music videos, premium sports events, concerts, online gaming and other kinds of video-on-demand. Scan the World Wide Web and you'll find even more pay-to-view TV-like material on mainstream and specialist hobbies, not to mention X-rated stuff both legal and illegal. In short, there's a vast choice of á la carte audiovisual delight and "narrowcasting" is the name given to this service that broadcasters do not provide.

Broadcast or narrowcast, the "infotainment" you watch amounts to the same data volumes to be downloaded. And since narrowcasting is by definition aimed at minority audiences, it cannot compete with mainstream broadcasts for the limited number of channels available to over-the-air broadcasters. As the choice and volume of both narrowcast and broadcast programming expands, so must the size of the "pipe" that delivers them.

And that's where our first challenge arises, do we go for copper or fibre. Of course it's not our problem actually; it's the telcos and cable companies who must contend with this poser. Copper is the traditional solution; coaxial delivers the greater bandwidth but even "twisted pair" telephone lines have a remarkable capability. What's more, there's plenty of copper in the ground, passing virtually every home, so it's little wonder that communication companies are looking to sweat their assets and make the most of their massive investment in copper.

On the other hand, fibre can do far more. With almost limitless bandwidth it has a potential that far exceeds copper. What's more, the production cost of optical fibre is falling all the time, whereas the price of copper is ratcheting up every week. No wonder that fibre to the home (FTTH) is looking increasingly attractive to operators who realise that their "legacy" copper cable networks will one day be unable to cope with their customers' bandwidth requirements.

POF-ALL

Traditionally, optical fibres have been made of ultra-pure silica to avoid transmission loss. Where attenuation is not a limiting factor, such as for the very short fibre-length systems used for networking in-car entertainment, navigation systems and cellphones in high-end automobiles, fibre made of a plastic material not unlike Perspex or Plexiglas is fine. Cables made of Polymethyl methacrylate show particular promise, so much so that the European Union has funded a Euro 1.6 (£1.1) million scheme to devise a fully affordable FTTH distribution technology.

Some nine European companies and research institutes are working on this project, which was launched earlier this year, to run until midsummer 2008. The project's contrived acronym, POF-ALL (Paving the Optical Future with Affordable, Lightning-fast Links), has the advantage that it sounds equally meaningless in every language.

Two transmission speeds are proposed for POF-ALL, 100 Mbit/s and 1Gbit/s, and even the lower of these is between 20 and 100 times faster than the ADSL technology used on today's wireline connections, allowing a DVD-quality movie to be downloaded in under three minutes.

The same fibres and electronics could be used to create affordable broadband distribution networks in the home, with the twin advantages of safety and simplicity. Plastic fibres use visible light instead of infrared, reducing the risk of retinal burns or blindness from high-power beams and simplifying testing (no light, no signal). The tough sheath used to protect silica glass fibres is not needed on the more flexible plastic fibre material, meaning the latter can be cut and spliced with simple tools.

Annoyingly Good

That's it then; the future really is fibre. Well, not according to Udo Steffens, FTTH Operations Manager for 3M Telecommunications. "The problem with making an argument in favour of fibre all the way is that the copper-based solutions are doing such an annoyingly good job of providing more and more bandwidth to homes," he quips in trade journal *Lightwave Europe*. Right now, he continues, proponents of FTTH are merely attempting to prove that fibre is affordable, rather than the most affordable alternative.

However attractive systems of the POF-ALL variety may turn out to be, they can handle only the last link from the street cabinet into the home. For the long-haul distribution cables from the city data hub to the street there is no alternative to traditional silica fibre, which still requires the services of highly skilled (and paid) technicians using expensive fusion-splicing equipment costing around £1,400. These costs will fall as 3M and other firms develop new-breed fibre connectors that can be installed by less highly skilled labour, but not overnight. Meanwhile there's definitely still plenty of life in copper!

Switch Chatter

Meanwhile, Negroponte's famous switch is chattering from state-to-state. Arguments rage whether cable or wireless is the optimal distribution medium for mass access to ultra broadband. New very-high capacity microwave wireless networks can deliver data speeds of between one and 10Gbit/s and government body OFCOM has opened consultation on exploiting unused 71-76GHz and 81-86GHz microwave frequencies for ultra-fast broadband connectivity. The vast bandwidth offered and the high deployment costs mean that initially these networks will be for business use alone and only in metropolitan areas.

Finally, one place where the two media, fibre and wireless, co-exist happily is in the fibre link solutions that entrepreneurs like British firm Vialite offer. These modular radio-over-optical links substitute fibre for wireless in situations where radio reception is either impossible (underground for instance) or suffers significant electrical interference. This means radio systems designers can treat the link as a "black box" and plan it into an RF communications system without any knowledge of the fibre technology used.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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

THOSE with some experience of electronic circuits do not usually give a second thought to component tags or pins that are left unused. Newcomers to electronic components and circuits tend to be much less laidback about components which have tags that lead to nowhere. The assumption tends to be made that every potential connection point should actually connect to something, and any unconnected pins or tags must be due to an error somewhere.

The reality of the situation is very different. Although an unconnected tag or pin could be due to a mistake in the article that features the project, it is very unlikely that an error has occurred. It is a fact of project building life that practically every electronic project features at least one or two components that have superfluous tags or pins. There are various reasons for some components having these unused assets.

Pin-Nouts

A common cause is simply that the unused pins do not have any connections to the internal workings of the component, so there is no point in making any external connections to them. This often occurs where components have some form of standardised case, and integrated circuits are probably the most prevalent example of this. If an integrated circuit has (say) eleven connections to the outside world, the manufacturer will not produce an 11-pin encapsulation specifically for that component. Instead, a standard 14-pin case would be used, with three pins being left unused.

If you look through the integrated circuit (IC) pinout diagrams in a components catalogue you will certainly find plenty of pins that are marked "NC" or "no connection". Rather than a lack of connections to these pins suggesting a possible error, it is a connection shown to one of these pins on a circuit diagram that would be a bit suspicious.

Even when an integrated circuit does not have these dummy pins, it is still quite common for several pins to be left unused. This is due to the fact that many integrated circuits have facilities that are not utilized in every application.

For example, operational amplifier (op amp) integrated circuits typically have an 8-pin encapsulation, but most circuits only utilize the basic set of five connections (two inputs, output, and two supply pins). The other three pins of the component provide functions such as offset null control or frequency compensation that are not needed in many practical applications. Fig.1 shows pinout details for the 741C operational amplifier and its many equivalents. This has two offset null pins that are normally left unused, plus a pin that has no internal connection at all.

Test Caps

Logic integrated circuits often have a number of pins left unused, and in some cases the majority of them are left unconnected. The more complex logic devices are often designed to be as versatile as possible, which means that they have some inputs and outputs that are superfluous in most real-world application.

Simple logic integrated circuits typically contain something like four gates or six inverters, but a practical circuit might only need a couple of gates or inverters. This will inevitably result in some sections of the device being left unused and a number of pins being left unconnected.

It is quite rare, but a few integrated circuits have a pin that is designated "IC" (internal connection), "Test", or something of this type. These are pins that have an internal connection, but they are always left unconnected. Their purpose is to provide a test point (TP) that is used in the manufacturer's final testing procedure. With unused pins it does not matter if there is an accidental connection due to something like a blob of excess solder. However, this is not the case with these test pins, which must be left totally unconnected.

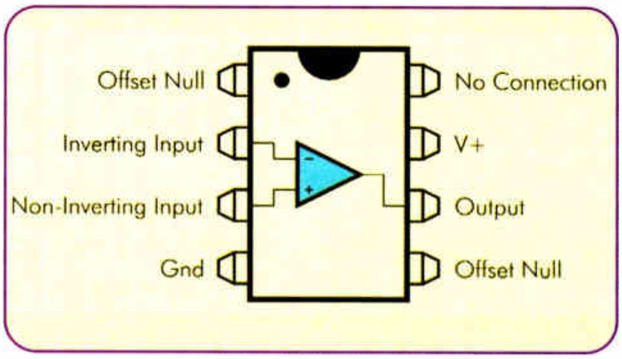


Fig.1. The 741C and similar operational amplifiers (op amps) have an unused pin plus two offset null pins that are little used in practice

Tying Up Loose Ends

You might occasionally encounter circuits that have partially utilized logic devices, but with some connections made to the unused sections of these components. The mystery connections will usually be from the inputs and one or other of the supply lines. Modern logic integrated circuits are mainly based on some form of MOS (metal oxide semiconductor) technology, and have extremely high input impedances.

One practical outcome of this is that unconnected inputs are vulnerable to stray pickup of electrical signals in the environment. Although any spurious input signals to an unused section of a device might seem unimportant, they can result in an unnecessary increase in the current consumption of the circuit. Unconnected inputs are also much more vulnerable to being zapped by static charges in the atmosphere or careless handling. Consequently, it is important that any unused inputs of this type are not simply left "floating" and vulnerable.

If you are concerned about integrated circuit pins that connect to nothing, try checking the circuit board and wiring diagrams against the circuit diagram. If the circuit diagram also shows that the pin or pins in question do not connect to anything, then it is fair to assume that these pins are genuinely unused. The "missing" pins will probably be included on the circuit diagram, but with no "wires" connected to them. Alternatively, unused pins will simply not be shown at all.

Although it only happens very rarely, it is possible that a definite discrepancy between the circuit diagram and other diagrams will be found. The publisher of the material should be able to provide corrections, and any errors in *EPE* articles are usually corrected in the next available issue. Where there is a strong possibility of an error in a constructional diagram, do not press on and hope for the best. Mistakes when building projects do not usually have dire consequences. However, there is some risk that components could be damaged, and there might also be safety concerns.

Rotary Switches

Unused tags are often the result of the designer having to make the best of what is available to the home constructor. This can result in the circuit designer having to "use a sledgehammer to crack a nut".

Switches are probably the most common example of this phenomenon. It can happen with the more simple switches, but it is something that is associated more with the relatively complex types. In particular, it often occurs with multi-way rotary switches. With switches of this type it is quite normal for more than half the tags to be left unused. It is rare for all the tags to be used.

The multi-way rotary switches used in most designs for the home constructor are supplied in four types, which are 3-way 4-pole; 4-way 3-pole; 6-way 2-pole, and 12-way 1-pole. Matters are complicated by the fact that modern rotary switches have an adjustable end-stop that enables the number of ways to be reduced. Suppose a 3-way 2-pole switch is required. One solution would be to use a 6-way 2-pole type with the end-stop set for 3-way operation. However, it would be equally valid to use a 3-way 4-pole type, with two poles of the switch being left unused.

Rotary switches are sometimes mounted directly on a printed circuit board, and where this is the case it is essential to use the type specified in the components list. There could be several options available where a rotary switch is under-utilised and hard wired to the circuit board. However, it is very easy to get confused with this type of thing, so it is best to make a precise copy of the original design unless you are quite sure you know what you are doing.

Component manufacturers have tended to rationalise their ranges over the years, and one result of this is that the full range of four basic switches is often reduced to just one or two types. It is useful to know that any of the four basic types of switch can be used to provide a simple on/off action (Fig.2 – top row). A SPST (single-pole, single-throw) switch is a simple on/off type, and a SPDT (single-pole, double-throw) switch is a changeover type. Ignoring one tag of a SPDT switch enables it to function as a SPST type.

The double-pole versions are effectively two switches that operate in unison. With these it is just a matter of ignoring the extra set of switch contacts and using them in the same way as the single pole varieties. It is also possible to use a DPDT switch as a DPST type (Fig.2 – bottom left) or as a SPDT type (Fig.2 – bottom right). As before, it is just a matter of ignoring the unnecessary tags.

Provided you can obtain DPDT switches it does not matter too much if there are supply difficulties with any of the other types. It also means that if you obtain a small stock of DPDT switches, they can be used whenever one of the four basic types of switch is required.

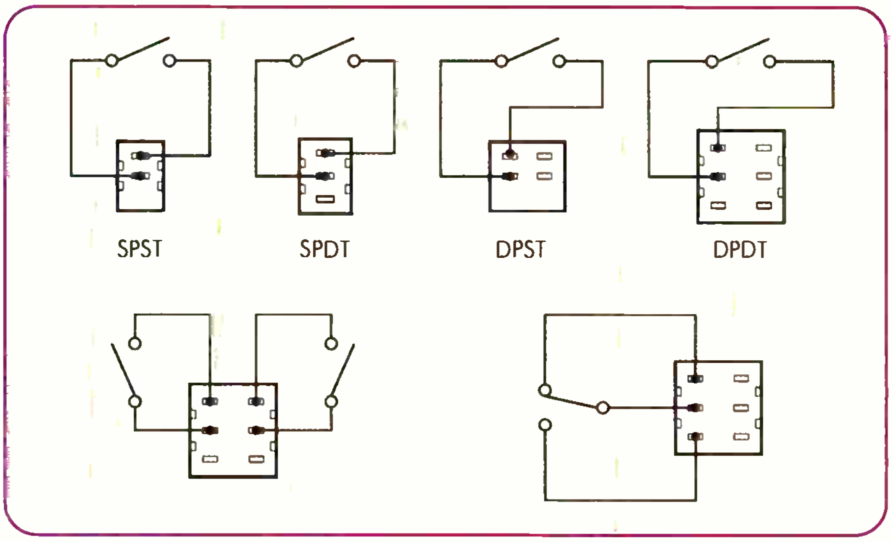


Fig.2. Any of the four basic types of switch can be used as a basic on/off type (top row). A DPDT switch can also be used as a DPST type (bottom left) or a SPDT switch (bottom right)

Potentiometers

There are two basic ways of using a potentiometer. One method has a voltage fed across the track, and a variable voltage is then obtained from the wiper terminal (or moving contact), as in Fig.3(a). A volume control is a common application of this type.

With the other method the component is used as a variable resistor, and this only requires two of the three terminals to be connected, as shown in Fig.3(b). However, in wiring circuit and wiring diagrams you will often find that the wiper tag is connected to the otherwise unused track terminal, as in Fig.3(c).

On the face of it, this extra connection serves no useful purpose. The rationale behind its inclusion is that it limits the maximum resistance that can occur if the control becomes "noisy" and there is a tendency for the wiper to lose electrical contact with the track. At most, the resistance provided is equal to the track resistance. Without the added link an infinite resistance is provided if the wiper loses electrical contact with the track. The rationale for omitting this connection is that a worn potentiometer will not work properly even with this connection included, and it will still have to be replaced as soon as possible.

I suppose that there could be circumstances in which the circuit could sustain damage if the variable resistance had a tendency to go open circuit. The added connection would then be important. Anyway, it should always be included if it is present in a wiring diagram, but there is probably no point in adding this connection if it is not shown.

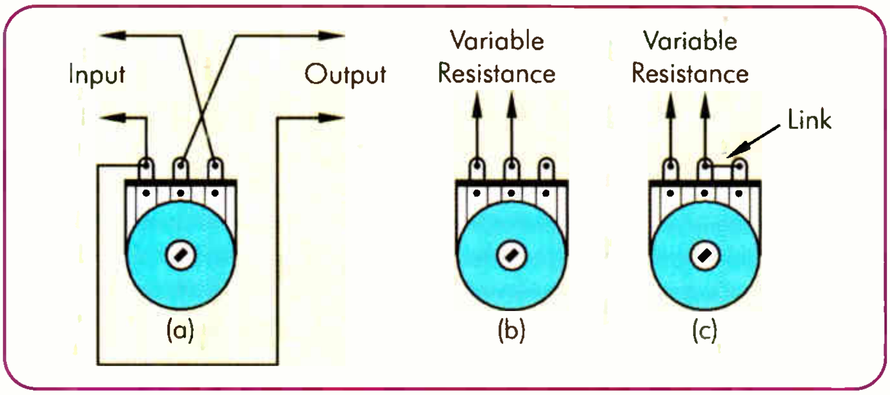
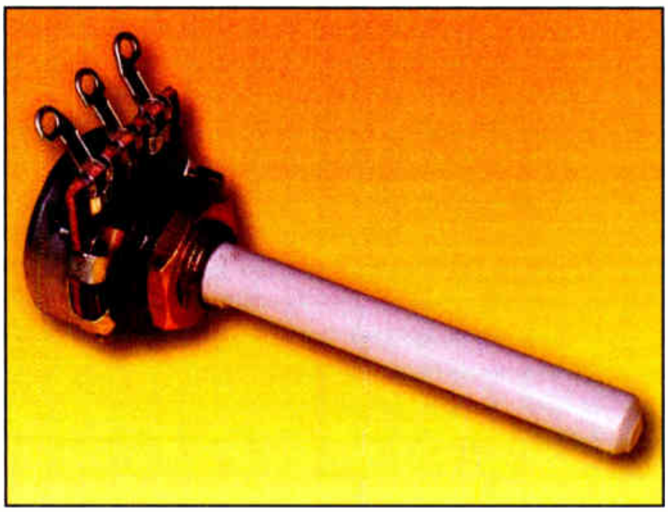


Fig.3. A potentiometer normally has all three terminals used (a), but only two are used when a variable resistance is needed (b). A link to the third terminal is sometimes included (c), but this is not strictly necessary

A 2-pole, 6-way rotary switch



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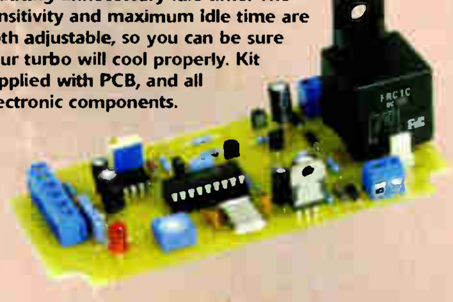

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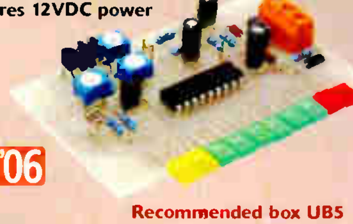
KC-5424 £6.00 + post & packing

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your vehicle. The kit features 10 LEDs that light up in response to the measured voltage, preset 9-16V, 0-5V or 0-1V ranges complete with a fast response time, high input impedance and auto dimming for night driving. Kit includes PCB with overlay, LEDs, all electronic components and clear English instructions.

• Requires 12VDC power



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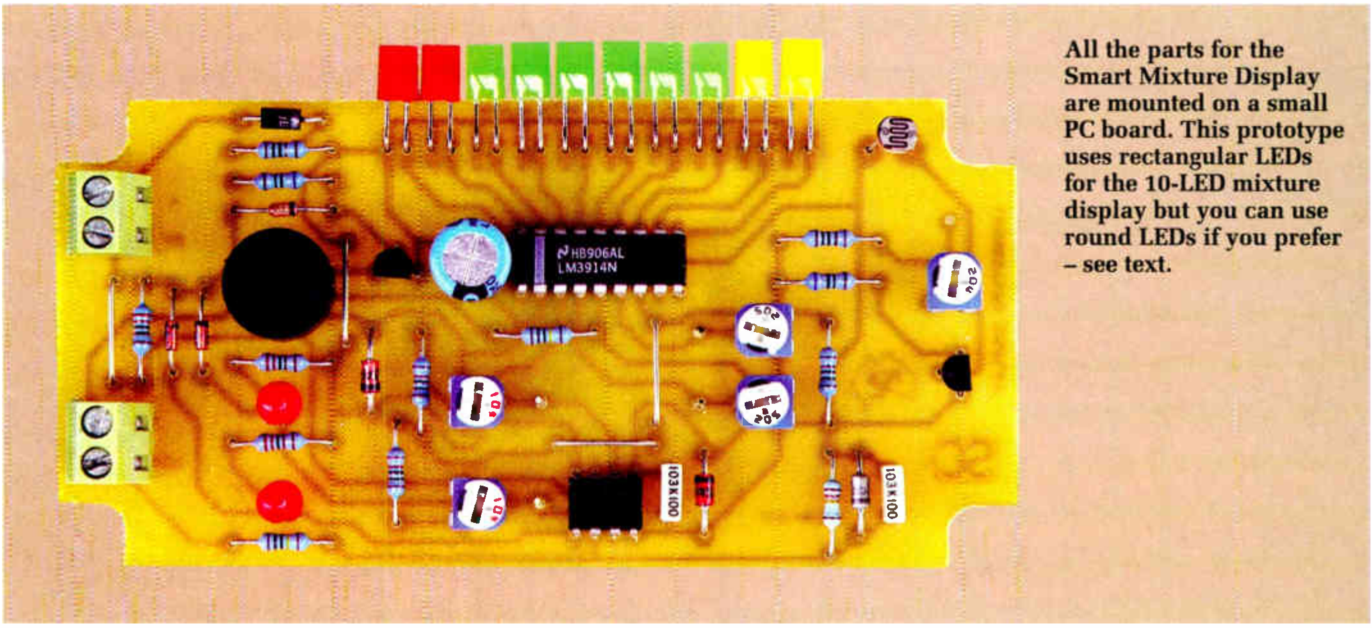


All the parts for the Smart Mixture Display are mounted on a small PC board. This prototype uses rectangular LEDs for the 10-LED mixture display but you can use round LEDs if you prefer – see text.

A Smart Mixture Display For Your Car

Track your car's fuel mixtures in real time, see the operating modes of the ECU and be warned if a catastrophic high-load "lean out" occurs. This Smart Mixture Display monitors your car's oxygen sensor and airflow meter outputs and gives an audible warning if mixtures go dangerously lean.

By JULIAN EDGAR & JOHN CLARKE

THE Smart Mixture Display presented here displays the mixture strength by means of 10 LEDs – red for lean (red is for danger!), green for mid-range mixtures and yellow for rich. However, we've added two important extra features:

(1). An automatic dimming function for night driving; and

(2). An audible lean-out alarm.

Lean-out alarm

The lean-out alarm is a great idea. It monitors both the air/fuel ratio and the engine load, sounding a buzzer if the air/fuel ratio is ever lean **at the same time** as the engine is developing lots of power. So why is this important? Well, if the engine – especially one with a turbo – goes lean under high loads, it's almost certain that you'll instantly do damage. One Impreza WRX that we know of lost part of an exhaust valve this way.

What could cause this sudden and catastrophic condition? Lots of things – from a dying fuel pump to fuel starvation during cornering. Even a couple of blocked injectors could cause a lean condition. It's not the complete answer – there are some conditions that the meter won't register. However, in most situations, it will act as an important warning that things aren't right.

The lean alarm works by also monitoring the voltage signal coming from the load sensor – usually the airflow meter. Most airflow meters have an analogue output voltage that rises with engine load, being around 1V under light loads (eg, at idle) and close to 5V under high loads. If the output voltage from the airflow meter is high, the meter knows that the engine load must also be high.

LED indicators

But what about the main section of the Smart Mixture Display – the LEDs? How do they work?

In broad terms, the oxygen sensors in most cars have an output voltage that varies between 0-1V, with higher voltages indicating richer mixtures. The meter lights one LED for each tenth of a volt coming from the sensor. so at 0·1V the far end red LED will

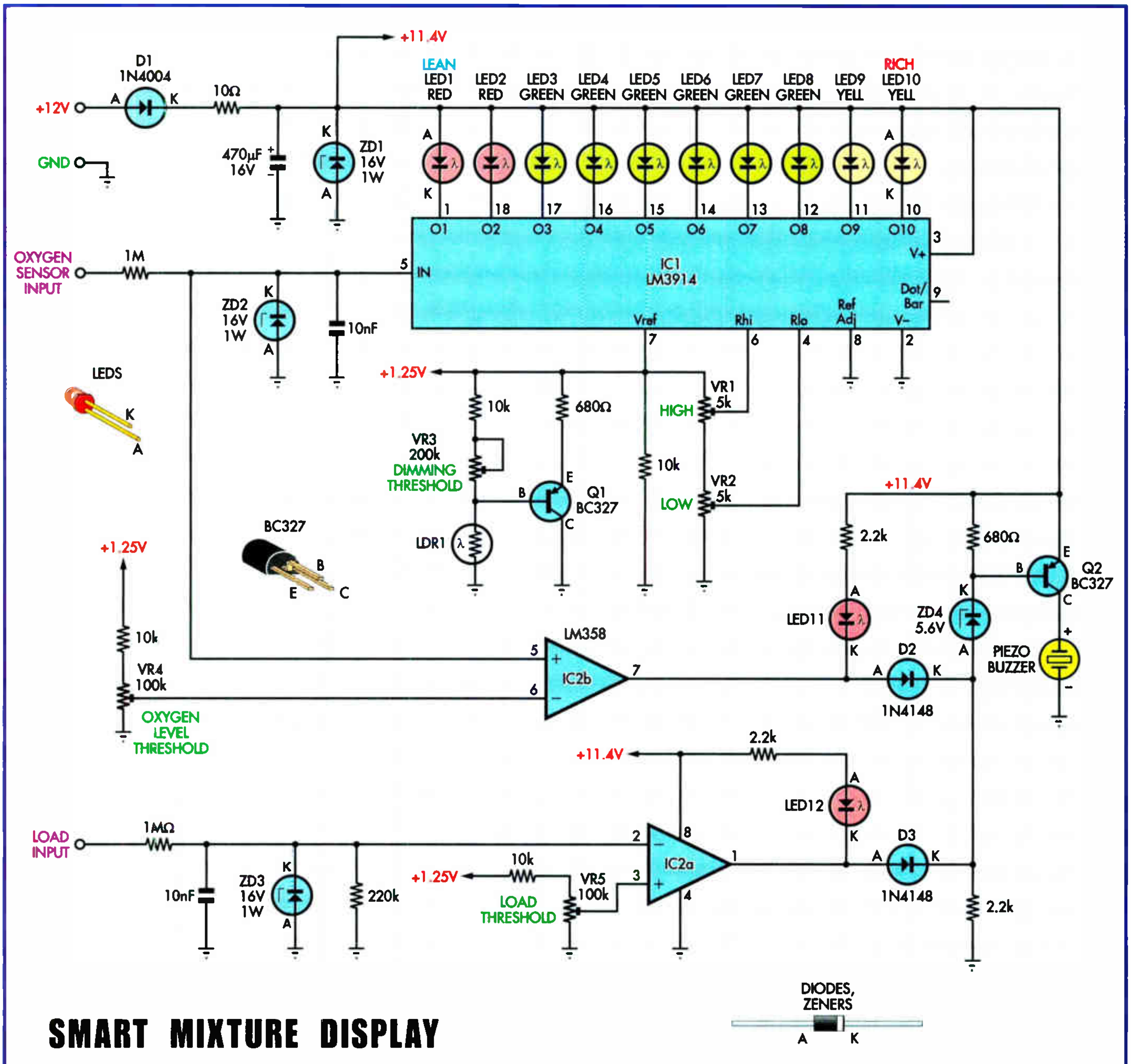


Fig.1: the circuit is based on an LM3914 dot/bar display driver IC. This accepts the signal from the oxygen sensor and directly drives a 10-LED display. Op amps IC2a & IC2b and their associated components (including Q2 and the piezo buzzer) provide the "lean-out" alarm feature.

be on, at 0·2V the next red LED will light up and so on. This doesn't give a precise indication of air/fuel ratio (see the "Air/Fuel Ratio Measurement and Oxygen Sensors" panel for the reasons) but in practice, it's still very useful.

So the oxygen sensor voltage is constantly displayed by means of the LEDs and if the oxygen sensor output voltage is low (ie, there is a lean mixture) at the same time as the airflow meter output is high (ie, a high engine load), the on-board piezo buzzer sounds.

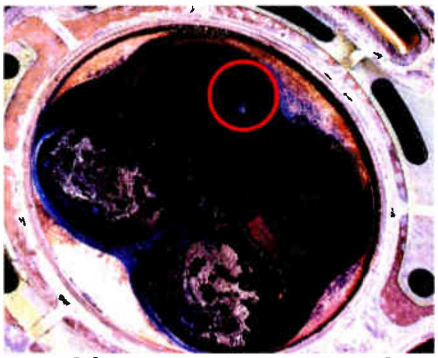
However, most of the time (we hope all of the time!), you won't have to worry about alarms sounding – instead you'll be able to glance at the dancing LED as you drive along. Dancing?

Won't the illuminated LED stay constant if the air/fuel ratio isn't changing?

One of the beauties of the meter is that it will show when the ECU is in closed loop operation, with the mixtures hovering around 14·7:1. This air/fuel ratio – called stoichiometric – allows the catalytic converter to work best, so at idle and in constant-speed cruise, the air/fuel ratio will be held around this figure.

To achieve this, the ECU monitors the oxygen sensor output. If the mixtures are a bit richer than 14·7:1, it leans them out a little. Conversely, if the mixtures are a bit leaner than 14·7:1, it makes them slightly richer.

This constant cycling of mixtures around the 14·7:1 point is called "closed loop" and will cause the lit



One of the most common causes of turbo engine damage (along with detonation) is a high load lean-out. That's what happened to this Impreza WRX motor – and in just a moment part of an exhaust valve was gone. [Michael Knowling]

The exhaust gas oxygen sensor delivers a mixture strength signal than can be monitored by the 10-LED Smart Mixture Display. All cars made in at least the last 15 years use an oxygen sensor. [Bosch]

LED to dance back and forth across the meter – as much as two or three LEDs either side of centre.

When some people see the LEDs flashing back and forth in closed loop operation, they quickly decide that the meter is useless. After all, the indication is "all over the place"! However, it's showing the very fast oscillations *that are actually occurring* in the mixture. By contrast, most aftermarket tail-pipe air/fuel ratio meters aren't sensitive enough to "see" this behaviour.

Closed loop operation does not occur in the following driving conditions: (1) during throttle lift-off; (2) when the engine is in warm-up mode; and (3) at wide throttle openings. At these times, the ECU ignores the output of the oxygen sensor, instead picking the injector pulse widths solely on the basis of the data maps programmed into it.

When the throttle is opened wide, the air/fuel ratio becomes richer, holding at that level. For example, the green LED second from the end may light and stay on. If you accelerate even harder, then the very end green LED may light. On the other hand, back right off and it's likely that all the LEDs will go out. That's because the injectors have been switched off on the over-run and the air/fuel ratio is so lean that it's off the scale. Watching the behaviour of a LED mixture meter really is a fascinating window into how an ECU is operating!

The mixture meter is also a vital tool when undertaking engine modifications. For example, if a particular LED lights at full throttle before and after making engine modifications (eg, to increase power), then you can be fairly confident that the mixtures haven't radically changed (under the same conditions, that is). Conversely, if the lit LED shifts two along after the modifications have been done, you can be fairly sure that the mixtures are different!

A word of warning though – the Smart Mixture Display shouldn't be relied on when making major engine modifications and/or working on expensive cars,

In summary, fitting the Smart Mixture Display to your car has three major benefits – you can roughly track your mixtures in real time, you can see the operating modes of the ECU and you can be warned if there is an unexpected catastrophic high-load lean out.

How it works

OK, let's take a look at the circuit details – see Fig.1. IC1 is an LM3914 dot/bar display driver. In dot mode, it drives the LEDs so that as the voltage at its pin 5 input increases, it progressively turns on higher LEDs. For example, at the lowest input voltage, LED1 is lit. At midrange voltages, LED4 or LED5 might be lit and at the highest input voltage, LED10 will be lit.

Trimpots VR1 and VR2 set the voltage range for the LED display. Normally, VR2 is set so that its wiper is at ground and VR1 is set so that its wiper is at 1V. Thus, the LED display covers a 0-1V range which is the normal output variation of an automotive oxygen sensor.

The LED brightness is set by the total resistance from pin 7 to ground and we vary this to dim the LEDs in darkness. In bright light, the Light Dependent Resistor (LDR1) is a low resistance and this provides current to the base of transistor Q1 which switches it on to set the LED brightness at maximum.

Conversely, in darkness, LDR1 is a high resistance and so transistor Q1 is off. This sets the LED brightness to minimum.

Trimpot VR3 adjusts the dimming threshold. If it's set fully clockwise (ie, to minimum resistance), the LEDs will be dimmed at a relatively high ambient light level. As VR3's wiper is rotated anticlockwise, the dimming begins at progressively lower ambient light levels until eventually, the LEDs are at maximum brightness in normal daylight.

Op amps IC2a and IC2b are used as comparators to monitor the load and oxygen sensor signals respectively. As shown in Fig.1, IC2b monitors the oxygen sensor signal at its non-invert-

Uhh, Ohhhh – Check Your Car First!

In some cars, this meter simply won't work and there can be several reasons for this.

First, it needs an oxygen sensor that outputs a voltage between 0-1V, with higher voltages corresponding to richer mixtures. The vast majority of cars produced over the last 15 years use this type of sensor but there are exceptions, so be sure to use your multimeter to check the oxygen sensor output signal before buying a kit.

Second, the car must use an airflow meter with an output voltage varying between about 1-5V, with the higher voltages corresponding to higher engine loads. However, some airflow meters use a frequency output signal and this circuit won't work with that type of design. Also, in non-turbo cars using a MAP sensor, the sensor voltage will go high whenever the throttle is snapped open. This may cause false alarms, as the air/fuel ratio won't immediately go rich.

By contrast, this design should be fine in turbo cars using a MAP sensor. Again, check the output of the load sensor with a multimeter first.

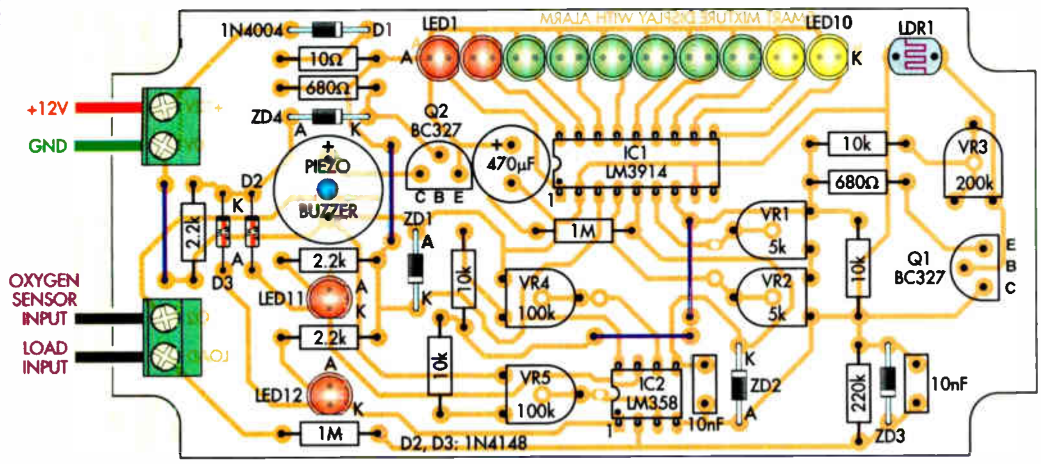


Fig.2: this diagram shows where each of the components is placed on the main PC board. Use this diagram, the photos of the completed board, Fig.1 and the parts list to help you assemble it correctly.

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ing input (pin 5), while VR4 and its associated 10kΩ series resistor set the voltage at the inverting input (pin 6). If the oxygen sensor signal level is below the voltage on the inverting input, then IC2b's output (pin 7) goes low and lights LED11.

Comparator IC2a operates in reverse fashion. It monitors the load signal at its inverting input (pin 2), while VR5's wiper sets the threshold for the non-inverting input (pin 3). If the load voltage is above the level set by VR5, pin 1 of IC2a goes low and LED12 lights.

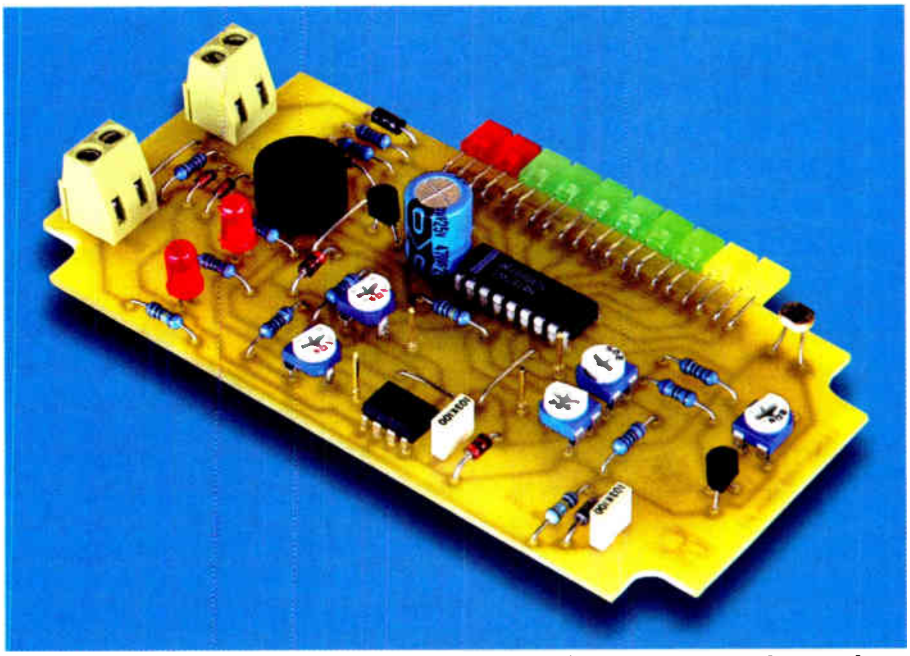
When the outputs of IC2a and IC2b are both low, transistor Q2 is switched on due to the base current through 5·6V Zener diode ZD4 and the 2·2kΩ resistor to ground. Q2 then drives the piezo alarm buzzer.

Now consider what happens if one of IC2's outputs goes high – ie, if the oxygen sensor signal goes above VR4's wiper or if the load input signal goes below the VR5's wiper. In that case, ZD4's anode is pulled high via either diode D2 or D3 (depending on which op amp output is high). This causes transistor Q2 to turn off and so the alarm stops sounding.

This means that the outputs of IC2a and IC2b must both be low for Q2 to switch on and sound the alarm.

Note the 1MΩ input resistors in series with the oxygen sensor and load inputs. These prevent loading of the circuits they are connected to and ensure that the car's ECU operation is not affected in any way by the addition of the Smart Mixture Display. The associated 10nF capacitors to ground are included to filter voltage transients on the inputs.

Power for the circuit is derived from the vehicle's +12V ignition supply.



The assembled PC board should look like this! Make sure that you observe the orientation of the 12 LEDs, two ICs, seven diodes and the electrolytic capacitor. Our prototype has rectangular LEDs for the mixture display but round ones are generally easier to mount in a panel. They can also be mounted remotely from the PC board to make it easier to package the meter in your car. Note that the LDR must be able to see ambient light, otherwise it won't work!

Diode D1 prevents damage if the battery supply connections are reversed, while the 10Ω resistor and 470µF capacitor provide decoupling and filtering. As a further precaution, 16V Zener diode ZD1 is included to prevent voltage spikes from damaging the ICs.

Construction

The Smart Mixture Display is straightforward to build, with all the parts installed on a PC board coded 584. Fig.2 shows the assembly details.

Begin the assembly by installing the wire links and resistors first. Table 1 shows the resistor colour codes but it's advisable to check each one with a digital multimeter as well, as some of the colours can be difficult to decipher.

The diodes, capacitors and trimpots can go in next, along with the two ICs. Follow these with the two terminal blocks and the piezo buzzer. Make sure that you install the polarised components the correct way around. These parts include the diodes, ICs, transistors, piezo buzzer and the 470µF electrolytic capacitor. Follow the overlay diagram and the photo closely to avoid making mistakes.

Air/Fuel Ratio Measurement & Oxygen Sensors

THE TOPIC OF measuring the voltage output of an oxygen sensor to quantify the air/fuel ratio is surrounded by misinformation. This is especially the case when people are attempting to perform critical tuning of modified engines while working within a budget that calls for the use of a low cost sensor.

Most exhaust gas oxygen sensors have an output voltage of approximately 0–1V, depending on the mixture strength (or air-fuel ratio). In most cars, the oxygen sensor is used in a closed loop process to maintain an air/fuel ratio of about 14·7:1 ("stoichiometric") during idle, light load and cruise conditions. In this way, emissions are reduced and the catalytic converter works most effectively.

However, this project attempts to quantify air/fuel ratios on the basis of the sensor output, which can be well away from the stoichiometric point. Commercially available air/fuel ratio meters utilising oxygen sensors – now widely used in automotive workshops – do the same thing. However, they use what are known as "wide-band" sensors, as opposed to the "narrow-band" sensors used in nearly all cars.

So what are the performance differences when it comes to wide-band sensors and can narrow-band sensors still be used to provide useful information?

The most common type of oxygen sensor is the zirconium dioxide design. In this sensor, part of the ceramic body is located such that exhaust gases impinge on it. The other part is located so that it has access to the atmosphere. The surface of the ceramic body is provided with electrodes made of a thin, gas-permeable layer of platinum.

Above about 350°C, the ceramic material begins to conduct oxygen ions. If the proportions of oxygen at the two ends of the sensor differ, a voltage proportional to the difference in the oxygen concentrations is generated. The residual exhaust gas oxygen component is largely dependent on the engine's instantaneous air/fuel ratio – thus the output voltage of the sensor can be correlated with the air/fuel ratio.

Fig.3 shows the typical output characteristic of a zirconia oxygen sensor. As can be seen, the output voltage varies rapidly either side of the 14·7:1 stoichiometric point. This is the characteristic curve output of a narrow-band oxygen sensor, as used in most cars. What is generally not realised is that a so-called wide-band sensor also has a very similar output, with just a little more linearity in its response at both ends of the air/fuel ratio scale!

In addition to the air/fuel ratio, the output voltage of a sensor is heavily dependent on its temperature. At very low temperatures – below about 350°C – the ceramic material is insufficiently conductive to allow the sensor to function correctly. As a result, the output signal of a "cold" sensor will be either non-existent or incorrectly low in voltage (note: the minimum operating temperature varies a little from sensor to sensor).

To overcome this problem, a resistive heating element is often placed inside the sensor to quickly bring it up to minimum operating temperature. Once this occurs, the heater is the usually switched off, with the flow of exhaust gases then responsible for heating the sensor.

The temperature of the sensor has a major bearing on the output voltage, even in the normal working range of 500-900°C. Fig.4 shows the change in output voltage characteristics of a sensor when it is at 550°C, 750°C and 900°C. (Note that here the air/fuel ratio is expressed as Lambda numbers – Lambda 0·75 is an air/fuel ratio of 11:1).

As can be seen, temperature variations can cause the output signal to vary by as much as one third of the full scale! It is also important to note that as the temperature of the sensor increases, its reading for the same air/fuel ratio decreases. Specifically, one tested sensor had an output of 860mV at 900°C, which corresponds to an air/fuel ratio of 11:1 (which is very rich). The same output voltage at 650°C would indicate an air/fuel ratio of 14:1 (ie, much leaner).

The temperature of the sensor also has a major effect on its response time. The response time for a voltage change due to a change in mixture can be seconds when the sensor is below 350°C, or as short as 50ms when the sensor is at 600°C.

These temperature-dependent variations occur in all zirconia-based oxygen sensors – wide-band and narrow-band.

So where does this leave us when we want to source a cheap sensor for use in measuring air/fuel ratios during tuning? First, an oxygen sensor which still has a variation in output well away from stoichiometric is required. Once that sensor is found, its temperature should be kept as stable as possible, while being maintained above 350°C during the testing.

As part of a general research project into the characteristics of common oxygen sensors, mechanic Graham Pring (a modification enthusiast) and the author (Julian Edgar) conducted an extensive series of tests on professional air/fuel ratio meters and sensors, both (supposedly) wide-band and narrow-band. We found that there were major variations between the readings of professional air/fuel ratio meters and that the use of a slightly used sensor could make a dramatic difference to the reading.

In short, when using zirconia oxygen sensors away from stoichiometric ratios, the professional meters were often not accurate to even one full ratio, let alone the one-tenth of a ratio shown on the digital displays.

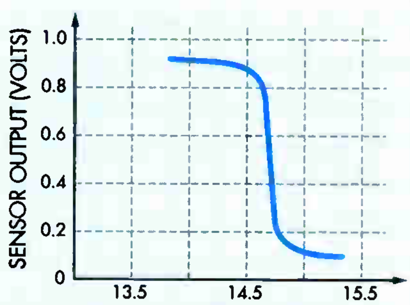


Fig.3: the output voltage from an oxygen sensor changes rapidly as the air/fuel ratio passes through 14·7:1. The degree to which the response curve flattens on either side of this ratio determines how useful the sensor is at measuring mixture strengths away from 14·7:1. [Ford]

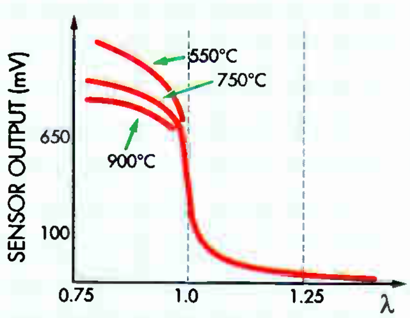


Fig.4: the operating temperature dramatically affects the output of an oxygen sensor. Sensors mounted close to the engine are particularly affected by temperature variations. [Bosch]

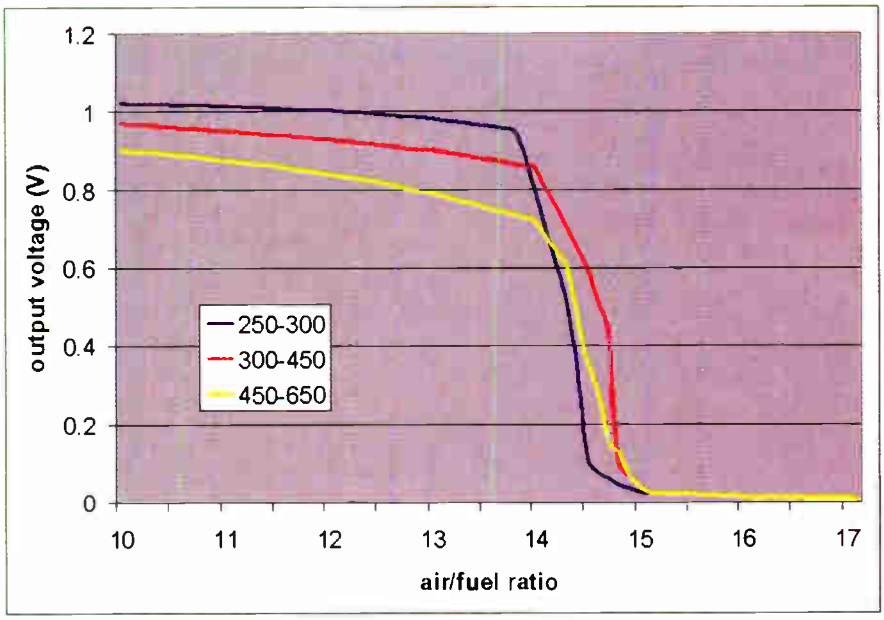


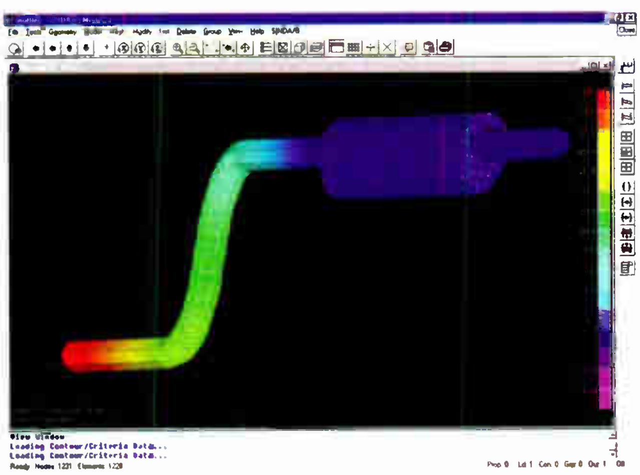
Fig.5: this diagram shows the relationship between the air/fuel ratio and the voltage output at different exhaust gas temperatures for the heated Ford E7TF 9F472 DA oxygen sensor (the best low-cost sensor we have found). This sensor is sufficiently wide-band that it can be used in conjunction with a digital multimeter to give a more accurate indication of mixture strength than is achievable with the 10-LED meter.

The best low-cost probe that we found was the heated NTK-manufactured Ford E7TF 9F472 DA oxygen sensor, which gave excellent results, even when compared with a new Bosch wide-band sensor.

To gain the best results from this sensor, it should be mounted at the tailpipe with its 12V heater active. Any testing should be consistent in approach so that the actual temperature of the sensor (due to both the internal heater and the exhaust gas) remains similar during each procedure. For example, the same warm-up and engine loading sequence should be undertaken for each test. By using the Ford sensor in this way, results are sufficiently accurate and a fast-response multimeter can be used to monitor the sensor output. However, realistically, an air/fuel ratio accuracy of only about 1-1·5 can be expected.

With this warning kept in mind, Fig.5 gives an indication of the response curves of the Ford sensor, measured at three different exhaust gas temperature ranges: 250–300°C, 300-450°C and 450–650°C.

However, tapping into the car's standard oxygen sensor and using the 10-LED Smart Mixture Display as described in the main text will still give data that is very useful. In fact, the lack of a digital readout is actually an advantage, as it stops people putting too much faith in numbers which in all likelihood are not accurate to even a full ratio.



The temperature of the exhaust reduces as it gets further from the engine. As this computer simulation shows, by the time it reaches the tail-pipe it is typically only at about 200°C whereas close to the exhaust valves, the gas temperatures can be over 800°C! [Network Analysis]

Parts List

1 PC board, code 584 available from the *EPE PCB Service*, 121 x 59mm
1 plastic case, 130 x 68 x 43mm
2 PC mount 2-way screw terminals, with 5mm pin spacing
1 12V piezo alarm siren with 7·6mm pin spacing
1 Light Dependent Resistor (LDR1)
1 100mm length of 0·8mm tinned copper wire

Semiconductors
1 LM3914 display driver (IC1)
1 LM358 dual op amp (IC2)
2 BC327 PNP transistors (Q1, Q2)
3 16V 1W Zener diodes (ZD1-ZD3)
1 5·6V 400mW Zener diode (ZD4)
1 1N4004 1A diode (D1)
2 1N4148 or 1N914 diodes (D2,D3)
4 5mm red LEDs (LED 1,2,11 &12)
2 5mm yellow LEDs (LED9,10)
6 5mm green LEDs (LED3-8)

Capacitors
1 470µF 16V PC electrolytic
2 10nF (0·01µF) MKT polyester

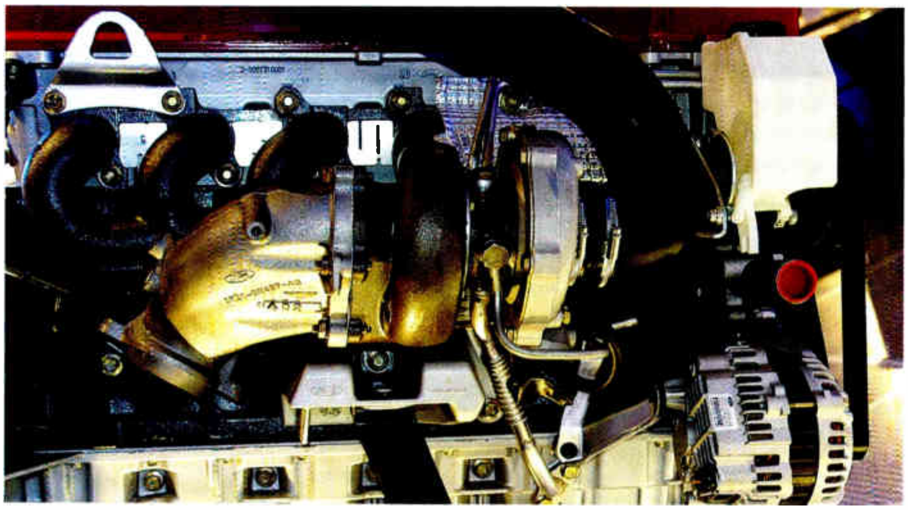
Trimpots
1 200kΩ horizontal trimpot (VR3)
2 100kΩ horizontal trimpots (VR4,VR5)
2 5kΩ horizontal trimpot (VR1,VR2)

Resistors (0·25W, 1%)

2 1MΩ	3 2·2kΩ
1 220kΩ	2 680Ω
4 10kΩ	1 10Ω

Finally, install the LDR and the LEDs. The LDR can go in either way, but the 10 bargraph LEDs must all be installed with their anodes (the longer of the two leads) to the left. LEDs 11 & 12 are installed with their anodes towards the top – see Fig.2.

Note that you can use high intensity LEDs if you want but because these are more directional, they may in fact not be any easier to see than normal LEDs. You may also used round or rectangular LEDs – the choice is yours.



Turbo engines like this are especially vulnerable to engine damage if the mixtures go lean under load. The Smart Mixture Display sounds an alarm the instant there is a high-load lean-out, allowing the driver to back off.

We used rectangular LEDs in our prototype for the 10-LED mixture display and these were installed with their leads bent through 90°, so that they were in line with the edge of the PC board – see photo. Alternatively, you can mount the LEDs vertically so that they later protrude through a slot (or a row of holes in the case of round LEDs) in the lid of the case. Another alternative is to use round LEDs which are mounted remotely from the board, to mimic the response curve of the oxygen sensor – see photo.

It's up to you what type of case you mount the PC board assembly in. As it stands, the board is designed to clip into a standard plastic case measuring 130 x 68 x 43mm. Note that if your car is very noisy, you may want to mount the piezo buzzer external to the box – or even fit a louder one.

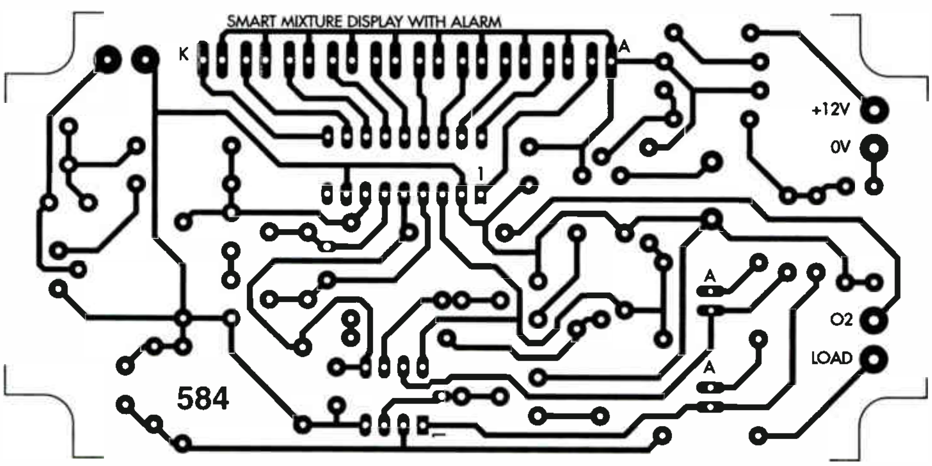


Fig.6: this is the full-size etching pattern for the PC board.

The buzzer can draw up to 60mA without causing any problems to the circuit.

Fitting

You will need to make four wiring connections to your car. It's easiest to do that at the ECU, so you will need to have a wiring diagram showing the ECU pin-outs. The four connections are:

(1). +12V ignition switched;
(2). chassis (0V);
(3) oxygen sensor signal; and
(4) airflow meter signal.

Use the car's wiring diagram to find these connections and then use your multimeter to check that they're correct. For example, when you find the +12V supply, make sure that it switches off when you turn off the ignition. In addition, you have to confirm that there is a fluctuating signal in the 0-1V range on the oxygen sensor lead (the car will need to be fully warmed up) and that the signal coming from the airflow meter rises when the throttle is blipped.

Note that the 0V connection for the Smart Mixture Meter should be made at the ECU.

Setting up

The step-by-step setting up procedure is as follows:

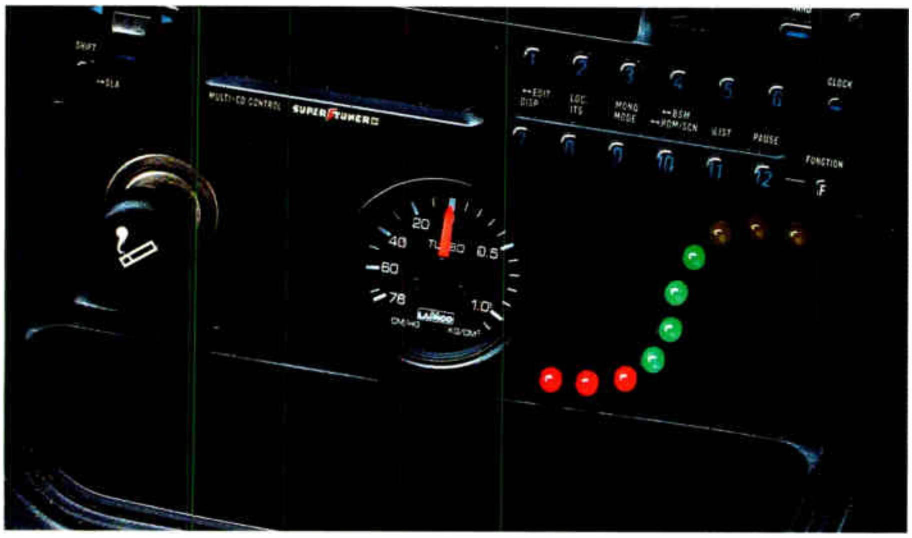
(1). Make sure that the "High" trimpot (VR1) is set fully clockwise and that the "Low" trimpot (VR2) is fully anticlockwise.

(2). Start the car, let the oxygen sensor warm up and confirm that the LED display shows one illuminated LED. It will probably move around, perhaps quite quickly.

(3). Go for a drive and briefly use full throttle. The end yellow LED should light up. Back off sharply – the end red LED should light and then the display should blank for a moment before resuming normal operation (ie, the over-run injector shut-off is visible).

Table 1: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	2	1MΩ	brown black green brown	brown black black yellow brown
❏	1	220kΩ	red red yellow brown	red red black orange brown
❏	4	10kΩ	brown black orange brown	brown black black red brown
❏	3	2·2kΩ	red red red brown	red red black brown brown
❏	1	680Ω	blue grey brown brown	blue grey black black brown
❏	1	10Ω	brown black black brown	brown black black gold brown



In this installation, round LEDs have been used for the mixture display, mounted remotely from the PC board. Note how the owner has chosen to arrange the LEDs to mimic the response curve of the sensor. This is a great approach if there is sufficient room available. [Michael Knowling]

Lambda vs Air/Fuel Ratio

The ratio of the mass of air to the mass of fuel is the most common method of describing the mixture strength. So an air/fuel ratio of 13:1 means that there is a mass of 13kg of air mixed with 1kg of fuel.

However, sometimes mixture strength is quoted as a Lambda (or excess air) value (λ). This is defined as the air/fuel ratio divided by the stoichiometric ratio (ie, on typical road fuels, 14·7:1). So an air/fuel ratio of 12:1 (rich) is 0·82 Lambda (12/14·7 = 0·82).

(4). Check that the illuminated LED travels back and forth when the engine is at idle (ie, the engine is in closed loop mode).

Adjusting the display to suit your oxygen sensor

(1). If the end yellow LED never lights, even at full throttle, adjust VR1 so that it lights when the mixtures are fully rich.

(2). In closed loop, the moving LED should move back and forth around the centre LED. If the oscillations are all down one end after adjusting VR1, adjust the "Low" pot (VR2) again to centre the display.

Adjusting the Lean Alarm

(1). Adjust the Load Threshold pot (VR5) until LED12 comes on at reasonably heavy loads. For example, in a turbo car, the pot should be set so that LED12 first lights when there's a little boost showing on the gauge.

(2). Adjust the Oxygen Level Threshold pot (VR4) until LED11 comes on for what would be regarded as a lean condition at the above load; eg, so that LED11 lights when the unit is showing the last green LED (LED3) before the red (LED2).

(3). When LEDs 11 & 3 come on together, the alarm sounds. If this occurs when there's no obvious problem, adjust VR4 until the alarm just no longer sounds when running high loads.

Adjusting the dimmer

(1). Turn the dimmer sensitivity pot (VR3) until the display dimming matches your preferences – clockwise will give a brighter display at night (so you need to cover the LDR to simulate night when you're setting it!) *EPE*

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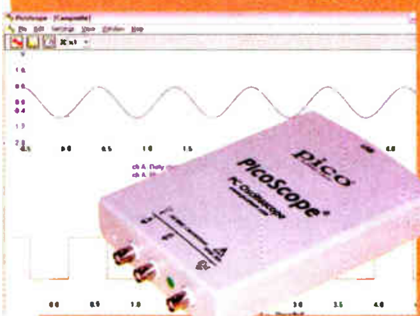

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Solar Radio

THIS little radio is powered by a miniature solar panel taken from a pocket calculator. These usually consist of four cells and generate about 2·5V in average light. The maximum current that they can provide depends on their size and the brightness of the light, and this will not always be enough to power the radio directly, although it will easily do so on a sunny day.

So a back-up supply is often needed, and in Fig.1 this is provided by the solar panel (not shown) and the 1F gold cap capacitor C5. This capacitor charges up continuously in normal lighting conditions and if the radio is kept near a window with the solar panel facing the light, it should always be well charged and ready for use at any time.

Gernmanium diode D1 prevents any leakage of current in the wrong direction, while only dropping the solar-generated voltage by about 0·3V. Resistor R2 protects radio receiving device IC1 from damage in case volume control potentiometer VR1 should inadvertently be turned up too far, i.e. towards zero resistance, when the supply voltage is high.

Starting at a typical voltage of 2·5V, the radio will play for several hours even in darkness before the voltage falls to 1·0V. If a good ferrite aerial is used some reception at a low volume level is still possible, and the total current consumption will only be about 70μA. Normally, however, the current level will be between 90μA and 130μA depending on the setting of VR1. Volume is adequate down to about 1.2V, at which point VR1 can be turned to minimum resistance.

A number of different measures have been taken to achieve the extremely low power requirement, which is an essential feature of this radio. The most important of these is the use of a crystal earpiece, X1, and high value resistors in the output stage around transistor TR1, a high gain device, as denoted by its "C" suffix.

The output stage only uses a fraction of the current that would be consumed by a similar stage. If required, a second crystal earpiece for the other ear could be connected in parallel, and this will give the impression of more volume without a significant increase in the current consumed.

The front-end, IC1, has also been modified with a view to saving power. The usual voltage stabilizing diodes have been omitted, and instead the supply to IC1 is adjusted manually by means of VR1, the best setting depending on the state of charge of C1 and the strength of the station being received. For weak stations it may need to be advanced to near the threshold of oscillation, while on strong signals it can be used as a volume control and turned well down to save even more current and to avoid overloading the output transistor.

Finally, the decoupling capacitor, C3, has been reduced in value to 10nF, from the more-standard 100nF, which gives a slight increase in both volume and clarity.

Any type of medium or long-wave ferrite aerial coil can be used, and a ferrite rod of about 10cm in length should give good results. If the coil is hand-wound, about 80 turns of 28 to 30s.w.g. enamelled copper wire are needed for a tuning capacitor of 200pF (medium wave) and about 250 turns of thinner wire, pile-wound, for long wave.

For a miniature receiver a ferrite slab aerial from an old pocket transistor set can be used and, since there are no batteries or loudspeaker, the set can be made very small indeed.

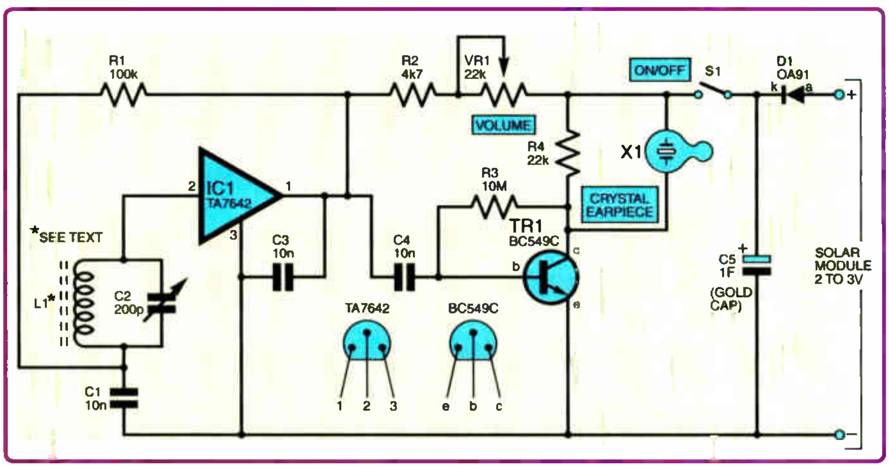


Fig.1. Complete circuit diagram for the Solar Powered Radio

Francis Hall, Meinerzhagen, Germany

We'd like to introduce our DIY human-powered electric torches. Using a deceptively simple design, a slow turn of the handle is enough to give a quite amazing output.

DEPENDING ON how you choose to build the torch, you can have anything from a pencil beam with a range of at least 50 metres (and incredibly, it will light reflectors at well over five times that distance!) to a broad and diffused light source perfect as a general purpose torch.

Plus, you don't need to turn the handle continuously; the light itself is ultra-white; and we would expect such a torch to last for, well, nearly ever.

And, to top it all off, if you play your cards right, the torch can also cost you very, very little to put together...

The Design Basics

So what's inside these human-powered torches? Just four basic components: a stepper motor, which generates the power to run the thing; a rectifier, which converts the AC (alternating current) from the stepper motor into DC (direct current), which the LED needs; capacitors, which store the power; and finally the LED itself, which produces the light.

Stepper Motor

The driving force in any of these designs is a stepper motor, driven as an alternator.

Stepper motors are used in electric typewriters, printers, photocopiers, faxes – a whole range of goods. They are most easily identified as a stepper because of the large number of wires that come out of the motor – usually six leads. When you turn the shaft, you'll also feel a "cogging" motion.

The huge benefit of using a stepper motor to produce the power (rather than the conventional brushed DC generator) is that the rotational speed needed is much, much slower. In fact, a stepper motor can be turned 10-15 times slower than a conventional motor-turned-generator.

So using a stepper motor in this application means that you can completely dispense with the gearbox – not only does that reduce noise and cost, it also decreases effort, as even a good gearbox has noticeable frictional losses. Longevity is also greatly enhanced.

And you shouldn't have to pay much for the stepper motor – not if you get it from inside a discarded printer, electric typewriter, fax, photocopier or similar.

The stepper motors used here came from laser printers and fax machines (each around £5 at jumble sales), while an old electric typewriter (for example, a daisy wheel design) can yield three or four suitable steppers. Steppers are available in many different sizes – smaller motors will generally yield less power than larger motors.

Rectification

Either four diodes or two bridge rectifiers are used to turn the AC output of the stepper motor into the DC that the LED and storage capacitor pack need.

Pretty well any small diodes can be used – they can be salvaged from equipment (the PC board from the aforementioned discarded electric typewriter had no less than 16 suitable diodes!) or they can be bought new for nearly nothing.

The wiring approach that you use depends a little on the stepper motor that you have at hand – more on this below.

Capacitor Storage

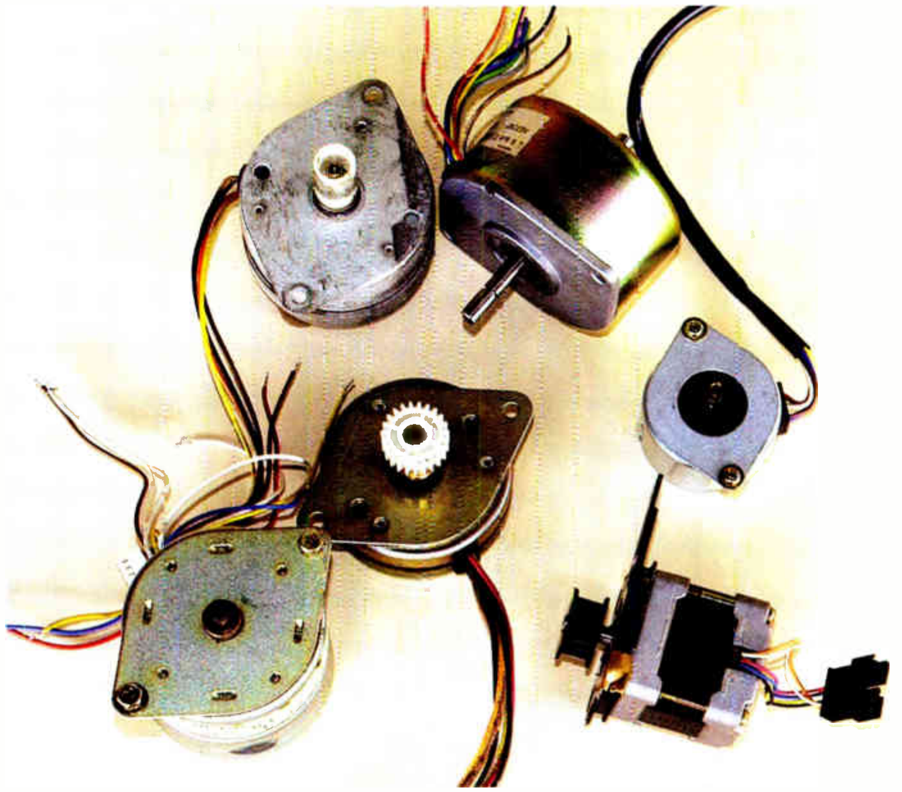
The low current draw of the LED makes something else possible – short-term energy storage. Using capacitors within the torch serves two functions:

1: it smoothes out the pulsing coming from the alternator, which otherwise causes the LED to flicker; and

2: it allows the LED to stay on for a short time after you stop cranking

How long the LED stays on for depends on how much capacitance you can squeeze inside the box. For example, using four 4700µF 16V electrolytic caps (ie 18,800µF total), typically gives a usable beam for about three seconds after you stop cranking – and the LED beam will stay dimly glowing for much longer. The latter means that it's easy to find the torch in the dark if you put it down.

However, if you decide to invest a little more money and use a super-capacitor (eg, a 1 Farad design), the torch will produce a dim beam all night without any further cranking!



The heart of the hand-cranked LED torch is a stepper motor. Several different types are shown here – these can typically be obtained from discarded electric typewriters and printers, amongst other goods.

LEDs

The torches use white LEDs rather than conventional bulbs. LEDs are replacing incandescent bulbs in many applications. However, until a year or so ago, even high-intensity LEDs were really marginal in high-output torches – the amount of light produced was simply not great enough for any distant

Using Stepper Motors To Generate DC

Stepper motors use a multi-pole design with four phases. When used as a motor, the computer puts a pulse of current into each phase coil in turn, moving the shaft on one step. As with a DC permanent magnet motor, driving the motor's shaft makes it work as a generator – in this case causing pulses of current to come out of the windings.

The developed current is AC, going positive as a magnet pole approaches a coil and then negative as it goes away again. Usually there are four phases at 90-degree intervals so when one comes down to zero, the next one has reached maximum. This is a benefit as it means the output can be rectified to produce much smoother DC with hardly any gaps, but it means these motors have a scarily large number of wires coming out. Luckily, it's quite easy to figure out which way around they are by using a resistance meter (preferably digital), and getting them the wrong way around won't do any damage.

The most common type of stepper has six wires coming out. The six wire stepper is actually two motors on one shaft, so the six wires can immediately be separated into two groups of three. Each group will have some connection to each other, but no connection to any of the other group. In each group, one wire is the common and the other two are the opposite ends of a winding which will give out oppositely-phased AC. In terms of resistance, the reading from the common to either end will be half the reading across the two ends. Having found the common on one set, you can use the same process to find the common in the other one. All four windings will have almost exactly the same resistance.

The majority of steppers are six wire, but there are other varieties. Five wire ones are easy; the two commons on the six wire have already been connected together for you, which makes things easier. Eight wire ones are just like a six wire but with all the windings separate, and four wire ones are half of an eight wire one (or half a six wire one with the two windings separate).

Courtesy of www.c-realevents.demon.co.uk/steppers/stepmotor.htm - used with permission

Fig.1: most stepper motors that can be salvaged from old equipment use this type of wiring configuration. Finding out which wire is which can be done with a multimeter.

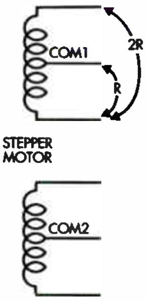


Fig.2: the simplest way of getting DC out of a stepper motor is to link the two commons to the 'minus' terminal and then connect the four live phases through small diodes to provide the positive output.

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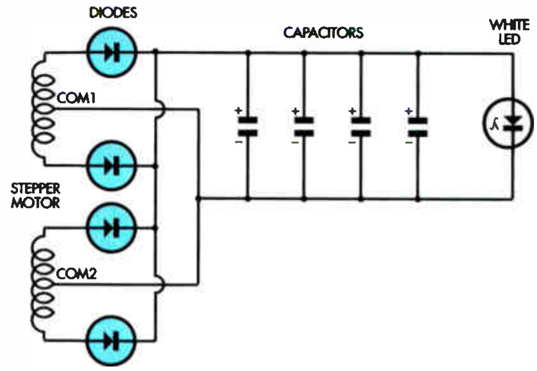


viewing. However, that limitation can be overcome by (a) using very bright white LEDs, and (b) using first-class coated optics to develop a very well focused beam.

The great advantage of using an LED is that its current draw is so low. The disadvantages (and of course, there are also disadvantages...) is that the LED costs more than an incandescent bulb, and in the final analysis, doesn't produce as much light as a hard-driven filament lamp. However, we're immensely pleased with how strong the beams of these torches are, especially considering that the effort put into turning the handle is really quite low.

Focusing Lens

A key ingredient in getting a good beam is the use of a focusing lens. High intensity LEDs are already very directional – some light comes out of the side of the LED but the vast majority is aimed straight out of the front. So while a reflector is good to channel the minor amounts of light scattering out of the sides, it's much more important to focus the beam that's already being formed.

The best lens that we have found is formed from some of the glass elements from an old standard 35mm SLR camera lens. These days, with the advent of digital cameras and with pretty well all SLR cameras being sold with zoom lenses, the standard lens is unloved and unwanted. In short, you can buy them secondhand for nearly nothing.

For example, one of these torch designs uses a lens formed from the reversed rear section of a 50mm f2 Ricoh lens. (Note that the 'speed' of the lens – ie in this case a maximum aperture of f2 – is important as the "faster" the lens, the larger will be its glass bits.) Using what was once a very good quality lens (ie, much better than a cheap plastic magnifying glass or similar) gives plenty of light transmission and also allows for the focusing of a tight beam. After all, how many commercial torches use high quality, low dispersion, coated glass optics!

Organising the Bits

1. Finding the Stepper

The first step is to find a suitable stepper motor that can be used to generate the power the LED needs. Digging through discarded equipment, it's not hard to come up with four or five steppers of different sizes and outputs.

A quick way of sorting out the better ones for the torch application is to firstly go for the larger motors (but which are still small enough to fit in your designated box), and then select those which most easily light a white LED wired directly to two of the output wires. (Despite the stepper producing AC when wired like this, the LED will still light when the stepper is turned – it will just flicker a lot). You will need to find a stepper where even when the shaft is turned quite slowly (eg, 1-2 turns a second), the LED shines brightly.

The experimentation that you do should be with a LED similar to that which you intend using in your final design – LEDs vary in their current requirements. For example, the Luxeon Star 1-watt models certainly can't be brought to full illuminance by a small stepper but that same stepper can work quite well with a conventional white 6000 mcd LED. The physically larger the stepper, the more likely that you will be able to drive a high-current LED.

2. Wiring Approaches

There are two wiring approaches that can be taken when building the torch – these are shown in Figs. 2 and 3. Fig.2 is the most common approach but Fig.3 has a distinct advantage in some applications – often it will increase the voltage available from the stepper. Deciding which approach is better for your application requires some further experimentation. First, use a multimeter to find out which wire is which, then wire the stepper to the LED as is shown in Fig.2.

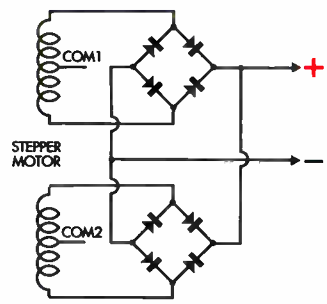


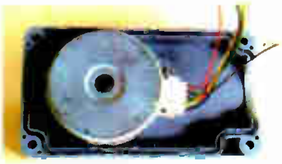
Fig.3: if you want to generate a higher voltage for the same cranking speed, you're usually better off using this circuit which uses two bridge rectifiers.

The next step is to turn the stepper as fast as you will ever be able to (you can use a bulldog clip to make a temporary clamp around the shaft of the motor to act as the attachment for a test handle) and measure the voltage being developed as the LED is powered up.

In addition, turn the shaft more slowly (that is, at a comfortable speed) and view the LED brightness. The ideal outcome is a peak voltage of around 3·5V – that's what is needed by the LED – and a "slow turn" voltage as close to this as possible. (In fact, of course, it's the peak current – rather than the voltage – that should be limited, but if the

Step by Step: Making a Narrow Beam Torch

1 We selected a rigid plastic box as the enclosure for the design. It is made from high impact ABS, uses a tongue-and-groove seal around the lid, and is dust and splashproof. Importantly to hand-holding comfort, it has rounded edges and corners.



2 The first step was to mount the stepper motor in the lid of the box, using the two screws that originally held the stepper in place inside the laser printer.

3 Next, the lens/reflector package needed to be organised. This Ricoh camera lens was disassembled and it was found that the rear lens elements (mounted in a sub-assembly) gave good results when placed about 20mm from the LED. The assembly is reversed in orientation to that used in the original camera lens.

4 A small torch was then disassembled, the reflector removed...

5 ...and the reflector opening for the bulb carefully drilled out (in small steps) until the LED was a tightish push-fit. (The reflector isn't critical but it adds a ring of light around the main beam.)

6 The pump-lid of a plastic container of skin cream was then selected as having a hole in one end about right for the reflector and a length about right for the LED-to-lens distance.

7 The lid was disassembled and the hole in the cap opened-up a little with a round file so that the reflector sat nicely in it.

8 The threaded top of the skin-cream container was then cut off, cleaned-up and then screwed back down inside the lid, holding the reflector firmly and securely in place.

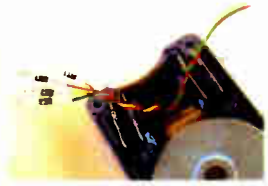
9 The holder from the camera lens was filed from its original semi-circular shape until it was about the same diameter as the reflector holder (that's the former skin cream cap, remember!).

10 Good quality electrical tape was then wrapped around the lens/reflector assembly, holding the two pieces together. Large diameter heatshrink could also have been used for this purpose.

11 Using a holesaw, a hole was then cut in one end of the box. The two halves of the box were then separated, the lens/reflector assembly inserted, and the box temporarily re-assembled to check that the lens/reflector assembly was held firmly in place.

12 The capacitors were placed into position next, being held in place inside the lid with double-sided tape.

13 The diodes were soldered to the four stepper motor outputs, making sure that all their bands were furthest from the stepper motor, then the wiring was completed. Note that the capacitors are polarised – their negative terminal is shown by a line of negative (-) symbols down the side of each of their bodies and they must be connected around the right way.



14 The final design is quite a tight fit – as you can see here, there's only just enough room for all of the bits.

15 The hand crank was made from a piece of polypropylene plastic kitchen chopping board. This material has a distinct advantage in this application: if a carefully-sized hole is drilled in the material, it can then be forced over the stepper motor shaft giving a good non-slip fit. In the case of the stepper motor shown here, a small diameter cog was already in place on the shaft and so the push-fit of the crank is even more secure.

16 At the other end of the crank, a high quality knob was made by using two ball-bearing pulleys, previously found inside an electric typewriter. Sandwiched together and with a couple of washers under them, they give an easily-grasped knob which has excellent quality bearings built right in.

17 Note that the distance centre-to-centre between the knob and the motor shaft (ie the working length of the crank) is very important to the 'feel' of the device: you should experiment with this distance until the leverage suits your preferences.

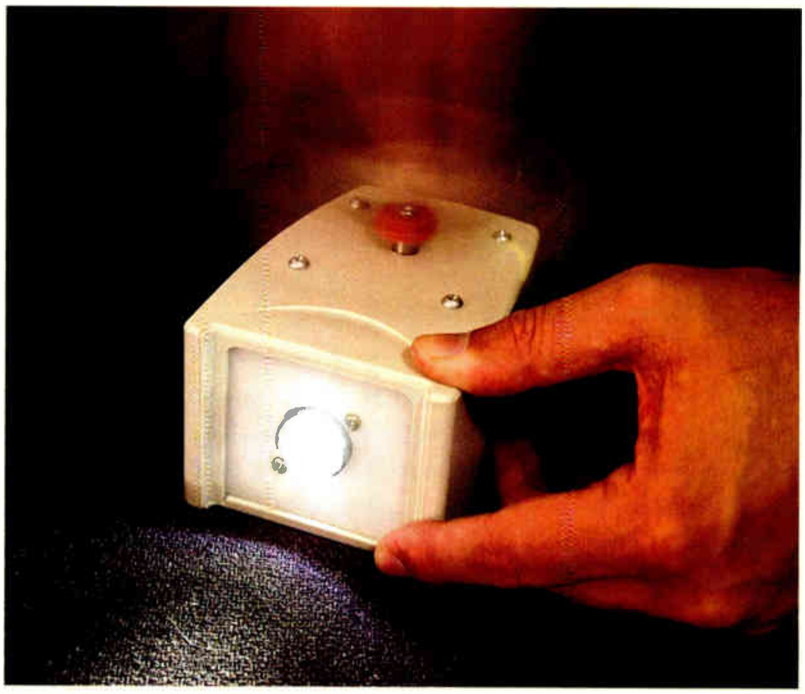
La Crème de la Crème – The Big-Buck Design

This torch is the big buck design – it uses an expensive 1-watt(!) Luxeon Star/O LED and super capacitor energy storage.

As you'd expect, in operation it's also the most impressive of the designs, able to light a room or create a swathe of light outside that – for example – is ideal for walking. Despite the fact that extra focusing optics would have given this torch an incredible beam reach, it was decided to use only the Luxeon built-in lens and reflector, resulting in a very even 20° beam.

When held close to a digital light meter, a reading of over 34,000 lux can be recorded! In practice, when walking down a road at night, the full width of the road is illuminated with a range of six metres or so.

The torch uses for its body a plastic housing that was originally one of the satellite speaker enclosures in a PC sound system. The knob is a ball-bearing equipped cog (with the teeth mostly sanded away) that was salvaged from an old fax machine.



Both wiring approaches were tried and the simple diode rectification gave the best output for the least cranking effort. Inside, a 0·47µF electrolytic capacitor and a 1 Farad super capacitor are used for energy storage.

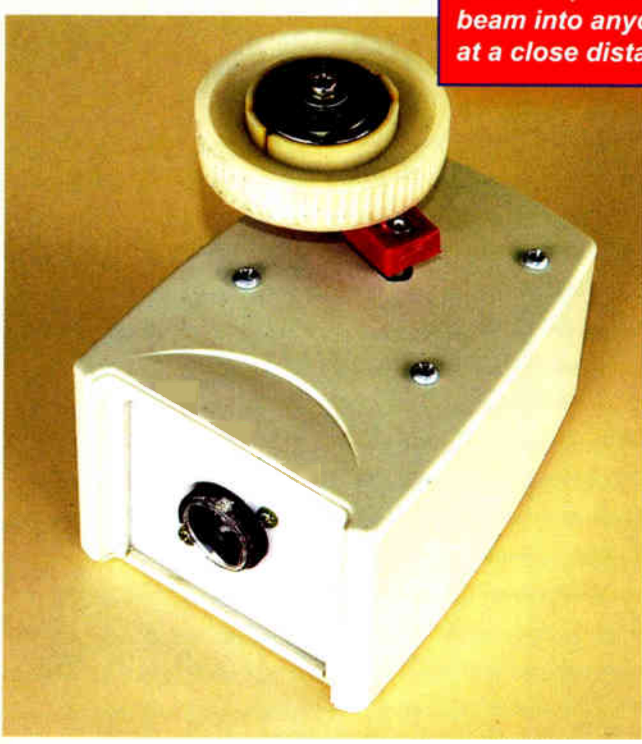
This is an enormously impressive torch. In fact, the only downside is that generating a full watt by a hand-cranked mechanism is hard to do quietly – despite the direct drive, the stepper motor makes a whirring noise when being turned. The size of the required stepper also makes this torch the heaviest of the designs – it weighs 600 grams – but the sheer light output is just staggering.

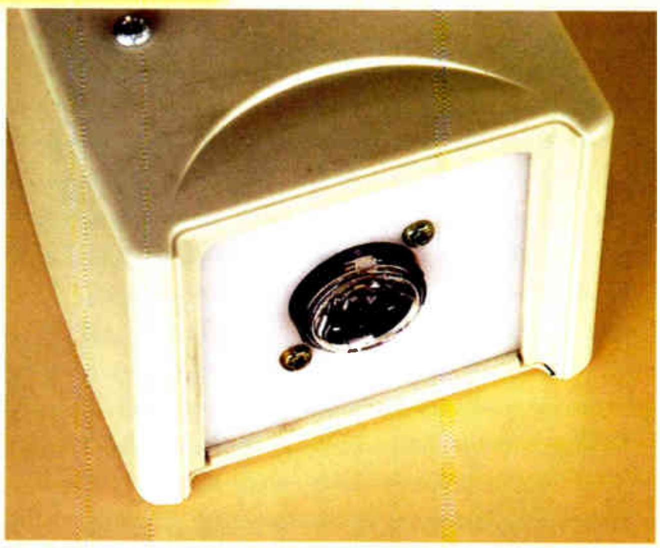
Very few people can believe that a simple turn of the handle can produce this much light – especially from a LED!

Warning!

The output of a focused beam or Luxeon Star LED torch is sufficient to cause eye discomfort and possibly eye damage.

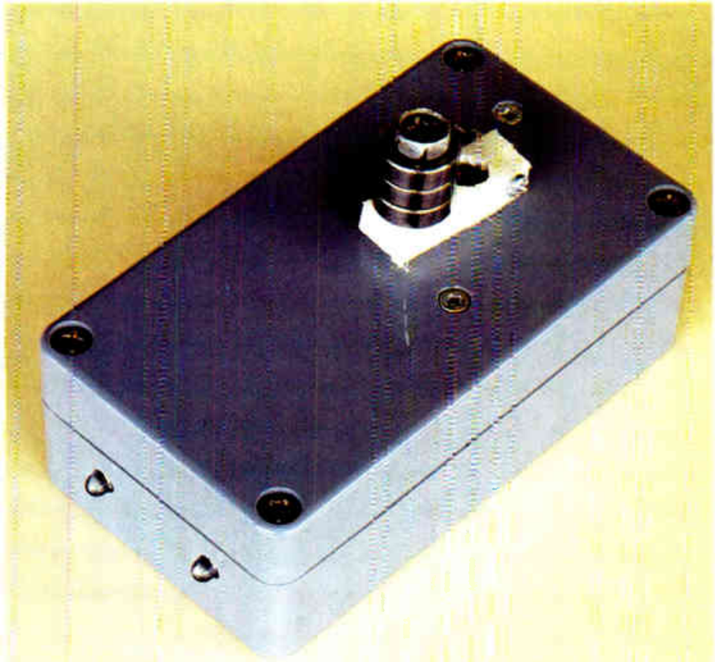
Do not look directly into the torch, and don't shine the beam into anyone else's eyes at a close distance.





If you want the best, you have to be prepared to pay for it. This torch uses the VERY bright LUXEON Star/O LED and a supercapacitor. But its performance is exceptional!

A Broad Beam Torch



After my partner saw the results of the narrow beam torch, She-Who-Must-Be-Obeyed decided that when out walking she wanted a torch that would light up the area immediately in front of her – that is, producing a very broad, diffuse beam.

This meant that a focusing lens was not required, so creating more room inside the box for storage capacitors – nine 4700µF capacitors were installed, giving a total capacitance of 42,300µF. Secondly, it was preferred that the torch weigh less than the first design, so in this model a smaller stepper motor was used. It was also decided to fit two of the high intensity LEDs, rather than just one.

The stepper motor is easily able to drive two LEDs (and probably more as well), and without the dramas of trying to integrate multiple LEDs into a reflector-and-lens system, it was easy enough to use two.

However, when wired with separate rectifying diodes, the smaller stepper proved to have a lower voltage output than the larger stepper used in the focused-beam torch. This meant that the crank had to be wound very fast to get a good light output, so a revision was made to the wiring. Two bridge rectifiers were then used (ie, Fig.3's wiring approach).

In practice this resulted in the voltage rising to 3·2V at an easy cranking speed – and peaking at 3·4V when the short handle was being turned as quickly as possible. While the effort in turning the handle rose when this alternative wiring configuration was adopted, it is still quite easy to turn.

In some respects, the handle is actually easier to use when working against the slight resistance – before, it was almost free-wheeling. A very short handle was fitted (about 10mm centre-to-centre), with its knob formed by three sealed ball bearings from discarded video cassette recorder video heads.

In a small room with a white ceiling and walls, the two-LED torch will dimly illuminate the whole room. Following an outside path at night, the torch casts a soft white glow that extends about five metres ahead and a metre or so either side of the path. In fact, the light output is similar to a small fluorescent lantern.

Interestingly, with the LEDs sticking out of the front of the "torch", any light being produced by them is more easily seen than in the focusing torch design (where the LED is buried from view behind a lens). In fact, the LEDs in this torch stay faintly glowing for a very long time after the handle has stopped turning – in pitch darkness, they can be seen for over six hours – and that's without using any expensive super capacitors!

This characteristic, and the diffuse spread of light that it develops, makes this an ideal torch for moving around a house at night when the lights are off, walking down a dark footpath, or for use as an emergency torch during blackouts.

stepper being turned flat-out develops only around 3·5V, in real use the LED will be well within its ratings.)

Matching the stepper motor to the LED in this way removes the need for a dropping resistor, saving valuable energy – energy, remember, that's being put in by you!

If the voltage that you see during the test is well below 3·5V, try the wiring approach shown in Fig.3. Often (but not always!), this will increase the voltage output of the stepper motor. If neither approach yields a high enough voltage when powering the LED of your choice, select another stepper and try again.

In our testing of more than 50 stepper motors salvaged from used consumer goods, we've not seen a stepper motor that, when cranked in this way, produced well in excess of 3·5V – so your chances of overpowering the LED are slim. On the other hand, probably half of these motors had enough "oomph" to drive a conventional white LED to a high brightness. In short, a great many small salvageable steppers are ideal for white LED torches.

3. Optics

Once you have found the right combination of LED and stepper, you will

Emergency?

These human-powered LED torches have some really good emergency applications. The light is visible from a very long distance (especially if you build it to have a narrow, focussed spot beam) and the torch will never get a flat battery. Because of the direct-drive system, the quality bearings used in stepper motors, and the LED light source, the torches should also have an almost unlimited life.

need to make some decisions about the optics. There are three basic choices:

- A narrow, intense beam – this requires a series of lenses, preferably an optical assembly from a 35mm camera lens as described above.
- A broad, bright beam – usually, a single lens can be used to achieve this – eg, a single element from a 35mm camera lens or a good stand-alone glass lens; eg, a quality magnifying glass. Alternatively, a very high quality LED lens-and-reflector combination (such as the Luxeon Star/O 1W white LED) can be used.
- A diffused, relatively dim beam – in this case, one or two LEDs can be mounted "bare"; ie, without any optics at all.

Think through the choice carefully – the utility of the final torch for the application that you have in mind is dramatically affected by the decision on optics.

4. Storage Capacitors

The type and number of storage capacitors that you use depends on how much room you've got inside your box/torch – and how much you want to pay. Electrolytic capacitors are the ones to go for and if you select those with a lower working voltage, the size of the capacitor becomes smaller for a given capacitance. In other words, a 1000µF 16V capacitor is physically much smaller than a 1000µF 63V capacitor. Since we're working with only 3 to 4V, the lower voltage capacitor is fine.

Basically, the more capacitance that you can squeeze in, the better – which brings us to "super" capacitors.

While these mighty marvels are available from a variety of sources, extensive testing showed that the cheaper super caps give poor results – we recommend the RS Components 339-6843 1 Farad component. Note also that a super cap used on its own won't work very well – you should always have a conventional electrolytic capacitor as well, of as high a capacitance as will fit in the box.

You might be wondering how all these capacitors are connected – again it's very easy, with the capacitors wired in parallel to both each other and the LED. No current limiting resistors, no Zener diodes, nothing. It works extremely well and wastes no energy.

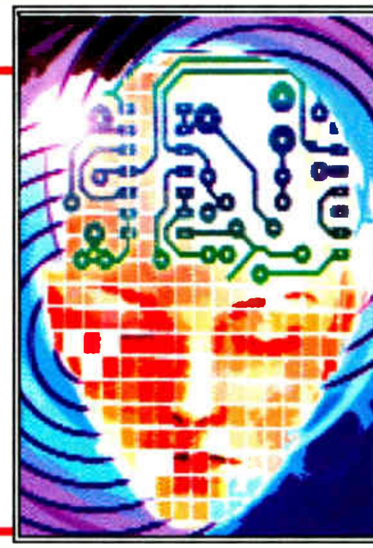
Conclusion

Despite being very simple in design and construction, these torches really cut it. They're effective and cheap, working well in both general-purpose and specialised applications.

Not one of the many people who have seen the prototypes was unimpressed – in fact most people had to have the torch removed from them by force, so intent were they on winding the handle and shining the torch into dark places! *EPE*

EPE Tutorial Series

TEACH-IN 2006



Part Eleven – Radio, Constructional Project, Teach-In 2006 Competition.

MIKE TOOLEY BA

Our Teach-In 2006 series provides a broad-based introduction to electronics for the complete newcomer. The series also provides the more experienced reader with an opportunity to "brush up" on topics which may be less familiar. This month we shall be bringing our series to a conclusion by taking a look at a particular application of electronics that has been in use for over a century. For those of you who may be looking for an opportunity to "put principles into practice" we conclude with a simple constructional project that brings together many of the ideas that we met earlier in the series as well as those that appear in this final part. We also introduce our *Teach-In 2006* Competition and the chance to win some fabulous prizes donated by our sponsors Rapid Electronics.

Radio

Radio is one of the longest established applications of electronics. In fact, prior to the Second World War, radio could probably be considered to be *the* application of electronics. Today, however, it is just one of many fields which are based on the use of electronic components, devices and principles. That said, radio plays a very significant part in our daily lives and thus an introduction to the subject makes a fitting end to our *Teach-In* series.

The existence of electromagnetic waves (on which radio depends) was first suggested by Maxwell nearly 150 years ago. Later, Heinrich Rudolf Hertz used an arrangement of rudimentary resonators to demonstrate the existence of these waves. Hertz's simple apparatus comprised two resonant loops, one for transmitting and the other for receiving. Each loop acted both as a tuned circuit (containing inductance and capacitance) and also as a resonant aerial. The transmitting loop was excited by means of an induction coil and battery. Some of the energy radiated by the transmitting loop was intercepted by the receiving loop and the received energy was conveyed to a spark gap, where it was released as an arc.

As predicted by Maxwell, the energy radiated by Hertz's transmitting loop took the form of an electromagnetic wave comprising both electric and magnetic field components travelling together at the speed of light.

Later, in 1894, Marconi demonstrated the commercial potential of the phenomenon that Maxwell predicted and Hertz had actually used in his apparatus. It was also Marconi that made radio a reality by pioneering the development of telegraphy without wires (i.e. "wireless"). Marconi was able to demonstrate very effectively that information could be exchanged between distant locations without the need for a "land-line" (or cable) connection between two points.

Marconi's system of wireless telegraphy proved to be invaluable for maritime communications (ship to ship and ship to shore) and was instrumental in saving many lives. The military applications of radio were first exploited during the First World War (1914 to 1918) and, during that period, radio was first used in aircraft. Broadcasting followed later in the 1920s and 1930s and most homes in the UK boasted a "wireless set" or "wireless apparatus" by the mid-1930s.

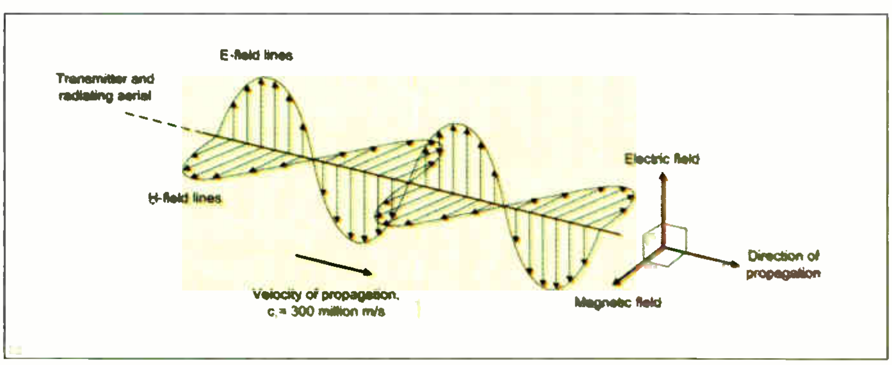


Fig.11.1. An electromagnetic wave

Electromagnetic Waves

As with light, radio waves propagate outwards from a source of energy (the transmitter and transmitting aerial) and comprise electric (E) and magnetic (H) fields at right angles to each other. These two components, the E-field and the H-field, are inseparable and the resulting wave travels away from the source with the E and H lines mutually at right angles to the direction of propagation, as shown in Fig.11.1.

Radio waves are said to be polarised in the plane of the electric (E) field. Thus, if the E-field is vertical, the signal is said to be vertically polarised. Whereas, if the E-field is horizontal, the signal is said to be horizontally polarised.

The transmitting aerial is supplied with a high frequency alternating current. This gives rise to an alternating electric field between the ends of the aerial and an alternating magnetic field around (and at right angles to) it.

The direction of the E-field lines is reversed on each cycle of the signal as the wavefront moves outwards from the source. The receiving aerial intercepts the moving field and voltage and current is induced in it as a consequence. This voltage and current is similar (but of smaller amplitude) to that produced by the transmitter.

Check Point 11.1

Electromagnetic waves consist of two inseparable field components, the electric or E-field and the magnetic or H-field. The fields act at right angles to each other and travel together at the speed of light, c = 300 million m/s, in air or vacuum.

Frequency and Wavelength

Radio waves travel in air (or space) at the speed of light (300 million metres per second). The velocity of propagation, v, wavelength, λ, and frequency, f, of a radio wave are related by the equation:

$$v = f\lambda = 300 \times 10^6 \text{ m/s}$$

This equation can be arranged to make f the subject, as follows:

$$f = \frac{300 \times 10^6}{\lambda} \text{ Hz} = \frac{300}{\lambda} \text{ MHz}$$

when λ is expressed in metres (m).

Alternatively, we can make λ the subject as follows:

$$\lambda = \frac{300}{f} \text{ m}$$

when f is expressed in MHz.

As an example, a signal at a frequency of 1MHz will have a wavelength of 300m. Similarly, a signal with a wavelength of 10m will have a frequency of 30MHz.

Note, however, that when a radio wave travels in a cable (rather than in air or "free space") it usually travels at a speed that is between 60% and 80% of that of the speed of light.

Example 11.1

Determine the frequency of a radio signal that has a wavelength of 150m.

Using the formula

$$f = \frac{300}{\lambda} \text{ MHz}$$

where λ = 150m gives:

$$f = \frac{300}{150} = 2\text{MHz}$$

Example 11.2

Determine the wavelength of a radio signal that has a frequency of 600MHz.

Using the formula

$$\lambda = \frac{300}{f} \text{ m}$$

where f = 600MHz gives:

$$\lambda = \frac{300}{600} = 0{\cdot}5\text{m} = 50\text{cm}$$

Radio Frequency Spectrum

Radio frequency signals are generally understood to occupy a frequency range that extends from a few tens of kilohertz (kHz) to several hundred Gigahertz (GHz). The lowest part of the radio frequency range that is of practical use

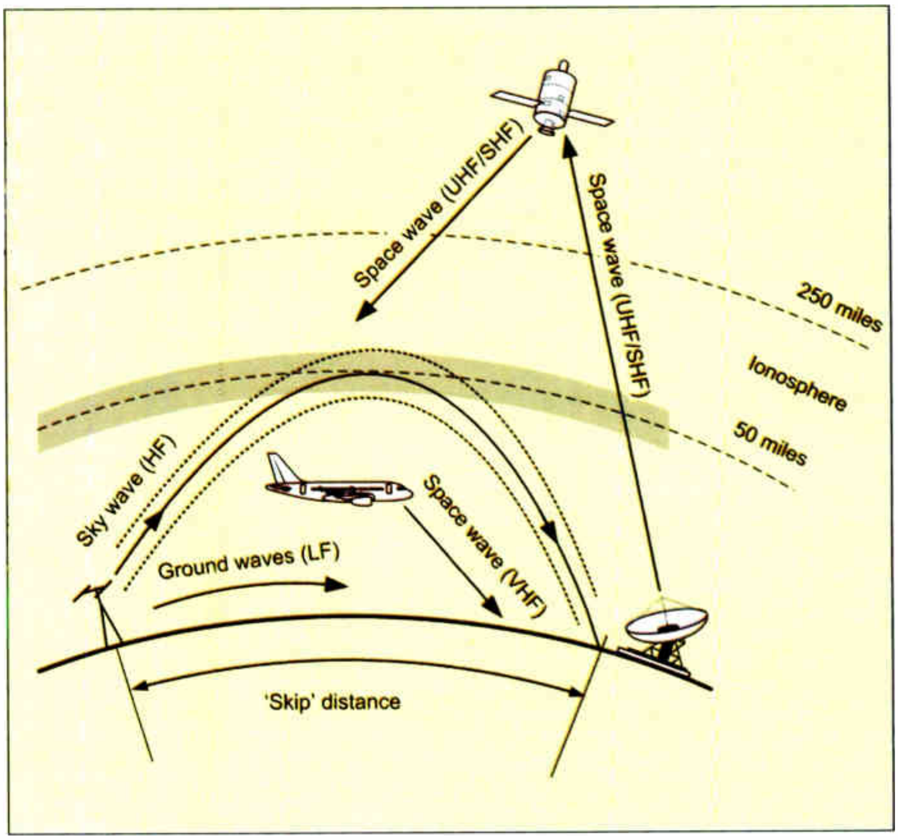


Fig.11.2. Propagation of radio signals at different frequencies

(below 30kHz) is only suitable for narrow-band communication. At this frequency, signals propagate as ground waves (LF) (following the curvature of the earth – see Fig.11.2) over very long distances.

At the other extreme, the highest frequency range that is of practical importance extends above 30GHz. At these microwave frequencies, considerable bandwidths are available (sufficient to transmit many television channels using point-to-point links or to permit very high definition radar systems) and signals tend to propagate strictly along line-of-sight paths (space waves – see Fig.11.2).

At other frequencies signals may propagate by various means, including reflection (or, more correctly, *refraction*) from ionised layers in the ionosphere (sky waves – see Fig.11.2). At frequencies between 3MHz and 30MHz ionospheric propagation regularly permits intercontinental broadcasting and communications.

For convenience, the radio frequency spectrum is divided into a number of bands, each spanning a decade of frequency. The use to which each frequency range is put depends upon a number of factors, paramount amongst which is the propagation characteristics within the band concerned. Other factors that need to be taken into account include the efficiency of practical aerial systems in the range concerned and the bandwidth available.

It is also worth noting that, although it may appear from Fig.11.3 that a great deal of the radio frequency spectrum is not used, it should be stressed that competition for frequency space is fierce. Frequency allocations are, therefore, ratified by international agreement and the various user services carefully safeguard their own areas of the spectrum.

Radio Communication

Fig.11.4 shows a simple radio communication system comprising a Transmitter and Receiver for use with continuous wave (CW) signals. Communication is achieved by simply switching (or "keying") the radio frequency signal on and off using Morse code to convey information.

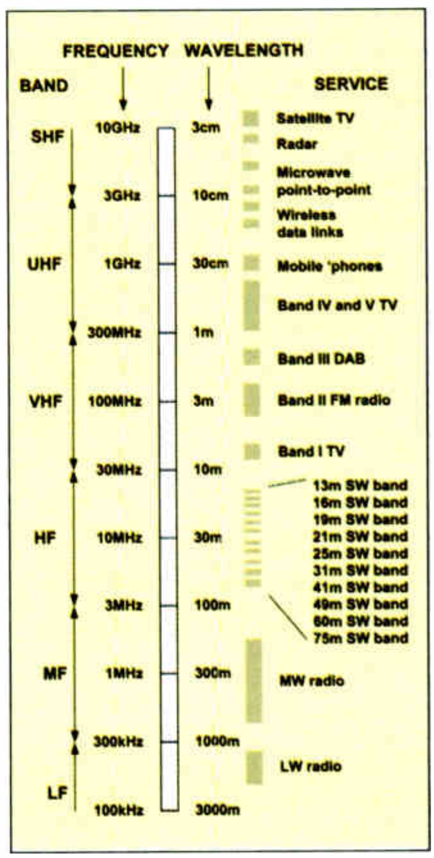


Fig.11.3. The radio spectrum

Check Point 11.2

The radio frequency spectrum is divided into a number of bands. Each band has different properties, largely determined by the way in which electromagnetic waves propagate. At low frequencies (LF) signals propagate as ground waves, travelling close to the surface of the earth. At medium and high frequencies (MF and HF) signals are reflected from layers in the ionosphere. At very high frequencies (VHF) and ultra high frequencies (UHF) signals travel largely as space waves following a line-of-sight path.

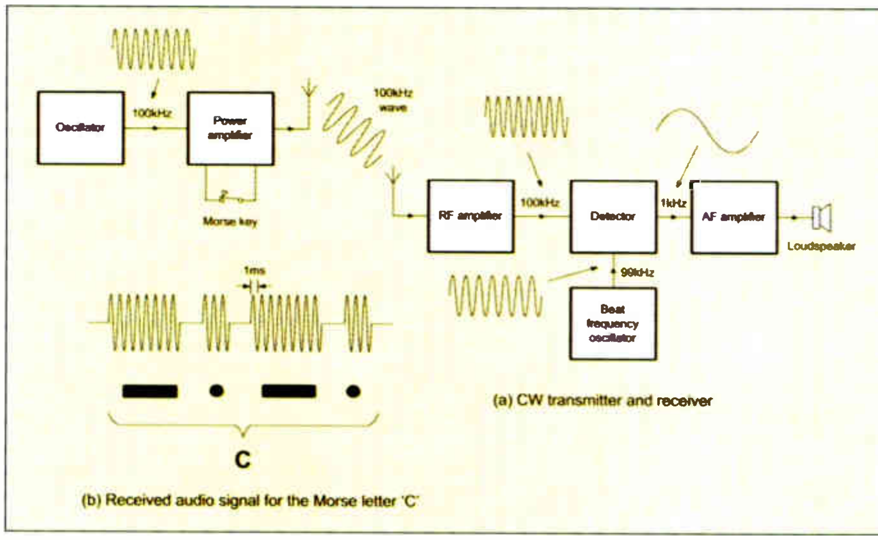


Fig.11.4. A simple CW radio communication system

Keying can be achieved by interrupting the supply to the power amplifier stage or even the oscillator stage. However, it is normally applied within the driver stage because that operates at a more modest power level. Keying the oscillator stage usually results in impaired frequency stability. On the other hand, attempting to interrupt the appreciable currents and/or voltages that appear in the power amplifier stage can also be problematic.

The simplest form of CW receiver need consist of nothing more than a radio frequency amplifier (which provides gain and selectivity) followed by a detector and an audio amplifier. The detector stage mixes a locally generated radio frequency (RF) signal produced by the beat frequency oscillator (BFO) with the incoming signal to produce a signal within the audio frequency range.

As an example, assume that the incoming signal is at a frequency of 100kHz and that the BFO is producing a signal at 99kHz. A signal at the difference between these two frequencies (1kHz) will appear at the output of the detector stage. This will then be amplified within the audio stage before being fed to the loudspeaker.

Example 11.3

A radio wave has a frequency of 455kHz. If a beat frequency of 500Hz is to be obtained, determine the two possible BFO frequencies.

The BFO can be above or below the incoming signal frequency by an amount that is equal to the beat frequency (i.e. the audible signal that results from the "beating" of the two frequencies and which appears at the output of the detector stage).

Hence, $f_{BFO} = f_{RF} \pm f_{AF}$

from which:

f_{BFO} = 455kHz ± 0·5kHz = 454·5kHz or 455·5kHz

Modulation

The simple CW transmitter/receiver system that we've just met has a number of limitations, not the least of which is that it is unable to cope with complex signals such as speech and music. In order to convey such information using a radio frequency carrier, the signal information must be superimposed or "modulated" onto the carrier. Modulation is the name given to the process of changing a particular property of the carrier wave in sympathy with the instantaneous voltage (or current), the signal.

The most commonly used methods of modulation are amplitude modulation (AM) and frequency modulation (FM). In the former case, the carrier amplitude (its peak voltage) varies according to the voltage, at any instant, of the modulating signal. In the latter case, the carrier frequency is varied in accordance with the voltage, at any instant, of the modulating signal.

Fig.11.5 shows the effect of amplitude and frequency modulation on a sinusoidal carrier (note that the modulating signal is, in this case, also sinusoidal). In practice, many more cycles of the RF carrier would occur in the time-span of one cycle of the modulating signal.

Note that there are several other forms of modulation, particularly those associated with digital communication, but the explanation of these modes would require much more space than is available here!

Demodulation

Demodulation is simply the reverse of modulation and is the means by which the original signal information is recovered from the modulated carrier. Demodulation is achieved by means of a demodulator (sometimes a little misleadingly referred to as a "detector"). As we will show later, the output of a demodulator consists of a reconstructed version of the original signal information present at the input of the modulator stage within the transmitter.

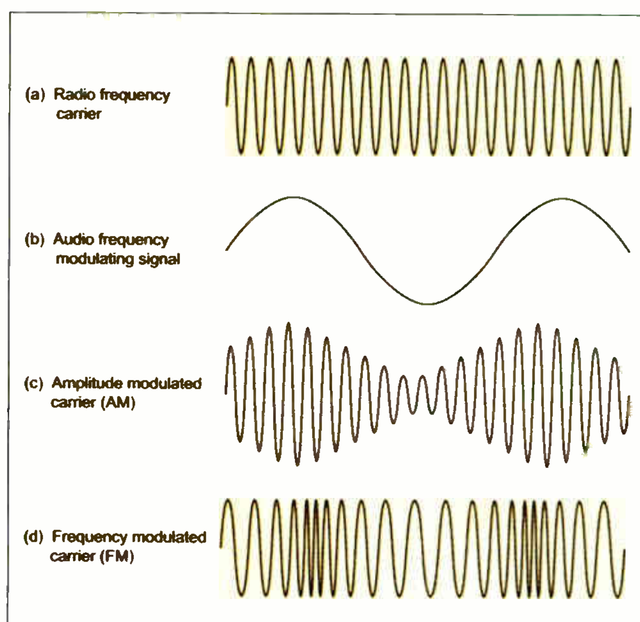


Fig.11.5. Various forms of modulation

Check Point 11.3

In order to convey information using a radio frequency carrier some form of modulation is required. The most common forms of modulation used for radio broadcasting are amplitude modulation (AM) and frequency modulation (FM). The process of superimposing signals on a carrier wave is referred to as *modulation*. The reverse process (i.e. recovering the original signal at the receiver) is known as *demodulation*.

An AM Transmitter

In a simple AM Transmitter, an accurate and stable RF oscillator generates the radio frequency carrier signal. The output of this stage is then amplified and passed to a modulated RF power amplifier stage. The inclusion of an amplifier between the RF oscillator and the modulated stage also helps to improve frequency stability.

The low-level signal from the microphone is amplified using an AF amplifier before it is passed to an AF power amplifier. The output of the power amplifier is then fed as the supply to the modulated RF power amplifier stage. Increasing and reducing the supply to this stage is instrumental in increasing and reducing the amplitude of its RF output signal.

The modulated RF signal is then passed through an aerial tuning unit that matches the aerial to the RF power amplifier and also helps to reduce the level of any unwanted harmonic components that may be present.

An FM Transmitter

In a simple FM Transmitter, an accurate and stable RF oscillator generates the radio frequency carrier signal. As with the AM transmitter, the output of this stage is amplified and passed to an RF power amplifier stage. Here again, the inclusion of an amplifier between the RF oscillator and the RF power stage helps to improve frequency stability.

The low-level signal from the microphone is amplified using an AF amplifier before it is passed to a variable reactance element (e.g. a variable capacitance diode) within the RF oscillator tuned circuit. The application of the AF signal to the variable reactance element causes the frequency of the RF oscillator to increase and decrease in sympathy with the AF signal.

The final RF signal from the power amplifier is passed through an aerial tuning unit that matches the aerial to the RF power amplifier and also helps to reduce the level of any unwanted harmonic components that may be present.

Tuned Radio Frequency (TRF) Receiver

Tuned radio frequency (TRF) receivers provide a means of receiving local signals using fairly minimal circuitry. The simplified block schematic of a TRF receiver is shown in Fig.11.6.

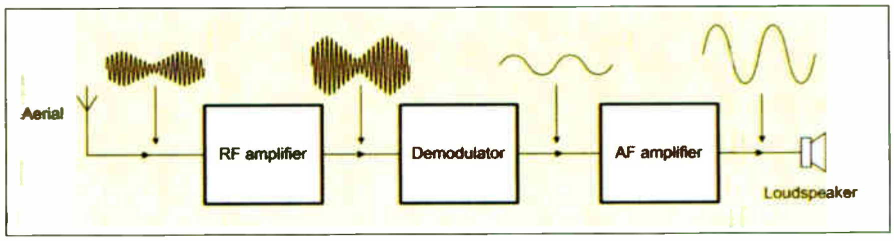


Fig.11.6. A tuned radio frequency receiver

The signal from the aerial is applied to an RF amplifier stage. This stage provides a moderate amount of gain at the signal frequency. It also provides selectivity by incorporating one or more tuned circuits at the signal frequency. This helps the receiver to reject unwanted signals that may be present on adjacent channels.

The output of the RF amplifier stage is applied to the demodulator. This stage recovers the audio frequency (AF) signal from the modulated RF signal. The demodulator stage may also incorporate a tuned circuit to further improve the selectivity of the receiver.

The output of the demodulator stage is fed to the input of the AF amplifier stage. This stage increases the level of the audio signal from the demodulator so that it is sufficient to drive a loudspeaker.

TRF receivers have a number of limitations with regard to sensitivity and selectivity and this makes them generally unsuitable for use in commercial radio equipment.

Superhet Receiver

Supersonic-heterodyne (or "superhet" for short) receivers provide both improved sensitivity (the ability to receive weak signals) and improved selectivity (the ability to discriminate signals on adjacent channels) when compared with TRF receivers. Superhet receivers are based on the "heterodyne" principle in which the wanted input signal is converted to a fixed intermediate frequency (IF) at which point the majority of the gain and selectivity is applied. The intermediate frequency chosen is generally 455kHz or 470kHz for AM receivers and 10·7MHz for FM receivers. The simplified block schematic of a superhet receiver is shown in Fig.11.7.

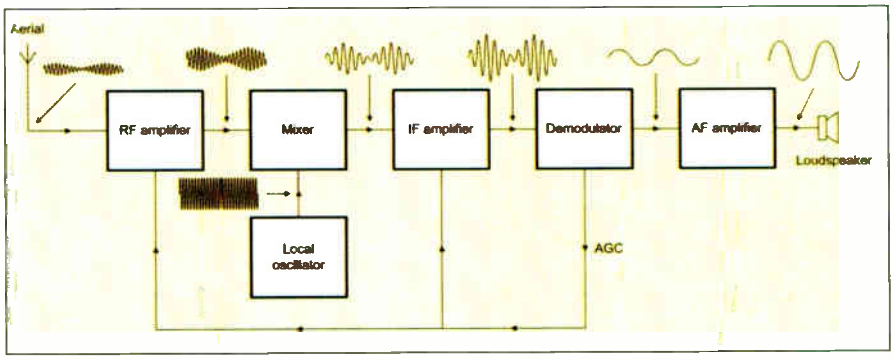


Fig.11.7. Block schematic for a superhet receiver

The signal from the aerial is applied to an RF amplifier stage. As with the TRF receiver, this stage provides a moderate amount of gain at the signal frequency. The stage also provides selectivity by incorporating one or more tuned circuits at the signal frequency.

The output of the RF amplifier stage is applied to the mixer stage. This stage combines the RF signal with the signal derived from the local oscillator stage in order to produce a signal at the intermediate frequency (IF). It is worth noting that the output signal produced by the mixer actually contains a number of signal components, including the sum and difference of the signal and local oscillator frequencies as well as the original signals plus harmonic components. The wanted signal (i.e. that which corresponds to the IF) is passed (usually by some form of filter) to the IF amplifier stage. This stage provides amplification as well as a high degree of selectivity.

The output of the IF amplifier stage is fed to the demodulator stage. As with the TRF receiver, this stage is used to recover the audio frequency signal from the modulated RF signal. Finally, the AF signal from the demodulator stage is fed to the AF amplifier. As before, this stage increases the power level of the audio signal from the demodulator so that it is sufficient to drive a loudspeaker.

In order to cope with a wide variation in signal amplitude, superhet receivers invariably incorporate some form of automatic gain control (AGC). In most circuits the DC level from the AM demodulator is used to control the gain of the IF and RF amplifier stages. As the signal level increases, the DC level from the demodulator stage increases and this is used to reduce the gain of both the RF and IF amplifiers.

The superhet receiver's intermediate frequency f_{IF}, is the difference between the signal frequency, f_{RF}, and the local oscillator frequency, f_{LO}. The desired local oscillator frequency can be calculated from the relationship:

$$f_{LO} = f_{RF} \pm f_{IF}$$

Note that in most cases (and in order to simplify tuning arrangements) the local oscillator operates above the signal frequency, i.e. $f_{LO} = f_{RF} + f_{IF}$.

Example 11.4

A VHF Band II FM receiver with a 10·7MHz IF covers the signal frequency range, 88MHz to 108MHz. Over what frequency range should the local oscillator be tuned?

Using $f_{LO} = f_{RF} + f_{IF}$, when f_{RF} = 88MHz then f_{LO} = 88MHz + 10·7MHz = 98·7MHz

Using f_{LO} = f_{RF} + f_{IF} when f_{RF} = 108MHz then f_{LO} = 108MHz + 10·7MHz = 118·7MHz

The local oscillator tuning range should therefore be from 98·7MHz to 118·7MHz.

Selectivity and Sensitivity

Two important requirements of a radio receiver are that it should be:

(a) selective (i.e. be able to select a wanted signal and reject all signals at other frequencies), and

(b) sensitive (have sufficient gain in order to raise the level of the signals provided by a receiving aerial to an amount sufficient to drive a loudspeaker).

Selectivity is achieved by means of multiple tuned circuits acting as filters to only accept the wanted signal frequency (or the intermediate frequency in the case of a superhet receiver) and reject all signals outside the wanted band.

Sensitivity is achieved by having multiple stages of amplification (note that the

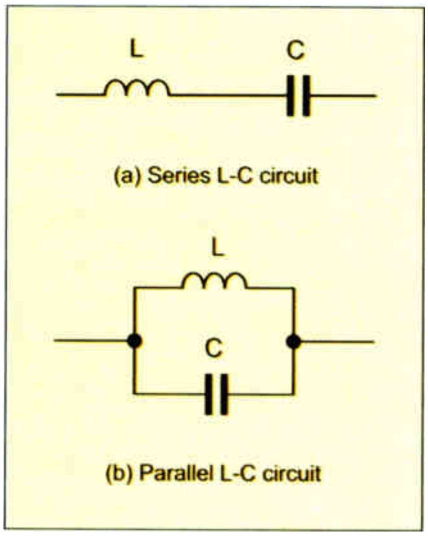


Fig.11.8. Series and parallel L-C circuits

amplitude of received signal from an aerial can be as low as a few tens of microvolts!).

Tuned Circuits

Earlier in our *Teach-In* series we introduced two useful components: capacitors (see Part 3) and inductors (see Part 5). These two components can be used together to form an L-C circuit which provides the selectivity that we need in a radio receiver. When used together we refer to them as tuned circuits or "resonant circuits". Fig.11.8a shows a series L-C circuit whilst Fig.11.8b shows a parallel L-C circuit.

The two circuits shown in Fig.11.8 behave quite differently. In the case of the series L-C circuit (and assuming that both of the components are "perfect") the impedance of the circuit will be zero at the resonant frequency. This circuit is thus sometimes referred to as an "acceptor" circuit (in other words it will "accept" signals at the resonant frequency and "reject" signals at other frequencies). In the case of the parallel L-C circuit (and again assuming that both of the components are "perfect") the impedance of the circuit will be infinite at the resonant frequency. This circuit is thus sometimes referred to as a "rejector" circuit (in other words it will "reject" signals at the resonant frequency and "accept" signals at other frequencies).

In all practical situations, there will be some resistance present in both the series and parallel tuned circuits shown in Fig.11.8. This resistance (sometimes referred to as "loss resistance") limits the effectiveness of the circuit as a filter. Fig.11.9 shows the effect of resistance in the case of a series resonant circuit whilst Fig.11.10 shows how resistance affects the performance of a parallel resonant circuit.

In the case of both the series and parallel circuits the frequency of resonance can be calculated from:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

where f_0 is the resonant frequency (in Hz), L is the inductance (in henries, H) and C is the capacitance (in farads, F).

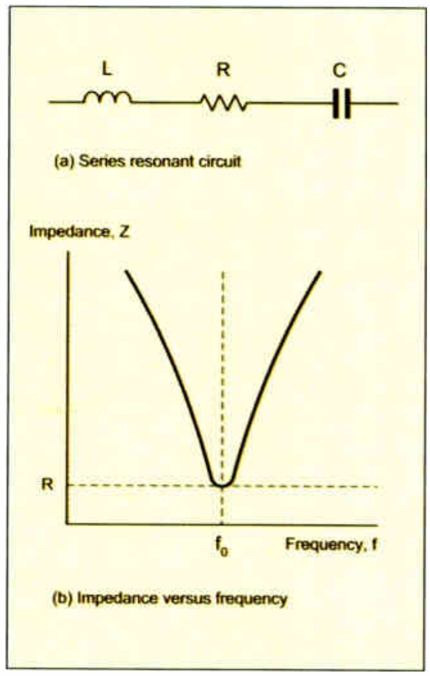


Fig.11.9. A series L-C-R resonant circuit

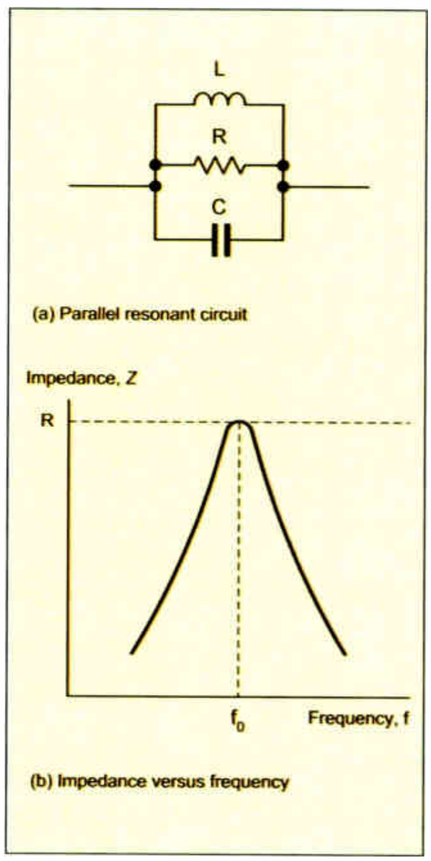


Fig.11.10. A parallel L-C-R resonant circuit

Bandwidth and Q-Factor

The range of frequencies accepted or rejected by a tuned circuit filter is referred to as its "bandwidth". As with an amplifier, this is defined as the difference between the two cut-off frequencies (in other words the difference between the two frequencies at which the voltage or current has fallen to 70.7% of its maximum value). Fig.11.11 illustrates this relationship.

The Q-factor (or "quality factor") of a tuned circuit is a measure of its ability to

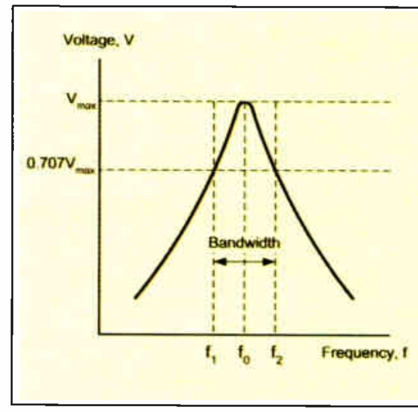


Fig.11.11. Bandwidth of a parallel resonant circuit

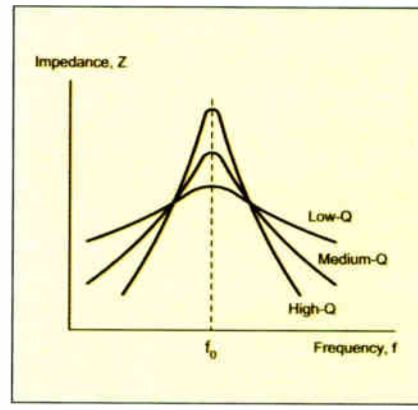


Fig.11.12. Q-factor of a parallel resonant circuit

reject signals outside the wanted range. The higher the Q-factor the more selective a tuned circuit, and vice versa. Fig.11.12 illustrates this relationship.

From what you have just read you will hopefully infer that bandwidth and Q-factor are related and, in fact, they are! If the bandwidth of a tuned circuit is reduced, its Q-factor is increased. Conversely, if the bandwidth is increased, the Q-factor of the tuned circuit is reduced. The relationship between bandwidth and Q-factor is simply:

$$\text{Bandwidth} = \frac{f_0}{Q}$$

The bandwidth of a tuned circuit depends on the amount of loss resistance present. For example, if the loss resistance (R) of a series tuned circuit is increased, the bandwidth will be increased and the Q-factor will be reduced, according to the following relationship:

$$Q = \frac{2\pi f_0 L}{R}$$

Example 11.4

A series resonant circuit comprises an inductor of 200μH and loss resistance of 5Ω connected in series with a capacitor of 500pF. Ignoring any other losses, determine:

(a) the frequency of resonance
(b) the Q-factor of the circuit
(c) the bandwidth of the circuit.

(a) To determine the frequency of resonance we use:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

where L = 200 × 10^{-6}H and C = 500 × 10^{-12}F

Hence:

$$f_0 = \frac{1}{2\pi\sqrt{200\times10^{-6}\times500\times10^{-12}}} =$$

$$\frac{0{\cdot}159}{\sqrt{10\times10^{-14}}} = \frac{0{\cdot}159}{3{\cdot}16\times10^{-7}}$$

f_0 = 0·5 × 10^7Hz = 0·5 × 10^6Hz = 500kHz

(b) To determine the Q-factor we use:

$$Q = \frac{2\pi f_0 L}{R}$$

where L = 200 × 10^{-6}H, R = 5Ω, and f_0 = 500 × 10^3Hz

Hence:

$$Q = \frac{6{\cdot}28 \times 500 \times 10^3 \times 200 \times 10^{-6}}{5} =$$

$$\frac{6{\cdot}28 \times 10^2}{5} = 126$$

(c) To determine the bandwidth we use:

$$\text{Bandwidth} = \frac{f_0}{Q}$$

where f_0 = 500 × 10^3Hz and Q = 126

Hence:

$$\text{Bandwidth} = \frac{500 \times 10^3}{126} =$$

3·97 × 10^3 Hz = 3·97kHz

Check Point 11.4

Q-factor and bandwidth are related. As the Q-factor is increased, the bandwidth is reduced, and vice versa.

Questions 11.1

Q11.1. Fig.11.13 shows the response of a parallel tuned circuit. Use this response curve to determine:

(a) the frequency of resonance
(b) the bandwidth of the circuit
(c) the Q-factor of the circuit.

Q11.2. If the value of capacitance used in the parallel tuned circuit of Question 1 is 500 pF, determine the value of inductance.

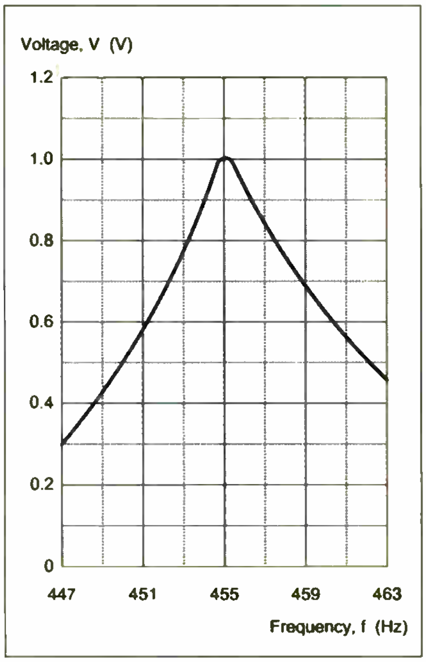


Fig.11.13. See Questions 11.1

More Complex Filters

Simple tuned circuits can be arranged in various ways in order to improve their selectivity and also to make them suitable for "matching" into the circuit in which they are used. Often this means that the tuned circuits take the form of tuned transformers in which the signals are coupled inductively from a primary to a secondary winding (in which one or both windings are tuned). A typical example of a tuned circuit filter where the tuned circuits are inductively coupled (via L2 and L3), is shown in Fig.11.14. Note that the frequency response of this type of filter has to be carefully adjusted for optimum (or "critical") coupling, as shown in Fig.11.15.

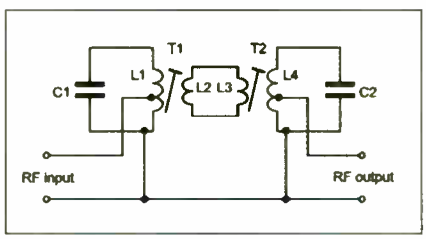


Fig.11.14. A filter based on two coupled tuned transformers

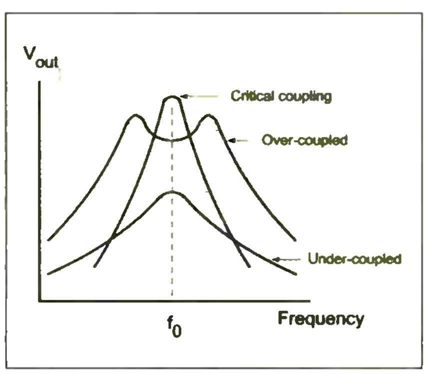


Fig.11.15. Effect of different amounts of coupling on the performance of the filter shown in Fig.11.14

If the two tuned circuits, T1 and T2, are too "loosely" coupled (they are said to be *under-coupled*) the frequency response characteristic becomes flat and insufficient output is obtained. On the other hand, if they are too "tightly" coupled (they are said to be *over-coupled*) the response becomes broad and "double-humped". The optimum value of coupling (when the two tuned circuits are said to be *critically-coupled*) corresponds to a frequency response that has a relatively flat top and steep sides. Photo 11.1 shows a physical example of coupled circuits.

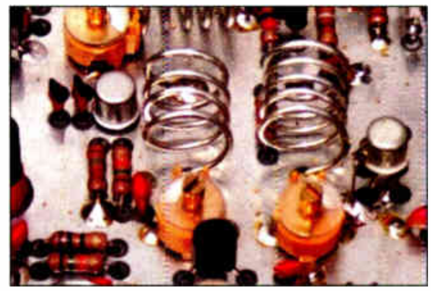


Photo 11.1. Coupled tuned circuits in the RF amplifier stage of a VHF receiver

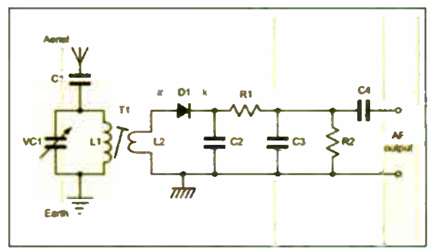


Fig.11.16. A simple AM tuner based on a diode demodulator

AM Demodulators

Fig.11.16 shows the circuit of a simple "crystal set" AM tuner. This is based on a simple diode demodulator stage. The RF input is applied to a parallel tuned circuit (L1 and VC1) which exhibits a very high impedance at the signal frequency and which is tuned using VC1. A secondary coupling winding, L2, is used to match the relatively low impedance of the diode demodulator circuit to the high impedance of the input tuned circuit. A germanium diode, D1, acts as a half-wave rectifier conducting only on positive-going half-cycles of the radio frequency signal. Capacitor, C2, charges to the peak value of each positive-going half-cycle that appears at the cathode (k) of D1.

The voltage that appears across C2 roughly follows the peak of the half-cycles of the rectified voltage. Components R1 and C3 form a simple filter circuit to remove unwanted RF signal components (this circuit works in just the same way as the smoothing filter that we met when we looked at half-wave rectifiers earlier in Part 5 of the *Teach-In* series).

The final result is a voltage waveform appearing across C3 that resembles the original modulating signal. As well as a providing a current path for D1, R2 forms a discharge path for C2 and C3. Coupling capacitor C4 is used to remove any DC component from the signal that appears at the output of the demodulator. Waveforms for the demodulator circuit are shown in Fig.11.17.

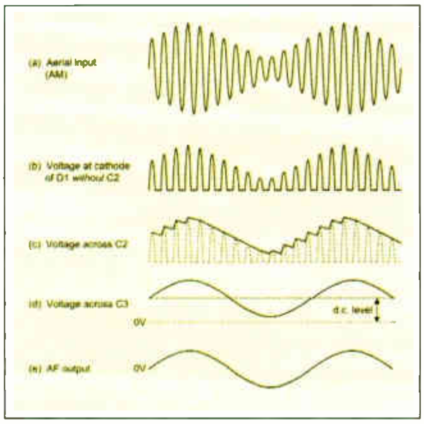


Fig.11.17. Waveforms for the diode demodulator

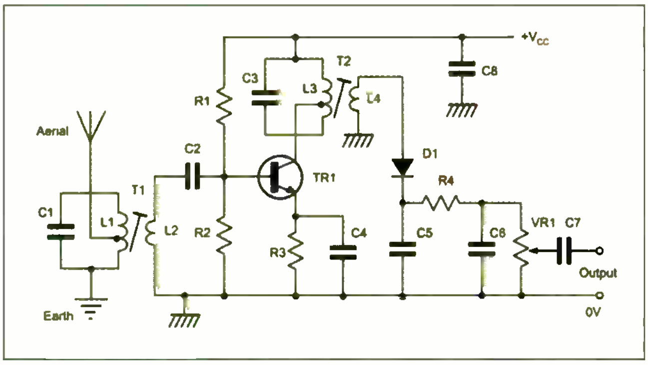


Fig.11.18. An AM tuner with an RF amplifier stage

RF Amplifiers

Fig.11.18 shows an improved AM tuner which uses an RF amplifier stage (this circuit can also be used as the basis of an IF amplifier in a superhet receiver) and two tuned transformers, T1 and T2. The amplifier operates in Class A mode and uses a small-signal *npn* transistor connected in common-emitter mode (see Part 6). The RF amplifier uses a parallel tuned circuit (L3 and C3) as a collector load. To improve matching and prevent "damping" of the tuned circuit (which results in a reduction in Q-factor and selectivity) the collector of TR1 is tapped into the tuned circuit rather than connected straight across it). Since the tuned circuit has maximum impedance at resonance - see Fig.11.10), maximum gain will occur at the resonant frequency. By using a tuned circuit with high-Q factor it is possible to limit the response of the amplifier to a fairly narrow range of frequencies. The output (to the diode demodulator stage) is taken from a secondary winding, L4. One further refinement is the addition of a Volume control, VR1.

Constructional Project

We bring our *Teach-In 2006* series to a conclusion with a simple constructional project designed to bring together some of the principles that we have introduced in the series. Our project takes the form of a simple TRF Radio Receiver for local signals in the Medium Wave (MW) and Long Wave (LW) bands. The receiver uses one transistor (as an RF amplifier), a germanium diode (as a demodulator), and an operational amplifier (as an AF amplifier).

For simplicity, the circuit diagram of the radio receiver has been divided into two distinct parts. Fig.11.19 shows the tuned circuit, RF amplifier and diode demodulator stages, whilst Fig.11.20 shows the AF amplifier/output stage.

The input tuned circuit comprises a parallel resonant circuit formed by L1 and VC1 for medium wave (MW) reception and L2 and VC1 for long wave (LW) reception. An SPDT switch (S1) is used for waveband selection. TR1 operates as a conventional common-emitter amplifier stage with signal input applied to the base (via C1) and the output taken from the collector (via C3). Note that, in order to improve the stability of the stage, base bias for TR1 is derived via R3 from the collector of TR1.

Germanium diode D1 and the associated components form a simple AM demodulator circuit. R5 and C4 comprises a simple low-pass R-C filter to reduce the amplitude of any residual RF signal components before the Volume control, VR1. Components R7 and C6 provides some additional DC supply decoupling and helps to improve the low-frequency stability of the amplifier.

An op amp (designed specifically for low-power audio amplification) is used for IC1 (see Fig.11.20). This helps to simplify the AF amplifier circuit and provides a few hundred milliwatts of audio output (sufficient for a small loudspeaker when operating from a 9V battery). A DPST switch (S2) is used to provide on/off control.

Construction

The simple TRF radio receiver can be built using a piece of standard stripboard with a minimum of 26 rows of strips each with 40 holes. The component layout and wiring details are shown in Fig.11.21 (note that this is the view from the upper side of the board).

The ferrite rod aerial can be mounted along one edge of the board using insulated stand-off pillars. The connections to the loudspeaker are made using short lengths of insulated copper wire. These should be twisted together and kept well away from the ferrite rod. Connections to the battery should be fitted with battery clips. A suitable battery is a PP3 or (preferably) a PP9 type.

Care should be taken to ensure that all of the links and track breaks conform to those shown in Fig.11.21.

The completed TRF receiver can be housed in a small ABS or wooden cabinet, allowing space for the ferrite rod, loudspeaker and batteryholder. The volume and frequency response of the loudspeaker will improve considerably when mounted in an enclosure.

Photo 11.2 shows the variable capacitor and ferrite rod inductor used in the prototype, and Table 11.1 shows the test voltages and resistances.

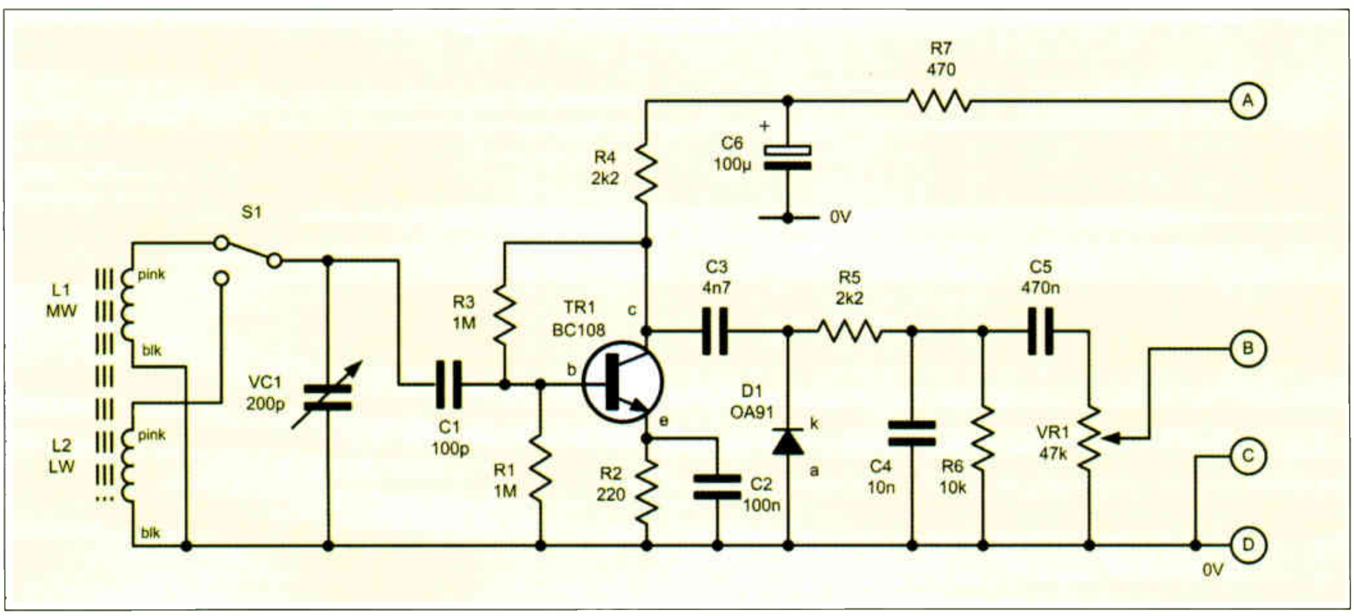


Fig.11.19. Circuit of the RF and demodulator stages of the simple TRF Radio Receiver

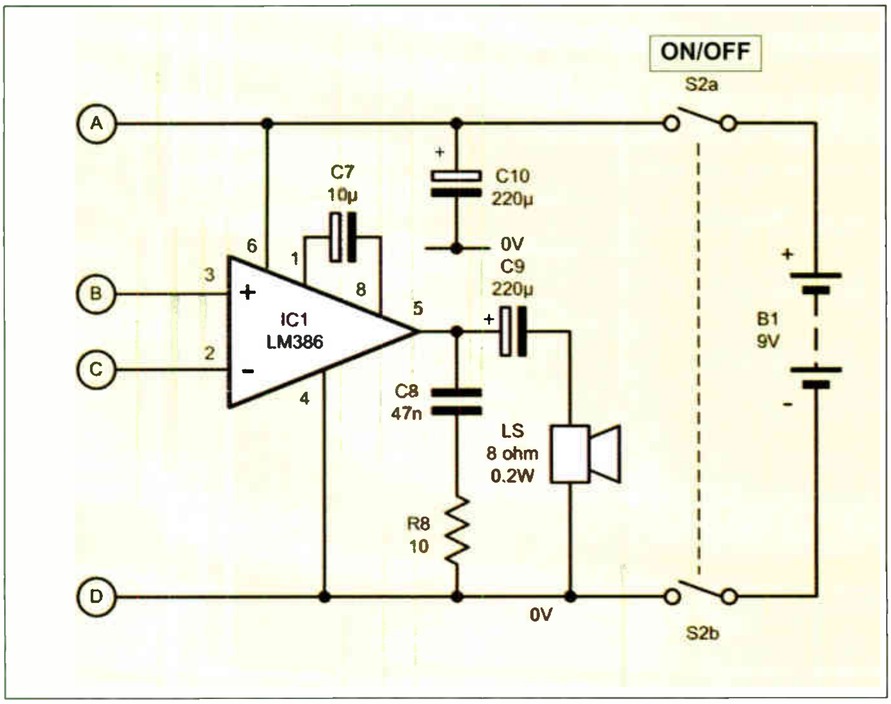


Fig.11.20. Circuit of the AF stage of the simple TRF Radio Receiver

Testing and Modifications

Apart from positioning the two inductors (L1 and L2) on the ferrite rod, the simple TRF receiver needs little adjustment. Best results can usually be obtained by placing L1 and L2 at opposite ends of the ferrite rod, setting VC1 to mid-position (centre of the tuning range) and VR1 fully-clockwise (maximum volume), and then adjusting first L1 and then L2 for maximum sensitivity on first MW and then LW.

Note that the ferrite rod is directional (and gives maximum response broadside to the station being received). The TRF receiver should be placed clear of any metal objects (e.g. radiators) and well away from possible sources of noise and interference (such as computers and TV receivers).

With L1 and L2 properly adjusted, it should be possible to receive several signals at reasonable loudspeaker strength. However, some experimentation may be required for optimum results.

The selectivity of the simple TRF receiver can be improved by increasing the Q-factor of the tuned circuit. If there are four connections to each of the ferrite rod inductors (instead of two) these indicate that the inductors in question are actually transformers. In this case, it is possible to disconnect C1 from the "hot" end of VC1 and instead feed it from the secondary winding of each inductor along the lines shown in Fig.11.18.

If this is not possible (and provided that reasonably strong signals are being received) the value of C1 can be reduced to 22pF, 33pF, or 47pF. This will improve the selectivity but may also have the effect of reducing the amplitude of signals. If desired, a short length of insulated wire can be used as an external aerial. This should be connected to the "hot" end of VC1 by a 47pF capacitor. Once again, it may be necessary to carry out some experimentation in order to achieve optimum performance from the receiver.

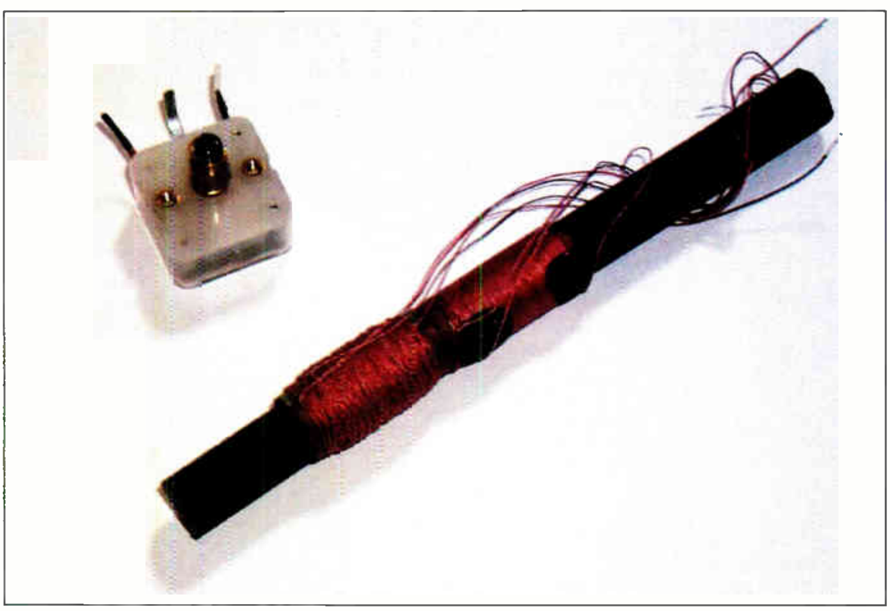


Photo 11.2. Tuned circuit components; variable capacitor and ferrite rod inductors

Parts List

Resistors

R1, R3	1M 2 off
R2	220Ω
R4, R5	2k2 2 off
R6	10k
R7	470Ω
R8	10Ω

All fixed resistors are 0·25W 5%

VR1	47k log. carbon potentiometer, fitted with DPST switch

Capacitors

C1	100p miniature ceramic
C2	100n miniature polyester
C3	4n7 miniature polyester
C4	10n miniature polyester
C5	470n miniature polyester
C6	100µ radial elect. 35V
C7	10µ radial elect. 35V
C8	47n miniature polyester
C9, C10	220µ 35V radial electrolytic 2 off
VC1	200p solid dielectric variable capacitor

Semiconductors

D1	OA91 (or similar germanium diode)
IC1	LM386 op amp
TR1	BC108 *npn* transistor

Miscellaneous

Ferrite rod inductor with MW (L1) and LW (L2) coils; stripboard (at least 26 rows of strips with 40 holes); SPDT or DPDT miniature slide switch; 9V battery connector or press studs; 8-pin dual-in-line IC low-profile socket; miniature 8 ohm loudspeaker; multi-strand connecting wire; solder etc.

Table 11.1. Test voltages and resistances (all voltages are with respect to 0V)

TR1	Collector	5·8V
	Base	0·9V
	Emitter	0·3V
IC1	Pin 1	1·3V
	Pin 2	0V
	Pin 3	0V
	Pin 4	0V
	Pin 5	4·7V
	Pin 6	9·3V
	Pin 7	4·7V
	Pin 8	1·3V
D1	Anode	0V
	Cathode	0V
C6	positive	8·7V
L1 (MW)	Pink-black, 2·7Ω (main tuned winding, L1) Blue-red, 0·4Ω (secondary winding – if fitted)	
L2 (LW)	Pink-black, 9·7Ω (main tuned winding, L2) Blue-red, 1·3Ω (secondary winding – if fitted)	

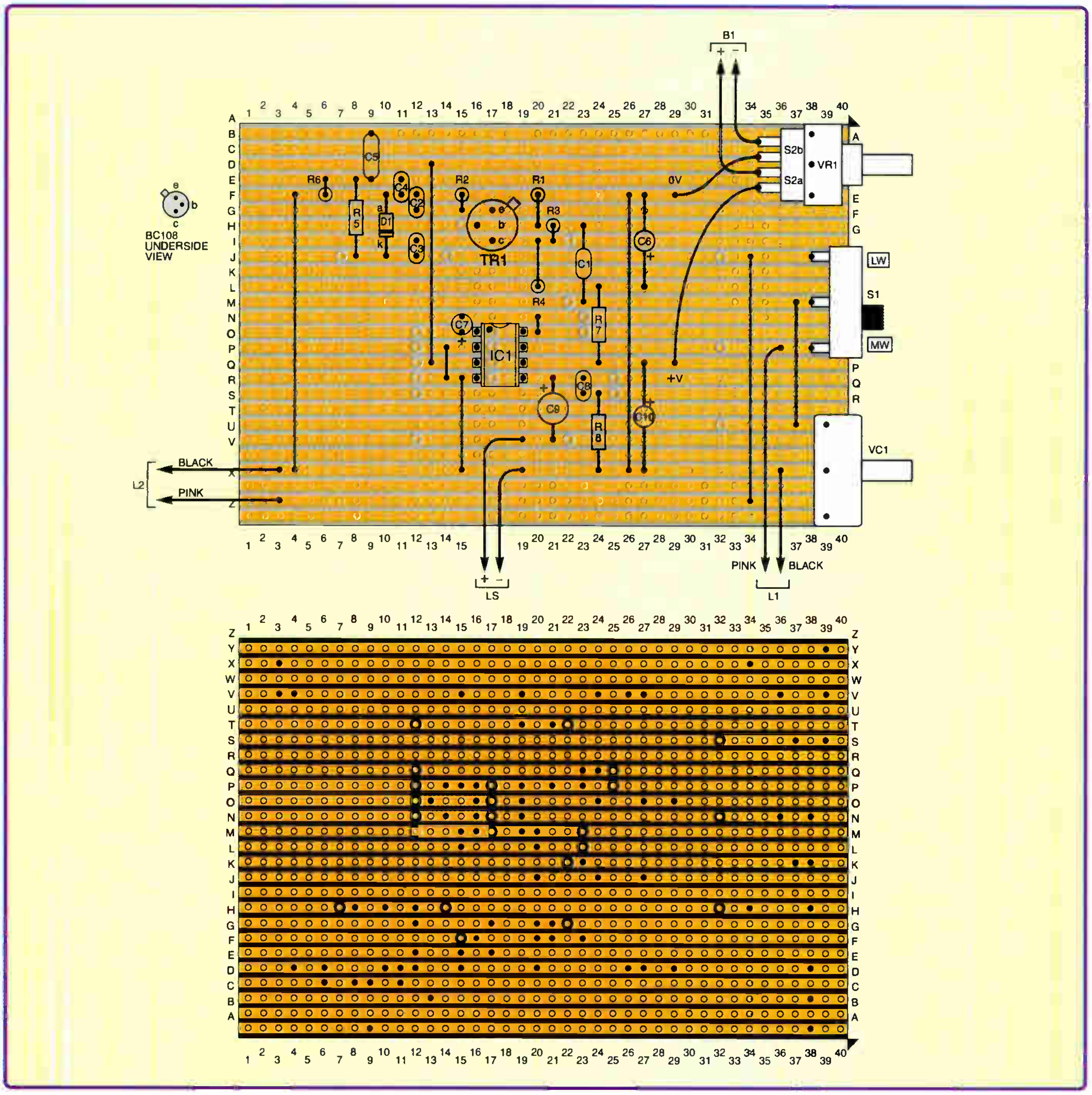


Fig.11.21. Component and track cuts layouts for the simple TRF Radio Receiver

Answers To Questions 11.1

1. (a) 455kHz
   (b) 6kHz
   (c) 76
2. 245μH

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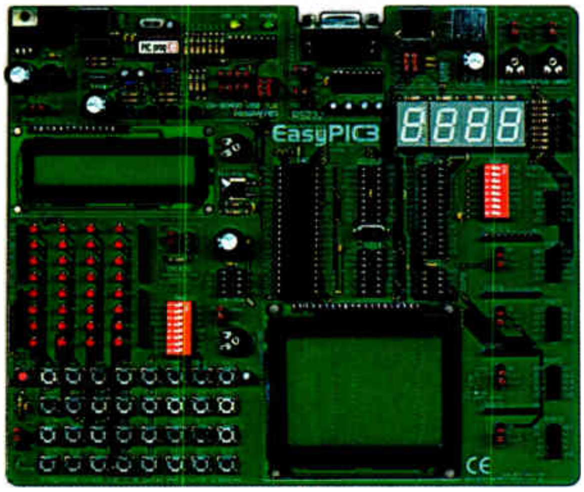

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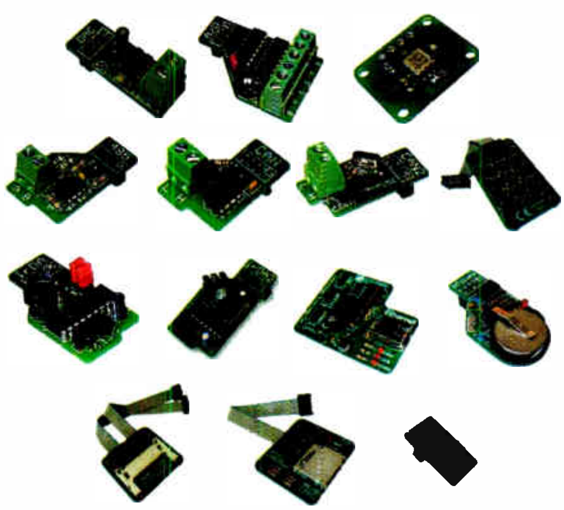

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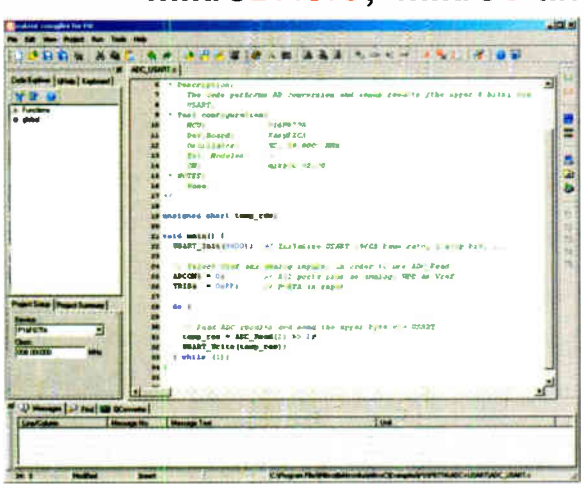

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Circuit Surgery

Ian Bell

Common Mode Rejection Ratio (CMRR) and op amps

CHATZONE member **Abhikg** has posted a couple of questions about op amp Common Mode Rejection Ratio, he writes: *"I want to feed a 400Hz AC signal or more to an op amp. So how do I choose an op amp to meet CMRR or what should be the CMRR value so that there should be very minimum noise? Practically, how does CMRR affect the op amp circuit and, to check the CMRR value, which types of analog circuits using an op amp should be considered?"*.

He also asks: *"For which applications is CMRR to be considered for an op amp and how? How does one measure CMRR for an op amp?"* We cannot discuss Abhikg's individual application as there is insufficient detail. However, we will look in detail at various aspects of CMRR. We will start with a quick overview of the op amp and then look at common mode and differential signals, as we need these.

Op Amps

An op amp (operational amplifier) is a high-gain, direct-coupled amplifier; its symbol is shown in Fig.1. The term "direct-coupled" means that the inputs and internal stages are connected directly, not via coupling capacitors, enabling the op amp to amplify DC and very low frequency signals. It has two inputs, the inverting and non-inverting inputs, and a single output. It amplifies the *difference* between the two input voltages.

Op amps often 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, although many "single supply" op amps are also available. The power supply connections are not always shown on schematics.

The output voltage of an op amp is given by $V_{out} = A_d (V_1 - V_2)$, where A_d is the open loop differential voltage gain, V_1 is the non-inverting input voltage and V_2 is the inverting input voltage. "Open loop" gain refers to the gain of the op amp itself, without any feedback circuitry. 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. "Differential" refers to the fact the gain multiplies the input difference $(V_1 - V_2)$.

A *differential signal* is carried on two wires (i.e. two voltages, V_1 and V_2) other than ground, with the actual signal being the difference between voltages on the two wires at any instant. Fig.2 shows a differential signal with a peak voltage of 2V and a peak-to-peak voltage of 4V. Fig.3 shows the same as Fig.2 as it would appear on a single wire.

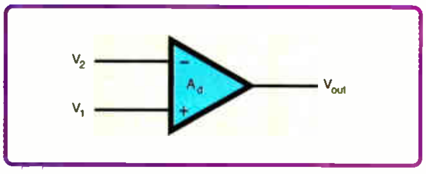

Fig.1. Op amp symbol

With a differential signal, if the signal voltage on one wire increases then the signal voltage on the other wire decreases by exactly the same amount. The actual signal is equal to the difference in the voltages on the two wires, each measured with respect to ground. So if the two voltages on the two wires are V_1 and V_2 the differential signal is $(V_1 - V_2)$.

If the two wires carrying a differential signal run closely parallel, then external effects (e.g. mains hum, interference etc) are likely to cause the same error (noise) on each wire. If this error is δ then the voltage on wire 1 will become $V_1 + \delta$ and the

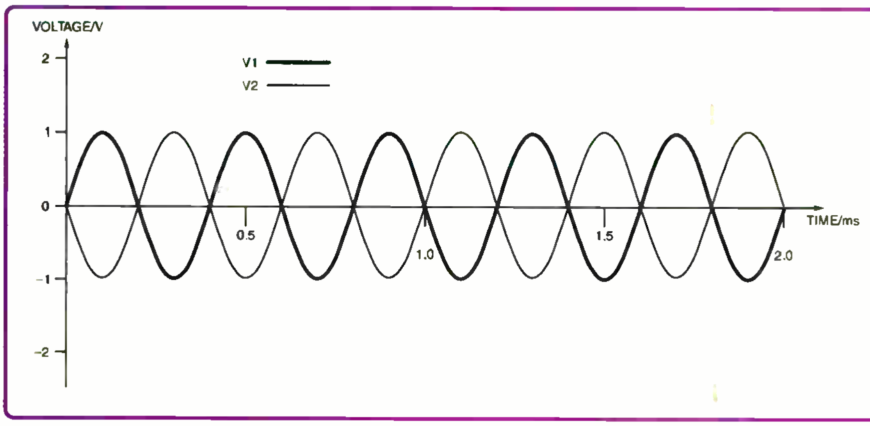

Fig.2. Differential signal. The signal is the difference between V_1 and V_2 and therefore has a peak value of 2V and a peak-to-peak value of 4V. The difference between these waveforms is the same as the signal in Fig.3

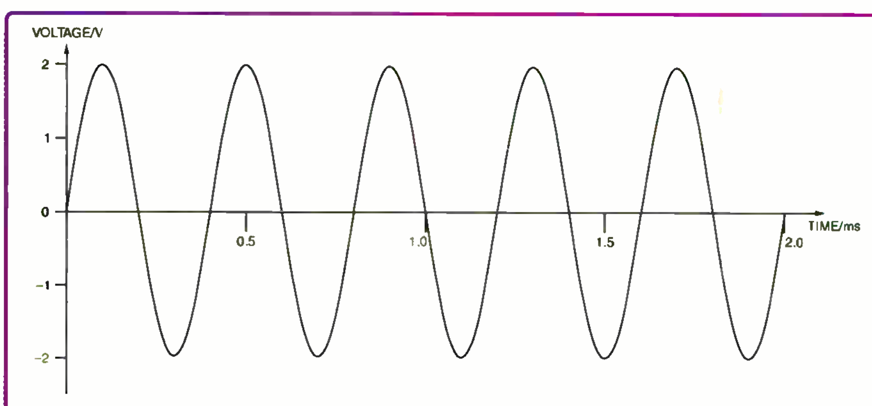

Fig.3. This is the single-ended version of the differential signal in Fig.2. The peak value is 2V and the peak-to-peak value is 4V

voltage on wire 2 will become $V_2 + \delta$. The signal is the difference between the two wires, that is

$$((V_1 + \delta) - (V_2 + \delta)) = (V_1 - V_2)$$

which is the same as without the error. For this reason differential signals are often used in electrically noisy environments. This is illustrated in Fig.4 and Fig.5.

Common Mode Voltage

The error voltage which we have just discussed is common to both halves of the differential signal. It is therefore called a common mode voltage and noise of this form is called common mode noise. If the two voltages on the two wires are V_1 and V_2, the common mode signal V_{cm} is $(V_1 + V_2) / 2$ (i.e. the average of the voltage on the two wires). Common mode noise may be at a higher frequency than the signal (as in Fig.5), or at the same or lower frequencies.

Differential signals quite often have a DC common mode component, for example a 4V peak-to-peak sine wave differential voltage with a 1.5V common mode DC signal is shown in Fig.6.

Ideally, a change in common mode voltage should not affect the output of an op amp, but in practice it does – remember the op amp is a differential amplifier, so it should ideally ignore signals which are the same on both inputs. Common Mode Rejection Ratio (CMRR) measures the ability of the op amp to reject common mode signals.

An ideal op amp amplifies the difference between V_1 (non-inverting input) and V_2 (inverting input). One way of looking at what the op amp does is to think of each input as having a separate gain. The output is then made up from the non-inverting input signal times its gain (A_1) minus the inverting input signal times its gain (A_2). We can write this as an equation as follows

$$V_{out} = A_1V_1 - A_2V_2$$

and note that if $A_1 = A_2 = Ad$ then this equation becomes the ideal $V_{out} = A_d(V_1 - V_2)$, which we quoted above. Ideally the gains for the two inputs are equal, however, this is not the case for a real op amp, due to mismatches in the components used. For example, the two op amp inputs are connected to two transistors; if these are not identical in every respect then the processing of the signals from the two inputs will be slightly different, leading to different values for A_1 and A_2.

With a little algebraic manipulation we can rearrange the above equation so that it includes the term $(V_2 - V_1)$ plus some other bits. It is useful to do this because we can then see an "ideal part" – something times $(V_2 - V_1)$, and an "error part" – the rest of the equation. We get

$$V_{out} = \frac{(A_1+A_2)}{2}(V_1-V_2)+(A_1-A_2)\frac{(V_1+V_2)}{2}$$

in which we can see that $(A_1 + A_2) / 2$ corresponds with A_d in the ideal part and is the average of the two gains. The other term contains $(V_1 + V_2) / 2$, which is common mode input signal (the average of the input voltages) which is multiplied by the difference in the two gains. In the ideal case the two gains are equal so $(A_2 - A_1)$ is zero and the common mode input has no effect on the output. The value of $(A_2 - A_1)$ is called the common mode gain, A_{cm}.

So we can rewrite the above equation as

$$Vout = A_d(V_1-V_2)+A_{cm}\frac{(V_1+V_2)}{2}$$

where A_d is the differential voltage gain and is A_{cm} the common mode gain. The smaller the influence of common mode signals on the op amp, the better the op amp. The ability of an op amp to reject common mode signals is expressed as the ratio of the differential and common mode gains; this is the common mode rejection ration (CMRR), which is often expressed in decibels as follows

$$CMRR = 20\log_{10}\left(\frac{A_v}{A_{cm}}\right)dB$$

Typical values for CMRR are 80dB to 100dB (10,000 to 1,000,000). Good CMRR enables op amps to be used to process real-world signals which have large unwanted common mode components (common mode noise). A poor

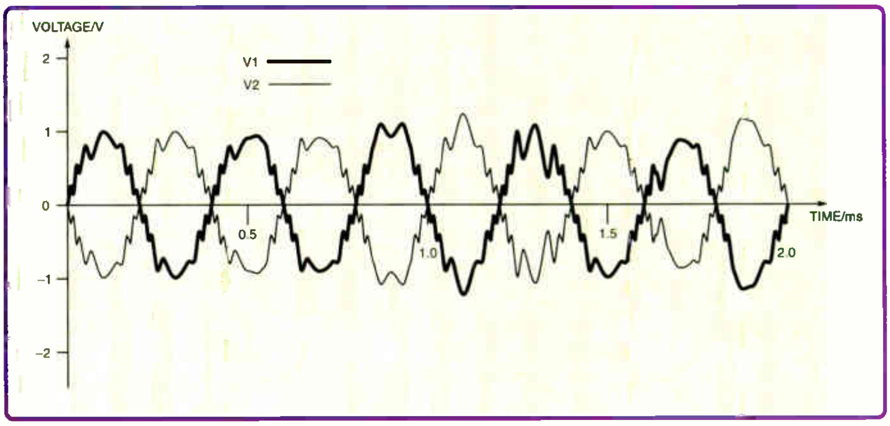

Fig.4. Differential signal with common mode noise. The difference between these waveforms is the same as the signal in Fig.2

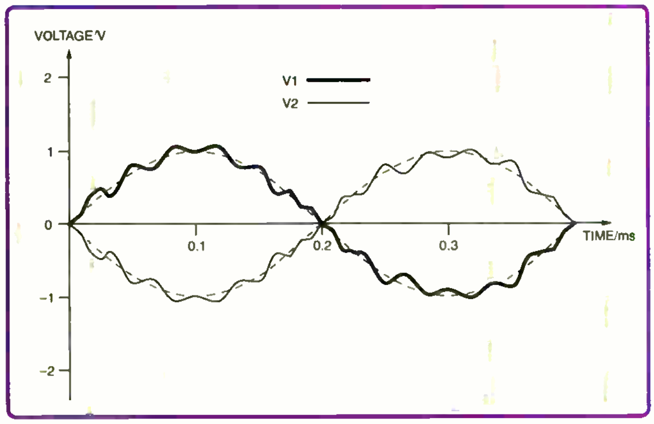

Fig.5. Zooming in on the first part of Fig.4 to see more clearly that the noise is common mode – i.e. the error is equal and in the same direction on both waveforms and hence the difference between these waveforms is the same as the signal in Fig.1

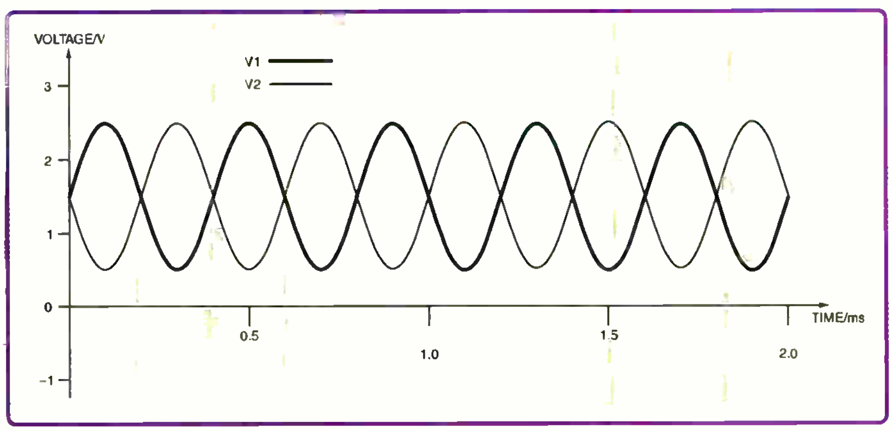

Fig.6. A 4V peak-to-peak differential signal with 1.5V common mode voltage

CMRR may also result in an error in the gain set by the resistors in the feedback network in the non-inverting configuration. This occurs because the common mode signal in a non-inverting op amp amplifier is equal to the input signal; however, in most circuits using discrete op amps the gain error due to resistor tolerance will be much larger.

Other Common Mode Properties

CMRR is not the only common mode related property of op amps. The common mode input range is also important. If a signal has a large common mode part then this may upset the bias circuits in the op amp, even if the differential signal is very small. Some op amps can handle common mode voltages close to the supplies, but others have a much more restricted range. As always, you need to check the data sheet if this may be an issue.

It is important to be aware that using an op amp with very good CMRR does not guarantee that the circuit you build with it will also have good CMRR. The most well known example of this problem is the basic differential amplifier circuit.

As we have noted, the op amp is a differential amplifier; however, in order to use it as a practical amplifier we have to apply negative feedback. The most straightforward op amp amplifier circuits (the inverting and non-inverting amplifiers) have a single ended input, but the differential amplifier configuration (Fig.7) would appear to provide us with a circuit that is insensitive to common mode noise.

Matching and CMMR

Unfortunately, the CMRR of the circuit in Fig.7 depends strongly on the matching of the resistor values. The differential gain of the circuit is given by R2 / R1 – the design assumes that the two R1 values, and the two R2 values are exactly the same. In fact

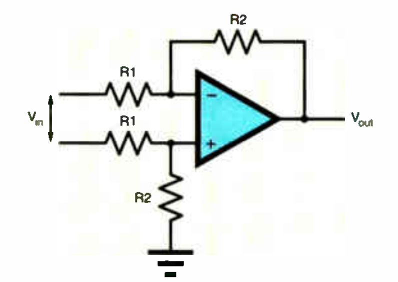

Fig.7. The standard differential op amp amplifier usually has very poor CMRR

with an ideal op amp and exactly matched resistors the CMRR would be infinite (ideal). With real resistors, however, we get a variation in individual values, which degrades the matching and reduces the CMRR.

For example, consider a typical differential amplifier with a gain of 100 in which R1 is 1kΩ and R2 is 100kΩ. If the value of both one of the R1 resistors and one of the R2 resistors is 5% different from the other corresponding resistor we get a CMRR of only 26dB, even with an ideal op amp. For resistors having a 1% mismatch we get about 40dB CMRR, for 0·1% about 60dB, but we need 0·01% resistors to get about 80dB, a typical op amp CMRR. So we need some very expensive resistors to get even a half-decent performance from this circuit.

A possible solution is to use a trimmer to vary one of the resistor values until the common mode gain is minimized. We only need one trimmer as it is the ratio of R2 to R1 which is of prime importance. However, this approach is not easy because the trimmer must be very stable and we still need very high accuracy resistors to get good CMRR. It is not really a viable solution.

Another Problem

Another problem with the circuit in Fig.7 is that it is difficult to adjust the gain (e.g. using a trimmer or potentiometer) as we have to vary two resistors by exactly the same amount. We could use a dual gang potentiometer, but the matching between the two values of the pot is likely to be poor, resulting, as we have seen, in very poor CMRR.

The solution for when we need to amplify a differential signal with good CMRR is to use a different circuit configuration, usually an instrumentation amplifier employing three op amps. These are available as single ICs and are probably what Abhikg needs to use.

Abhikg raised the issue of measuring CMRR. This is actually a far from trivial issue as is evidenced by the publication of a paper (Zhou and Liu, from Texas instruments and University of Texas) on this topic in a leading academic journal as recently as 2005. This discusses the limitations of several commonly used CMRR measurement configurations and the discrepancies which can occur between them.

Unless you are designing your own op amps from scratch you probably do not need to measure CMRR. Datasheets usually give you a DC CMRR figure and often a plot of CMRR against frequency (yes, it does vary). Zhou and Liu's paper can be purchased from **http://ieeexplore.ieee.org/**. Details of one of the techniques cited can be found at **www.intersil.com/data/an/an551.pdf**, which is a document from Intersil detailing measurement procedures for a number of op amp characteristics. A number of advanced textbooks on analogue circuit design and test also detail CMRR measurement procedures.

Reference

Jian Zhou; Jin Liu, *On the measurement of common-mode rejection ratio*, *IEEE Transactions on Circuits and Systems II*, Vol.52, No.1 pp. 49- 53, Jan. 2005.

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PIC N' MIX

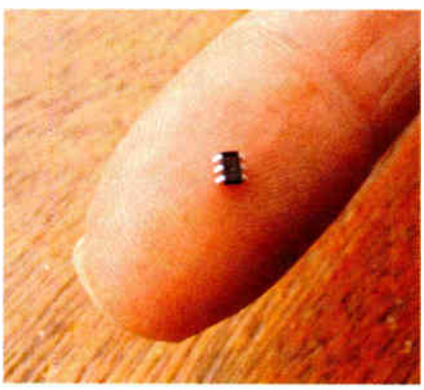
MIKE HIBBETT

Our periodic column for your PIC programming enlightenment

Smart Dust – How Small Can a PIC Get?

THE range of processors readily available from Microchip is enormous. The parts are getting more complex and providing a greater range of features that make the developer's life simpler, from a circuit design point of view at least. The PIC10F range of processors is, however, an unusual exception to this trend; the parts are a return to the early days of Microchip with tiny code and data space, few peripherals and no interrupt support.

Why on earth would Microchip want to do that? The answer is simple: to minimise the size of the device. The PIC10F comes in a 6-pin SOT23 package which as you can see from the photo is a tiny device indeed!



A PIC10F device

Smart Dust

So why would Microchip want to produce such a small, limited device? Well, in recent years there has been a rising interest in tiny computing devices, which has coined the phrase "Smart Dust". Coupled with tiny sensors, power source and feedback elements Smart Dust products enable a whole new class of devices to be developed. It's a new market in which few processor manufacturers are competing so there is probably some kudos in producing what is claimed to be "the worlds smallest processor". And, of course, to some experimenters there is a certain satisfaction in producing a design in the tiniest of form factors, so there is likely to be quite a bit of interest in these parts.

Although the device looks rather intimidating from the solderability perspective, soldering is actually fairly easy given a small tipped iron and a steady hand. There are only six pins to solder and so few opportunities for mistakes! It's also not difficult creating PCB designs by hand to take a 6-pin SOT23 package. Soldering wires directly to it is rather harder, and removes some of the benefits of the size reduction, so avoid taking that route if at all possible.

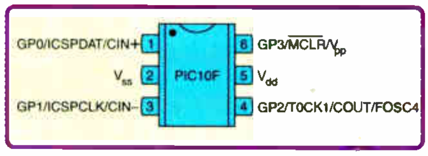


Fig.1. Pinouts of the 6-pin surface mount PIC10F

For initial development an 8-pin DIL part is available which makes prototyping the early design stages straight forward. The DIL part is not pin compatible with the SOT package, obviously, but it is electrically and functionally the same so you can create a design on stripboard first before moving to a surface mount PCB. Fig.1 shows the pinout of the surface mount SOT23 package.

Programmer Capabilities

You may want to check that your PIC programmer supports the part (*TK3 does not and is unlikely to. Ed*), and look for software updates if not. Being a fairly new device it may not be available in your existing programmer software. The electrical programming interface follows the normal PIC rules so you should not have a problem with most programming interfaces.

Once you have your design completed the easiest way to program the smaller SOT23 package is to place it on the PCB before fitting any other components, soldering some thin hookup wires to the board and programming it "in-circuit". Once done, remove the programming wires and fit your other parts.

We are jumping a little ahead though. What features do the devices provide, and how do we cope with their limitations?

Smart Dust Features

The PIC10F comes in four variants that all have a watchdog timer, general purpose 8-bit timer and four I/O lines. The PIC10F204/206 are in addition equipped with a simple comparator. The comparator is not an analogue-to-digital converter (ADC); it allows detection of when one analogue input voltage is above or below another. The device provides a 0·9V "band gap" reference voltage source which can be used as one of the comparator inputs. The PIC10F200/204 have 256 words of code space and 16 bytes of RAM, while the PIC10F202/206 have 512 words of code space and 24 bytes of RAM.

PC programmers would probably laugh at the impossibility of designing anything useful with such small code and data space footprints; even seasoned PIC aficionados will probably raise an eyebrow, but it just adds to the fun of the challenge. This is not a device for sloppy programming! Lots of careful thought at the design stage will be essential, and you should be prepared to accept that this device will not always be suitable.

A key omission within these parts is any form of interrupt handling. The SLEEP instruction is provided, however, which can be "exited" (i.e. processing resumed) by changes to port input lines or a comparator toggle. This feature does allow for very low power designs to be produced, where the processor is essentially switched off for large periods of time, waking only when an external event occurs.

The hardware stack is only two levels deep so take care when calling subroutines – you can only go to a level of two calls "below" the main code that runs after reset. An oddity in the instruction set is the return of the TRIS instruction for setting I/O pin directions – this command has been deprecated in other processor types. Once again this is an example of the "paring down" of the part, perhaps to help get it to fit inside the package.

A major "plus" is the voltages at which these devices can operate: 2·0V to 5·5V, making them ideal for operation from a 3V lithium battery or two small coin cells. The current consumption is minuscule even at full power – 170μA at 2·0V when running at 4MHz. When in sleep mode the current falls to 100nA. No need for a power switch!

Clock Oscillator

There is no external oscillator required, or even provided for; you must use the internal, calibrated, 4MHz RC oscillator. This is guaranteed to be accurate within 1% at 5·0V, or 2% across 2·5V to 5V, making it stable enough to implement an RS232 interface to a PC, so long as your ambient temperature does not change much. Microchip have not released any specification for variation with temperature yet, but do not expect the oscillator to be accurate to 2% at extremes of temperature!

To achieve the oscillator calibration each device has an individual calibration factor set during manufacture. This value is stored in the last code space location (yes, you lose one precious word of code space!). To achieve the accuracy stated you must load this value into the OSCCAL register following a reset. The processor automatically loads the calibration value into the W register; you simply add the line:

```
movwf        OSCCAL
```

at the beginning of your program.

Be careful when reprogramming your chip that you do not accidentally erase the calibration value. Some programming applications "know" that the PIC10F has a calibration value, and automatically read it first before re-programming. A healthy sense of paranoia suggests that reading the value and writing it down is a good idea to be certain that you do not loose it!

Datasheet Matters

As processors get more complex and feature rich, an important skill that must be learned is knowing what information can be safely ignored when reading the larger datasheets. It becomes impossible to hold every piece of information about a device inside one's head.

The PIC10F, however, is a very simple processor with very few peripheral features; there are only eight special function registers to learn, significantly simplifying the learning process. The device is a blow- back to the old days of the PIC – there are no interrupts, which eases the learning process. Their absence causes a few problems later on when building more complex applications, however, which we will pick up on later. As a device with which to learn PIC programming the PIC10F certainly has some merits for those who do not wish to jump in at the deep end. And it is a very cheap device, for example approximately 1/10th the price of a PIC16F877.

When considering physically small designs, power consumption and battery size are often important factors. There is not much point in having a small circuit if you must have a massive battery to power it! Therefore you will want to make the most of the power saving features of the device, and the best tool is the SLEEP instruction. This shuts down the main oscillator, halting operation until a "wake from sleep" event occurs. This can be a change on an input pin, comparator change or a watchdog timeout.

The first two will cause the processor to continue execution after the sleep instruction; the latter will cause a device reset, starting from memory location zero. Design your code accordingly. You can detect if the reset was as a result of a power-up or watchdog timeout by inspecting the TO bit in the STATUS register.

The lack of interrupts generates a serious challenge to the design of an application. On the plus side, however, it will make you appreciate interrupts more when you return to complex processors!

The implication of no interrupts is serialisation: your application must poll for and respond to events one at a time. So for example if your system has a keyboard, a serial port and an LCD you will have to ensure that your keyboard scanning code and LCD update code can execute quickly enough that you do not miss an incoming serial start bit. Alternatively, you can accept that incoming data may get lost some times and rely on a "retry" system. Or perhaps pepper your code with quick tests for an incoming start bit (which will make your code untidy).

As you can see, there are various trade-offs that need to be made. You need to consider these carefully during the design stage.

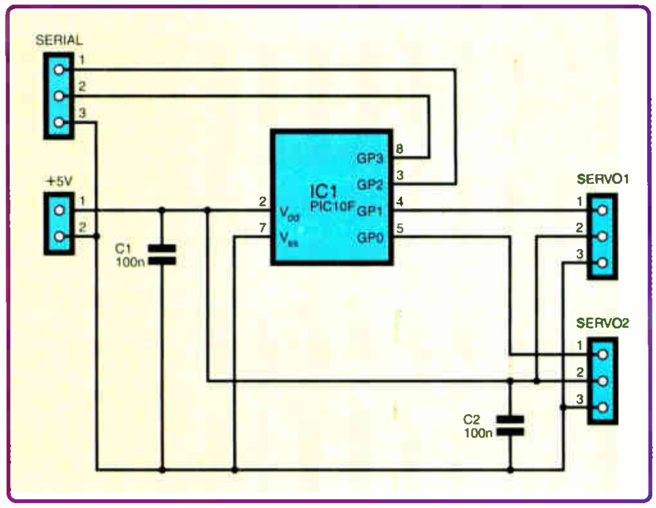


Fig.2. Circuit for a suggested 2-channel servo controller, using the 8-pin DIL development version of the PIC10F

Event Timing

An even more difficult scenario is where some event must occur at an accurate periodic rate. Consider the following code:

```
loop
    call    togglePins
    call    scanKeyboard
    call    updateDisplay
    goto    loop
```

If togglePins must be called every 10ms then the other two calls must take exactly the same time, every time they are called. So you will need to "balance out" the code inside them to make sure that under different situations (e.g. key pressed/no key pressed) the different code paths execute the same number of instructions. This is a painful task requiring accurate measurement of the number of instructions executed and the addition of small delay loops to even things out.

Possible Uses

So what possible uses could we have for such a device?

The most simple use is as a replacement for discrete logic; a multiple input NAND gate for example, or perhaps an exotic flip-flop. In other words a cheap, small, programmable logic device. A more interesting suggestion would be a homebrew remote control consisting of just a button, resistor and an IR led. Imagine how small you could make that! Other quick ideas: RF transceiver controller for remote monitoring; Dallas 1 wire sensor interface; smart jewellery (multi coloured LEDs and a temperature sensor perhaps); two channel servo controller.

The last suggestion is quite interesting and worth studying in a bit more detail. Fig.2 shows an example circuit diagram, offering a serial (TTL level RS232) interface to two RC Servo motors. This circuit could be built on a board smaller than a postage stamp – the connectors would take up more board space than the circuit. It may appear an impossible task to achieve RS232 control over two servos in such a basic device but the requirements are quite flexible. Servos require a pulse ranging in width from about 1ms to 2ms every 20ms, but the repeating period is quite flexible.

You can also make assumptions that no servo movement occurs during RS232 communication. Given compromises such as these, it would be interesting to see just how little code would be required to implement it.

Designing anything with the PIC10F is certainly going to be an interesting challenge, so why not give it a go? It's a chance to hone your assembly language programming skills!

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Everyday Practical Electronics, periodicals pending, ISSN 0262 3617 is published twelve times a year by Wimborne Publishing Ltd., USA agent USACAN at 1320 Route 9, Champlain, NY 12919. Subscription price in US $60(US) per annum. Periodicals postage paid at Champlain NY and at additional mailing offices. POSTMASTER: Send USA and Canada address changes to Everyday Practical Electronics, c/o Express Mag., PO Box 2769, Plattsburgh, NY, USA 12901-0239.

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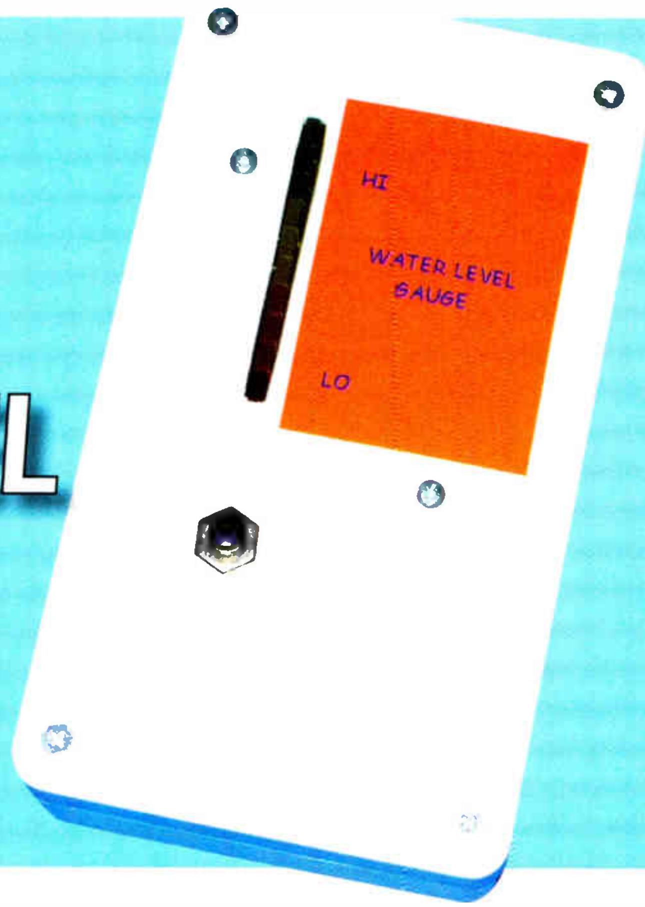
WATER LEVEL GAUGE



How much water is left in your garden butt?

By Terry de Vaux Balbirnie

WATER companies in the UK have been subsidising the sale of water butts at certain retail outlets. When the author called at his local garden centre recently, a 200 litre unit normally selling for £30 carried a "special" price tag of only £12. This design reveals how much water is left in an opaque butt.

Butt the lid's tight!

One problem with a modern water butt is that it has a tight lid that may need a screwdriver to release it. Although it prevents pets, children and leaves falling in, it makes it difficult to know how much water remains inside. This information is useful because the water used may, to some extent, be tailored to the amount held in reserve.

This device indicates the water level without having to remove the lid and, unlike a dipstick, can display it remotely. Also, there seems no reason why it could not be used for other purposes, such as for showing the amount of heating oil in a tank, but the prototype was only tested with water.

The Water Level Gauge comprises two parts – a Sensor section and a Display unit. The sensor section is attached to a point near the butt and a plastic tube connected to it responds to the water level. This will be described in detail later. The display unit contains two 9V PP3 batteries which power the entire circuit. It may be situated any reasonable distance from the sensor section and is connected to it using inexpensive wire.

The display takes the form of ten LEDs (light-emitting diodes) – three green (indicating degrees of "high"), three yellow ("medium"), three orange ("low") and one red ("empty"). When a "Check" switch is pressed, one of these will light to indicate the level.

On the level

Water depth may be found by measuring its pressure. As any diver

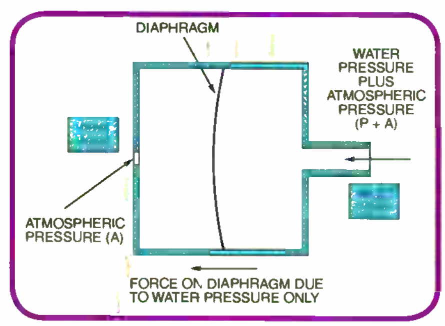
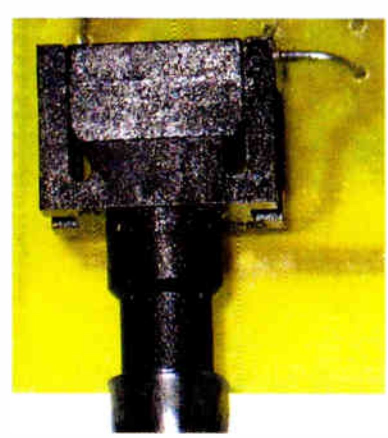


Fig.1. Basic principle of the pressure sensor. The sensor unit is shown below



or submariner knows, the deeper one goes, the greater this will be. The pressure depends on the depth, the density and the acceleration due to gravity.

The latter two are reasonably constant so, for non-critical work, the only factor involved is the depth. Atmospheric pressure also acts on the water adding to the total pressure (the *absolute pressure*). This will vary with weather conditions but its effect is easily removed leaving only the pressure due to depth (the *gauge pressure*).

A pressure sensor has a diaphragm with one side subjected to the pressure being measured. In the type used here, the other side is vented to the atmosphere. The pressure on one side of the diaphragm is then ($P + A$) where P is the pressure due to the water and A is atmospheric pressure. On the other side there is only A. The diaphragm therefore responds to a force due to the water pressure only (see Fig.1).

In the specified sensor, the force is converted into a voltage by the piezoresistive effect. This is the change in resistance of a material due to mechanical stress and is particularly pronounced with semiconductors such as doped silicon. The sensor's diaphragm is fabricated as part of a silicon chip with four equal-value resistors diffused into its surface.

With force applied, two resistors rise in value and two fall. Whether a resistor increases or decreases its value depends on its orientation on the diaphragm.

Parts List – Water Level Gauge

- 2 PC boards, 1 code 585 (Sensor) and 1 code 586 (Display); both available from the *EPE PCB Service.*
- 1 waterproof plastic box (Sensor), 100mm x 100mm x 50mm
- 1 plastic box (Display), 143mm x 82mm x 44mm
- 2 3-way screw terminal block
- 1 min. pushbutton switch, push-to-make (S1)
- 2 9V alkaline (PP3) batteries, with connectors (B1, B2)
- 3 8-pin d.i.l. sockets
- 1 18-pin d.i.l. socket
- Length of 4-way cable (see text); length of plastic tubing (see text); multistrand connecting wire, solder etc.

Semiconductors

- 2 1N4001 50V 1A rect. diode (D1, D12)
- 1 red LED (D2)
- 3 orange LED (D3 to D5)
- 3 yellow LED (D6 to D8)
- 3 green LED (D9 to D11)
- 1 LM4041DIZ 1·2V voltage ref. (IC1)
- 3 CA3140A op.amp (IC2, IC4, IC5)
- 1 24PCBFA6G pressure sensor, 0 to 5 p.s.i. (IC3)
- 1 78L12 12V 100mA voltage reg. (IC6)
- 1 LM3914-1 bargraph driver (IC7)

Capacitors

- 2 10n metal poly. (C1, C2)
- 2 220n metal poly. (C3, C4)
- 2 100n metal poly. (C5, C7)
- 2 220µ radial elect. 25V (C6, C8)

Resistors (All 0·6W 1% metal film)

- 3 100k (R1, R5, R6)
- 5 10k (R7 to R11)
- 4 4k7 (R3, R4, R12, R13)
- 1 1k2 (R14)
- 1 680Ω (R2)
- 1 560Ω (R15)

Potentiometers

- 1 4M7 carbon preset, vertical (VR1)
- 2 10k carbon preset, vertical (VR2, VR4)
- 1 10k multiturn preset, top adjust (VR3)

Wheatstone bridge

The resistors are connected into a Wheatstone bridge arrangement (see Fig.2). With force applied, resistors A and B are those which rise in value while C and D fall. A voltage (say, +12V) is applied as shown. With no force acting, resistors A and C form a potential divider with equal "arms" so +6V will appear at point P. With force applied, this will fall.

Resistors D and B do similarly so +6V appears at point Q. When force is applied, this will rise. The voltage between points P and Q will therefore vary with the force. With no force, P and Q are both at +6V so there is no voltage difference.

If the resistors all had an identical unstressed value, this would be true. However, even a minute difference will upset the "balance" and result in a significant voltage difference (the Offset Voltage) with no force applied. With the specified sensor, this can be as much as 30mV.

For small pressures, the offset voltage will probably be the major factor. The output will then be a large constant (offset voltage) plus a small voltage which varies with pressure (at a depth of one metre of water, some 12mV using the specified device). The offset voltage must be removed, for if it were amplified along with the "wanted" change, the latter would be swamped.

The bridge voltage and ambient temperature also affect the sensor's output. Pressure sensors therefore often contain compensation circuitry. The specified device is uncompensated but is reasonably immune to temperature changes providing it is fed from a constant current rather than a constant voltage source.

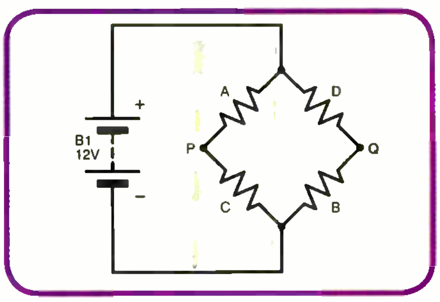
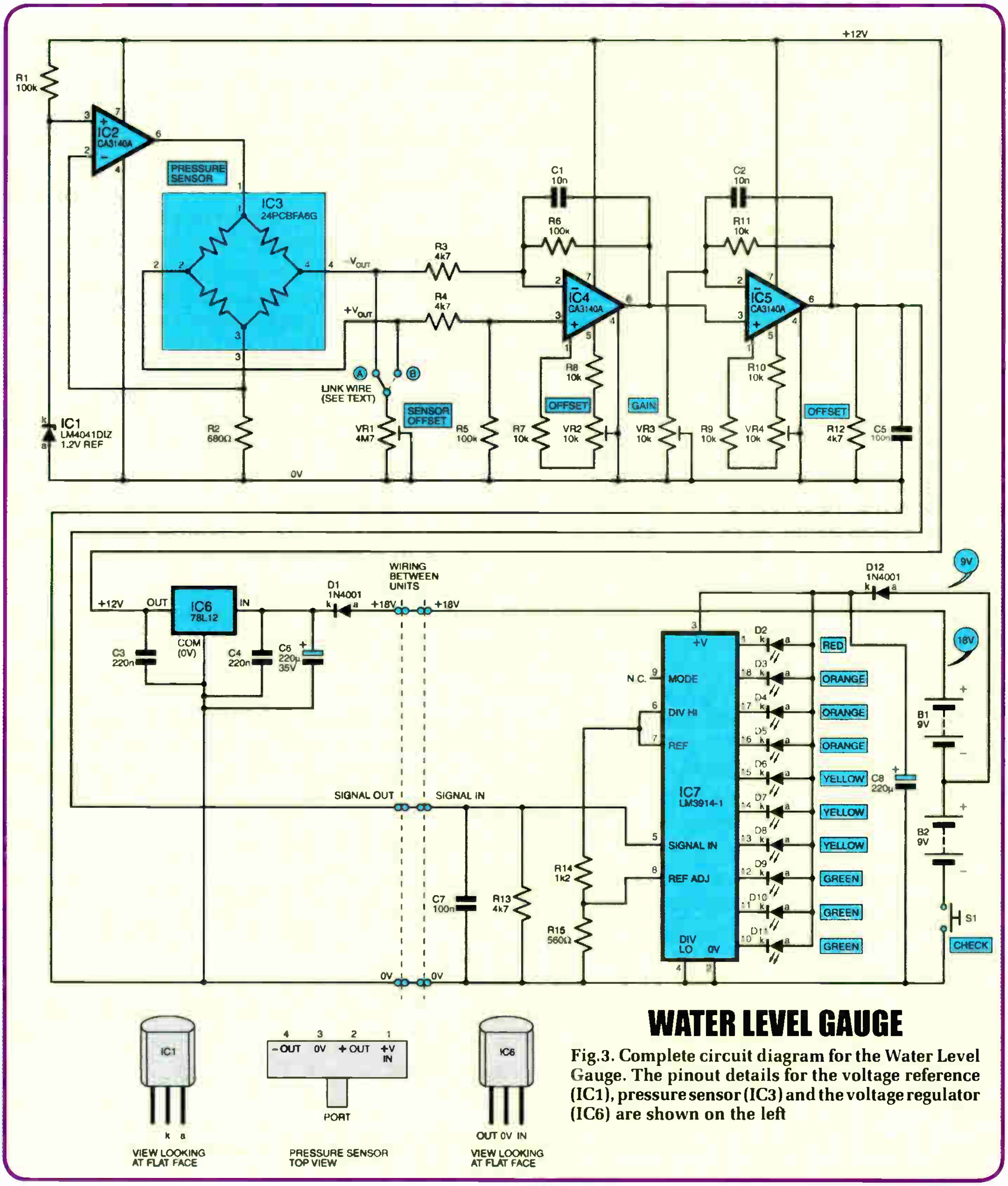


Fig.2. Simplified Wheatstone Bridge circuit formed by the sensor's four silicon resistors

Circuit description

The complete circuit diagram for the Water Level Gauge is shown in Fig.3. When Check switch, S1, placed in the 0V ("negative") battery line is operated, current flows from batteries B1 and B2 in series (18V supply) via diode D1 to the sensor section. It also flows from battery B2 alone (9V supply) through diode D12 to the display. Capacitors C6 and C8 provide a reserve of energy for the sensor and display sections respectively.

Regulator IC6 provides a stable 12V supply for the sensor section. Capacitors C3 and C4 improve circuit stability. IC3 is the actual pressure sensor (the traditional "diamond" of the Wheatstone bridge is shown within the device outline). The "+Vout" voltage (pin 2) rises on applied pressure while that of "–Vout" (pin 4), falls.



WATER LEVEL GAUGE

Fig.3. Complete circuit diagram for the Water Level Gauge. The pinout details for the voltage reference (IC1), pressure sensor (IC3) and the voltage regulator (IC6) are shown on the left

Constant current

Op amp IC2 provides a constant current for the sensor. Its non-inverting input (pin 3) receives a voltage of 1·2V from voltage reference, IC1. Resistor R1 allows a small current (100μA approximately) to flow through it which is needed for its operation. Current flows from IC2 output, pin 6, through the sensor returning to the 0V line via resistor R2.

IC2 inverting input (pin 2) receives the voltage developed across this resistor (R2). The op amp adjusts its output current so that the voltage across R2 and therefore at the inverting input is the same as that at the non-inverting one (1·2V). Resistor R2 therefore determines the bridge current. This will be 1·8mA approximately, which is within the manufacturer's specified range.

There are several ways of removing the bridge offset voltage but this is not a critical application so it may be done very simply. This involves connecting preset potentiometer VR1 in parallel with one of the lower bridge "arms" (and resistor R2). A jumper lead selects which "arm" is used. VR1 reduces the resistance of that "arm" and hence the voltage across it. The effect on R2 is negligible.

Preset VR1 is adjusted at the end of construction to balance out the Offset Voltage. Since it cannot be predicted which sensor output (+Vout or -Vout) will need to be adjusted, it will be a matter of using trial and error at the end of construction to find it.

Bit of a boost

The sensor's outputs are connected to the inputs of a differential amplifier based on op amp IC4. This increases their voltage difference. The gain is determined by the ratio of resistors R6 and R3, which is 21 times approximately. IC4 will introduce its own offset voltage and this is removed by adjusting preset VR2, which is connected in series with fixed resistors R7 and R8 to the op amp's "offset adjust" inputs (pins 1 and 5).

The output of IC4, pin 6, is connected to the non-inverting input (pin 3) of op amp IC5, which is configured as a non-inverting amplifier. The gain is set by the value of R11/VR3 + 1, which allows a boost from approximately two times upwards. Preset VR3 is a multiturn unit which makes adjustment easier.

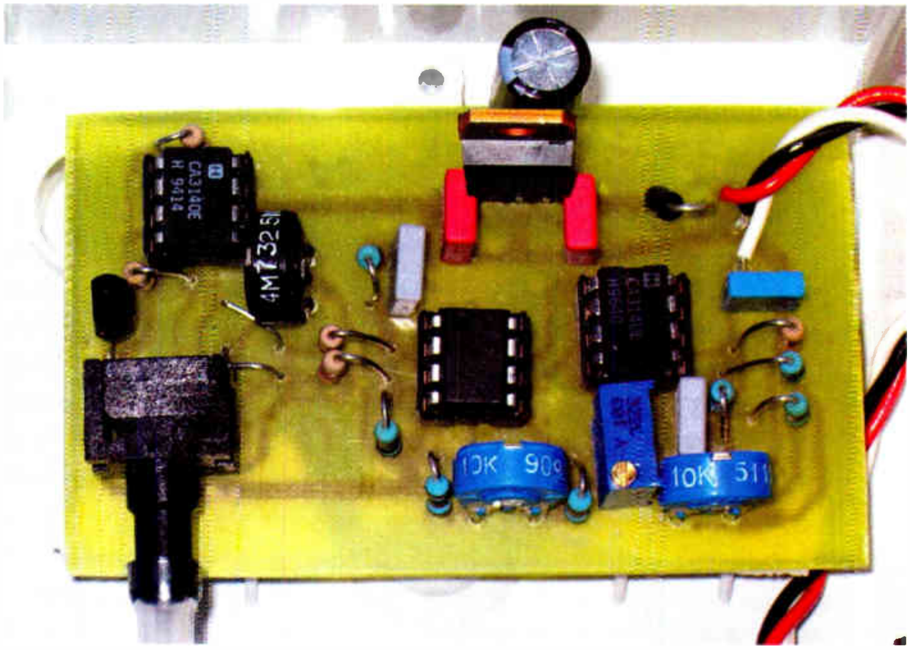
The combined gain (IC4 and IC5) may be adjusted from some 42 times upwards and will be set at the end so that the final l.e.d. in the display operates at maximum water depth.

Op amp IC5's offset voltage is removed using the network R9/VR4/R10 in a similar way to IC4. However, this is much less critical because the signal is now at a relatively high voltage.

Capacitors C1 and C2, included in IC4 and IC5 feedback loops, reduce the gain at high frequencies and improve circuit stability.

Display

The display section is centred on bargraph driver IC7. This has ten outputs (pins 1 and 18 to 10). With an increasing voltage applied to the signal input (pin 5), the outputs go low in turn. Any low output will allow current to "sink" through the appropriate LED in the group D2 to D11. Pin 9 ("mode") selects either "bar" or "dot" operation. Here, it is left unconnected providing "dot mode" – that is, only one LED is on at a time (in reality, there is a slight overlap). Note that no current-limiting resistors are needed for the LEDs because regulation takes place within IC7.



Components mounted on the completed sensor board

The bargraph driver produces a reference voltage for its operation and this determines the voltage at pin 5 needed to operate the last LED This voltage is given by:

$$V = 1{\cdot}25(1 + R15/R14)$$

With the specified values, this is approximately 1·8V so each 0·18V increment operates successive LEDs. The introduction of a little controlled offset voltage (using VR2) will provide an output of 0·18V at zero pressure so that D2 (the "empty" LED) will be on.

Resistors R12 and R13, in conjunction with capacitors C5 and C7, condition the signal by bypassing to 0V any stray alternating current which is picked up along the interconnecting wires.

Construction

Construction of the Water Level Gauge is based on two single-sided printed circuit boards. These boards are available from the *EPE PCB Service*, code 585 (Sensor) and 586 (Display). The component layout and actual size copper master patterns are shown in Fig.4 and Fig.5.

Sensor board

Start with the sensor section and begin with the jumper lead arrangement, the wire "loop" and two "stalks". Add the i.c. sockets, resistors (including the presets) and capacitors taking care over the polarity of electrolytic capacitor C6. Solder short pieces of stranded wire to the "+18V", "0V" and "signal out" points.

Solder diode D1 taking care over its polarity, IC1 (with its flat face towards the left-hand side of the PCB) and regulator IC6 (flat face towards the PCB centre) in position. Solder pressure sensor, IC3, in place using the minimum time needed to make good joints. Note that the regulator used in the prototype was a 500mA device housed in a TO220 case. The specified 100mA version was not available at the time and would be smaller. This does not matter as long as the pinout is the same.

Insert the dual-in-line i.c.s into their sockets. However, before handling them, remove any static charge from your body by touching something which is earthed (for example, a metal water tap) to prevent possible damage.

Display board

Drill the mounting holes in the display PCB and solder the IC socket in place. Follow with the resistors and capacitors. Take care over the polarity of electrolytic capacitor C8, which should be mounted flat on the board – see photograph.

SENSOR BOARD AND DISPLAY BOARD CONSTRUCTION

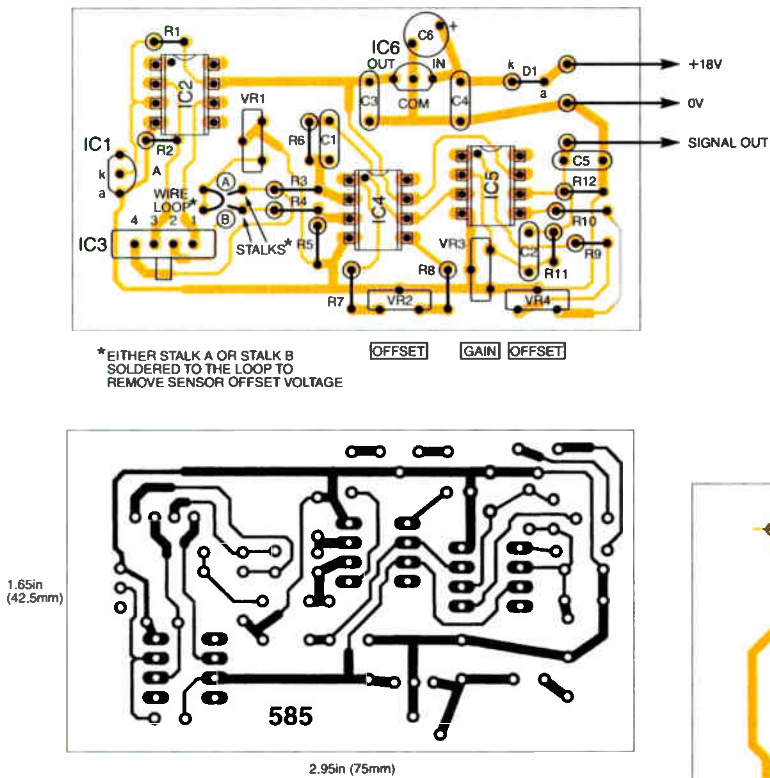
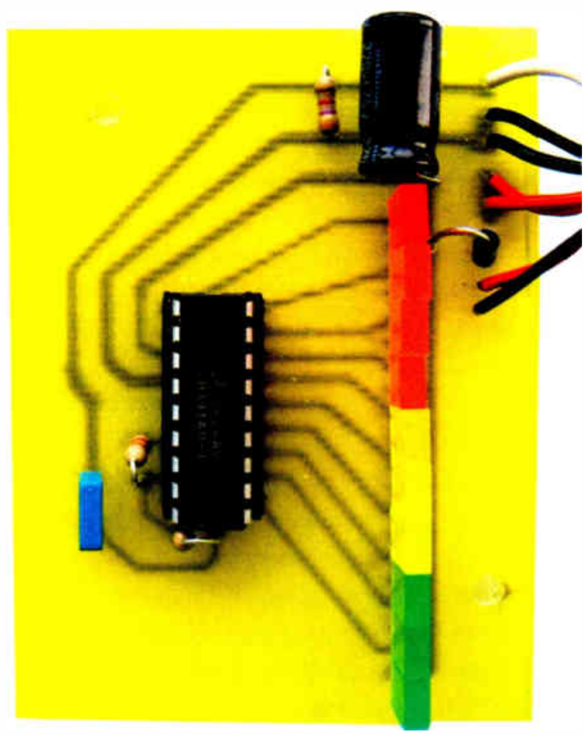


Fig.4. Sensor printed circuit board component layout and full-size copper foil master. Don't forget the small wire loop and "bridging" stalks



Complete display circuit board

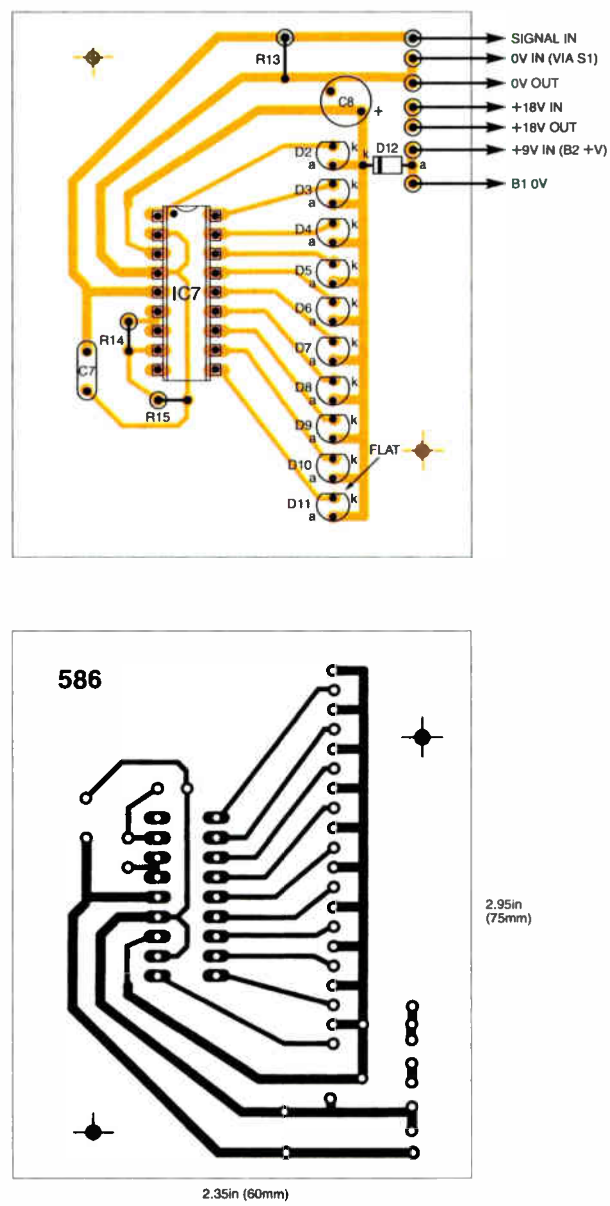


Fig.5. Printed circuit board component layout and full-size copper foil master for the display board

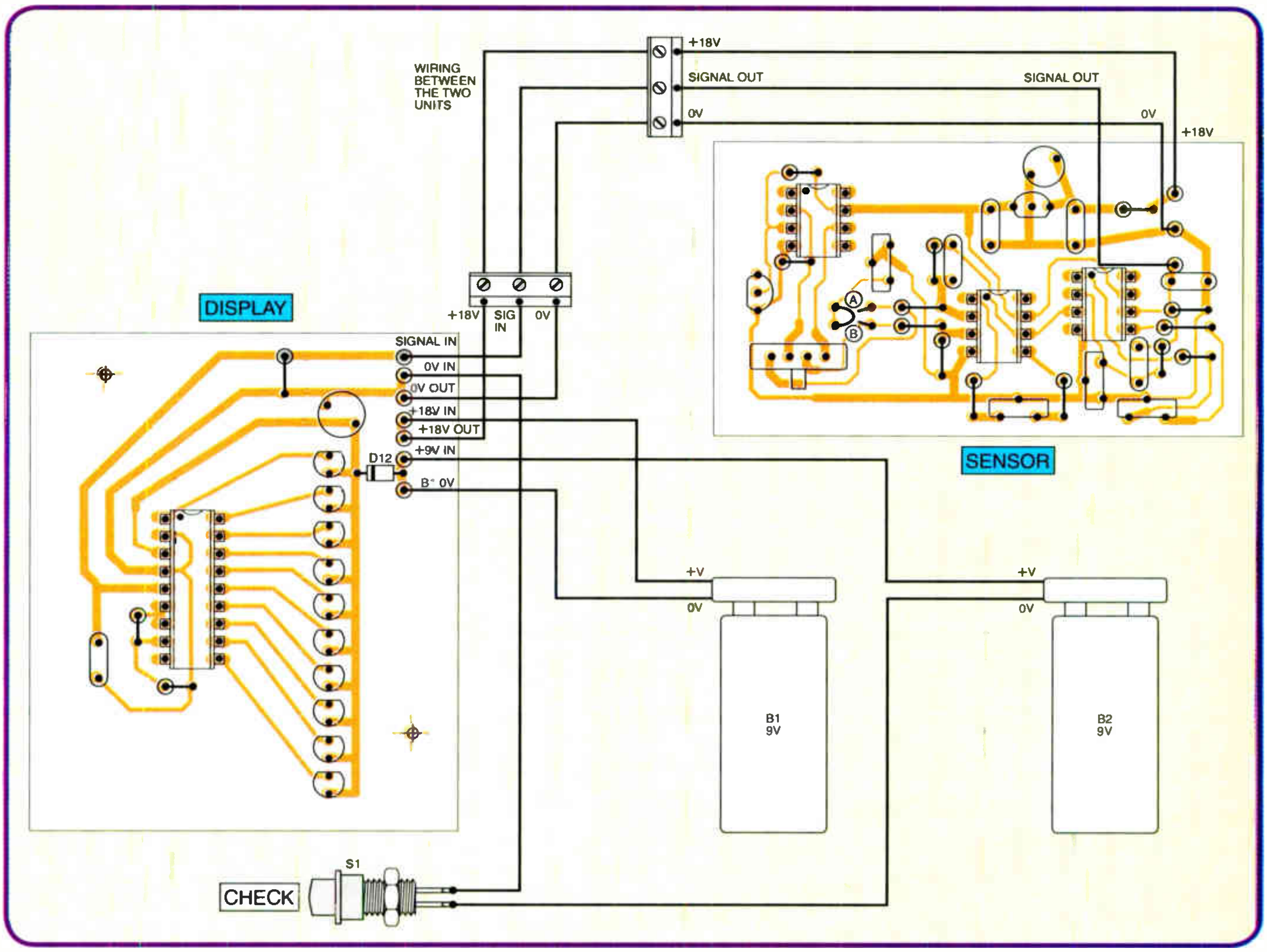


Fig.6. Interwiring details between the display, sensor board and off-board components

Solder the LEDs (D2 to D11) taking care over their polarity. The tops should be level, make a straight line and stand higher than C8. Rectangular units were used in the prototype but round ones could be used if preferred.

Solder the battery connectors in place (ignore switch S1 for the moment) also pieces of stranded wire to the "signal in", "0V in", "0V out" and "+18V" out points. Connect battery B2 "0V" wire temporarily to the "0V in" wire. Adjust all the presets to approximately mid-track position.

Offset removal

Refer to Fig.6 and connect the circuit boards together by linking the "+18V", "0V" and "signal" wires in each. Use a 3-way section of screw terminal block to prevent short-circuits. Connect the batteries. With neither "stalk" on the sensor PCB touching the "loop", apply digital voltmeter probes to the "stalks" (that is between IC3 pins 2 and 4). This will indicate the sensor offset voltage.

Touch one of the "stalks" on to the "loop" and adjust preset VR1. If the voltage can be reduced to near-zero, this is correct. If adjustment makes the offset voltage higher, touch the other "stalk" onto the loop and re-try. Having established which is correct, solder it in place and adjust VR1 for the lowest voltage.

Apply the meter probes between IC4 pin 4 (0V line) and pin 6 – the offset voltage due to IC4 will be indicated. Adjust preset VR2 to minimise this.

Practicalities

One end of a piece of plastic tubing is connected to the sensor's inlet port. The other end is placed at the bottom of the butt and the tube is filled with water. The specified sensor is of the "wet" type which will withstand the effect of water coming into contact with the diaphragm. For other liquids, such as heating oil, the sensor should be chosen accordingly.

One method is to pass the end of the tubing through a hole in the lid of the butt so that it makes an inverted "U" shape (Fig.7a). The sensor should be mounted a little lower than the minimum water level. The pressure of water in the left hand "limb" of the "U" would then roughly balance that in the right hand one, leaving only the pressure due to the water depth.

It is not satisfactory to use an air-filled tube even though this might seem attractive. Some water would enter the free end and compress the air into a smaller volume. This column of water would exert a pressure of its own in opposition to that due to the water.

This would not normally matter but an increase in temperature would cause the air to expand and some would bubble out to be replaced with water when it cools. This would change the length of the water column and hence the pressure "seen" by the sensor.

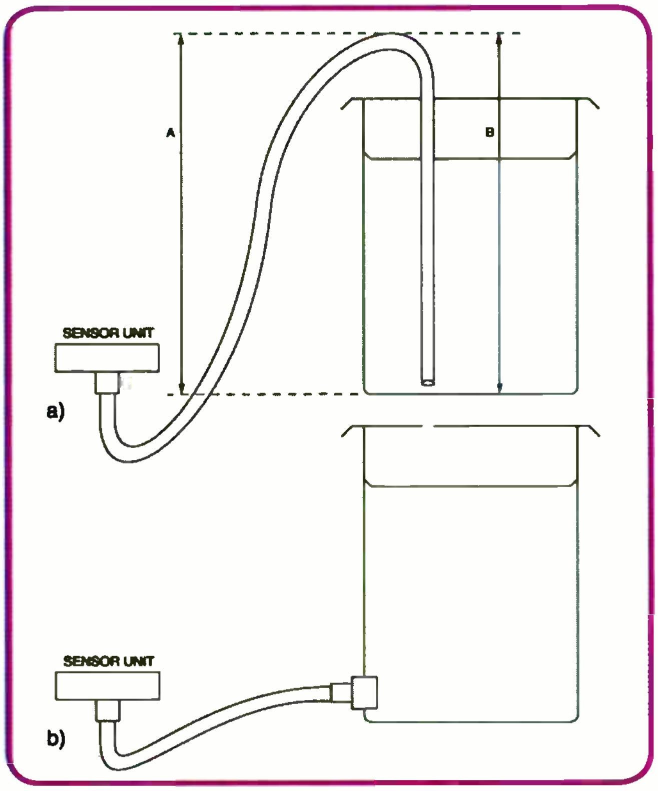
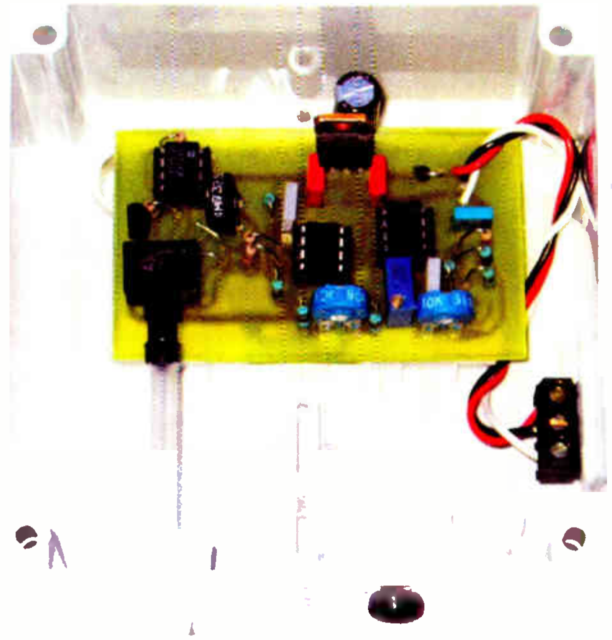


Fig.7. Two suggested methods of "linking" the sensor unit to the water butt. (a) Using the inverted "U" method and (b) direct connection method. If using the inverted U method, note that pressure due to the height of water A is equal and opposite to that due to the height of water B



Layout of components inside the sensor waterproof plastic box. Note the small piece of plastic tubing from the board mounted sensor device to the external "nozzle"

A direct method would be to make a hole in the bottom of the butt and use an adaptor to connect a piece of tubing to the sensor (Fig.7b). Again, the sensor unit should be placed slightly lower than the minimum water level. This is probably the best method but would involve draining the butt. If you do decide to do this, fit a small tap so that the sensor unit may be removed.

Boxing up

The sensor section is built in a waterproof box. Avoid unnecessary strain on the inlet port by using an external connector linked to it through a short piece of tubing (see photograph). The connector should be a tight fit in a hole drilled for it and waterproofed using silicone sealant. In the prototype, a nozzle from a plastic tube was used.

Drill a small hole and fit a rubber grommet to make a tight fit with the inter-connecting wire entering the box. Any holes should be on the lower side (to reduce the possibility of rain water entering) when this is mounted in position. Secure the PCB using adhesive fixing pads (to avoid drilling holes and the possible ingress of water).

Providing the display is used in a dry place, it may be built in an ordinary plastic box. In the prototype, the p.c.b. was mounted on the rear of the lid (see heading photograph). Note that the red LED is placed at the bottom for the display to "grow" upwards. Drill the mounting holes and those for the LEDs to show through. Drill the hole for the switch and attach it. Mount the PCB on stand-off insulators so that the LED tops protrude slightly through the lid.

Decide on a suitable position for the sensor unit and route the inter-connecting wire to the display – four-core stranded burglar alarm cable with one of the wires ignored would be ideal. Refer to Fig.6, and complete all the wiring. Pass one end of the inter-connecting wire through the grommet at the sensor end and, and leaving a little slack, connect it to the wires already in place using a 3-section piece of screw terminal block.

Connect the other end of the wire to the display PCB in a similar manner and check that the three wires are connected correctly. Apply a cable tie to the wire inside each box to provide strain relief.

With an assistant pressing the Check switch, adjust preset VR2 (IC4 offset) so that only the red LED is on. Now, cut off sufficient plastic tubing to reach between the sensor and the bottom of the water butt (depending on the method used).

Siphon

If you are using the inverted "U" method for connecting the sensor (Fig.7a), start a siphon by sucking at the end of the tube and holding the end below the water level. The water might not be clean so don't get any in your mouth! Put your finger over the end of the tubing then quickly push it on to the sensor connector. A short piece of rubber tubing at the end might be found helpful to make the connection.

With switch S1 pressed, adjust preset VR3 (Gain) so that the last (green) LED operates (assuming the butt is full – if it is not, adjust it so that the appropriate LED operates). Re-adjust VR2 so that the red ("empty") LED operates when the water level reaches, say, 10cm. It will probably not be necessary to adjust VR4 but it may be used as a "fine" offset adjustment if needed.

Check for correct operation over a period of time, re-adjusting multiturn preset VR3 if necessary.

When checking the level, press the Check switch for one second or thereabouts to allow the sensor to respond correctly. If the water is likely to freeze in the winter, drain the tubing and take the sensor unit indoors – ice forming inside the sensor is likely to ruin it. *EPE*

READOUT

Email: john.becker@wimborne.co.uk

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

All letters quoted here have previously been replied to directly.

WIN AN ATLAS LCR ANALYSER WORTH £79

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

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

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★ LETTER OF THE MONTH ★

VB6 Sorting

Dear EPE,

I refer to Craig Patterson's request (*Readout* July '06) for a function to convert a string into its alphabetical equivalent. Here is a possible solution for Craig, written in Visual Basic. It assumes that any non-alphabetical characters that might be in the string to be converted are not to be included – this could be removed if necessary:

```
Private Function stringSort(ByVal strOriginal As String) As String
'------------------------------------------
'Function that returns a string based on the alphabetical order of the
'letters passed as a parameter of the function
'Where there are more than 1 of the same letter, each instance is returned
'and if relevant, the Uppercase letter positioned before its Lowercase version
'The string passed can be of any length and could be a phrase or sentence. The
'function removes all spaces and non-alphabetic characters before carrying
'out the sort
'------------------------------------------
Dim x As Integer, y As Integer, z As Integer
Dim a As String, b As String, swap As String
Dim strLeft As String, strRight As String, strToConvert As String, strConverting As String
'------------------------------------------
'remove any spaces and/or special characters in the string
'------------------------------------------
strToConvert = ""
For x = 1 To Len(strOriginal)
a = Mid(strOriginal, x, 1)
If (Asc(a) > 64 And Asc(a) < 91) Or (Asc(a) > 96 And Asc(a) < 123) Then
'Asc 65-90 is A to Z, 97-122 is a to z
strToConvert = strToConvert & a
End If
Next x
'------------------------------------------
'Now sort the 'clean' string into its alphabetic sequence
'------------------------------------------
'A simple "bubble sort" is used to convert the string.
'Neighbouring letters are checked and swapped if necessary
'The first test uses LCase to check for non-similar letters,
'the second test puts Uppercase before Lowercase of same letter
'
'Note that the Inner loop iteration reduces through the sort
'as each pass guarantees that the 'largest' letter e.g. z
'moves to the end of the string and therefore does not need to
'be checked again.
'------------------------------------------
strConverting = strToConvert 'set to initial position
z = Len(strToConvert)
For x = 1 To Len(strToConvert) – 1
strLeft = ""
For y = 1 To Len(strToConvert) – x
strRight = Right(strConverting, z – (y + 1))
a = Mid(strConverting, y, 1)
If Asc(a) = 32 Then GoTo space
b = Mid(strConverting, y + 1, 1)
If Asc(LCase(a)) > Asc(LCase(b)) Then
swap = a
a = b
b = swap
ElseIf Asc(LCase(a)) = Asc(LCase(b)) Then
If Asc(a) > Asc(b) Then
swap = a
a = b
b = swap
End If
End If
strConverting = strLeft & a & b & strRight 'letters swapped if necessary
strLeft = Left(strConverting, y)
space:
Next y
Next x
stringSort = strConverting

End Function
```

I am a relatively recent reader of *EPE* (from Jan this year) and have been consistently impressed with the content. Thank you.

Richard Graham, via email

Thank you Richard. I hope Craig finds your offering suitable.

Adaptors and Li-ion Batteries

Dear EPE,

Regarding *Practically Speaking* July '06, take care with the sort of power "adaptor" supplies that look like overgrown mains plugs (integral three pins, the earth pin often being plastic) with a low-tension wire emerging. These devices indeed conform to relevant standards – where the requirement for a fuse does not exist! Inside, you'll find a crude arrangement of a transformer wired directly to the mains plug pins and no sign of any kind of protection.

I always plug these in through a fused multiplug adaptor, those white cubes that also have the three pins and offer two or three sockets. All 3-way (but only some 2-way) multiplugs are fused and I put a 1A fuse in, dedicating that multiplug to one PSU. The fused multiplug and the PSU remain coupled as a unit and the redundant socket(s) on the multiplug are blanked off.

Also, why risk a big bang if a low-powered device fails? Mains plug fuses are made with 1A, 2A, 3A, 5A, 7A, 10A and 13A ratings. If a device intended to draw a few tens of milliamps goes short-circuit, the blowing of a 1A fuse is a non-event. If you rely on the 5A fuse commonly found in IEC connector leads, the bang is spectacular! Or, ask my Chris who shorted her curling tongs (100W fused at 13A) or another lady colleague who had an unnecessary fright from a low-powered hairdryer also with 13A fuse.

Also, my understanding of lithium-ion batteries is that they have high specific energy density, high peak current availability and will not suffer "memory" effect – assuming that they are subject to the specific stepped-voltage charging protocol. My neighbour, keen photographer, uses these in his cameras and tells me that their life is short and that, quote, "They start to die off from the moment they are made" and that there is no way to stop this, so life expectancy is short. Is that correct?

Godfrey Manning G4GLM, Edgware, Middx, via email

Hi again Godfrey, I regret I don't know about Li-ion battery technicalities and can only repeat your letter here through Readout. *Well readers, can you help Godfrey via me?*

PC PSUs

Dear EPE,

I was interested by your article (July '06) on using a PC power supply as another power source. I have for years been using several ex-PC PSUs as a cheap way to provide good strong 5V and 12V supplies for all manner of consumer gadgetry.

I just short the two leads that provide 5V when the PSU is plugged into the mains, and this trips the PSU "on" to deliver 5V and 12V from the other leads. I've been doing this with no ill-effects – and saved a lot of cash on 5V and 12V mains adaptors.

Barry Fox, via email

Many thanks Barry

PIC n' Mix Names

Dear EPE,

I'd like to thank Mike Hibbett for the advice in *PIC n' Mix* May '06 about using meaningful names, particularly for 1-bit flags. Although his advice is a step in the right direction, I think it is useful to take one or two more steps to do this a little more elegantly.

Instead of names like Flags1, MnemonicBit and Flags2, MnemonicBit2, I use names like MenemonicByte, MnemonicBit. That is, I make the meaning even more explicit by including it in the name of the byte, as well as in the name of the bit. This has the advantage that as my program grows and I need to tidy which bytes hold which bits, I need to change only the few lines of code where I make the assignment and I don't need to wade through pages of code changing some – but not all – instances of "Flags1" to "Flags2".

If an assembler directive like the #define statement is available, it is possible to be more elegant still. Bytes and bits are assigned by statements like:

```
;Appropriate explanatory comments go here.

TimeValidByte
TimeValidBit equ 0
#defineTimeValid
TimeValidByte,TimeValidBit
;more comments.
ReadKeypadGoByte
ReadKeypadGoBit equ 1
#defineReadKeypadGo
ReadKeypadGoByte,ReadKeypadGoBit
;etc for more bits in this byte.
;Allocate the byte.
    res     1
```

Notice that there is no "res" statement after the definition of the mnemonic for each byte, but one after all bits that share a common byte have been defined. The next bits will be assigned to another byte.

```
;comments.
PowerOnByte
PowerOnBit equ 0
#definePowerOn
PowerOnByte,PowerOnBit
;etc.
ManualStartByte
ManualStartBit equ 1
#defineManualStart
ManualStartByte,ManualStartBit
;Allocate the byte.
res   1
```

The bits are used in statements like:

```
bsf   ReadKeypadGo
bcf   TimeValid
btfss ManualStart
```

I often need to use Exclusive-OR to toggle bits. The trick is:

```
movlw (1<<MnemonicBit)
xorwf MnemonicByte,f
```

I hope other readers find these tips useful.

Keith Anderson, Kingston, TAS, via email

Thanks Keith, I'm sure they will. I sent your email on to Mike Hibbett, who replied:

Always nice to get feedback, especially the positive type! I agree wholeheartedly with Keith. In my article I kept the examples simple to make the idea as clear as possible. There is one caveat that springs to mind though; be careful with abstractions like this:

```
bsf   ReadKeypadGo
```

If "ReadKeypadGo" is addressing a PORT register, then you may get the "read-modify-write" problem so well known to PIC enthusiasts. I completely agree with using meaningful names for registers, but try to avoid hiding important details. I like to add _PORT to any port registers I redefine to make sure I don't miss the point when coding.

Mike Hibbett, via email

Graphic LCDs Backlight

Dear EPE,

Just a bit of info that may be useful if you don't already know. I recently purchased a Powertip 128 × 64 graphics LCD with LED Backlight (with the same 18 pin connection as your GLCD).

I plugged this into your demo board for illustrating how GLCDs can be used with PICs and could get nothing out of it. I then noticed that the regulator was roasting. After some checking about it became obvious that the LED backlight is powered from the same 5V supply as the logic, not via the two connections at the end of the panel that connect to the LED array. Fitting a 7805 in place of the 78L05 allowed the demos to run.

I have no knowledge of a way to disable the backlight via software commands to the panel – though that would be useful! There is a 3Ω3 surface mount resistor that can be lifted to disable the LEDs (I need to be able to turn it off to conserve power, so am using a PIC line to turn off a transistor).

On another trail – I bought another display, this time a Varitronix 128 × 64 – 18 connections. This one again has a backlight but is not powered via the logic supply – you have to apply a supply to the two connections on the end of the panel – no resistor this time.

Again I could not get a display on screen, this time due to lack of contrast drive. After searching the net, I discovered that some of the Varitronix panels need –5V or so to work. I rigged a supply and discovered that the panel I have needs about –9·5V. This is a real pain as I have 24V and 5V. I've made a 555 based negative voltage generator. This will give me down to about –13V, but I need to supply the 555 with no more than 15V.

Tried a similar device using a discrete multivibrator running from 24V but could not get this to give enough current for reasons unknown. Might try a 7660 running at 10V via a Zener setup, though I'm concerned that I'm sailing close to the wind with this panel, and another batch may need that other 0·5V or so.

Kevin Binder, via email

That's interesting Kevin and not something I was aware of, indeed I've never used a backlight on a GLCD. Thanks.

Digital TV Again

Dear EPE,

Referring to Godfrey Manning's comment about Digital TV in July '06 *Readout*, I have never experienced black-and-white only pictures, except on an analogue signal from a very poor aerial.

Digital is all or nothing. Well, almost, because the picture breaks up and freezes as it goes down through the threshold. Freeview signals are also a lot more immune to thick rain clouds than Sky transmissions are.

I rather think the root of his problems are that the old Freeview boxes that were rushed out. When On Digital went belly up, I originally had a make of box which used to freeze, reset and then run about every 10 minutes before the whole cycle would start again. While I got a good picture on Scart, on the RF output, the top 10 lines used to tear. Add to that, there was no way you could actually make a recording, because the digital rights management system was locked on to prevent you from doing so.

When you consider that Freeview boxes can be bought for as little as £30, you must expect things like RF modulators to be removed from the spec. But judging by the drastic alterations in software that have been transmitted, any changes from MPEG 2 to 4 must surely come. As it is, the unit has to cope with two different multiplexing systems, the 16 and the 64.

George Chatley, via email

Thank you George.

Net Work

Alan Winstanley

WELCOME to *EPE Net Work* – launched back in the 14.4k dialup and Windows 3.1 days of the August 1996 issue, and now celebrating ten years of helping readers get more out of the Internet. Last month I suggested another messaging application for webcam users – MSN Messenger. This and similar products such as Skype permit video calls and teletype "chat" calls to be placed to other users anywhere in the world, in effect at no additional cost – except for that of a broadband connection.

Webcam Security System

This month I describe a neat Internet monitoring application for your webcam, and I show how to use some readily available software to display snapshots on a web page or send them, or video grabs, by email.

Assuming that a suitable webcam is installed and working on your PC, the next port of call is the web site of Ledset Software at **http://www.ledset.com/camwiz/index.htm** and download the 30 day trial of CAM Wizard (XP/ NT/ 2000 only, £17.21 full version).

This software is a budget-priced but fully featured webcam and motion detection package that includes many powerful features found in more expensive CCTV software. CAM Wizard can directly handle up to four webcams, and its motion detection system will take a snapshot when triggered, or start a video recording of the event. After detecting motion within a predetermined area of the image, it can play a warning siren over the PC speakers, or play a sound instead (.wav or .MP3): CAM Wizard provides the sound of a fierce dog growling but you could play your own sound tracks.

When triggered by motion, CAM Wizard can capture stills or motion video to hard disk or upload a file to a web server using FTP (file transfer protocol) at preset intervals or whenever motion is detected; the Ledset website provides the javascript that can be pasted into a web page in order to display images online.

The software can send images by email after every capture, so you could mail them anywhere in the world, which opens up the possibility of sending them to e.g. a Smartphone mobile phone or Internet-enabled PDA. Even dial-up users can use CAM Wizard, as the compression can reduce file sizes to manageable levels for uploading via a 56k modem; again consider the costs and remember the minimum 5p BT phone call.

Cam Wizard in use monitoring a garden

The video capturing facility allows motion video to be written to a hard disk in compressed .wmv files or high quality raw .avi mode (the latter being used in CCTV mode with large drives, and not intended for email or web based applications). It is also possible to email a captured .wmv movie as well, and attach the first frame as a separate preview JPG image, but mobile phone users should check their mobile phone tariffs carefully because this option could prove very expensive indeed. (For comparison Orange GPRS starts at £1 per megabyte of data.)

In Motion

Setting up CAM Wizard's motion detection feature is commendably simply. Just define an area on the image to be monitored and double-click to add a "node" that can be dragged around the image with a mouse. The designated green area is then protected and monitored, and movement in this area will be recorded. A variable sensitivity slider control prevents nuisance tripping caused by e.g. birds or pets. In the example screenshots from my own webcam, a tree has been excluded from the monitoring area so that when it sways in the wind it does not trigger the alarm. The software runs as an icon in the System Tray, and the main camera window pops up on-screen when motion is sensed. The protected area is superimposed with green squares that turn red when movement is detected (see screenshot).

There is a scheduler included that enables the software during preset times and days, and it has its own built-in SMTP engine that can email the images or movies out without relying on your own ISP's mailserver (this feature has not been tested, however).

If you want to try a webcam for security purposes then CAM Wizard is a fun and versatile piece of software that won't break the bank. Consider using an old laptop (Windows 2000 or higher – see eBay) with a USB webcam, possibly on a wireless network or a VNC (virtual network computer), and you have a cheap wireless security system that will enable you to monitor premises from anywhere in the world during daylight hours: *EPE* readers might want to experiment by making an IR l.e.d. illuminator for night-time use as well.

You can contact the writer at **alan@epemag.demon.co.uk**

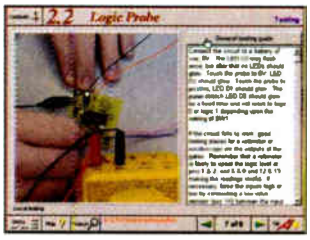
Defining the area to be triggered by CAM Wizard motion detecting software. The tree has been excluded to prevent nuisance triggering

Motion detected (red highlights) in the area being monitored (green squares) triggers the alarm

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

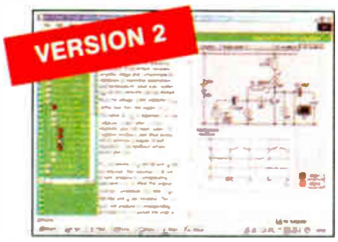
ELECTRONICS PROJECTS



Logic Probe testing

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

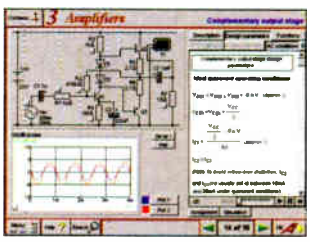
ELECTRONIC CIRCUITS & COMPONENTS V2.0



Circuit simulation screen

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

ANALOGUE ELECTRONICS

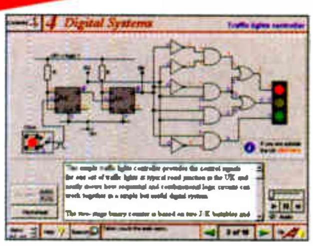


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

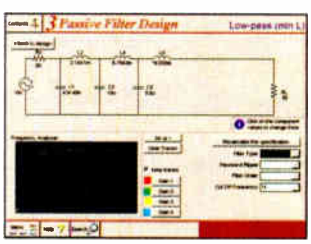
VERSION 2



Virtual laboratory – Traffic Lights

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

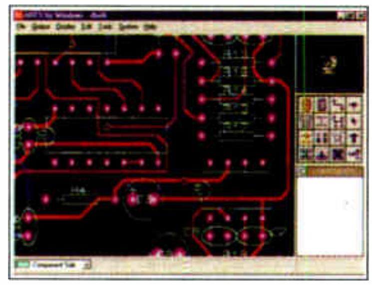
ANALOGUE FILTERS



Filter synthesis

Analogue 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

ELECTRONICS CAD PACK



PCB Layout

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

ROBOTICS & MECHATRONICS

Case study of the Milford Instruments Spider

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

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

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student	£45 inc VAT
Institutional (Schools/HE/FE/Industry)	£99 *plus* VAT
Institutional 10 user (Network Licence)	£249 *plus* VAT
Site Licence	£499 *plus* VAT

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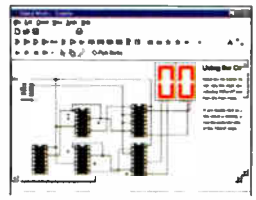
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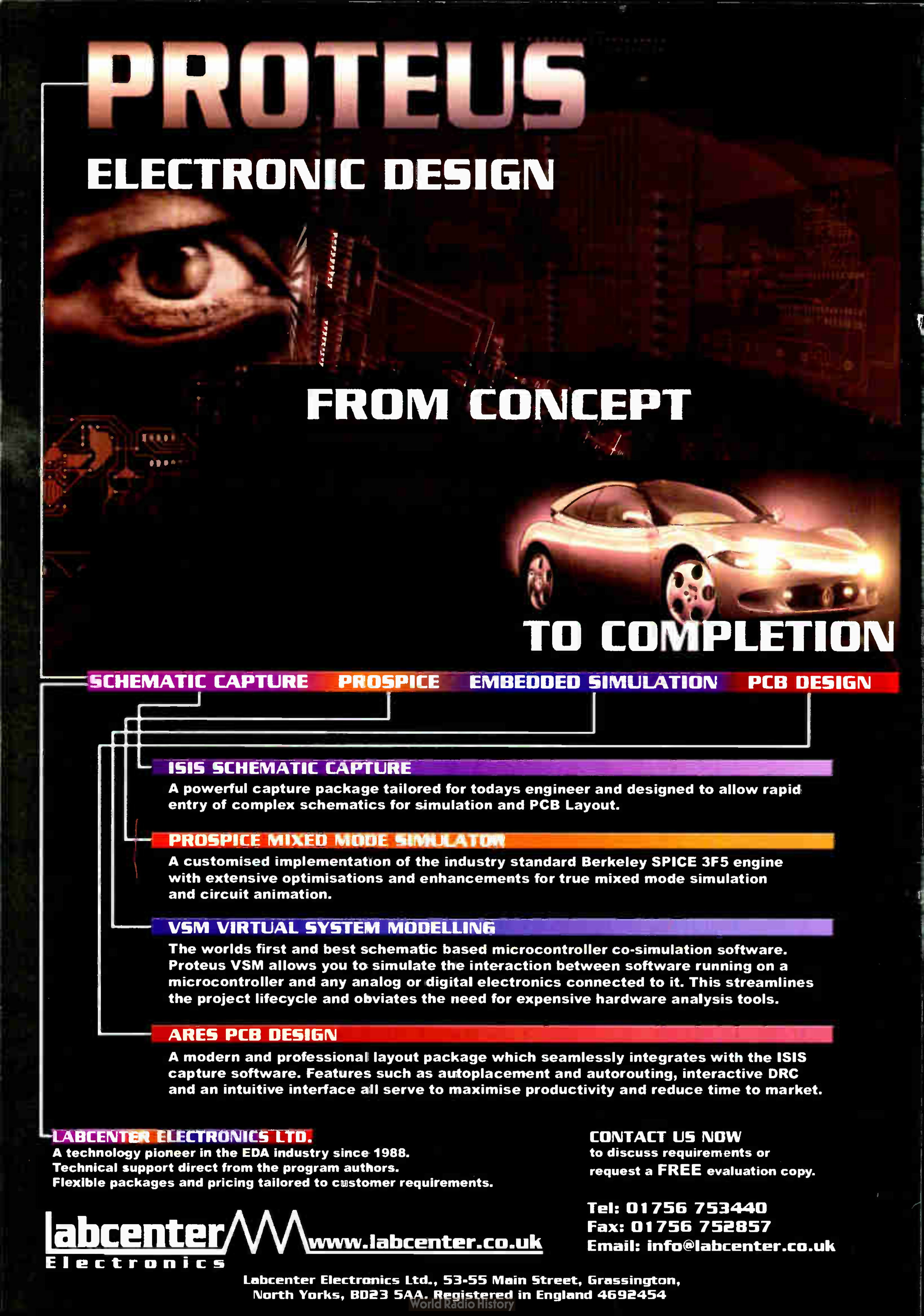
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